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RESEARCH ARTICLE

The Reductive Roots of Mechanistic Explanations

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Abstract: Mechanistic explanations play an important role in the scientific understanding of the mind. Mechanistic explanations reflect the commitments of *mechanistic philosophy*. This philosophy stresses a methodology based on decomposition into constituent parts and the synergistic integration of their activities. The methodology provides the *identity types* required for the formulation of explanations targeting the explanandum phenomenon. The basic relationship between mechanisms and their target explananda is mereological. A system is in intrinsic *compositional* relation to the participation of its constituent parts in the system's overall functionality. The compositional relation is primarily *inter-level*. The stability of the system requires also the existence of *intra-level causation* within the boundaries of minor sub-mechanisms. In combining the compositional relation with intra-level causation mechanistic explanations would track *nonreductive* relations. Intra-level causation and inter-level compositional effects are also reflective of a mereological relation. The mind-brain system is an example of a mereological relationship and so according to this logic, the mind would be rendered irreducible. Combining both intra-level *causation* and inter-level material *constitution* is nevertheless *not* sufficient to warrant mechanistic explanations being non-reductive. By emphasizing identity types as the bearers of

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the mereological relation, mechanists in general regard special-sciences and their kinds as actually reducible to the subsuming mechanisms. Applied to the mind-body relation this means the reduction of mind to brain states.

Keywords: Abstraction; intra-level causation; explanation; mechanisms; reduction.

1. Introduction

This article explores the way mechanistic explanations and their application specially in the neurosciences relates to the character of the mind as informed by special sciences like psychology. I argue here that despite mechanistic philosophy offering a reading of the part-whole relationship between mind and brain as implying irreducibility for the mind it nevertheless fails because of its commitments to type identities. Many special sciences refer to the existence of kinds like subjective mental states, economic transactions and biological processes as *irreducible* to basic physical kinds and their properties (Beckage et al. 2013; Hermida and Ladyman 2025; Weiskopf 2011). Thus, mental states as those present in for example economic transactions would be irreducible to neuroscientific states and their properties. At the same time, these examples of irreducible kinds are grounded on the operations of individual brains. It is here where mechanistic explanations approach psychological and mental phenomena by way of referring to the constitutive character of neural mechanisms and their characteristic activities as responsible for the synchronous "here and now" realization of mental phenomena. A basic assumption is that mechanistic explanations track composing structures and their properties representing subvenient bases on which higher-order phenomena are *physically* realized. Further, mechanistic explanations are explanatory to the extent that they successfully identify these structures as cases of natural kinds and their properties representing *types*. Thus, the explanatory power of mechanistic explanations rests on the recognition of *type identities* as the grounds on which mechanisms function and work for their capacity to realize higher-order phenomena. In that sense, mechanistic philosophy is in spirit reductionistic. Still, depending on how we understand the defining characteristics of mechanisms there is a possibility to read mechanistic philosophy as implying non-reductivism for mental properties. Mechanistic philosophy in general understands the existence of a certain explanandum as the result of objects, their parts and activities organized in such a manner that in conjunction with their here-and-now *physical occurrence* realize the target explanandum (Machamer, Darden and Craver 2000). Non-reductivism adds to this picture the idea that despite the explanandum being ontologically based on the realizing mechanisms, because of properties and characteristics unique to its macro-based behavior, it remains nonetheless non-identical to those mechanisms. The combination of mechanistic philosophy and non-identities would then in principle make a case for mechanistic explanations being non-reductionistic. To work, this combination requires a view of mechanisms as part of a mereological relation characterized by both inter-level and intra-level properties. Usually, the neurosciences approach the mind mechanistically by assuming causation between different *levels* of organization, i.e., both mind and brain "located" at their own level in the hierarchy of natural phenomena. Moreover, being there a causal pathway between brain and mind we can develop an explanation of the mind in terms of physical realization by the occurrence of brain states. Nevertheless, many mechanistic models are also examples of a *mereological relation*, i.e., the reciprocal structural as well as functional integration between the system and its component parts. The mereological relation holds not only between the explanandum phenomenon and its subvenient mechanisms but also between *major mechanisms* and their composing *sub-mechanisms* at the level of the realization bases. A major mechanism then is an example of a constitutive and functional part of the system composed by more basic underlying structures and their functions, i.e., a sub-mechanism. Given the possibility causal pawers inherent to the system are restricted to the instantiation of functional roles at the *intra-level* of local sub-mechanisms we speak of a *horizontal explanatory relation* (Kaiser and Krickel 2017). This relation confronts with a vertically oriented *constitutive* relation between explanandum and mechanism. If correct, mechanistic explanations would have the virtue of being explanatory at the intersection of this horizontal and vertical confluence. Thus, they explain the phenomenon by means of an epistemology grounded on intra-level causal effects working *within* and along the sub-mechanisms, i.e., their horizontality, together with an ontology working "between" the sum effect of the constitutive major mechanisms i.e., verticality. "Horizontal" here then refers to causal pathways operating internally at the local constitution level of sub-mechanisms. Further, mechanisms explain their target phenomenon also by means of an ontological constitutive relation operating inter-level *between* mechanisms, i.e., their verticality. Additionally, horizontal causation operating at the sub-mechanistic level is also *conditioned* by the mereological relation of parts to their wholes and vice versa: i.e., the whole system has a modolutary effect on the causal profile of the sub-mechanisms. Furthermore, combining intra-level causation with material inter-level constitution renders the entire mereological system irreducible; the structures and properties occupying intra-levels and inter-levels are mutually integrated as parts and wholes. This is why psychological properties as systemic properties are not reducible to the elementary units of the entire system. Psychological properties are expressions of a constitutive mereology conditioned in part by internal causal effects proper to subsuming micro mechanisms and in part by the global effects of systemic macro properties. Moreover, local intra-level causal effects are not necessarily inherited by the global systemic behavior. The entire system as such is in itself *causally distinctive*; there are separate systemic causes not necessarily reducible to the horizontal local causes found at the level of sub-mechanisms (Romero 2015). It is then paramount to understand why causation in a system is mainly confined to the mechanistic "intra" level of organization. Any system operates through the composing activities of its parts. At the same time the operation of the parts is conditioned by the qualities and behavior of the system as such. Causal effects from the parts resonates at the systemic level and in addition globally based systemic effects resonates at the elemental level of constituent parts. Causation here is reciprocal. Think of Sperry's wheel (Sperry 1991, 1980). Here the wheel is in motion and so even its components. The material components of the wheel participate in grounding the mere possibility of being there a wheel in motion at all but the wheel as a global system in motion determines also the location and displacement of its components atoms in space-time. Causation as a systemic property is integrated into the whole system. At the same time it can and must be instantiated simultaneously by different local elements at different times, i.e., its synchronous character (Cabral et al. 2022). The local elements here correspond in the mereology of mechanistic systems to the existence of sub-mechanisms. Sub-mechanisms are then causally synchronous. In other words, they "happen" at once and they "contain" the causal efficacy of "local spots" in the system i.e., its components. It is the synchronous existence of the sub-mechanisms' causal activity that together support the integrity of the system in its here and now condition. As a result, these sub-mechanisms operate on their own basis following their own internal "causal clock" and can be operationally recruited when so necessary for the instantiation a certain property in the system. At the same time, the system is characterized by its inherent robustness, resilience and graceful degradation of functionality. There is an inbuilt redundancy to the operation of sub-mechanisms that causally speaking is available to the needs of the entire system when so needed (Bernard 2023). The role of the subsystems then is to perform and realize causal roles that can be recruited for safeguarding the resilience and redundancy of the whole system. Thus, causation as a structuring and organizing power is not evenly distributed across the entire system but must be *localized* to the function of certain systemic units, i.e., sub-mechanisms. Moreover, given the integrity, redundancy and robustness of the system it means that individual sub-mechanical units are to a certain degree in principle dispensable. The system can still operate in the relative presence or absence of sub-mechanisms as long as the functional integrity of the entire system is secured. This is the primary reason why the instantiation of causal powers must be *multiply distributed* across different sub-mechanisms to support the integrity of the system. Moreover, seen from the perspective of neural structures every such sub-mechanism must also be *plastic* or adaptable enough to instantiate different causal profiles. Transferred to the way the brain realizes mental properties, this reflects the structural and functional malleability typical for neuronal network organization. This plasticity-based brain property represents how neuronal networks perform and carry out different computational operations required for the implementation of cognitive functions (Bassett and Sporns 2017; Bassett, Zurn, and Gold 2018). On the other hand, this intra-level characterization of the brain's systemic organization is not the way mechanistically oriented neuroscientists interpret the explanatory relationship holding between cognitive function and brain physiology. Rather, they assume that mechanisms explain this relationship in virtue of instantiating *inter-level* causation responsible for the implementation of a specific cognitive function. This means that according to many mechanists the correct view of realization between a higher-order property and it subvenient bases is dependent on its "verticality". In other words, a phenomenon is cosntituted by the synchronous presence of its fundamental components. Yet, even if the idea of intra-level causal operations. In line with the scale free and multiscale character of brain function and organization gives some support for the irreducibility of cognition to brain physiology, this is not a sufficient reason to believe that mechanistic explanations in general can be non-reductive. The main reason is that an essential aspect for mechanistic models to make sense is that they both causally (horizontally) as well as constitutive (vertically), must rely on the existence of *Types* when formulating explanations. It is the very type as such as a basic and recurrent unit of oranization that integrates in its essence both causation and material constitution. The identification of those types is based on the very standards of mechanistic methodology, i.e., localization, decomposition and integration of parts and their operations. The methodology of mechanistic research is reflective of the metaphysics behind mechanistic frameworks and that metaphysics is inherently reductionistic. This means that despite mechanistic philosophy apparently offering a mixture of grounding (vertical "constituent" realization) and irreducibility (horizontal "causal" autonomy), higher-order property kinds cannot be explanatory subsumed nor reflected by the sum of mechanistic mereology. The main reason for this failure is that the grounding of mechanistic explanations cannot be separated from the requirement of that grounding being the expression of identity types.

2. The Mereological Character of Mechanisms

Mechanisms do exist in many natural and artificial contexts, and they constitute in part *epistemic tools* that help us comprehend the world. They also enhance our understanding of reality by representing not only empirically based heuristic methods but also by revealing the very structure of the world. Thus, the analysis and discovery of mechanisms represents an *ontological attitude* to the world, i.e., natural phenomena in the world are made up by mechanisms. Whatever phenomenon of interest we would like to analyze, it is then according to mechanistic philosophy a complex structure composed of units and their parts working together in the performance of activities at different levels of organization (Craver and Darden 2001). Mechanisms appear both between and within levels at different scales of organization in one and the same complex structure or system. Mechanisms compose or make up their referents or target phenomena. They explain the explanandum phenomenon by means of *major* or minor *sub-mechanisms.* A major mechanism would then be the kind of physical structure the organization of which encompasses or engulfs the key defining characteristics of a higher-level structure. The encompassing organization is instantiated by a constituent relationship, i.e., the sum total of the parts of the mechanism matches the totality of the phenomenon. A minor mechanism or sub-mechanism is a proper part of a major mechanism. The minor sub-mechanism is autonomous in terms of its unique or specific constitutive causal character, i.e., the minor mechanism defines a *certain* aspect of the more general phenomenon. Generally, a major mechanism is composed by minor mechanisms. Further, it is the defining features of the target phenomenon together with the level of analysis applied to it that makes the integration of a sub-mechanism into the wider hierarchy of the major mechanism relevant or not. In other words, a minor mechanism would, depending on the circumstances, be necessary and sufficient for the physical realization of a certain property and so exercise its constitutive causal effect on the wider phenomenon. Depending on the circumstances the minor mechanism is recruited or not into the functional organization of the wider mechanistic system. Those circumstances are reflective of the sensitivity of phenomenon to contextual and environmental effects. Moreover, the structural organization of the minor mechanism together with its defining functional roles is generalizable and applicable to distinct major mechanisms. Thus, once the relevant constitutive character of a minor mechanism is recognized as participatory in a plurality of different phenomena, the minor mechanism's causal profile is accordingly instantiable in a plurality of ways. Minor sub-mechanisms are then categorized according to their effective causal contribution to the formation of higher-order phenomena. In other words, one and the same sub-mechanism can be recognized as constitutive for a plurality of phenomena. As such it can be recruited into the workings of a major mechanism according to its explanatory relevance in the final analysis of the target phenomenon. Inversely, a major mechanism might recruit or even silence the effect of a minor mechanism in the general framework of the constitutive relationship. Thus, within the main mechanisms there exists sub-mechanisms behaving as constituents of entire mechanisms. This relationship between the effect of the sub-mechanisms on their major mechanistic counterparts and the effect of latter on the way the sub-mechanisms are expressed as part of the total defining systemic activity is the expression of a mereological relationship. Thus, mechanisms might vary in their functional and constituent characteristics but maintain their capacity to collectively explain the target phenomenon as the result of their participation in the grounding of a complex part-whole relationship. Moreover, mechanisms participating in mereological relations means that they explain the occurrence of a certain phenomenon by means of *physical realization* both causally and constitutive; mechanisms are physical entities. Causally speaking, the mechanisms instantiate and carry out the characteristic causal role description of the phenomenon. Constitutively speaking, mechanisms represent the very material occurrence of objects and their elements participating in the physical structuring and configuration of natural phenomena. Furthermore, mechanisms explain also by means of their *directionality.* This means that mechanisms in the context of their overall position in the "topology" of the comprising mereological relation are explanatory relevant either "vertically" or "horizontally." In a vertical explanatory understanding, major mechanisms and their recruited sub-mechanisms explain *synchronously.* This means that the very presence or manifestation of the mechanism in the topology of the entire system is sufficient for the higher-order phenomenon and its properties being instantiated. Here, "vertical" refers to the condition that the realizing relation is achieved through material synchronous constitution. There is then basically no need for a causal relationship to hold between the realizing mechanism and the higher-order object. To compare, any causation at the proper level of mechanisms is *internal* to the workings of single mechanisms. In other words, every sub-mechanism implements a certain functional role by means of integrating into its activity a causal role description. The execution and integration of the sub-mechanism's causal role in a wider upper-level mechanism is dependent on the overall *contextual characteristics* of the overarching mechanistic hierarchy. Thus, if a mechanism in general and its contributory sub-mechanisms in special explain something causally this is due to processes based at the *intra-level* causal structure of organization, i.e., the system's *horizontal directionality.* Importantly, causation as such is explanatory to the extent that objects at different levels of organization causally interact with each other. Composition as synchronously organizing mechanisms explain by way of their very physical occurrence not necessarily by their causal contribution. This difference is relevant when it comes to the kind of phenomena we want to mechanistically analyze. Thus, if mental properties like qualia are in principle *functionalizable* it means that their causal role description can be replicated in ways independent of the character of their implantation platform. Given this condition, the intra-level causal structure of the participating minor mechanisms is then also explanatory relevant. On the other hand, if qualia as an example of a mental category are not functionalizable, then causal explanation does not necessarily track them. Nevertheless, they can still be explained in the sense of their *occurrence as a matter of fact* or as the result of the very physical occurrence of the mechanical constituents composing them. That mechanisms do not primarily explain by casual structure can also be understood when considering that for example one and the same sub-mechanism can implement many *different* casual roles, some relevant other irrelevant, to the realization of one and the same higher-order phenomenon and its properties. This is so because, if mechanisms in general are intended to explain by means of *type-to-type identities,* then causation as described here cannot track the kind of stable identities required for those Types to obtain. The reason is twofold. First, type identities do not work through causal identifications when applied to non-functionalizable properties like qualia if functionalization understood here as psycho-physical functional instantiation fails. Second, the possibility of the same sub-mechanism instantiating one and the same higher-order property implies the multiple realization of the higher order phenomenon by its subvenient sub-mechanisms. Traditionally, *multiple realization* blocks type identities. Consequently, the concrete causal occurrence of a certain mechanism in the overall mereological hierarchy is not an absolute condition for the realization of the target phenomenon. Other alternative mechanisms *causally relevant* in the topological organization representing the target phenomenon can do the same work. It is then important to keep in mind that any causal effect related to a mechanism is an internally grounded process. Thus, the causal explanatory role of a mechanism is an *intra-level* local effect reflective of its specific structure and organization. The explanatory contribution made by a sub-mechanism is therefore a condition that can be isolated to the structural organization of the local sub-mechanism.

3. Explaining through physical constitution

Importantly, local sub-mechanisms are part of a major mechanism not causally but constitutively. This is so because any causal relevance on behalf of the sub-mechanism is an expression of the sub-mechanism's own self-contained *physical composition*. Thus, in terms of causal contribution or referring to casual powers the *causality* of the sub-mechanism is grounded on its own internal mereology. According to this picture, causation is physical constitution and constitution is mereology. Thus, the mereological relation is mainly explanatory in the physical constitutive sense, not necessarily explanatory in a causal sense. What the causal contribution of the sub-mechanisms add is to construe the flow of information relevant for the stability of the system as a process primarily localized to the internal composition of local structures. This has an important consequence for the analysis of the mind-body relation. Thus, for example, higher-order psychological phenomena like attitudes are mechanically explained as the constitutive "vertical aggregation" of a many sub-mechanical components acting together in a synchronous way. The attitudes *are* ontologically speaking this vertical aggregation, but we know or understand the behavioral dimension of the attitudes by the causal implementation of the involved sub-mechanisms, i.e., their horizontality. This means that a higher-order phenomena cannot be reductively understood as just as the total sum of causal effects realized by component mechanisms. As major mechanisms are "vertical" *constituents* of their co-related higher-order phenomena they are mereologically speaking not necessarily dependent on the *causal* contribution of sub-mechanisms for the realization of the phenomenon. There is no causal dependency relation holding between levels in a hierarchy of mechanisms but rather any dependency relation is only constitutive. To realize is to constitute not to cause. Thus, there is no inter-level *causal* constitution between the major mechanism and its sub-mechanisms. There is therefore at least a sense in which the target phenomenon is casually irreducible to the sum total of the causal role descriptions representing the whole set of sub-mechanisms. Mechanisms then metaphysically speaking constitute their associated phenomena; they do not cause them. The causal relevance of the sub-mechanisms is to perform a certain activity characteristic of its own local part-whole organization. At the same time, the very same sub-mechanism can implement many different causal roles and so there is no fixed or defining overarching causal role hallmark. Therefore, it is the very physical constituent-based occurrence of the sub-mechanisms as objects that matters for their contribution to the realization of the overall phenomenon. We could say that the *causality* of the mechanisms represents the *epistemology* part of mechanistic explanations while the *constitution* part is the *ontology* part of the explanations. This means that a phenomenon could in principle just be there so to speak without doing anything significant. Mechanistic models in general explain by tracking first and foremost the ontology not the epistemology. The epistemology guides the methodology, but the ontology grounds the phenomenon. Mechanistic models explain by tracking the ontology back to relations holding among *physical types*, thus mechanistic explanation is physical *type* constitution. Types are explanatory relevant as constructs tracking the existence of natural kinds. Thus, we have organisms composed by certain types of cells, certain types of tissues and organs as well as certain types of molecular pathways. As a result, mechanistic explanations of the mind and its causal powers are to a certain degree non-reductivist if mechanistic explanations playdown the role of causation and emphasize the mind's "vertical" constituent dimension. If causation plays any explanatory role in mechanistic philosophy, it is secondary and due to the *intra-level* or "within mechanisms" causation relevant to the identity of the mechanism. This is certainly most counterintuitive to many mechanistically oriented scientists. Especially, neuroscientist who view explanation as a causal relation holding *among* mechanisms at different levels.

4. Interventionism

According to mainstream mechanists, mechanistic explanation is in the first place an *inter-level causal* relation. I believe this reflects a confusion regarding the role that manipulation through *interventionism* plays when identifying the explanatory role of mechanisms behind the instantiation of a cognitive or mental function (Woodward 2007). Thus, the *inter-level-mechanist* believes that when intervening by means of physical intervention and manipulation on the function of a certain structure, the observed effects on the phenomenon are first and foremost *causally mediated* effects (Kubska and Kamiński 2021). Explanation then is a causal relation holding among mechanisms at different levels where the causal effects of one mechanism at one level explains the behavior of another mechanism at another level. Importantly, the sum effect of this interlevel causal relationship is also explanatory in terms of the type of mechanisms relevant for sustaining the integrity of the higher-order phenomenon. Thus, as an example in the neurosciences for this kind of inter-level causal explanation we can take the formation of spatial navigation memory maps (Farzanfar et al. 2023). The maps are the result of cellular and molecular mechanisms instantiating long-term potentiation and long-term- depression involved in the formation of spatial maps representations (Durand, Kovalchuk, and Konnerth 1996). An intervention on the cellular basis responsible for long-term potentiation and long-term depression reveals the causal contribution of the molecular level activity to the formation of the spatial orientation maps. Still, this is just one way that intervention and manipulation could be conceived as explanatory relevant. From an interventionist point of view regarding the character of causation, intervening means something being causally *symmetrical.* Thus, an intervention at the level of the phenomenon is also revelatory of the way that lower-level physical mechanisms contribute to the realization of the phenomenon. Interventionism represents a kind of causal *mutualism* in the framework of explanatory models. Still, this "mutualist" interpretation is limited because the intervention on the targeted mechanisms would also include more drastic interventions than just correlative manipulation. Thus, manipulation could refer to both invasive direct cell recordings or non-invasive techniques like transcranial magnetic stimulation (TMS)

(Leodori et al. 2022; Spampinato et al. 2023; Fregnac et al. 2009; Sparing and Mottaghy 2008). An invasive more drastic way of revealing the causal contribution of neuronal ensembles to the targeted function represents obliterating studies (Suzuki 2022; Qvist et al. 2018). Such studies reveal the importance and constitutive character of a certain component in the hierarchy of mechanisms once the targeted sub-mechanisms have been obliterated and removed (Gotzsche et al. 2022). Thus, adding or removing the occurrence of one or more sub-mechanism into the mereological hierarchy would be evidence also of their compositional in the realization of higher-order phenomena (Rolls 2021). One important consequence of understanding mechanisms as components is that the causal powers of the mental would be secured. In the total mereological relation among major mechanisms and their sub-mechanisms the entire part-whole system *is* the phenomenon represented by the total sum of relevant mechanisms. Sub-mechanisms are describable by their local intra-level causal profiles and by their capacity for *pluripotentiality*, i.e., meaning one and the same sub-mechanism being participatory in the realization of many different properties.

5. Mereological Irreducibility of Mind

Further, the mind is an example of a mereological relation embodied by the entire mind-body system. The causal profile of the individual mechanisms is then incorporated onto the causal profile of the entire system as an expression of its mereology (Juarrero 2015). Thus, putting things together, whatever causation there is, it is inherently distributed across the sum total of the system. Causation is then embodied at the intra-level of mechanisms; causal effects are primordially locally confined to the internal composition of the sub-mechanisms. There is then a kind of locally based causal closure that makes sub-mechanisms causally irreducible to each other. Given that sub-mechanisms are mereological components in the *entire* mind-body system, the mind is both causally effective and irreducible to just certain types of mechanisms in the part-whole topological configuration. This is so because, many different causal profiles can be instantiated by one and the same sub-mechanism and one and the same causal profile can be instantiated by many different sub-mechanisms. Also, one and the same overall mechanism and its component sub-mechanisms can be constituents participatory in many parts of the systems. Further, because of the inherent resilience and redundancy of many systems, especially biological ones, the entire system can remain functionally intact up to a certain degree with or without the presence of a specific main mechanism and its composing sub-mechanisms. The mind being an embodied systemic quality of the entire organism would then be irreducible to either the horizontal causal dimension of specific sub-mechanisms or to the vertical dimension of specific component mechanisms. As a result, we might say that the mind is an irreducible topological quality of the entire mind-body system. It is actively engaged with its surroundings by means of its embodiment in the realizing mereology of its constituent mechanisms. This has also an important consequence for the question whether mechanistic explanations for the mind are reductivist or not. Thus, the only way to secure a reductive turn on the mind in terms of reducing mechanisms is for the mechanists to insist on the occurrence of identity types. However, if the former observations are correct, this would not work because neither causally nor compositionally speaking can the mind be identified with mechanical types. As a result of the significance put on compositional mereology, we can discern a kind of *species chauvinistic* move. To be a certain organism is to be a certain conglomerate of certain types of microconstituents standing in compositional relation to each other both biologically and physico-chemically. In other words, an organism is a dog or a human only to the extent that *the right kind* or types of constituents are present in the mereology of the realizing biology. As we remember, according to this logic what matters is not so much causation being instantiated by different components but rather the very occurrence of the components themselves. Thus, in this sense mechanistically oriented explanations based on the mereological relation are in fact reductivist explanations but only to the extent that we insist on the reducing necessity of identity types. On the contrary, the very mereology of the system renders this requirement hollow. The mind then being an embodied systemic quality is both causally and compositionally irreducible to mechanisms.

6. Defining Mechanisms

As there are variations on the kind of properties that mechanists want to explain there are also variations of mechanisms. Furthermore, the very definition of what constitutes a mechanism varies. Thus, mechanisms are understood in a diversity of ways. Yet they hold certain qualities in common:

- "A mechanism for a behavior is a complex system that produces that behavior by the interaction of a number of parts, where the interactions between parts can be characterized by direct, invariant, change-relating generalizations." (Glennan 2002, 344)
- "Mechanisms are entities and activities organized such that they are productive of regular changes from start or set-up to finish or termination conditions." (MDC 2000, 3)
- "A mechanism for a phenomenon consists of entities and activities organized in such a way that they are responsible for the phenomenon" (Illari &Williamson 2012, 120)

Common to these definitions is the emphasis on entities being responsible for the existence of other entities. Mechanisms in general represent the instantiation of a behavior or the occurrence of a higher-level phenomenon by means of their constitutive parts or entities being systemically organized into realizing activities.

Mechanists can further be divided into three fractions or generations depending on how strictly they consider the constituent parts of their mechanistic explanatory models to be identical in relation to the explanandum phenomenon. Thus, *strict localization of function* mechanists, maintain a modular view of the mind-brain relationship viewing the mind as strongly correlated with the operation and activity of certain computationally encapsulated brain areas. Dynamical *systems-oriented* mechanists incorporate context sensitive and time-bounded aspects to the modular picture of the mind-brain continuum (Bechtel 2015, 2020). They usually refer to brain networks and circuits as the locus of identification in the brain for the execution and maintenance of a certain mental faculty. Mechanists referred to as *epigenetic-molecular* oriented mechanists take the environment and its effects on the molecular level of cellular organization as the locus of identification for cognition by means of referring to the role that molecular-genetic pathways play in the realization of higher-order mental properties (Bickle 2020; Tonegawa et al. 2015).

Even as there are similarities, there are also conceptual differences among these three examples of mechanistic generations. The differences refer mostly to the degree of *empirical resolution*; meaning the level of analysis at which mechanists carry out their investigations. Thus, mechanistic investigation encompasses descriptions of a higher-order phenomena all the way down from the contribution of specific brain areas and structures, through the way these structures represent patterns of brain-network activity, down to the lower level of molecular organization (Robertson and Cohen 2006). Mechanisms can then operate at *multiscale dimensions* and together contribute to the instantiation of the explanandum phenomenon. The level of empirical detail and resolution for the responsible mechanisms varies depending on the kind of mechanistic framework applied to the target explanandum. Thus, as the kind of explanations provided by mechanists moves from a more or less static view regarding the contribution of specific brain areas to a more dynamically oriented understanding of the mechanisms involved, so even changes their view towards a more pluralistic oriented interpretation of the phenomenon itself (Witherington 2014). In other words, the target phenomenon is considered the sum of different organizational scales operating together to enable the realization of the phenomenon (Khaluf et al. 2017). It must also be observed that not all sub-mechanisms necessarily contribute at the same time to the integrity of the target phenomenon as a particular entity. Rather, depending on the character of the phenomenon and often on the embedded dynamics in which it evolves, some sub-mechanisms might be activated while others deactivated, all depending on the circumstances (Deco et al. 2017). Thus, if we take episodic memory as an example, the character and quality of the episodic engrams is affected by the environmental circumstances where the experiences were acquired (Ramirez, Tonegawa, and Liu 2014). The environmental characteristics relevant to the memory acquisition process contribute to the characteristic content of the memory (Wang et al. 2024). These environmental effects activate different sub-mechanisms at different stages in both memory formation and retrieval (Ruiz et al. 2023). Meanwhile the identity of the target phenomenon, the episodic memory as such, remains specifically the same. Thus, the memory of granny's 80^{th} birthday party remains basically the same semantic unit of information distinctive from alternative episodic engrams codified by alternative contexts and situations. Whatever the experiential content of the engram, subvenient neurophysiological mechanisms are active at different scales of physical organization. These scales involve time-bounded activity patterns covering different neuronal structures and network connectivity patterns supporting the distribution of separate cognitive functions (Buzsáki and Vöröslakos 2023, Buzsáki and Tingley 2023). One and the same cognitive function can then be mechanistically realized at the intersection of different scales. The scales range from network-based topology configurations referring to *structural connectome* issues to the functional pattern distribution of nerve cells firings referring to *information processing* issues (Sporns 2013). Therefore, differences exist at the level of the responsible brain-based mechanisms emphasizing both structure and stability as well as dynamism and activity. These constitutive differences at the level of empirical resolution affects also the kind of methodologies mechanists use in their analysis. Thus, while a mechanistic locationalist emphasizes the contribution of a certain brain area to a given psychological phenomenon, an epigenetic-molecular mechanist refers to the realization of the same phenomenon by means of molecular processes and pathways. Still, the three generations of mechanists share an implicit reductionist attitude in the sense that *there is* a basic computation instantiated by specific brain types. This computation, sometimes called a metacomputation, is carried out by a determined brain area or a specific molecular pathway performing a dynamical operation responsible for the integrity of the phenomenon (Piccinini 2010).

7. New Wave Reductionism

Further, all generations combine pragmatically into the framework of *New Wave Reductionism* which is essentially a localist enterprise oriented towards the establishing of type-to-type identity relations between brain mechanisms and mind (Richardson 1999; Bickle 1995). In addition, mechanists assume their models to be explanatory only to the extent that those models track the ontic structure of the world, i.e., the existence of distinguishable parts and objects responsible for the instantiation of observable phenomena and their behaviors. In other words, the models represent the *actual* physical conditions of realization for the phenomenon under investigation. Mechanists start by targeting a suitable phenomenon of investigation like memory consolidation or object pattern recognition. Based on their physicalist commitments and on the level of analysis being applied they proceed further through the following steps and strategies: decomposition of the phenomenon into its constitutive parts, i.e., the neurologically based properties, identification of the activities that those parts engage in, and the creation of a model that integrates the way those activities organize to form the targeted higher-order phenomenon. The decomposition aspect is essential. The identification of the constitutive parts is guided by a metaphysics and methodology reflective of things being made up and nested into each other. Once this strategy has been completed, the type of mechanism mainly involved in the process of decomposition is regarded as *synonymous with* the phenomenon itself. As a result, the explanandum phenomenon has also become *localized*. A crucial requirement for the process of decomposition to work is the following: the mechanisms must be concrete and real entities. In other words, the mechanisms answer to the ontic constraint as stated by Craver (2019), i.e., whatever the units of organization might be they must correspond to *real* things in the world. Neurologically speaking this means the localization of *concrete areas and pathways* in the brain responsible for the instantiation of the target cognitive function. Mechanisms being ontic means further the *reification* and *concretization* of the relevant parts and structures constitutive of the very phenomenon. Mechanistically oriented researchers in the neurosciences that conform to the former strategy are regarded as *classical mechanists*. In other words, they implement and develop the strategy of strict localization of function in line with the ontic constraint. They also search to identify *what* and *where* in the brain the different steps are specifically realized that correspond to the instantiation of a given cognitive function. Important in this procedure of mechanization of function is that the mechanisms as such *integrate* the different parts and steps of the process into a coherent and unified construct, i.e., the mechanism. Only then can mechanistic explanations have both epistemological as well as metaphysical weight. That is, the discovered major mechanism explains the phenomenon by being the phenomenon.

Another fraction of mechanistically oriented researchers, *the modern mechanists*, are ambiguous in their view on the relevance of the ontic constraint. They are very well aware of the *non-strictly localizable* and dynamically changing structure of many cognitive functions and the way their functional patterns are *temporally distributed* in the brain (McCaffrey 2023, 2015). This means that not only the *what* and *where* of the responsible entities such as brain areas bear the explanatory burden but also the "*when*" aspect of the time-bounded correlations between phenomenon and brain states is significant in terms of explanation (Love 2018). For the modern mechanist then any limitations based on the purely ontic relevance of the mechanisms representing real, recognizable and isolated objects is problematic. One reason for this is that mechanistic explanations as mentioned earlier, methodologically speaking rely most of the time on interventionist manipulation techniques to establish the mapping of brain structure to phenomenon. To manipulate and so intervene, the mechanists need to intervene on *concrete* objects of analysis. One caveat with this interventionist strategy is the way in which not only brain areas but also neuronal groups in general change and share functionality in the distributed network-like processing of information implemented by the brain (Ptak, Doganci and Bourgeois 2021). Thus, the more time-bounded and dynamical the behavior of the elements become the more difficult it becomes to *disentangle* them from their relational networks as so the more the difficult to intervene on, i.e., the intended object of intervention becomes less objectual and more difficult to formalize and operate on (van Gelder 1998; Eliasmith 1996; Chemero 2000). The issue here refers to the way mechanists are supposed to understand what it means to concretize and reify entities, i.e., their ontic constraint. Given the more time-bounded perspective on neuronal functionality and communication the character of the entities as such becomes more *malleable* and diffuse. As a result, the more difficult but not necessarily intractable it becomes to translate that dynamics into synchronous *static* models of behavior (Dewhurst 2018). Meanwhile, the classical mechanists have a stricter conception of how concrete and identifiable mechanisms are the same as the targeted phenomenon. For them, the dynamics of the system plays a less conclusive role compared to the coordination of parts by their participation in constitutive relations where structure determines function and causation. The modern mechanists are also committed to identification of mechanisms with the phenomenon, but they are open to questioning the requirement on identification based on strict localization of function. These different attitudes towards localization have consequences when it comes to the role that reduction plays in their mechanistic explanations. There seems to be two alternatives to understand the disagreement on how localization of mechanisms, either strict or distributed, could be compatible with the reduction of the phenomenon to relevant brain mechanisms. The alternatives can be summarized like this:

> **Alternative one**: the mechanisms are strictly reductive because they track identities in terms of type identities; *the explanandum phenomenon is the same as the corresponding brain area or brain state.*
>
> **Alternative two**: the mechanisms are not necessarily reductive because time-dependent and plasticity-based processes observed in the distributed dynamics of brain mechanisms blocks type identities. *Changes in functional networks over time, the brain dynamics, block the one-to-one reduction between the explanandum phenomenon and corelated brain state.*

8. Mechanistic Mereology

Mechanists of both sorts are also committed to the idea that phenomena showing systemic properties cover many levels of organization. Nevertheless, they disagree on the need for causally oriented explanations. Thus, for the dynamically oriented mechanists the actual realization of the phenomenon is determined by the mereological organization, i.e., the effects of the parts on the whole and vice versa. Thus, causation among levels and their objects is irrelevant for the relation between the whole and its parts. The part-whole relation is synchronously constitutive and not causal, i.e., any causation inherent to the system is derivative on the character of its constituent elements. Moreover, being a constitutive relation, *mechanistic mereology* explains the phenomenon in terms of *identities* holding between the relational and topological configurations among the whole and its parts. Thus, for a statue made of copper any causal operations relating parts to the whole at the level of physical organization are identical with the occurrence of the entire statue. Thus, any causal relations among parts of the statue are derivative from the fundamental copper structure. If the statue represents Don Quixote, then constitutively speaking the statue *is* Don Quixote. In a sense there cannot be any causal relations holding among parts of the figure. Thus, Don Quixote's nose is not *caused* by Don Quixote's arm. Rather any part of the statue is constituted by its participation in the form of the whole. Thus, Don Quixote's nose *is* identical with the topological composition of the whole statue system. Don Quixote and its copper statue is here reflective of a basically static relationship. Following this analogy, we may think that even organisms stand in this kind of constitutive relationship. Nevertheless, organisms not only are composed and configurationally located in space by their material structure but are also part of evolutionary and developmentally time-bounded processes. Still, mechanistic philosophy highlights the role that material composition plays in the *identification* of the parts involved. Thus, from a point of view where mechanisms represent reified parts, the phenomenon is identical with its realization mechanisms. The phenomenon must then be *the result of* a bottom-up process of analysis; from the most fundamental levels and their parts to the more derivative and complex ones. This process is based on recognizing the *relevant* level of physical organization, i.e., where in the system do we find the bottom-level of fundamental parts relevant for the integration of the phenomenon. Thus, fixing the relevant bottom-up level of analysis is necessary for the prospects of decomposition, localization and integration of activities to work. Given all these factors obtain, mechanistic philosophy assumes the *metaphysical completeness* of mechanistic explanations.

9. The Bottom Level

Without a relevant or common-ground level of analysis regarding the significant parts or entities from where to start decomposing and localizing, there is a risk that the mechanisms would become too broad and too diffuse and so metaphysically speaking vacuous and unreliable. This means that parts and their properties irrelevant for the explanation of the phenomenon could sneak in into the explanatory models. In other words, mechanists need to implement a principle or criterion of *demarcation and limitation* to establish what are relevant and reasonable boundaries for the identification of bottom-level mechanisms. Moreover, mechanists are physicalists. Thus, whatever that bottom level might be, it must be physical independently of the physical scale of organization referred to. Therefore, when studying the mind-brain relationship, neuroscientific mechanists often opt for the level of neurons and their physico-chemical properties as the relevant bottom line of investigation. As physicalists, they agree on that fundamentally there is only one relevant level of analysis for the mind-brain relationship to start with: the neuronal one; neurons are physical. At least, this should be the starting point from which mechanistic explanations on the brain-mind relationship should originate. Additionally, this way of fixating the relevant level of analysis would not necessarily exclude the possible contribution of *more basic* physical levels of organization. Thus, the *microphysics* of the brain is a contributory level of analysis for the understanding of brain structure and function. The leading metaphysical idea common to mechanistic philosophy is that we can follow the rabbit hole until we reach the very fundamental level from which the mind bottoms out. Here is where the reductive endeavors of the mechanists in general are exposed because they are interested in finding out that fundamental level of physical organization out of which higher-order properties arise. For the mechanistic neuroscientist this means *where* in the physical organization of neuronal components the sum and integration of those components gives rise to the mind. It is in their search for unity and fundamental organization that they share metaphysical commitments with the new wave reductionists (Bickle 2006; Bickle, De Sousa, and Silva 2022). New wave reductionists assume basically that there is only *one* relevant level of reality from which true explanations can be derived: one all-encompassing, undivided physical level of reality (Bickle, 2007; Hemmo & Shenker, 2022). Every mental phenomenon then is *ultimately* identical to the way in which the physical components at this basic level are organized and behave. Thus, mechanists and new wave reductionists share a metaphysical commitment to reductionism in their search for basic identities. They base their reductivist commitment on a 'flat view' of physical realty, i.e., any property in the world is ultimately the expression of synchronous and non-causal physical processes originating at that *fundamental level*. Such level encompasses everything there is in the world. All kinds of higher-level macrophenomena like language and perception can be explained by their relation to that constitutive "flat world" level. Also, mechanists of all generations follow new wave reductionists in their view on how mechanistic mereology explains higher-order properties like mental ones. Thus, mental properties are identical with physical mechanisms in a way that is basically synchronous and non-causal. As an expression of a part-whole relation the mechanization of brain function is characterized by the mereology of the system going all the way back to "flat world." This means that the blueprint behind the organization of significant entities and their relational character at the bottom level is recognizable all the way up to more complex levels of organization. There is then a kind of bottom-up constitutive *mereological inheritance* ascending all the way up to higher-order levels of organization. In other words, the brain represents a mereological unit of organization and mereological inheritance represents a principle of organization. This principle of organization says that at whatever level of physical organization and scales we may encounter the existence of wholes, they are but the sum of their components. Furthermore, any systemic property we refer to as macro-based is the sum or relations holding among microscopic units. Neurons being the basic units of organization in the brain function as an example of physical structures following the mereological inheritance principle. Thus, neuronal structures inherit their organizational characteristics from basic mereological constitution, i.e., the functions of the brain are the expression of microscopic bottom-up constitution. The important question is then whether the inherited characteristic of micro based mereological organization is *continuous* in the sense that at no relevant level of organization higher up in the hierarchy, *emergent* or systemic properties might appear (van Hateren 2015). As an example, we can ask whether biological properties such as heredity and phenotype development are by their very biological character *different* from their more basic physical mereological underpinnings, i.e., their molecular-based genotype networks. A reductively minded neuroscience mechanist would probably agree with saying that at no relevant level of organization there is a break in the ontology of macro properties made up by their more basic parts. Therefore, fundamentally speaking no new properties other than those dictated by physics would organize in such a manner as to facilitate the realization of new functional configurations. In other words, biological properties are in no sense different from their physical constituents. More importantly, mechanists will agree that this mereological linearity will reveal basic identities at the bottom line of analysis being explanatory relevant for higher-level phenomena. In a sense, there is a fundamental level of *memory physics*, *language physics, love physics* and so on. The role of mechanistic explanations operating at the higher-level of the neuronal activity is to mimic the explanatory powers of fundamental physical science. Neuroscientific explanations based on the properties of neurons and their assemblies re-represent an ontological linearity starting with the physics of the brain. Mechanistic neuroscientists represent this mereological linearity by means of the kind of explanatory frameworks typically developed in their field. There are then metaphysically speaking *no ontological gaps* in the mereological understanding of the mind-brain system.

10. Special Sciences

In contrast, a special science researcher will disagree and say that there is no language or memory physics alone but that there is a *psychology* of memory and of language as well representing properties other than solely physical and neuroscientific ones. Thus, the meaning and semantics of language and the contextual embedment of memory contents represent properties not immediately readable from the physics of the brain. Furthermore, these properties are not unambiguously deducible from the syntax of the physical structures alone, but they are part and parcel of a level of organization other than just the neurological. Many higher-order properties are also open to contextual effects that even mechanistically speaking determine their specific qualities (Schauenburg et al. 2024). This is not to say that special scientists deny or undermine the relevance of psychological properties being physically and biologically grounded. It is only that those properties are not reducible to the former, basically because many of their intrinsic characteristics are either *multiply realizable* and/or pluripotential (Suzuki and Vanderhaeghen 2015).

Thus, independently of the mechanistic generation we refer to, there is a tension related to the understanding of what a mechanism is and on how to identify and delimit its structural and functional borders. Moreover, there is also a pressure between the way mechanists interpret and understand the explanatory power behind their mechanistic models. Thus, being aware of the dynamic character and behavior behind many organic processes, mechanists recognize the need and usefulness of dynamically oriented models and explanations. Still, many mechanists remain suspicious about dynamical models and their alleged explanatory powers. According to them the dynamics *describe* the behavior but to describe is not the same as to explain. According to the mechanists it is the synchronous presence and organization of the parts that matters for the development of real explanations in the neurosciences. Only by knowing what the relevant bottom-up neuronal structures are and how they relate to each other mechanistically can we develop explanatory models suitable for the neurologically based behavior of mental operations. Explanation consists then in the operation of the details, i.e., the objects and entities involved in the processes. The problem with this view is that the more the dynamics are recognized as integral elements to the nature of the phenomenon under analysis, the more the effects of intercorrelated patterns of activity play a role in the explanations. Moreover, the mechanisms themselves at the level of components behave dynamically (Bechtel 2019; Gilbert 2016). The more interconnected the parts, the more "nested" the character of the constituents. Mechanists seek for explanatory unity by highlighting the identity character of the components. Thus, at one level of analysis where constitution and parthood are primordial the relevant details are pretty much static and essentialist in character, i.e., unchangeable and fixed. At another level of analysis where the dynamics of the system and its complexity is considered, the more the malleable and irregular the identity of the parts. The tension then becomes obvious on the one hand between stable and recognizable elements and on the other hand partially concrete and dynamically malleable patterns of organization. Thus, the more dynamic, meaning the more distributed and flexible their identity, mechanisms as theoretical constructs explain in virtue of their participatory role in the activity flow. This is in line with the ontological commitment of mechanistic explanations; to explain is to discover the role that real objects of the world play in the making of natural phenomena. It is only that the reality of these components is now due to the dynamics of the system more flexible and relational. On the other hand, if the identity of the components becomes "unbounded" or muddied by the dynamics of the system then the more difficult to meet the requirements on localization, decomposition, identification and integration of objects into wholes. To solve this problem mechanistic philosophy would have to sacrifice its commitments to essential types and emphasize both the synchronous and diachronous character of the phenomenon. Thus, mechanistic explanations would need to take more seriously the time-bounded *diachronic evolution* of the phenomenon together with the *here and now* synchronous character of the components. Leaving out the diachronous "historicity" of the explanandum would from the point of view of many complex systems like biological ones seem almost impossible. For a living organism or an organ like the brain such a separation between its synchronous and diachronous dimensions would seem unbearable (Jablonka and Ginsburg 2022; Noble 2012). An organism as a living entity including all its embodied characteristics, both physiological and cognitive, is inseparable from the conjunction of both its synchronous and diachronous realization bases. One solution to this conundrum would be to sacrifice the ontic commitments of mechanistic philosophy and its requirements on "reification" and go full-blown "dynamic." Thus, mechanistic models would just pick up powerful *epistemic tools.* Mechanisms then pragmatically *describe* the phenomenon without any requirement on the identification of fixed identity types. The problem then is that mechanistic explanations would by means of becoming epistemic be *relativized* to the kind of descriptive background in which the dynamical processes are conceptually framed.; information flow diagrams, schemas, mathematical models and so on (Miłkowski and Hohol 2020). There is no more any "ontic power" or ontological weight behind the explanations and so they are no longer "mechanical" explanations at all.

11. Staying "Ontic"

The solution to this conflict would be to remain "ontic" and try to reify the relation between mechanism and dynamism. Mechanists would achieve this by insisting on that at the very ultimate level of physical analysis we still can describe the dynamics in term of identities. Moreover, we need to explore this possibility because of the requirement on *identification of parts* imposed on mechanistic explanations for them to make sense at all. If there are no identities in terms of clearly delimited parts, then mechanisms do not really explain, because it is the very identity of specific mechanistic entities that perform the work associated with the phenomenon. The problem with this solution is that at the very critical bottom-up physical level of analysis, there might be no more than *relational patterns of activity* and time-framed processes performing the work associated with the phenomenon (Davies and Gribbin 2007, Polkinghorne 2000). Thus, no matter what type of mechanist you are, appealing to the possibility of a physical bottom level of reality composed of delimited and unchanging parts won't work. A way to avoid this situation would be to say that the conflict between mechanistic and dynamical explanations is just linguistic. This is so because eventually only mechanisms and their parts are real. Dynamicists as well as mechanists refer in their explanations to properties the character of which represent natural structures and properties typical for *objects.* The dynamicist deals with objects the reality of which are mainly abstract while the mechanist deals with objects the reality of which is essentially physical. The mechanist either knows or intuitively recognize this condition as essential for explaining the matching of properties at different levels of organization to each other. The matching must refer to something being stable and recurrent enough to constitute an *object* of reality. Thus, my episodic memory of my granny's 80th birthday might be how embedded, dynamical and relational you want it to be but ultimately the memory is a natural kind the character of which picks up the presence of an undivided, recurrent and essentially "self-confined" *physical* property, the engram. It is this self-enclosed and delimited structure that makes the memory of granny's birthday party part of the world at all. If I want to explain the character of this memory in scientific terms then I do best according to the mechanists and new wave reductionists to frame it in an explanatory framework that involves a recognizable state of the world, i.e., an object. This object as a self-contained physical property is part of a memory-forming brain-based mechanism. Only in this way would any dynamical account of grandma's birthday party engram make sense. This way both mechanistic and dynamically oriented explanations are compatible. On the other hand, if natural kinds in general are not the sort of self-contained and indivisible properties the reductivists have in mind then the problem reappears. Thus, if even at the "flat world" level of Flat Physicalism preferred by many machinists as the appropriate metaphysical background, there really are no objects but rather continuously changing, coming and reordering multiscale *relational patterns*, then the very idea of objects and their parthood essential to the mechanists becomes rather hollow. Furthermore, if there really are no parts as self-contained objects then there are ontologically relevant mechanisms either. What really becomes a threat to the mechanist philosophy is then the possibility that the sort of natural kinds they refer to in their models of explanation bear no ontological status as *objects and things* and so cannot account for the discovery of identities. This is not to deny the existence of things being localizable and identical to the possession of certain recurrent properties in space and time. Rather, this is to recognize the possibility that what we take to be localizable natural kinds is but an epiphenomenon or at best an abstraction from a more basic relational space-time background (Austin 2016, 2020; Stengers 2008). If this is the correct interpretation of reality at the bottom level of physical organization then the principle of mereological inheritance would be broken. This in turn represents a bigger threat to the explanatory *completeness* of mechanistic models. This is mainly so because the braking down of mereological physical continuity would open for gaps in the ontology of the world. Those gaps might be filled by natural phenomena and their properties representing irreducibly autonomous units if organization at their own distinctive levels of organization. i.e., minds, species, economies. Also, natural kinds not being identical to types and their physical instantiations defies decomposition as the essential step in the final goal of mechanization of function which is the localization of identity types. Furthermore, a "relationalist" view on the character of natural kinds is compatible with the tenets of multiple realizability. Thus, given the case that one and the same higher-order phenomenon is stable enough to be realized by a multitude of different relational configurations and their properties, that phenomenon is multiply realized. A phenomenon can still be mechanistically realized by many different mechanisms. In that case, the realizing mechanistic units would because of their multiple realizability be *tokens* rather than types. In that case where a phenomenon is multiply realized by different mechanisms what we physically speaking at best can talk of are *tokened* physical properties instead of type-based identities.

12. Alternatives for the Mechanist

Nonetheless, because of their reductionist commitments, mechanists are compelled to reject these non-reductionist implications regarding the multiple realizability of mind (Baetu 2022). This is not to deny that the work of the mechanists in fact plays an important role in the understanding of how higher-order properties are physically instantiated by means of neuronal properties (Simons et al. 2017; Gouin et al. 2017). Nevertheless, mechanistic explanations cannot replace psychological explanations as such. The mechanists can *contribute* to the work done in the special sciences like psychology, but they must be prepared to give up their reductionist attitudes. They need to do this because of some unpalatable options reflecting the character of many higher-order systemic properties like psychological ones:

a) Higher-order properties have causal effects of their own. Higher-order properties are endowed with systemic effects recognizable at the lower level of their physical components. Thus, there *are* interlevel effects regarding properties located at different levels of organization; "the mind *moves* the body." Mechanists must therefore reconsider to abandon their strong commitment to non-causal mereology blocking *interlevel* causation (Krickel, 2017).
b) Dynamical models of psychological functions do not only describe but explain. The behavior and function of cognitive agents is a dynamically grounded process best analyzed with the methods of systems theory and their mathematical tools. Mechanists must therefore at least be willing to accept the need for mechanistic models being

complemented by the virtues of time-dependent dynamical models; “the mind *happens* at different times.”

c) Thus, they must also accept that many phenomena in nature are dynamical and that the proper level of *explanation* for those phenomena is at the quantitative abstract level; “the mind *abstracts from* the complexity of its environment.”
d) They must also accept that cognitive phenomena are also neuronally distributed and plasticity-based processes cutting across levels and scales of organization in the brain. Distributed here means variability at the level of realization. The mind is thus a *multiscale realization phenomenon* based on a variety of physical bases available for its instantiation.
e) They must therefore be prepared to endorse multiple realizability as a serious metaphysical option.
f) Methodologically speaking, they must also be prepared to accept that multiple realizability represents a proper way of guiding research on the mind by means of emphasizing a *pluralistic* attitude to the brain-mind relationship.

The following is a final description of why mechanists should recognize their failure to explain properties endorsed by the special sciences in essentially mechanistic and reductivist terms (Fodor 2008).

13. Cognition as Adaptive Abstraction

Perception, memory systems and even language rely on both evolutionary and developmentally imposed constraining conditions. This is reflected on the way brains encode information at the neuronal level (Friston and Kiebel 2009; Bates 1994; Hardcastle 2001), i.e., the cognition. Thus, perception, memory and even language depend on limited physiological and computational powers. Analogically speaking, the cognitive work performed by the brain in the framework of those constraining conditions corresponds to the brain’s software. The brain is also a physical object characterized by the performance of different mechanisms. Yet many of those mechanisms and the properties they instantiate are distributed and dynamic in character; the *where* and *when* of cognition. One essential function of the brain-cognition system is to *predict* adaptive behavior in terms of the recurrent re-evaluation of the information flow between perception and the neuronal systems encoding that information (Friston 2012; Mastrogiorgio 2022). The cognitive and perceptual work of the brain as prescriptive and anticipatory is dynamical in character (Hohwy 2020, 2021). This means perception and cognition are time-bounded processes with embodied, embedded, and enactive characteristics (Feiten 2020; Froese 2015; Silberstein and Chemero 2013). These characteristics are constitutive of a *cognitive agent,* and they bring with them borders as for example, between the agent's body perception–and the agent's physical world. As such the existence of these borders involve a necessary perceptual and cognitive *abstraction* from the details in the environment where the agent dwells. Such abstractions are dynamical in character. To function, they need to track the *actual* position and goals of the agent in its trajectories across physical phase-space. Those trajectories reflect the time-dependent dimension of cognitive and perceptual processes (Pöppel 2009; Smith and Katz 1996). Thus, the mapping of relevant physiological brain mechanisms onto cognitive processes is also dynamical in character. Such dynamism should facilitate the implementation of *abstraction* as a general feature in the agent's cognitive behavior. In other words, the agent's brain is continuously calibrating its position and goals in reference to the agent's proximal and distal needs by means of forecasting anticipatory models of reality (Krupenye 2016). The reliability of these anticipatory models is continuously evaluated in terms of their relevant adaptability and survival fitness to the organism. Furthermore, *abstraction from the details* is a continuous process formed by interplay between the brain and its environment and as such it represents a level of analysis proper to the macroscopic needs of the organism. Abstracting away from irrelevant details is adaptive and meaningful for a cognitive agent. There is no need for an agent to be aware of the detailed computational mechanisms and processes of its own brain; a kind of brain-based computational impenetrability. Cognition and brain form an *adaptive axis* of information processing, a *brain-cognition axis*, that is constrained, among other things, by the access and flow of energy available to the system (Pepperell 2018). What makes the abstractions at the level of the brain-cognition axis truly relevant for the needs of the organism is their capacity to enable the agent to react properly by making use of context sensitive brain-based networks representing the agent's cognitive, social and physical environment (Hovhannisyan and Vervaeke 2022). Thus, the brain forms abstractions that encode knowledge from its current environmental niche both *synchronously*–here and now–as well as *diachronously*, i.e., from past experiences. In this way it forms possible time-based prognoses and ways of action into the future preparing the organism in advance for possible outcomes; the *when* of cognition (Leuridan and Lodewyckx 2021). Mechanistic explanations in seeking to identify the agent's cognitive strategies with strict mechanisms and properties localized to specific brain structures- the *where* of cognition- fail to fully explain and cover the adaptive value and character behind "in time grounded" brain abstractions. The abstractions represent the dynamics of organismal networks the existence of which is "coarse," yet adaptive for the needs of the agent. The modelling of those networks, and the abstractions based on them, requires that we view the agent in its integrity as an adaptive dynamical system. The existence of *coarse cognition* and the kind of abstractions based on them represent the *how* and *why* of the brain-cognition axis. The brain is the carrier of macrolevel representations implemented by a macrolevel-organized creature whose adaptive needs have developed in response to reliable environmental signals exerting developmental pressure both on its genotype and phenotype (Mazzocchi 2008, 2016). Brains evolved under such conditions need to respond quickly and effectively to the ongoing communication between agent and its physical environment. This is achieved by the acquisition of a biologically based general adaptive capacity; the instantiation of *survival interface structures* both mentally and neuronally (Hoffman 2019). These brain-based survival interface structures are neuronally embodied circuits actively representing the world. They work without the need for explicitly detailed-loaded computations. These neuronally embodied circuits process *enough* information in a way just sufficiently detailed for promoting the subject's main goal, survival. That is, both the circuits and the informational structures they realized are *coarse* biological adaptations. This is how the brain systemically interacts with its world and why that interaction must for survival reasons be coarse but effective enough to enable the development of fast anticipatory mental and cognitive structures (Kano 2019). This is also why an organism's psychology is coarse because it lives in a world of macro dimensions involving both other agents and material macroscopic objects (Falikman 2023). The macro character of the world as perceived by the agent exercises an evolutionary pressure on its nervous system to develop the right kind of mental and computational representations. At the physical implementation level, the corresponding neuronal realization bases must also keep the same pace as the computational structures. Thus, they must also accommodate to the coarse character of the organismic needs. As a result, brains develop neuronal networks configurations to implement their ability to develop parallel distributed computations. These networks represent dynamical activation patterns specialized for abstraction from details both at the level of their single neuronal units as well as at the level of their connective topology (Quiroga et al. 2005). The main message here is that the characterization of these neuronal patterns is determined by their malleability, processual properties, dynamical patterns of organization and behavior as well as their multiple realizability (Anderson 2010, 2016).

Conclusion

The mind-brain relationship can be characterized in terms of mechanistic constitution. Here the synergistic effect of neural mechanisms represented both by single cell as well as network-based processes is simultaneously constitutive. It means that brain structure and function work as parts of a mereological relation. Here the system's activity results from components acting in parallel at many scales of organization through the instantiating effects of grounding mechanisms and their substructures. This organizational topology as instantiated by brain networks constitutes the physical realizing base on which higher-order properties such as mental ones depend on (Wu 2021). Under the condition of there being a difference between the intra-causal activity of minor sub-mechanisms and the interlevel coordinated activity of a main mechanisms, there is a possibility that the mind as a *systemic property* is even mechanistically speaking irreducible (Krickel 2018). This would symbolize the explanatory power behind mechanistic philosophy which assumes the *concrete* reality of mechanisms.

Mechanistic philosophy relies on three conditions. One being that we have a coherent common ground of analysis for the understanding of what it means to be a mechanism. The second refers to a methodological concern where decomposition and integration of *objects* and their relations into structural and functional complexes realize the characteristics of the explanandum phenomenon. The third condition refers to the possibility of *localizing* the phenomenon qua mechanism through the establishing of *type identities* representing the structural and functional complexes of mechanisms. Were all these conditions fulfilled it would imply the in-principle completeness of mechanistic explanations and the actual *mechanization* of the mind. This would be in line with the commitments of mechanistic philosophy. The analysis conducted in this work contends that hardly all these conditions are really met. Mechanists have a difficult time trying out an unambiguous definition of what it means to be a mechanism specially when considering the ontic constraint imposed on the *reification* of constituent parts. As we have seen ontological commitments behind mechanistic philosophy rely on an interpretation of natural kinds as basically *essentialist* objects. This is not the only possibility of conceiving of natural kinds even in the context of mechanistic explanations. A *process-oriented* view based on a *relationalist* grounding of natural kinds involves an alternative metaphysical view. This has effects on the role that neuronal structures and their components play in the realization of mental properties. We have also seen that decomposition and integration of components into the mereology responsible for the realization of higher-order properties requires having a clear-cut boundary for the implementation of *relevant* mechanisms. Such a boundary is in many cases the result of an *ad-hoc* decision based on the theoretical and methodological mechanist background of the researcher. Thus, there is no such epistemically independent fundamental level out of which bottom-out mechanistic explanations in general. Finally, many higher-order mental properties are integrated into contextually sensitive frameworks for the guiding of behavior. The social dependency of many intentional mental properties reflects their evolutionary roots as well as intrinsic adaptive value (Grosse 2010; Tomasello 2023). The synchronous and diachronous characteristics of *predictive models* as implemented by the brain guide behavior both probabilistic and intentionally (Friston 2010).

Such models are oriented towards a balance between costs and benefits with the goal of optimizing the organism's behavior. An important feature of this optimization is the development of both coarse mental and neuronal structures specialized in the abstraction from the details. The brain's abstracting mechanisms realized by large scale neuronal topologies and assemblies inform the organism about the relevant number of details necessary to compute the conditions of its macro-based environment. Such abstracting characteristics even when grounded on physical brain properties are not defined by one-to-one *type identities*. Rather, the *functionally enough* abstracting capacity of brains is based in the contextual multiscale properties of brain networks responsible for the *multiple realization* of mental states (Wu 2021). We recognize the irreducibility and context dependent character of the mind in the functional malleability of our attitudes, beliefs and intentions (Liu 2014). Mechanistic philosophy needs to address all these points either by reconsidering its metaphysical or methodological axioms or by way of reinterpreting the completeness of mechanistic explanations. The emphasizes in mechanistic explanations of the mind remains on the establishing of type identities between mental properties and neurophysiological brain states. Thus, mechanistic explanations are inherently reductionistic. On the other hand, much speaks against such a reductive view of the mind even when considering its physical underpinnings. The irreducibility of mental states and their dependency on physical states opens for a *non-reductive physicalist* metaphysics of mind. The result of this analysis leads to the conclusion that mechanistic explanations remain *reductive* about the mind.

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