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PHYSICALISM AND THE PART-WHOLE RELATION

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 behavior of the compound obtains *in virtue* of the behavior of the parts. Physics does not dictate part-whole-physicalism.

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

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.

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:

> 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, p. 100)

(The qualification in the parentheses has to be dropped for physicalism proper.) Kim uses 'because' to express that the macro-world *depends* on

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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, pp. 220–221)

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, p. 253)

What is important in this context is that these metaphors characterise the dependence in question as *asymmetrical*. This will be essential for my later argument. Another expression that is sometimes used to characterize the asymmetric 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*. (Loewer 2001, p. 37)

I will use Loewer's formulation as my starting point for an explication of physicalism.[1]

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.[2] 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 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

[1] There are various problems I will bypass. One of these 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, pp. 11–20; Stoljar 2009).
[2] For a more detailed analysis of the difference between levels-physicalism and part-whole-physicalism see (Hüttemann and Papineau 2005).

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]

[3] The term "physicalism" in this context is only appropriate if it is assumed that there are fundamental parts, which can be characterized as physical parts. This is clearly a contentious issue but nothing in what follows will depend on this choice of terminology.

[4] The formulation is due to Barry Loewer (Loewer 2001, p. 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:

> 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, p. 14)

However, as Loewer points out Jackson's principle (P) fails to capture the asymmetry or *in virtue*-claim (Loewer and Jackson discuss what I have called "levels-physicalism"):

> 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, p. 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, p. 39)

In the remainder of this paper I will argue that classical and quantum mechanics fail to provide good reasons for the claim that in the case of part-whole-physicalism the *in virtue*-claim does hold. Physics does not dictate part-whole-physicalism. 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 2012). The terminology developed in this context allows me to define part-whole-physicalism as precise as is necessary for arguing against it.

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."
$[p] \twoheadleftarrow [q] =_{def}$ 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 the claim that for all wholes w there are parts $p_1 \ldots p_n$ and further facts Δ such that

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

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.:

$[w] \twoheadleftarrow [p_1]$
$[w] \twoheadleftarrow [p_2]$
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 true in all those cases where we seem to understand *in virtue*-talk. The first such principle is asymmetry (and that is all I will need):

asymmetry: if $[p] \twoheadleftarrow [q]$ then: not $[q] \twoheadleftarrow [p]$

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. (As a matter of fact the asymmetry principle is controversial among grounding-theorists (see for instances Wilson forthcoming). However, since I intend to explicate the *in virtue*-expression as it is used in the limited debate about part-whole-physicalism, where – as we have seen – it is used as expressing some kind of asymmetry, there is no problem accepting this principle for the purpose of this paper.)

We have seen in sections 1 and 2 that part-whole-physicalism is associated with asymmetry-claims. Rosen's terminology provides us with the means to make this claim sufficiently precise so as to work with it.

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 behavior 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, pp. 59–60)

So, the argument runs like this: The fact that we can explain the behavior of compound systems (wholes) in terms of the behavior 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 behavior of compound systems in terms of their parts may mean more than one thing. So what does 'behavior' mean in this context? With respect to the behavior 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 classical particles, we can, for instance, distinguish their positions and momenta as changing quantities, while other quantities (that might be relevant for the system under consideration) such as the gravitational constant remain constant. The values of the variable 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 at a particular time do not exhaust what is commonly understood as the system's behavior. 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 behavior 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 macro-state) 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 counterexample to this kind of micro-explanation. 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 (see e.g. Maudlin 1998).

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 (see Hüttemann 2005 for this distinction).

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 behavior of the compound (the dynamics of the system) is explained in terms of the behavior (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 behavior 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

$H = p^2/2m$, 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 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 behavior of subsystems have to be combined so as to obtain the description of the behavior 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: $H = p_1^2/2m_1 + p_2^2/2m_2$.

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) behavior is explained in terms of the behavior 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, p. 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: $H_{rot} = L^2/2I$, where 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: $H_{osc} = P^2/2\mu + \mu\omega^2Q^2/2$, where P is the momentum operator, 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, p. 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.[5]

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 behavior of compound systems are the way they are *in virtue* of the behavior of their parts (and some further facts about how the parts interact and how they are related).

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

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, p. 60).

This is a claim I will concede. But much depends on how we understand "determined" in this context. 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 bare determination, i.e. 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 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 assume that the cause determines the event to be explained (assuming certain factors can be held fixed) and we furthermore 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 behavior (dynamics) of the compound system in terms of that of the parts, we can conclude that the parts *determine* the behavior of the compound.

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

As we will see bare determination will not be sufficient to establish an *in virtue*-relation and thus part-whole-physicalism (this relates back to our discussion in section 2). For the argument from micro-explanation to part-whole-physicalism to be successful the relation between parts and wholes that has to be presupposed in micro-explanation has to qualify as something stronger than bare determination, it has to qualify as an *in virtue*-relation, i.e. minimally as bare determination plus the principle of asymmetry. So the question we have to answer is whether the relation that obtains between parts and wholes is indeed such that not only bare determination but also the asymmetry principle obtains.

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

I will first argue for this claim by considering non-interacting parts and will then take into consideration the more general case of interacting parts of a compound.

5.1. *The Non-Interaction Case*

In the last section I characterized micro-explanation as the explanation of the behavior 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 relation between parts and wholes that is involved in micro-explanation. The behavior of the compound is determined by the behavior of the parts and the general laws of composition. (For the sake of simplicity I will disregard interaction terms in this sub-section). Given the behavior of the parts it is the laws of composition that make the behavior of the compound nomologically necessary.

Clearly, there is a direction of explanation from the parts to the whole. Whenever we explain the behavior 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 behavior of the parts in terms of the behavior 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.[6] But what about the underlying part-whole relation? Does it, as Klee suggested, mirror the explanatory asymmetry? Does it obey the asymmetry principle?

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.

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

[6] The explanatory asymmetry might, for instance, be due to pragmatic reasons.

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

$$H_{comp} = H_1 + H_2 + \dots + H_n$$

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 behavior (dynamics) of the subsystems (represented by H_1, H_2 and H_3 respectively) determines the behavior (dynamics) of the compound (represented by H_{comp}).

A bare determination relation between the behavior of the parts and the behavior of the compound 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 is *mutual*. Let me be very clear on one point: I am not claiming that the behavior of the compound on its own determines the behavior of any of the parts. The claim is rather, that if H_{comp} is given and two of the other Hamiltonians for the parts, the Hamiltonian for the third part is determined. The parts' behavior determine the behavior of the compound and any part's behavior is determined by the compound's behavior plus the behavior of the other parts. This is what I mean by "mutual determination" and it suffices to reject the *in virtue*-claim.

The result of these considerations is: The relation that has to be presupposed in order to understand the success of the micro-explanation cannot be an *in virtue* relation as it is presupposed in the discussion about part-whole-physicalism. The reason is that *both* of the following claims come out as true:

> $[w] \twoheadleftarrow [p_3]$, because the compound's behavior is partially determined by that of the third component or part. (The other determining factors are the fact that the law of composition obtains as well as $[p_1]$ and $[p_2]$.)

> $[p_3] \twoheadleftarrow [w]$, because the behavior of the third component is partially determined by that of the compound. (The other determining factors are the fact that the law of composition obtains as well as $[p_1]$ and $[p_2]$.)

By appealing to laws of composition we are appealing to relations of mutual determination not to *in virtue*-relations.

To sum up: micro-explanations in physics essentially invoke laws of composition. Laws of composition describe the relations that obtain between parts and wholes (they underlie the micro-explanations). These relations are relations of mutual determination. Because laws of composition describe relation of mutual determination they fail to establish the principle of asymmetry and thus an *in virtue*-relation. Therefore, appeal to micro-explanations provides no evidence for part-whole-physicalism.

5.2. *The Interaction-Case*

One may object that the non-interaction case is rather trivial and not very interesting. Taking into account interactions does indeed complicate the picture. But the complications have to do with the question what to consider as the parts in a part-whole-explanation with interactions – rather than with the *nature* of the relation between parts and wholes. When the physicalist argues that micro-explanations provide evidence for the claim that the behavior of the compound obtains in virtue of the behavior of the parts, the physicalist has to specify what she means by "the behavior of the parts." I will consider two specifications and argue that in both cases the same conclusions as in the non-interaction case hold.

Let us take a classical case with interaction. 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. In such a case the physicalist probably has two options of describing what an explanation in terms of the behavior of the subsystems might mean. According to the first (very natural) option the relevant subsystems are the isolated particles in the absence of any forces acting on them. In order to explain the compound's behavior we do not only rely on the general law of composition. Furthermore the term for the gravitational field potential has to be added. This reading of 'the behavior of the parts' accords with the claim that the compound's behavior is explained in terms of the behavior of the parts *and their interactions*. This yields the following Hamilton-function for the compound system:

$$H_{1+2} = p_1^2/2m_1 + p_2^2/2m_2 - Gm_1m_2/r$$

or

$$H_{1+2} = H_1 + H_2 - Gm_1m_2/r$$

The bare determination relation holds because we are dealing with an equation, and once the three terms on the right hand side are specified, so is the fourth for the compound on the left hand side. But, as before, the same is true for any of the other terms as well. If H_{1+2}, $-Gm_1m_2/r$ and H_2 are given, H_1 is determined according to the equation $H_1 = H_{1+2} - H_2 + Gm_1m_2/r$.

Each of the four terms is determined as soon as the other three are fixed. The relation between the subsystems, the interaction and the compound with respect to determination is *mutual*.[7]

We get the same conclusion as in the non-interaction case: Both of the following claims come out as true:

> [w] ↞ [p_1], because the compound's behavior is partially determined by that of the first component or part. (The other determining factors are the fact that the law of composition obtains, the fact that the law of gravitation obtains as well as [p_2].)
>
> [p_1] ↞ [w], because the behavior of the first component is partially determined by that of the compound. (The other determining factors are the fact that the law of composition obtains, the fact that the law of gravitation obtains as well as [p_2].)

As in the non-interaction case this result is incompatible with the principle of asymmetry, which is constitutive for the *in virtue* relation as presupposed in the discussion about part-whole-physicalism.

The physicalist might hold that there is a different reading of "the behavior of the parts." It is not the behavior of the particles considered on their own, but rather the particles' actual behavior in the field that is generated by the other particle. (The other particle itself is not part of the subsystem.) Thus, the behavior of the first subsystem consists of the

[7] The claim that the determination relations that underly physical laws are mutual has already been invoked by Bertrand Russell. He famously argued that the fundamental physical laws provide no room for an asymmetrical casual relation. Russell observed that "the future 'determines' the past in exactly the same sense in which the past 'determines' the future." (Russell 1912/13, p. 15). The determination relation that is described or presupposed by the fundamental laws of physics implies (given that the universe is closed and we are dealing with the physics of 1912/13) that past and future determine each other mutually and does not give rise to any kind of asymmetry. While Russell's claim about the determination relation pertains to the temporal development of systems my analogous claim concerns the synchronic part-whole relation.

first particle's behavior in an external gravitational field generated by the second particle. The second subsystem is described analogously. The two subsystems behave according to the Hamilton equations with the following Hamilton functions:

$$H_{1*} = p_1^2/2m_1 - (Gm_1m_2/r)\,|_1$$
$$H_{2*} = p_2^2/2m_2 - (Gm_1m_2/r)\,|_2$$

'$|_i$' indicates that the function (Gm_1m_2/r) is restricted to the phase-space of particle *i*. Let me stress that I am not committed to the claim that this can in general be consistently done. The physicalist who takes this option is confronted with a dilemma here: Either the particle's actual behavior (i.e. the particle's behavior in the external field) cannot be individuated as indicated above. Then it is not clear in what sense part-whole explanations provide evidence for the in virtue-claim because it remains unclear what the parts' behavior is. Or there is some way of individuating the parts' behavior in this sense, but then it wouldn't help the physicalist's argument. What we would end up with is a Hamiltonian that has the same form as in the non-interaction case:

$$H_{1+2} = H_{1*} + H_{2*}$$

So, by the same kind of argument as in the non-interaction case the determination relation would turn out to be mutual.

To conclude: Whether we consider non-interaction cases of part-whole explanations or interaction cases: The relations between parts and wholes invoked in micro-explanations turn out to be mutual. Therefore, an *in virtue*-relation between parts on the one hand and the compounds are not presupposed. Micro-explanations provide no evidence for part-whole-physicalism. Physics does not dictate part-whole-physicalism.

6. Objections and Replies

For the part-whole-physicalist there are various possible ways to react to the argument 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, p. 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.

Finally, and maybe most importantly, a physicalist might doubt that what I have presented is what anyone ever meant when they were thinking that the properties of the whole are determined by the properties of the parts in an asymmetrical way. After all, we are dealing with microscopic physics, and not just with two or three particles. So the objection is to point to further physical relations between parts and wholes that I have not taken account of. The objections dealt with in the following sections, in particular those in sections 6.2 and 6.3 will 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 believe 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 behavior of the compound obtains *in virtue* of the behavior of the parts.

The reply is that the two cases are in a relevant way disanaloguous. In the case of the flagpole 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, p. 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, p. 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, p. 15)

An analogous argument in the case of part-whole-physicalism runs as follows: While the behavior of the parts fully determines that of the compound, the behavior 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 behavior 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) $m_1 + m_2 + m_3 = m_4$

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. 1 kg/5 kg/11 kg, 6 kg/6 kg/5 kg, 7 kg/6 kg/4 kg – 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 5 kg, that is compatible with an infinite number of values for m_2 to m_4: 5 kg/5 kg/15 kg, 6 kg/6 kg/17 kg, 3 kg/7 kg/15 kg – 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 behavior of the compound on the basis of the behavior of the constituents. (Calculation presupposes determination of the relevant magnitudes.) However, they equally allow calculating the behavior 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 behavior of the parts fully determines that of the compound and the behavior of the compound grossly underdetermines that of the parts. It is however also true that the behavior of the first and second part together with that of the compound fully determine the behavior 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 behavior of the parts vs.

gross underdetermination by the behavior 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 behavior is fully determined by that of the third parts (*P*lus some compositional facts).

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

because the behavior of the third part is fully determined by that of the compound, the first two parts (*P*lus some compositional facts).

As a consequence the following two claims about partial grounding/ partial obtaining *in virtue of* would hold:

$$[w] \twoheadleftarrow [p_3],$$
$$[p_3] \twoheadleftarrow [w].$$

Again, this result, is incompatible with the principle of asymmetry which is constitutive for the *in virtue* relation as presupposed in the discussion about part-whole-physicalism.

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 N-th 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 mean 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. Strictly speaking, this is a case where the variables representing the behavior of the compound system are determined by the variables representing the behavior of the parts, whereas it does not hold that the variables representing the behavior of $N - 1$ parts plus the variable(s) representing the behavior of the compound determine the variable for the N-th particle's behavior.

However, I think we have good reasons not to take this asymmetry at face value, i.e. not to read it realistically as telling us something about the underlying the ontology. The reason is that the asymmetry is generated by our choice of coarse-grained variables for the compound system. The asymmetry disappears if we choose the more precise mechanical description. Furthermore, asymmetries that are due to coarse-grained variables can be generated at will. This can be illustrated by the following 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 N-th 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 can be 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').

What this shows is that we can generate asymmetries at will wherever we introduce coarse-grained variables. Therefore we should not read these asymmetries realistically. They are entirely due to the choice of coarse rather than precise variables and do 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 favorable 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 behavior of the compound obtains *in virtue* of the behavior of the parts (and some further facts about how the parts interact and how they are related). Physics does not dictate part-whole-physicalism.

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