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ORDER: GOD'S, MAN'S AND NATURE'S

Physicalism and the Part-Whole Relation

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Abstract: In this paper I intend to analyse whether a certain kind of physicalism (part-whole-physicalism) is supported by what classical mechanics and quantum mechanics have to say about the part whole relation. I will argue that not even the most likely candidates – namely cases of micro-explanation of the dynamics of compound systems – provide evidence for part whole-physicalism, i.e. the thesis that the behaviour of the compound obtains *in virtue* of the behaviour of the parts.

In this paper I intend to analyse whether a certain kind of physicalism (part-whole-physicalism) is supported by what classical mechanics and quantum mechanics have to say about the part whole relation.

1. Physicalism

In this section I will first characterize what I take to be the core physicalist intuition. Next I will disambiguate two physicalist claims and will then make one of the physicalist claims as precise as is necessary for the purposes of this paper.

In the last decades physicalism is no longer taken to be a linguistic thesis about the vocabulary used in the sciences[1] nor as a methodological claim but rather as metaphysical or ontological thesis:

„As a preliminary, note that contemporary physicalism is an ontological rather than a methodological doctrine. It claims that everything is physically constituted, not that everything should be studied by the methods used in physical science." (David Papineau 2001, 3)

Different authors use different vocabulary when they characterize what they take to be the core physicalist intuition. Jaegwon Kim, for instance, describes his own view (which he calls "physicalism" elsewhere) as follows:

[1] Carnap and Neurath advocated physicalism as a thesis about the unity of science. They assumed that this unity can be achieved to the extent that statements containing non-physcial vocabulary can be translated into sentences containing physical vocabulary only (see Neurath 1932 and Carnap 1932).

The broad metaphysical conviction that underlies these proposals is the belief that ultimately the world – at least, the physical world – is the way it is because the micro-world is the way it is [...]. [Kim 1984a, 100]

(The qualification in the parentheses has to be dropped for physicalism proper) Kim uses 'because' to express that the macro-world *depends* on the micro-world. A central tenet in the debate about physicalism is to say something informative about this dependence relation. Philip Pettit invokes political metaphors for this purpose:

The fundamentalism that the physicalist defends gives total hegemony, as we might say, to the microphysical order: it introduces the dictatorship of the proletariat [Pettit 1993, 220/1].

And elsewhere:

[M]icrophysicalism [...] is the doctrine that actually (but not necessarily) everything non-microphysical is composed out of microphysical entities and is governed by microphysical laws [Pettit 1994, 253].

Another expression that is sometimes used to characterize the dependence relation is "in virtue of". Barry Loewer, for instance, writes:

„Physicalism claims that all facts obtain *in virtue* of the distribution of the fundamental entities and properties – whatever they turn out to be – of completed *fundamental physics*." (Barry Loewer 2001, 37)

I will use Loewer's formulation as my starting point for an explication of physicalism. There are (at least) two respects, in which Loewer's formulation is in need of clarification: First, as long as we do not know whether or not the inventory of a completed fundamental physics contains e.g. mental properties we do not know how to argue for or against the plausibility of physicalism.[2] My approach in this paper is to bypass this problem and to simply assume that a completed physics will be relevantly similar to today's physics. Under this premise it makes sense to ask whether physical theories that are currently in use shed some light on the credentials of physicalism.

The second notion that is in need of clarification is "in virtue-of". It is often taken to be notoriously vague. In order to evaluate to what extent (a certain form of) physicalism is supported by classical or quantum physics the *in virtue*-relation has to be made sufficiently precise.

However, before I approach the issue of clarifying the *in virtue*-claim I will disambiguate two different kinds of physicalism – levels-physicalism and part-whole-physicalism: The different issues at stake can be illustrated by an example. Consider a case in which the state of a whole (the ferromagnetic state of a piece of iron) is explained in terms of the states of the parts (magnetic dipoles of the iron-atoms). Two questions/issues can be distinguished: First, we can ask whether

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[2] This problem is a variant of what has been called Hempel's dilemma. Physicalism can either be defined via reference to contemporary physics, but then it is most probably false or it can be defined via reference to a future or ideal physics, but then it is trivial in the sense of not falsifiable, because we are unable to predict what a future physics will contain (see Hempel 1969; Crane and Mellor 1990; Melnyk 2003, 11-20 and Stoljar 2009).

the ferromagnetic state of the piece of iron corresponds to some microstate of the piece of iron for instance a state that can be described as a so-called spin-wave state of the piece of iron. This issue concerns the relation of two kinds of states of the same system—the ferromagnetic state and the spin-wave-state of the piece of iron. A second question is whether the spin-wave state of the piece of iron can be explained in terms of the states of the individual atoms and certain relations and interactions among them. This question concerns the relation between the state of the whole piece of iron on the one hand and the states of its components on the other hand: how do the individual states of the atoms add up to the spin-wave-state of the whole? The latter issue concerns the relation between parts and wholes, not between two states of the same system.
More generally, one issue concerns levels. How do entities picked out by non-fundamental terminology, such as biological or psychological terminology (or "magnetization"), relate to fundamental physical entities? A physicalist with respect to levels claims:
Levels physicalism: Putatively non-physical properties obtain *in virtue* of (fundamental) physical properties.
A second issue concerns parts and wholes. A physicalist with respect to the part-whole-relation claims:
Part-whole physicalism: The properties of compound systems are the way they are *in virtue* of the properties of their parts (and some further facts about how the parts interact and how they are related).[3]
In this paper I will be concerned with the question whether part-whole physicalism is supported by what classical mechanics or quantum mechanics have to say about the part-whole relation.

2. Physicalism, Supervenience and Duplicates

Loewer's characterization of physicalism as well as my own characterizations of levels-physicalism and part-whole physicalism contain the expression „in virtue". Very often the *in virtue*-claim is spelled out in terms of supervenience and related concepts such as duplicates. I will not go into the details of this discussion but only briefly indicate why this approach is not satisfactory.
Loewer discusses Frank Jackson's explication of physicalism. According to Jackson physicalists hold:
(P) Physicalism is true iff every world that is a minimal physical duplicate of the actual world is a duplicate simpliciter.[4]

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[3] For a more detailed analysis of the difference between levels-physicalism and part-whole-phyicalism see (Hüttemann et al. 2005):

[4] The formulation is due to Barry Loewer (Loewer 2001: 39). Frank Jackson defends his position in (Jackson 1998: Chapter 1).

Principle (P) is meant to capture the idea that once the physical facts of our world are fixed all the facts of our world are fixed. If (P) is true all non-physical facts globally supervene on the physical facts.

As Jackson acknowledges definitions of physicalism have to capture asymmetry claims that are associated with it.[5] However, as Loewer points out Jackson's principle (P) fails to capture the *in virtue*-claim (Loewer and Jackson discuss what I have called "levels-phyicalism"):

"The worry is that (P) may not exclude the possibility that mental and physical properties are distinct but necessarily connected in a way that neither is more basic than the other. In this case it doesn't seem correct to say that one kind of property obtains in virtue of the other's obtaining." (Loewer 2001:39).

Claims about supervenience and duplicates do not *entail* that properties of one kind obtain *in virtue* of properties of another kind. Loewer acknowledges this problem without providing a solution:
"if considerations about the nature of necessity do not rule this possibility out then we must admit that (P) is not quite sufficient for physicalism. However, it seems to me that if we had good reasons to believe (P), then, unless we also had some reason to believe that despite (P) mental facts (or some other kind of facts) do not hold in virtue of physical facts, we have good reason to accept physicalism." (Loewer 2001, 39)

In the remainder of this paper I will argue that classical and quantum mechanics provide good reasons for the claim that in the case of part-whole-physicalism the *in virtue*-claim does not hold. This argument, however, presupposes that something more is said about the *in virtue* relation.

3. The *in virtue*-relation

Recently various authors have attempted to explicate such expressions as „fact F obtains in virtue of fact G" or „fact F is grounded in fact G" (Rosen 2010; Audi forthcoming). My aim is not to present a complete account of the *in virtue*-relation. For the purposes of my argument I only need to point to one feature of the *in virtue*-relation that I take to be rather uncontroversial. My presentation will follow a recent paper by Gideon Rosen.

Rosen starts with the observation that *prima facie* we seem to understand claims as the following:

- The dispositions of things are grounded in/obtain in virtue of their categorical properties.
- If an act is wrong, it is wrong in virtue of the act that makes it wrong.
- Semantic facts such as *John means addition by '+'* are grounded in/obtain in virtue of non-semantic facts.

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[5] "Physicalism is associated with various asymmetry doctrines, most famously with the idea that the psychological depends in some sense on the physical, and not the other way round." (Jackson 1998, 14).

In the face of doubts whether there is a univocal *in virtue*- or *grounding*-relation Rosen proposes to develop a sketch of a theory of the *in virtue*- or *grounding*-relation and then to see whether it proves fruitful.

What needs to be analysed are sentences like „The fact that p obtains *in virtue* of (is grounded in) the fact that q“ where ‘p’ and ‘q’ stand for propositions. Following Rosen, I will introduce some notation:

[p]: the fact that p

[p] $\leftarrow$ [q]: „[p] is grounded in [q] “

[p] $\leftarrow \Gamma$: “The fact that p is grounded in the collection of facts Γ.”

[p] $\perp \leftarrow$ [q] $=_{def}$ for some Γ: [p] $\leftarrow \Gamma$, [q]: „[p] obtains partially in virtue of (is partially grounded in) [q] “

We can now reformulate the doctrine of part-whole-physicalism in terms of this terminology. The claim

„The fact that a compound has certain properties obtains *in virtue* of (is grounded in) the facts that the parts have certain properties and some further facts about how the parts interact and how they are related.“

can be reformulated in terms of the following abbreviations:

[w]: the fact that the compound/whole has certain properties

[p_1]: the fact that part p_1 has a certain property, etc.

Δ: further facts about how the parts interact and how they are related.

Part-whole-physicalism can now be written as:

$$[w] \leftarrow [p_1], [p_2], ... [p_n], \Delta$$

Furthermore, we can reformulate claims like the following: “The fact that a whole has certain properties *partially* obtains in virtue of (is *partially* grounded in) the fact that part [p_1] has certain properties.” and similar claims for [p_2] etc.:

[w] $\perp\leftarrow$ [p_1]

[w] $\perp\leftarrow$ [p_2]

etc.

Rosen’s approach in developing a theory of the *in virtue*- or *grounding*-relation is to distil certain principles, which we hold to be uncontroversially true in all those cases where we seem to understand *in virtue*-talk. The first such principle is asymmetry:

- asymmetry: if [p] $\perp \leftarrow$ [q] then: not [q] $\perp \leftarrow$ [p]

To give an example: When we claim that semantic facts obtain in virtue of non-semantic facts we (implicitly) deny that non-semantic facts obtain in virtue of semantic facts.

From the principle of asymmetry the principle of irreflexivity follows:

- irreflexivity: not [p] $\perp \leftarrow$ [p]

Rosen furthermore argues that a principle of transitivity holds:

- transitivity: if [p] ← [q], Γ and [q] ← Δ, then [p] ← [q], Γ, Δ

and that we take the *in virtue*-relation to be non-monotonous: If we claim that dispositional facts obtain *in virtue* of the intrinsic categorical facts of an object we do not therefore endorse the claim that dispositional facts obtain *in virtue* of the intrinsic categorical facts of an object plus certain extrinsic facts.

Be that as it may, all I need for the purposes of this paper is the asymmetry-principle. The argument to be presented does not commit me to Rosen's overall project. From the above considerations only the following claim is relevant for the remainder of the paper: Whatever else we imply by endorsing the claim that the fact that p obtains *in virtue* of the fact that q, we do thereby endorse the principle of asymmetry.

4. Micro-explanation

Part-whole physicalism claims that the properties of compound systems are the way they are *in virtue* of the properties of their parts (and some further facts about how the parts interact and how they are related). There is an *asymmetrical dependence* of the behaviour of the compound on that of the parts. Physics seems to provide ample evidence for this claim. Robert Klee, for instance, argues:

Micro-explanation is powerful in virtue of the fact that when a level of organization within a system can be explained in terms of lower-levels of organization this must be because the lower-levels (i.e. the micro-properties) determine the higher-levels (i.e. the macro-properties). This is why micro-explanation makes sense – the direction of explanation recapitulates the direction of determination. (Klee 1984, 59/60).

So, the argument runs like this: The fact that we can explain the behaviour of compound systems (wholes) in terms of the behaviour of its parts supports the claim that there is a direction of determination from the micro-level to the macro-level. The fact that determination is directed warrants the claim, that what happens at the macro-level happens *in virtue* of what happens at the micro-level.

In what follows I will take a closer look at this kind of argument from physics to physicalism.

Explaining the behaviour of compound systems in terms of their parts may mean more than one thing. So what does 'behaviour' mean in this context? With respect to the behaviour of a physical system, we can distinguish the state of the system, its constants, and its temporal evolution. Some quantities of a physical system are constant; others vary with time. In the case of a single classical particle, we can distinguish position and momentum as changing quantities, whereas mass remains constant. The values of the varying quantities at a particular time are called the state of the physical system at this time. However, the constants and the state of a system do not determine the complete system's behaviour. Furthermore, we have laws

that describe the connections between the various quantities involved, and in particular, they describe how the state of the system develops in time. What these laws describe is the temporal evolution or dynamics of the system. Explaining the behaviour of compound systems in terms of their parts may either refer to the state or to the dynamics.

Micro-explanation of the *state* of a compound system explains the state at a certain time in terms of the states of the parts at the same time. Thus, we might explain why a compound system, such as an ideal gas, has the determinate energy value E* (the macrostate) by pointing out that the constituents have the determinate energy values E^1 to E^n (the states of the parts).

Quantum entanglement is a prominent *counter*example to this kind of microexplanation. It is not, in general, possible to explain the state of compound quantum mechanical systems in terms of the states of the parts because quantum mechanics does not, in general, specify such states for the parts.

This is bad news for the part-whole physicalist (assuming that the evidence for part-whole physicalism consists in successful micro-explanations), but not as bad as it might seem. There is another dimension to micro-explanation – micro-explanation of the dynamic of the compound system – that is not confronted with counterexamples from quantum mechanics.[6]

Micro-explanation of the dynamics of a compound specifies the temporal evolution or dynamics of the system in terms the dynamics of the parts (plus interactions among the parts). This is why it is appropriately considered as a form of micro-explanation: the behaviour of the compound (the dynamics of the system) is explained in terms of the behaviour (dynamics) of the parts.

In what follows I will focus exclusively on the micro-explanation of the dynamics of a system, because it is the only option for the part-whole physicalist.

So, how does this kind of micro-explanation work? By way of illustration, a simple example is a non-interacting two-particle system. The first step in the explanation or analysis of the dynamics of this system is the identification of its parts, i.e. the two (isolated) one-particle systems.

The second step consists in the determination of the dynamics of the isolated one-particle system. According to classical mechanics the complete behaviour of a one-particle system is specified by its path in six-dimensional phase-space. A point in phase-space represents a state of a classical system. The Hamilton equations specify the system's time-evolution or dynamics and thus its path in phase-space. These equations in turn require a classical Hamilton-function. The dynamics of an isolated particle, for instance, can be described by a classical Hamilton-function of the form $H = \mathbf{p}^2/2m$, where p is the momentum and m the mass of the isolated particle.

For a non-interacting two-particle system we first need to specify two six-dimensional phase-spaces, one for each of the particles as well as a classical Hamilton-function of the above form for

6 See (Hüttemann 2005) for details.

each of them. That, however, is not yet a description of a two-particle system. It is a description of two separate one-particle systems.

What we furthermore need is something that tells us how the descriptions of the behaviour of subsystems have to be combined so as to obtain the description of the behaviour of the compound system. We basically need the following information: 1) The phase-space for a compound system is the direct sum of the phase-spaces of the subsystems. Thus, for the two-particle system we obtain a twelve-dimensional phase-space. 2) The Hamilton-function for the compound system is the sum of those for the isolated constituents. Thus the dynamics of the system of two non-interacting particles in classical mechanics is described by a Hamilton-function of the form: $H = \mathbf{p}_1^2/2m_1 + \mathbf{p}_2^2/2m_2$.

This is the third and final step of the explanation or analysis of the dynamics of the non-interacting two-particle system: adding up the contributions of the parts according to laws of composition.

In the presence of interactions we have to introduce a further term into the Hamiltonian, e.g., a term for gravitational interaction such as $-Gm_1m_2/r$, where G is the gravitational constant and r the distance between the two particles.

Let me add an example from quantum mechanics: carbon monoxide molecules consist of two atoms of mass m_1 and m_2 at a distance x. Besides vibrations along the x-axis, they can perform rotations in three-dimensional space around its centre of mass. This provides the motivation for describing the molecule as a rotating oscillator, rather than as a simple harmonic oscillator. The compound's (the molecule's) behaviour is explained in terms of the behaviour of two subsystems, the oscillator and the rotator. These parts are not spatial parts, they are sets of degrees of freedom. The physicist Arno Bohm, who discusses this example in his textbook on quantum mechanics, describes this procedure as follows:

We shall therefore first study the rigid-rotator model by itself. This will provide us with a description of the CO states that are characterised by the quantum number n=0, and will also approximately describe each set of states with a given vibrational quantum number *n*. Then we shall see how these two models [The harmonic oscillator has already been discussed in a previous chapter. Author] are combined to form the vibrating rotator or the rotating vibrator (Bohm 1986, 128).

This is a perfect illustration of a quantum-mechanical micro-explanation. It is in carrying out this programme that Bohm considers the following subsystems: (1) a rotator, which can be described by the Schrödinger equation with the Hamiltonian: $\mathbf{H}_{rot} = \mathbf{L}^2/2I$, where $\mathbf{L}$ is the angular momentum operator and I the moment of inertia. (2) an oscillator, which can be described by the Schrödinger equation with the following Hamiltonian: $\mathbf{H}_{osc} = \mathbf{P}^2/2\mu + \mu\omega^2\mathbf{Q}^2/2$, where $\mathbf{P}$ is the momentum operator, $\mathbf{Q}$ the position operator, ω the frequency of the oscillating entity and μ the reduced mass. He adds up the contributions of the subsystem by invoking a law of composition:

IVa. Let one physical system be described by an algebra of operators, A_1, in the space R_1, and the other physical system by an algebra A_2 in R_2. The direct-product space $R_1 \otimes R_2$ is then the space of physical states of the physical combinations of these two systems, and its observables are operators in the direct-product space. The particular observables of the first system alone are given by $A_1 \otimes I$, and the observables of the second system alone are given by $I \otimes A_2$ (I = identity operator). (Bohm 1986, 147)

The explanatory strategy both in the quantum and the classical case can be summarized as follows:

The dynamic (temporal evolution) of a compound system is micro-explainable if it is - at least in principle - possible to deduce (to explain) it on the basis of
(i) general laws concerning the dynamics (temporal evolution) of the components considered in isolation
(ii) general laws of composition and
(iii) general laws of interaction.

The following point is essential: laws concerning constituents considered in isolation are never sufficient to explain even the simplest kinds of compound systems. We always need a law of composition.[7]

On the basis of this analysis of micro-explanation I will now examine whether micro-explanation provides evidence for part-whole physicalism – more precisely: whether successful micro-explanation of the temporal evolution of compound systems provides evidence for the claim that the behaviour of compound systems are the way they are *in virtue* of the behaviour of their parts (and some further facts about how the parts interact and how they are related).

5. Determination and the *in virtue*-relation

Let us return to Klee's argument quoted at the outset of section 4. He claimed that explanation presupposes determination.

The intuition behind this is that when we have something explained to us we understand it, and a large part of understanding something is knowing how it is determined. (Klee 1984, 60).

This is a claim I will concede. That is, I will concede, first that if we have an explanation we have to assume that, e.g. the event that the *explanans* refers to determines the event that the *explanandum* refers to and, second, we know why this determination relation holds. I understand determination as a modal notion, such that, for instance, the values of x determine those of y iff for any value i of x there is some value j of y such that, necessarily, if x has i, y has j. The exact sense

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[7] In this sense the behavior of wholes always transcends that of the isolated parts.

of “necessarily” depends on whether the determination relation holds in virtue of laws of nature, causation or something else. To give an example: For a (deterministic) causal explanation to work we have to first assume that the cause determines the event to be explained (assuming certain factors can be held fixed) and we have to assume that there is some kind of relation in nature (causation) that underlies a given explanation and makes the determination relation feasible.

If we make the above concession, the case of micro-explanation has the following implication: because we are able to explain the behaviour (dynamics) of the compound system in terms of that of the parts, we can conclude that the parts *determine* the behaviour of the compound.

Isn’t that exactly the conclusion the part-whole physicalist was looking for? Doesn’t the concession imply that the behaviour of compound systems is the way it is *in virtue* of the behaviour of the parts?

For the argument from physics to physicalism, from micro-explanation to part-whole-physicalism to be successful the determination relation that we have just come across has to qualify as an *in virtue*-relation. So the question we have to answer is whether the determination that obtains between parts and wholes is indeed an *in virtue*-relation.

In what follows I will argue that this is not the case. The determination relation between parts and wholes is *mutual* and thus fails to comply to the principle of asymmetry. The determination relation is thus no *in virtue*-relation. The success of micro-explanation therefore fails to establish part-whole physicalism.

In the last section I characterized micro-explanation as the explanation of the behaviour of compound systems in terms of (a) general laws about how the constituents would behave in isolation and (b) general laws of composition and (c) general laws of interaction. On the basis of this analysis we are now in the position to pin down the exact nature of the determination-relation that is involved in micro-explanation. The behaviour of the compound is determined by the behaviour of the parts and the general laws of composition. (For the sake of simplicity I will disregard interaction terms). Given the behaviour of the parts it is the laws of composition that make the behaviour of the compound nomologically necessary.

Clearly, there is a direction of explanation from the parts to the whole. Whenever we explain the behaviour of compound systems in quantum mechanics on the basis of the Schrödinger equation, our starting point is the set of Hamiltonians for the subsystems. This is an asymmetry with respect to explanation: We do not (at least not generally) explain the behaviour of the parts in terms of the behaviour of the compound. While it is an interesting question why there is this explanatory asymmetry, it on its own does not give us an ontological *in virtue*-relation that we need for part-whole-physicalism.[8] But what about the underlying determination relation? Does it, as Klee suggested, mirror the explanatory asymmetry? Does it obey the asymmetry principle?

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[8] The explanatory asymmetry might, for isntance, be due to pragmatic reasons.

Let us take a look at the law of composition. The law of composition for quantum mechanics gives us a prescription for the Hamiltonian that describes the temporal evolution of a compound system. In the absence of interactions we have, strictly speaking, the following.

$H_{comp} = H_1 \otimes I_2 \otimes I_3 \ldots \otimes I_n + I_1 \otimes H_2 \otimes I_3 \ldots \otimes I_n + \ldots I_1 \otimes I_2 \otimes I_3 \ldots \otimes H_n$

The index i ranges over all subsystems and I_n is the identity operator for the n-th subsystem's Hilbert-space. That looks somewhat cumbersome. Instead we typically encounter the considerably simpler

$H_{comp} = H_1 + H_2 + \ldots H_n$.

Let us consider the case of a compound consisting of three subsystems. Thus we have

$H_{comp} = H_1 + H_2 + H_3$.

The law of composition gives rise to this formula for the Hamiltonians. It ensures that the behaviour (dynamics) of the subsystems (represented by H_1, H_2 and H_3 respectively) determines the behaviour (dynamics) of the compound (represented by H_{comp}).

The determination relation holds because we are dealing with an equation, and once the three Hamiltonians on the right hand side are specified, so is the fourth for the compound on the left hand side. But obviously the same is true for any of the other Hamiltonians as well. If H_{comp}, H_1 and H_2 are given, H_3 is determined according to the equation $H_3 = H_{comp} - H_1 - H_2$, and so forth.

Each of the four is determined as soon as the other three are fixed. The relation between the subsystems and the compound with respect to determination is *mutual*.

In other words: The determination relation that has to be presupposed in order to understand the success of the micro-explanation cannot be *in virtue* relation. If we were to consider the determination as an in virtue-relation, *both* of the following claims would come out as true:

[w] $\perp\leftarrow$ [p_3], because the compound's behaviour is partially determined by that of the third component or part.

[p_3] $\perp\leftarrow$ [w], because the behaviour of the third component is partially determined by that of the compound.

This result, however is incompatible with the principle of asymmetry, which is constitutive for *in virtue* relations.

To sum up: micro-explanations in physics essentially invoke laws of composition. Laws of composition describe the determination relations that obtain between parts and wholes (they underlie the micro-explanations). These determination relations are mutual. We thus do have good reasons for the claim that asymmetrical dependence, grounding or the *in virtue*-relation between parts on the one hand and the compounds on the other does not obtain. Therefore, micro-explanations provide no evidence for part-whole physicalism.

6. Objections and Replies

For the part-whole-physicalist there are various possible ways to react to the agument just presented. First, one might object to the argument by pointing out that there might be genuinely metaphysical relations that obtain between parts and wholes, but are not dealt with in physics. Answer: While there might be such relations they are not my concern in this paper. My aim is merely to figure out whether part-whole-physicalism is supported by what classical mechanics and quantum mechanics have to say about the part whole relation.

Second one might argue that the equations of physics that I relied on do not capture all that classical and quantum mechanics have to say about the part whole relation. An analogous position is sometimes attributed to Nancy Cartwright with respect to causation (Field 2003, 443). However, while there is no a priori argument against this possibility, there is no account that I know of that tells us what additional physical facts concerning the part whole relation there might be (that is over and above those captured in the equations of classical and quantum mechanics). In the absence of such a positive account it is difficult to evaluate this objection and I will refrain from doing so.

A third kind of objection is to point to further relations between parts and wholes that do not transcend what can be captured in terms of physical equations, but that I have nevertheless not taken account of. The objections dealt with in the following sections consider the possibility of further candidates for the *in virtue*-relation.

6.1. Flagpole

In the literature on explanation there is the well-known case of the height of a flagpole and the length of its shadow. According to the laws of geometrical optics the length of the shadow is determined by the height of the flagpole holding fixed certain circumstances like the position of the sun. At the same time, these circumstances plus the length of the shadow determines the height of the flagpole. So we have a case of mutual determination. With respect to this determination relation the principle of asymmetry does not hold. However, we do nevertheless belief that the fact that the shadow has a certain length obtains partially in virtue of the fact that the flagpole has a certain length but not *vice versa*. By analogy, even though the determination relation between parts and wholes might fail to obey the principle of asymmetry, it might still be true that the behaviour of the compound obtains *in virtue* of the behaviour of the parts.

The reply is that the two cases are in a relevant way disanaloguous. In the case of the flagpole case we can give an account of how the asymmetry arises, whereas we cannot do the same in the case of the relation of parts and wholes.

Here is one way of explaining the origin of the asymmetry in the case of the flagpole. Geometrical optics is a simplified model of the situation at hand. A more detailed description would mention the

propagation of the light waves. In the more complete picture it is possible to explain in what sense the length of the shadow is the dependent variable. Gerhard Schurz suggested that what's essential in this context is the fact that a change in the dependent variable is brought about *later*:

"The crucial idea […] is that the distinction between those variables which are directly influenced by an allowed intervention, in contrast to those which are only indirectly influenced by it, is possible by considering the delays of time in the process of disturbing the system's equilibrium state." (Schurz 2001, 61)

And with respect to our example:

"Hence in every intervention allowed by C [circumstances like the position of the sun, Author] which disturbs the equilibrium state of the systems variables, the length variation of the shadow will take place slightly after the variation of the pole's length – because of the finite velocity of light." (Schurz 2001, 61)

I will not discuss whether this suggestion does indeed give a complete account of the asymmetry in this example. The essential point is that this strategy to break the symmetry cannot be applied in the case of parts and wholes. What is essential for Schurz's strategy is that we supplement the original description of the relation of the length of the shadow and the height of the flagpole by *additional physical facts* such as the propagation of the light wave. The simultaneous and mutual determination of the height of the flagpole and the length of its shadow is only apparent. It is a feature of a simplified and incomplete description of the situation only. Breaking the symmetry relies on a better and more detailed description.

However, the case of parts and wholes is different in this respect. There are no additional physical facts. For all we know the description of the part-whole relation given in section 4 is the most complete we have.

6.2 One-To-Many-Relation

However, even though our account of the part whole-relation as described in classical and quantum mechanics may be complete, the account may give room for the obtaining of asymmetries that have been overlooked so far. Frank Jackson, for instance, argues – in the context of levels-physicalism – that the asymmetry characteristic for the physicalist claim is due to an asymmetry of determination:

For the physicalist, the asymmetry between physical and psychological (or semantic, or economic, or biological, …) lies in the fact that the physical fully determines the psychological (or semantic, …), whereas the psychological (or semantic, …) grossly underdetermines the physical. (Jackson 1998, 15).

An analogous argument in the case of part-whole-physicalism runs as follows: While the behaviour of the parts fully determines that of the compound, the behaviour of the compound grossly underdetermines that of the parts. In other words: The relation between the whole and the parts

surely seems asymmetrical insofar as to a certain behaviour of the whole (dynamic or state) there correspond many different arrangements of the parts.
However, as I will argue, even though there is this one-to-many-relation, it does not suffice to establish an asymmetry claim. Let me illustrate this through a simple example. Suppose we are dealing with a massive compound system consisting of three subsystems. We are only interested in mass. Leaving out relativistic effects we know that the mass of the compound (m_4) adds up as follows:
$m_1 + m_2 + m_3 = m_4$ (M)
Thus, (M) is our law of composition for our three masses. m_4 characterizes the compound or macro-system whereas m_1 to m_3 characterize the constituents or micro-systems. Let us assume that the compound system has a mass of 17 kg. This value is compatible with a plethora of values for m_1 to m_3. 1kg/5kg/11kg, 6kg/6kg/5kg, 7kg/6kg/4kg – all of these micro-states are compatible with a macro-state of 17 kg. We have a one-to-many-relation between the compound and its constituents, which seems to support an asymmetry claim and therefore (maybe) the obtaining of an *in virtue*-relation (asymmetry being a necessary condition for the obtaining of an *in virtue*-relation). However, the same kind of one-to-many-relation occurs if we fix a value for one of the constituents, say m_1. If m_1 is fixed at 5kg, that is compatible with an infinite number of values for m_2 to m_4: 5kg/5kg/15kg, 6kg/6kg/17kg, 3kg/7kg/15kg – all of them will do. The fact that the compound has a certain mass value is compatible with lots of value distributions for the subsystems. But that does not single it out as something special.
The laws of composition give rise to equations that allow calculating the behaviour of the compound on the basis of the behaviour of the constituents. (Calculation presupposes determination of the relevant magnitudes.) However, they equally allow calculating the behaviour of a constituent given the relevant information about the compound and the other constituents. Whenever we have three values in (M) we can calculate the fourth value. In this respect there is nothing special about m_4, the value for the macro-state. With respect to determination all of the values are on a par. In this sense the laws of composition (in quantum mechanics as well as in classical mechanics) are impartial with respect to the micro and the macro. It is true that the behaviour of the parts fully determines that of the compound and the behaviour of the compound grossly underdetermines that of the parts. It is however also true that the behaviour of the first and second part together with that of the compound fully determine the behaviour of the third part, while the third part on its own grossly underdetermines that of the rest. If the issue of full determination by the behaviour of the parts vs. gross underdetermination by the behaviour of the compound were sufficient for the obtaining of an in virtue-relation between parts and wholes *both* of the following claims would come out as true:

$[w] \leftarrow [p_1], [p_2], [p_3], \Delta$

because the compound's behaviour is fully determined by that of the third parts (plus some compositional facts).

$[p_3] \leftarrow [w], [p_1], [p_2], \Delta$

because the behaviour of the third part is fully determined by that of the compound, the first two parts (plus some compositional facts).
As a consequence the following two claims about partial grounding/partial obtaining *in virtue of* would hold:

$[w] \perp\leftarrow [p_3]$,

$[p_3] \perp\leftarrow [w]$.

Again, this result, is incompatible with the principle of asymmetry which is constitutive for *in virtue* relations.

6.3. Coarse Concepts

When it comes to the thermodynamics of, say, ideal gases, we not only encounter the one-to-many-relation as discussed in the previous section. There seems to be a further candidate for an asymmetrical relation.
The macro-description in terms of pressure (p), volume (V) and temperature (T) plus the exact specification of N-1 particles doesn't determine the state of the 'last' particle (the Nth particle). There are various possible states that are compatible with the given constraints. On the other hand, the specification of all particles does determine the values for p, V and T. Is that an asymmetrical relation of the relevant kind?.
For example, if temperature is average kinetic energy, the velocities and positions of N-1 particles and the temperature of the gas don't determine the velocities and position of the Nth particle. There is a whole set of velocities of the Nth particle compatible with a certain temperature of the gas plus the velocities and positions of the N-1 particles.
Rejoinder:
For a start I will leave out the thermodynamic description of the ideal gas and focus on the mechanical description. Let's assume we have a complete description of the compound system (the gas). The state of the compound can be represented as a point in 6N-dim phase-space. Given the state of the compound as well as the states of N-2 parts, the state of the second but last particle is not yet completely determined, because it can get into either the N-1-slot or the N-slot. However, given the state of the compound and the states of N-1 particles, the state of the N-th particle is determined. Of course the particles' states also determine the state of the compound. In this sense we have mutual determination of parts and wholes on the level of a purely mechanical characterization.
When we describe the ideal gas in terms of thermodynamic properties such as temperature and pressure, we use a coarser description of the compound system. It is coarse in the sense that a lot

of micro-states are compatible with given values for p, V and T. Because we use this coarse terminology, i.e. p, V, T for the compound system, the states of N-1 particles plus the state of the compound fail to determine the state of the Nth particle. However, if we were to use a coarse terminology for one of the particles rather than for the compound, the parts wouldn't determine the compound either. Let me illustrate this with an example.

Let's define an object as *heavy* if it weighs, say 150, 151, … or 200 kg. If the object has N parts then the masses of the n parts determine whether or not the object is heavy. But the object being heavy plus the masses of N-1 parts do not determine the mass of the Nth part. The parts determine the whole, but the whole plus N-1 parts do not determine the remaining part.

However, the same kind of coarse concept could have been defined for one of the parts. Take part no. 7. Part no. 7 is *quite heavy* if it weighs 50 or 51 or 52 or 53 kg. If the compound that no. 7 is a part of has N parts, then the mass of the compound plus all the masses of the other parts determine whether or not no. 7 is quite heavy. However, the mass of the compound is not determined by no. 7 being quite heavy plus the masses of the other parts (because of the coarseness of 'quite heavy').

As a matter of fact we tend to use coarse concepts for compounds rather than for parts, but this choice of concepts or predicates does not seem to have any implication with respect to the question what kind of ontological relations obtains between parts and wholes.

7. Conclusion

To sum up: Part-whole-physicalism is not supported by what classical mechanics and quantum mechanics have to say about the part whole relation. Not even those cases in classical and quantum mechanics, which are most favourable to the part whole physicalist (in the sense of *prima facie* support) – namely cases of micro-explanation of the dynamics of compound systems – provide evidence for the thesis that the behaviour of the compound obtains *in virtue* of the behaviour of the parts (and some further facts about how the parts interact and how they are related).

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