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A Method for Constructing an Intertheoretic Reduction between the Special Sciences

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Abstract

With the proliferation of the special sciences, sciences which are not fundamental physics, the scientific community has discovered incredible complexity in even the simplest biological, meteorological, or psychological systems. The methods of the special sciences are often different from the controlled methods found in fundamental physics and the kinds of claims that can be made are often far more contingent than those made by physicists. This has led to much speculation about whether or not physics can serve as *the* foundational science, whether or not all of the other sciences are really just “special cases” of physics. Perhaps these disciplines cannot ever be understood in terms of physics; perhaps each special science’s subject matter and fundamental ontology cannot ever be understood in terms of the ontology of fundamental physics. This paper will argue for a method to show how the fundamental ontology of any special science can be related to the ontology of fundamental physics through carefully constructed bridge laws which allow one to state under what conditions something will satisfy a type from a special science given that it satisfies a type from fundamental physics. To do so we must argue for a method that would allow the construction of bridge laws which relate terms in any special science to those of fundamental physics. Someone would be able to start with the statements of fundamental physics, and with the addition of these bridge laws, be able to deduce the statements of any special science. Though these bridge laws have not been fully fleshed out by science, if they could be found it would mean that fundamental physics can reduce any special science.

It is considered a great triumph of science that as time goes on and our theories become more powerful and more inclusive, many of the older or more specific theories are shown to be subsumed by the new or more inclusive ones. We often say that an old theory has been “reduced” to a new theory and that the older or specific theory can be derived, using suitable approximations or laws, from the newer or more inclusive one. Ernest Nagel settles on the following definition of intertheoretic reduction in the sciences: a reduction is an explanation with the form of an argument, so that every reduction can be construed as a set of statements from the new theory which, together with suitable approximations or bridge laws, entail the conclusion, which is the older theory. For terminology’s sake, we will refer to the new theory as the “reducing theory”, and the old one as the “reduced theory”. The type of addition that must be added to the reducing theory, the approximations or bridge laws, to properly reduce a theory partition the intertheoretic reductions into two kinds: homogenous and inhomogeneous. I will briefly elaborate on these two kinds of intertheoretic reductions, focusing on the *predicate relationship* version for inhomogeneous reduction. With this in mind, I will argue that it is possible, using empirically motivated bridge laws, to show that the extensions of the predicates of a reduced theory are subclasses of extensions of the predicates of the reducing theory. By constructing a transitive subclass chain, the extensions of the predicates of the special sciences can be shown, by many iterations of this process, to be subclasses of the extensions of the predicates of fundamental physics. Should we be able to construct such a chain, one can use the bridge laws that allowed the construction of the chain to create a final biconditional bridge law for use in the intertheoretic reduction. The premises will be the statements of fundamental physics and will include the bridge laws, and the conclusion will be the statements of any special science.

Preliminaries

A homogenous reduction is one in which the theoretical terms of the reduced theory are present in the premises or can be defined explicitly only using terms from the reducing theory. One example of this is the reduction of Galileo's law for free falling bodies by Newtonian mechanics. In this example, the premises of the intertheoretic reduction will come from Newtonian mechanics. These will be things like mathematical statements and terms that represent fundamental properties, such as time, distance, mass, and so on. Now, we see that if we look at the properties that are fundamental in Galilean mechanics, i.e., make up the ontology of Galilean mechanics, we will find that all of them are also present in Newtonian mechanics. So, we find that we needn't introduce any sort of definition relating terms in Newtonian mechanics to terms in Galilean mechanics. Once we have the mathematical and terminological tools from Newtonian mechanics, we need only add an approximation to the set of premises, such as "ignore the small gravitational variance from the top of the fall to the bottom", and we can arrive at Galileo's mathematical formulation of free fall. In this way, homogenous intertheoretic reductions are, according to Nagel, easier and the argumentative form is more obvious.

However, there are some objections to this type of reduction. One such objection arises in the use of approximations. If we require an approximation that *is not true* (such as there being no variance between the gravity at the top and the bottom of a fall on Earth) in order to derive a reduced theory, then shouldn't we simply say that the reduced theory has been *replaced* by the reducing theory? Well, it is commonly understood that a reducing theory is more comprehensive in its applicability and generality than the reduced theory, and furthermore that the reduced theory is but a *special case* of a reducing theory. When we increase the generality of a theory, it will hopefully be applicable to many different and perhaps not obviously related domains of

application than its predecessor. For example, if Newtonian mechanics is the successor to Galilean mechanics, then we should expect that Newtonian mechanics can be applied to more situations than Galilean mechanics. In fact, that is the case. Newtonian mechanics can be applied to celestial as well as terrestrial mechanics, whereas Galilean mechanics can only be applied to terrestrial mechanics. However, if we wish to increase the scope of a theory so that we may apply the new theory to different domains of application, we must recognize that the conditions that influence how and why we apply the theory to any specific problem in these separate domains are very different. These differences affect how we will apply the theory and the assumptions that might be made for various reasons, such as to make the math easier or because we only need limited accuracy. These assumptions are the approximations and/or simplifications that if added to the reducing theory allows the derivation of the reduced theory. Although the reduced theory is strictly speaking “wrong”, it follows from the reducing theory with the added approximations that are commonly employed to use the reducing theory effectively. Essentially, scientists do this each and every time they switch domains of application from a more general domain to a more specific or limited case. It just so happens that some of these approximations, when applied to the reducing theory, give us earlier, simpler theories that we already knew about and named, as is the case with Newtonian and Galilean mechanics. Galilean mechanics is often used in terrestrial applications when the accuracy needed is less than what one would get when using Newtonian mechanics. The math is simpler in Galilean mechanics as well.

If someone never knew the name “Galilean mechanics” but was using Newtonian mechanics to calculate the fall time on Earth for an object to within a seconds accuracy, they would probably, to make their calculations simpler, assume that there is no gravitational variance from the top to the bottom of the fall. Some terms would be disregarded for having too little

influence on the accuracy, and it is likely that one would not even need to use anything more than grade school algebra, as opposed to a more advanced and cumbersome math, such as calculus. The equations that would be written on the page once they made this assumption would resemble those of Galilean mechanics. If later on he wished to calculate the fall time to within a millionth of a second, he might disregard the assumption that he made earlier. However, we wouldn't say that the equations that he had written down before were "replaced" by the new ones. We would probably say that the first equations were adequate in a limited case, such as when the accuracy needed was less, and they were subsumed under the newest equations. This is how one switches between Galilean and Newtonian mechanics, and in fact, any pair of reduced and reducing theories that meet the above criteria for homogenous reductions. So in this way, one can still say that the reduced theory follows from the reducing theory so long as we have suitable approximations and/or simplifications.

The second type of reduction is an inhomogeneous reduction. This is a reduction in which at least one fundamental term in the conclusion neither occurs in the reducing theory nor is explicitly definable by those that do occur in them. An example of this is the reduction of Classical Thermodynamics (CT) to the Kinetic Theory of Gases. When one explores the terms used in CT, they would find fundamental terms such as "heat" or "entropy". Those terms are not found in the Kinetic Theory of Gases (KTG). This lack of agreement between the theoretical terms of the two theories under consideration makes a homogenous reduction impossible. For this kind of intertheoretic reduction, Nagel discusses three broad types; the *instrumentalist analysis*, *predicate relationship*, and the *replacement view*. The *instrumentalist* view roughly corresponds to instrumentalism in the philosophy of science. These types of reductions are ones that are instrumentally useful for us. They might reduce or unify theories independent of whether

or not there actually exists a physically true reductive or unification relationship between them. The *replacement* view is just about what it sounds like. Those who expound it, like Feyerabend, would argue the lack of equivalence of the fundamental ontology of two theories (as is the case with CT and KTG) warrants a complete replacement of the reduced theory by the reducing theory. Of these, the only one that will be focused on as a candidate for total reduction of the special sciences to physics will be the *predicate relationship* version.

As stated earlier, Nagel takes the form of intertheoretic reduction to be that of an argument. Thus, in an inhomogeneous reduction, the conclusion (which is the reduced theory) will have terms that do not appear in the premises (the reducing theory) unless there is a way to relate the terms of the reducing theory to those of the reduced theory. What is needed is a “bridge law/s”. These bridge laws are statements which relate the terms in the reduced theory to the terms in the reducing theory. Consider the following example. “Heat” does not occur in the KTG, so we must formulate a bridge law that connects some terms in the KTG to “heat”. The one that is used is (roughly) “Heat is the total kinetic energy of the constituent particles”. These bridge laws allow us to have the terms of the reduced theory relate to the terms in the reducing theory. The statement “heat is the total kinetic energy of the constituent particles” is an empirically motivated terminological bridge between the terms “heat” and the fundamental terms in the KTG which include “kinetic energy”. In this way, if one takes the statements of the KTG as the premises, and introduces the proposed bridge law above, then one can deduce the statements of CT that contain the term “heat”. This intertheoretic reduction has the form of an argument and can in principle be done for each term that occurs in CT but not in the KTG.

However, we should note that the bridge law is not explicitly defining “heat” in terms of kinetic energy of the constituent molecules in the same way that, for example, velocity is defined

as the change in distance with respect to time; for if it was, then we would get along just as fine without “heat”. We could eliminate it on purely logical grounds, since if A is explicitly defined in terms of B, then we can simply replace A with B, and no meaning or usefulness is lost (albeit the result might be more cumbersome). The problem is that “heat” was understood and used to make predictions well in advance of the bridge law stated above. The branch of CT makes no use of the term “kinetic energy” in its ontology. “Heat” is a basic term that stands alone and without reference to kinetic energy in CT, and CT can be used to make predictions, build machines, and the like just as well if we never knew the empirical connection relating “heat” to terms of the KTG. Thus, no amount of logical analysis can make sense of heat purely in terms of the kinetic energy of the constituent particles in a CT setting. In general, bridge laws are just that, empirical hypothesis relating terms in one theory to another that are made after the ontology of two theories has been developed.

However, one should ask about the structure and function of these bridge laws if they are not explicit definitions. There are two proposals advanced by Nagel as to how a bridge law functions; bridge laws either increase the class of entities or situations that satisfy a predicate from the reducing theory to include those entities or situations that satisfy a predicate from the reduced theory, or the bridge laws claim that the extensions of two predicates, one in the reducing theory and one in the reduced theory, are the same. This second type of bridge law is biconditional.

Bridge laws of the first type are those that broaden the class of entities or situations that satisfy a given predicate from the reducing theory to include those situations or entities that satisfy a predicate from the reduced theory. Every fundamental predicate used in a scientific theory refers to a class of objects or situations that satisfy a fundamental or natural type in that

science. A fundamental type of a science is a descriptive property that an object or situation possesses that is part of the ontology of that science. Predicates are used to refer to those types. For example, I might say that “mass” is a fundamental type in Newtonian Mechanics. Then the predicate “massive” will refer to those objects that satisfy the type “mass”, i.e. the things in the universe that have mass. An instantiation of some type will be an x that satisfies that type. So if x has mass then x is an instantiation of “mass”; x will also satisfy the predicate “massive”.

The predicate “viscous” refers to the property of being thick, sticky, and to be of a consistency that is between that of a liquid and solid. The extension of any predicate is the class of entities or situations that satisfy that predicate. Thus, the extension of the predicate “viscous” is exactly the class whose members are viscous. However, molecular theory explains viscosity in terms of the frictional forces between layers of the constituent particles. The statement that a liquid is viscous and the statement that there are frictional forces between layers of particles for the given object are certainly not the same, they have different meanings, but with the bridge law stating that viscosity is merely a consequence of frictional forces between the layers of particles of the liquid in question, the predicate “viscous” now denotes a class of objects that is a subclass of those entities that have frictional forces between the layers of constituent particles. Here I am using “subclass” to mean: A is a sub-class of B if all members of A are members of B. The class of things that satisfy the predicate “have frictional forces between its constituent layers of particles” (F) has been extended by the proposed bridge law from molecular theory to include the members of the class of entities that satisfy the predicate “viscous”. We should note here that it is not to say that we have equivocated two or more classes of objects with the extension of “viscous”. As in, it is perfectly possible that an entity belongs to the extension of the predicate F but not belong to the extension of the predicate “viscous”. An example of this is Graphite. It

exists as a series of layers of carbon lattices of different arrangements. These layers interact with each other to give Graphite all kinds of properties that one would not use when referring to a liquid because Graphite is not a liquid. So, a sample of Graphite satisfies the predicate F but not the predicate “viscous”. However, every member of the extension of the predicate “viscous” will belong to the extension of the predicate F. We now see that the bridge law that relates “viscous” with F has increased the size of the extension of the predicate F to include the members of extension of the predicate “viscous”, but not the other way around. Though it might have always been the case that viscous things are viscous because of the frictional forces between layers of the particles, it is an empirical claim that that the property “viscous” arises from those frictional forces. Thus, before that empirical connection was discovered, someone who uses the predicate F to describe an object (or class of objects) will not be aware that they are also potentially referring to viscous objects. Through empirical inquiry, we now believe that the extension of F also contains all the members of the extension of “viscous”.

Correspondences of the second kind establish the equivalence of the extensions of two or more predicates. They allow us to say that the class of objects that satisfy predicate A is the same class that satisfies predicate B. Here we are using equivalence between classes to mean having the same members. So for example, the bridge law stating that water freezing is identical to the water’s molecules slowing down and settling into a lattice formation under standard temperature and pressure (STP) conditions would equate the extensions of the predicates “water freezing” and “the molecules slowing down and settling into a lattice formation under STP”. In this case, the instances in which water would freeze are the exact same as the instances in which the molecules that comprise that sample of water slow down and align into a stable lattice under STP conditions. Thus, with the bridge law stated above, the classes of instances that satisfy each

predicate are the same. We should be careful here to note that a bridge law of this type does not claim that the meanings of the predicates in question are the same, but only that the extensions of those predicates have the same members. So, for example, the predicates “creature with a heart” and “creature with a kidney” do not mean the same thing. We might use them in different contexts and it seems reasonable that the terms cannot be interchanged without some loss of understanding. However, with our modern biology we now understand that these properties appear together. Any creature which satisfies one predicate will satisfy the other. The extensions of the two predicates are the same even though their meaning is not. In a similar fashion with “water freezing” and “molecules slowing...”, the two do not have the same meaning and so cannot be interchanged without confusion, but their extensions have the same members and with the bridge law relating the two the predicates denote the same class of objects. Bridge laws of the second type function in this way, to equate the extensions of two predicates, not their meanings.

Part I

It is the intertheoretic reduction that has the form of an inhomogeneous reduction that will allow each special science to be reduced to fundamental physics. If we are looking for prediction in the special sciences (SS) starting from fundamental physics (FP) and a sufficient computational tool, I do not think that is realistic. However, we can reduce all SS theories to FP by embedding each SS predicate in a FP predicate through a series of intermediate steps in a Russian Nesting Doll fashion. A predicate A is said to be embedded in another predicate B when the extension of A is a subclass of the extension of the predicate B. So, in the example with the predicates “viscous” and F, the extension of “viscous” was posited to be a subclass of the extension of F by the stated bridge law from molecular theory. The predicate “viscous” was therefore embedded in the predicate F. The nesting doll attempt to embed all SS predicates into

FP predicates will be made possible by taking advantage of the transitivity of the subclass relation. It is not hard to check that the subclass relation defined above is in fact transitive and I will leave that to the reader.¹

Now, the program of reducing all of the SS to FP will involve finding bridge laws through mathematical and/or experimental inquiries between theoretical frameworks of the SS which takes the theoretical predicates of a more specific SS and embeds those predicates in predicates from a more general SS. We can then repeat the process until we arrive at the predicates of FP. By the transitivity of the subclass relation, we can conclude that any predicate member of the chain is embedded in the predicates of FP. An example of this is the following. Consider the complex weather phenomena known as a “hurricane”. It is no secret what a hurricane looks and behaves like. There will often be deafening winds, rain, and their physical structure is similar to a spiral. However, the predicate “hurricane” is a theoretical term that is found in meteorology that characterizes a specific meteorological phenomena complete with its own mathematical, chemical, and physical characteristics that differentiate it from other similar phenomena (like a tropical storm).

However, from the atmospheric sciences we are moving towards understanding what causes a hurricane and the conditions that are necessary (though we have not developed all of the sufficient conditions) for a hurricane to form. One necessary condition that must obtain for a hurricane to occur is that the area in which a hurricane forms must have particularly high humidity. Hurricanes do not form in dry environments. Though a specific humidity is no guarantee of a hurricane forming, a hurricane cannot form without high humidity. We see that humidity is a theoretical predicate of the atmospheric sciences. Our reduction proceeds as follows. So, one might have the list of predicates $\{H_i\}$ that all describe the phenomena that must

obtain for a hurricane to happen. So, the instances in which a hurricane happen will also be instances in which $I\{H_i\}$ also obtain, where $I\{H_i\}$ is the intersection of the extensions of H_i , i.e., the instances in which each predicate of H_i obtains at the same time. Thus, any instance which is a member of $I\{H_i\}$ will result in a hurricane. For each H_i , there was at least one instance of that predicate that is needed for a hurricane to happen (otherwise it wouldn't be included in our list), so that each instance of a hurricane was also an instance of H_i . Thus, the extension of the predicate "hurricane" is a subclass of the extension of the predicate H_i for each H_i , and the predicate "hurricane" is thus embedded in each H_i . We can see that a bridge law relating "hurricane" to any H_i would now have extended the extensions of each H_i to include the instances of "hurricane". So, the bridge law that relates the predicate "hurricane" to the predicates H_i is of the first type of bridge law described above.

Now, we can then look at the predicates H_i and we should find that they are simpler predicates than "hurricane". They could be things like "the humidity in the troposphere is higher than normal" (T). Now, we can look at the conditions that must obtain for the humidity of the troposphere to be higher than normal; call them T_i . Then the predicate T will be satisfied by the same instances that $I\{T_i\}$ are satisfied. Thus the extension of T is a subclass of the extensions of each T_i (same argument above) and the predicate T is embedded in each T_i . We should ask at this point whether or not "hurricane" is also embedded in each T_i . As shown above, every instance of a hurricane is also an instance that satisfies each predicate H_i . So, if we consider just H_0 to be "the humidity of the troposphere is higher than normal", which we call T, we have just argued that T is embedded in each T_i . So, if each member of the extension of "hurricane" is also a member of the extension of T, and each member of T is also a member the extension of each T_i , then by the transitivity of the subclass relation, the extension of "hurricane" is also a subclass of

the extension of each T_i . The predicate “hurricane” is thus embedded in each predicate T_i . It is important to note that though we chose H_0 to be T , it will make no difference which H_i we choose. We could have chosen the predicate which describes the wind shear of the given area instead. Similarly, if we wish to continue this pattern, we could choose some T_0 and consider the predicates that must be satisfied for an instance of T_0 to obtain. We can then show that the predicate “hurricane” is embedded in each of those as well. Now, the goal is to keep doing this until we get all the way through the atmospheric science’s predicates, to the predicates of chemistry, and finally to the predicates of physics. Since embedding predicates comes from the subclass relation applied to extensions of those predicates and the subclass relation is transitive, the extension of “hurricane” will also be a subclass of the extension of some FP predicate. Thus, the predicate “hurricane” is embedded in some FP predicate.

Part II:

Now, if we wish to construct an intertheoretic reduction that has the reducing theory as premises and, with the addition of bridge laws, concludes the reduced theory, we proceed backwards through the chain that I constructed. The bridge laws to be used in the argument will be the same bridge laws that allowed the predicates of the reduced theory to be embedded in the predicates of the reducing theory with a slight modification. They will function as a map between the fundamental types in the two theories as well as provide restrictions that must be in place for the extension of a reducing theory predicate to be culled (typically the specific instances under which one is considering the predicates from the reducing theory), leaving only the instances which satisfy a predicate of the reduced theory. This will allow the bridge laws to be biconditional and thus one-to-one from the predicate of the reduced theory to a restricted predicate from the reducing theory. The restriction will be required to preserve biconditionality

when one extension of a predicate ends up being a proper subclass of the extension of another predicate. Here A is a proper subclass of B if A is a subclass of B but B is not a subclass of A. For example, in the case where “viscous” was embedded in F, the bridge law that would show up in the argument would something like “viscosity is the frictional forces between constituent layers of particles *in a liquid*”. This bridge law will relate the terms from molecular theory to the term “viscous”, but will also restrict that relation to the cases that are relevant to the context in which one would use “viscous”, e.g., when discussing Fluid Dynamics. Since the predicate F has a larger extension than “viscous”, we need to strip away all of the extraneous cases that won’t be useful for Fluid Dynamics and destroy the biconditional (such as Graphite). In the paragraph where F and “viscous” were first discussed, we were only interested in finding a bridge law that related the term “viscous” to the terms of molecular theory for the purposes of constructing our subclass chain. The proposed bridge law only showed that the extension of “viscous” was a subclass of the extension of F, but to go to the other direction, to use the bridge law to go from F to “viscous” (for our reduction), we will need to specify the conditions under which the property viscous relates F, since their extensions are not the same.

In the same vein, humidity and wind shear alone do not by themselves (along with the other, not discussed causes) give rise to a hurricane. There must be other restrictions for a hurricane to arise, such as specific numerical values for humidity and wind shear occurring together. However, this is a more complicated case since “hurricane” is embedded in more than one predicate, whereas “viscous” was only embedded in F. We must tread more carefully in such an example. The bridge laws that must be used to reduce Cyclonography (the study of hurricanes) to meteorology/atmospheric sciences will be conjunctive in nature. Since argued that “hurricane” is directly embedded in “wind shear” and “humidity” and so on, we will need a

bridge law for each of predicate. Each bridge law will still be biconditional but will have to mention each of the other predicates involved due to the complex nature of hurricanes. Each bridge law will be the same and will be conjunctive in nature, something along the lines of “hurricane is wind shear of such and such value, along with humidity of such and such value, along with ...”. Due to this, our conjunctive bridge law gives rise to an interesting result. Since each bridge law that relates “hurricane” is the same for the predicates “wind shear”, “humidity”, and so on, and the bridge law mentions each of these predicates, each predicate will be restricted in the same way. So, the extensions of each restricted predicate will be the exact same.

Furthermore, the extension of each restricted predicate will be exactly $I\{H_i\}$! This is exactly the result that we desired. It is likely that the reductions that occur between the higher sciences such as psychology, neuroscience, meteorology, and so on will have the same form. In fact, the simple case that we encountered between “viscous” and F will likely be in the minority.

Now, this is the most important part for our reduction of any SS to FP. We should hope that for each H_i there will be a bridge law relating it to some fundamental predicate of a reducing science such as Chemistry/Atmospheric Chemistry (in the case of humidity), or Fluid Dynamics (in the case of wind shear), and so on. For the sake of length I will merely suppose that these reductions are not as contentious since they involve simpler phenomena. So, we now have a biconditional bridge law between “hurricane” and “wind shear”. A reduction that relates “wind shear” to a predicate from a more fundamental SS will create a biconditional bridge law from “wind shear” to a fundamental predicate in that SS. However, biconditionals are themselves transitive and so there will be a biconditional bridge law from “hurricane” to that predicate from the next SS, it will be the conjunction of the bridge law from “hurricane” to “wind shear” and the bridge law from “wind shear” to the predicate from whatever SS we go to next. We can continue

this process until we have a biconditional bridge law from “hurricane” to some fundamental predicate from FP. With this bridge law we can construct the intertheoretic reduction from FP to Cyclonography.

Part III

We have thus far been concerned with creating a method for constructing the reduction from FP to any SS. However, the main example of a hurricane, while interesting, is primarily not the example that must be dealt with when trying to make sense of reduction. The rest of the paper will focus on examples from Economics and Psychology/Neuroscience, and in particular, Jerry Fodor’s arguments against intertheoretic reduction.

Fodor believes that intertheoretic reduction is far too strong of a claim. He believes that what is usually happening is that those who believe that reduction can be done are often confusing *type physicalism* and *token physicalism*. He does not deny that every event is in fact a physical event. This is the claim of token physicalism, that every event that happens is a physical event. There are no “mental” events that are not physical for example. However, this is not the same as claiming that every *fundamental type* from a SS has a directly corresponding fundamental type from an ideally completed FP. This is the claim of type physicalism. To argue his point he focuses on the example of Gresham’s Law from Economics and various issues in psychology/neuroscience.

To start, he paints a somewhat different picture for an intertheoretic reduction (which we will soon show to have nearly the same structure as the one introduced in the introduction). He takes the form of an intertheoretic reduction to be:

(1) If S_1x , then S_2x

(2a) S_1x if and only if P_1x

(2b) S_2x if and only if P_2x

(3) If P_1x , then P_2x

Here line (1) is a lawful statement from a SS. Laws usually have the form “If x satisfies S_1 , then it will satisfy S_2 ”. Line (3) is a law from FP, and lines (2a) and (2b) are bridge laws of the form “ x satisfies S_i if and only if x satisfies P_i ”. Fodor then considers exactly how we should read the “if and only if” connective and decides on this following reading that is truest to the intentions of a reductivist. “Bridge laws thus state nomologically necessary contingent event identities.” With this understanding of a bridge law, he settles on the familiar belief of the reductivist, namely that “any prediction which follows from the laws of a special science and a statement of initial conditions will also follow from a theory which consists of fundamental physics and the bridge laws, together with the statement of initial conditions”. Now that the preliminary remarks are out of the way, we see the consequence of the last few lines.

Reductivism is too strong of a claim because it claims that *every* fundamental type from a SS is, or is co-extensive with, a fundamental type from FP; where two (or more) predicates are “co-extensive” if they apply to the same things.

Part IIIi

To argue against this point, Fodor gives the example of Gresham’s Law about monetary exchanges. Gresham’s Law states that “When a government overvalues one type of money and undervalues another, the undervalued money will leave the country or disappear from circulation

into hoards, while the overvalued money will flood into circulation”². Fodor grants that any event which is a monetary exchange is in fact a physical event and is governed by the laws of physics, but believes that to give a description of Gresham’s Law in terms of physics, one would have to have a wildly long and convoluted disjunction of terms from physics to correspond to the types found in Gresham’s Law, owing to the multitude of methods of monetary exchanges (writing a check, a wire transfer, physical handing of money over, etc.), monetary systems (dollars, sea shells, etc.), along with whatever else must be in play for Gresham’s Law to be relevant. As in, if x were to satisfy “ x is a monetary exchange”, then it must satisfy (according to Fodor’s reductionism) a predicate P from physics. However, this P would likely have to be of the form $P_1 \vee P_2 \vee \dots \vee P_n$ to account for the incredible generality of the predicate “monetary exchange” and the circumstances or instances to which it could be applied. How would one go about constructing such a disjunction of physical predicates? Are we really guaranteed that such a disjunction could even be constructed given what we know about the extreme contingency of money, monetary exchanges, and so on? Fodor admits that it might be possible that brute enumeration might be able to pull this off, but that it would take nothing short of brute enumeration to convince us that it were possible. That long disjunction would then have to be found as an antecedent or consequent of a conditional of the form of (3), *otherwise it would not be a fundamental type from physics*. What kind of law would use such a disjunction within physics as the antecedent or the consequent? If we cannot find one, then this disjunction is not a fundamental type and the reduction fails.

Fodor does allow the transitivity of “if, then” and “If and only if”, but even if we could find a long chain of “if and only if” statements linking us from Gresham’s Law, all the way through the intermediary SS (such as psychology, neuroscience, etc.), the chain must terminate

in physics. The end predicate that anchors the chain must be from physics and would still, no matter the content of the other predicates from the other sciences used in the chain, likely need to be of the form $P_1 \vee P_2 \vee \dots \vee P_n$ to cover all monetary systems and exchanges. As in, the fact that there might be a transitive chain linking predicates through the SS does not diminish the type of predicate that must be found from physics to relate to “monetary exchange”.

To deal with the Fodor’s example from economics we will first argue that it can be reduced to psychology. To do this we must consider the predicates “x is a monetary exchange” and “x is a money”, both of which are fundamental types in economics. Fodor brings up an interesting point when he talks about the myriad of things that can be money and the things that count as monetary exchanges. We should explore some of these criteria. For something to be money it must be *valuable* for some reason to *someone*. It also has to be barter-able; that is the whole point of money. In general we gather money so that we can trade it for something. To some people certain money might have a value other than its barter-ability. A king might wish to bathe in gold and so gathers gold for that purpose, but presumably most of the people who gather gold do so in the hopes of trading it to the king (or those acting on his behalf) for things that they want that are not gold. Money must also be valued by the person that you are bartering with. I cannot go to the local supermarket and trade seashells for bread. The store does not recognize seashells as currency because it does not value it. Similarly, someone might value musical talent, but I cannot give away some of my musical talent for bread either, even if the bread owner was willing to make the trade. The point of this analysis is to show that “money” *cannot* be understood without reference to a mental state, namely “valued”. However, the fact that some things are valued but cannot be used as money points to the extension of the predicate “x is a money” being merely a subclass of the predicate “x is valued”. This is very important for our

purposes because it means that the type “money” found in economics is intimately linked with the psychological state that is “value”. It is a psychological state that determines what we value and thus what can be money. I take it that this is not too controversial and so will move forward.

Now that we have explored the ways in which the extensions of “x is a money” and “x is valued” relate, we can create the biconditional bridge law, complete with the initial conditions that map the restricted predicate “x is valued” in a one-to-one fashion onto “x is a money”. The bridge law will be the following: “x is money if and only if x is barter-able, valued by two or more people and...”. The “...” include the other conditions that delineate money from any particular valued thing. So with this bridge law we have established that the predicate “x is money” is co-extensive with the restricted predicate “x is valued”. Now, we can do the same thing with “x is a monetary exchange” by understanding that monetary exchanges are merely exchanges of certain valued things. Fodor believed that the multitude of types of money and types of monetary exchanges posed a problem for reduction, but if we merely recognize that they are indicative of a much more fundamental criteria, which we found to be “x is valued”, then we see that the multiplicity arises when one realizes the multitude of things that *can* be valued. Fodor worries that this multitude in things that can be money will not map in a one-to-one way with some P from FP and this multiplicity will show up as a disjunction of predicates at the level of FP. However, if every type of money maps into *one* type form psychology, namely “value” then the task becomes whether or not “value” maps into some P from FP. We have made the problem simpler (albeit by only a small amount). In this way we recognize that Gresham’s Law is merely making statements about how humans behave given changes in what they value. This appears to make it a claim from Behavioral Psychology, albeit on a scale this is unmanageable for the young science. It seems likely that one could do this for all of economics’ laws.

Part IIIii

Now that the task to show that economics can likely be reduced to economics, we can move on to more interesting and complicated tasks. The more complicated task is to show that psychology can be reduced by the method argued for here.

To argue against for the impossibility of this task, Fodor claims that there is nothing but the grossest correspondence between psychological states and neurological states. Furthermore, it is possible that the more complex neurological systems found in humans arrive at the same psychological state by different neurological means than simpler organisms would use to arrive at the same psychological state. There might also be more than one way to arrive at a given psychological state even within the same neurological system. This would seem to be an issue if we wished to find a neurological natural kind that corresponds to a given psychological natural kind and vice versa. We would likely need to relate through a bridge law a given psychological state with another long disjunction of neurological states to account for all the neurological states between humans that give rise to the same psychological state, and this would be just the first step in the reduction of psychology to physics. If it is true that there is more than one neurological state that corresponds to a given psychological state, then it seems even more unlikely that one could construct the transitive chain of “if and only if” statements between natural kinds of psychology, neuroscience, and so on until we arrive at physics. We would arrive at the same problem that we found before with “x is money”; different psychological states all mapping onto different predicates from FP, giving rise to a disjunction of P_is which is not itself a natural kind in FP. If we then move beyond the bounds of human neurological structures the situation becomes more complex. We might have two or more creatures that feel pain even though they have very different neurological systems. So it would seem that in this case we

would have that Q (a psychological types) is so and so in a human, or it is so and so in an octopus, or it is so and so in an ... This disjunction will certainly not be a natural kind from neuroscience. The existence of a sort of law linking “pain” and a neurological state which would allow one to reduce the psychological state of “pain” to a neurophysiological state seems increasingly implausible.

The case of multiple neurological states corresponding to one psychological state can be handled in the following way. Let us suppose that for some type in psychology (a mental state), call it Q, there is the set of neurological types that we believe are involved in that mental state, $\{N_i\}$. We must be careful to distinguish two different ways in which these N_i can relate to Q. There is the simpler case, in which some N_i , under certain initial conditions, will simply be Q. In this case we have that the extension of Q is a subclass of the extension of N_i , and with the bridge law that shows us under what conditions an instantiation of N_i results in Q, we can create a biconditional bridge law that includes those initial conditions which maps in a one-to-one fashion Q to a restricted N_i . This is the standard case that has been discussed at length. The more complicated case is one in which more than one N_j is involved in some instantiation of Q. This is rather like the “hurricane” case and will proceed the same way. Our bridge laws that relate each N_j to Q will have to restrict the extensions of each N_j in the same way so as to preserve the biconditional. Thus, under the bridge law applied to each N_j , the extension of each N_j will be exactly $I\{N_j\}$. Now, we have posited at least two cases in which more than one neurological state gives rise to a psychological state. It can either be that Q relates to the restricted N_i biconditionally or that Q relates to $I\{N_j\}$ biconditionally (or both). So, we see that the extension of Q is exactly the class of the restricted extension of N_i or $I\{N_j\}$, which we can write as $U\{N_i, I\{N_j\}\}$. This is the union of: the extensions of each N_i that we believe is involved in Q

independently, and the intersection of each N_j that is involved in Q dependently. The question is whether or not this has actually gotten us anywhere. Well, we can then use the disjunction of the individual bridge laws that we found in each case above to create a biconditional bridge law that relates the extension of Q to the set $U\{N_i, I\{N_j\}\}$. We now have a one-to-one mapping from the extension of Q to a class whose members are instantiations of the N_i that we, in our present ignorance, think are involved in Q . However, this bridge law, though it could be incredibly long and cumbersome, will be a proper bridge law for the reduction of psychology by neuroscience. As in, if x is in $U\{N_i, I\{N_j\}\}$, then x will also be an instantiation of Q . The issue arises when we go the other way, from an instantiation of Q to an instantiation of some N_i . We will know which neurological types an instantiation of Q *cannot* be; it cannot be a type from neuroscience that is not represented in $U\{N_i, I\{N_j\}\}$, but we will not know exactly which N_i is being satisfied by x in general. This is a concession to our lack of information and it is hoped that with further time and inquiry this disjunctive bridge law will shrink until it is as precise as some of the other bridge laws that have been explored in this paper.

The last case, where different neurological structures in different creatures can result in the same psychological state is actually very similar to the above problem and so the explanation will be brief. In this case our bridge laws must be equipped with the conditions in which a neurological type relates to a psychological type and they must also include which animal/neurological structure this particular bridge law will apply. A neuroscientist will no longer be able to speak in generalities, but will have to distinguish between neurological structures that are sufficiently different from each other. So, instead of merely N_i relating to Q through a bridge law, we will have to specify N_i^H to mean that we are talking about a neurological state in a *human*, which might be different in an octopus. No matter the animal, we

can construct the same kind of bridge law that we did in the preceding paragraph from Q to $U\{N_i, I\{N_j\}\}$ for each Q that we find in that animal. Only now we will actually be talking about how Q^H relates through a bridge law to $U\{N^H_i, I\{N^H_i\}\}$, if we are discussing human neuroscience and psychology. Now, as neuroscience progresses I believe that we will find that many of these neurological states are more similar than we thought and that we will find similar or the same neurological states in any given creature giving rise to the same psychological state, though this cannot be empirically supported at this time.

Concluding Remarks

So have we actually answered the objections that are commonly raised by those who believe that a reduction cannot be done? Yes and no. Recall that in the opening paragraph we defined a reduction to be an argument where the premises are statements from the new or more inclusive theory, along with bridge laws, which allows us to conclude statements from the older or less inclusive theory. This appears to be unidirectional. Physics would reduce chemistry; Newtonian Mechanics would reduce Galilean Mechanics, and so on, but not the other way around. However, in creating the structure that we have in this paper we actually see that this method can be used to reduce FP by psychology, though with some restriction. It is reasonable to think that an instantiation of a predicate from FP might not result in an instantiation of a predicate from psychology; surely before the evolution of consciousness we should never expect that anything could ever be an instantiation of a predicate from psychology even though plenty of things are instantiating predicates from FP. This method captures our intuitive understanding of reduction, namely that every instantiation of a predicate from a SS is an instantiation of a predicate from FP, and that with the proper initial conditions, a specific instantiation of a predicate from FP will result in an instantiation of a predicate from some SS. To give an example

of how this works, let us return to the example of Q, the type from psychology. The biconditional chain of bridge laws that will relate Q to a type from FP, call it P, will be a conjunction of the biconditional bridge laws that pass through each of the SS from psychology to FP. So, the first step will be the bridge law that we found to relate the extension of Q to $U\{N_i, I\{N_j\}\}$, and the next conjunct will be the bridge law that relates whatever N_i that x (in the extension of Q) satisfied to some type from Neurochemistry/Neurobiology. The next conjunct will be the bridge law that relates that type from Neurochemistry/Neurobiology to a type from Biology, and so on. This final bridge law will be biconditional, so that any x which is in the extension of Q will be found in the extension of some P in FP. Also, any x in the extension of P, *should it satisfy each of the conditions in the conjunctive bridge law*, will also be found in the extension of Q. So we have a bridge law that is a one-to-one mapping from Q to a subclass of the extension of P. This is exactly what we expect. Some instantiations of P will never result in an instantiation of Q, but all instantiations of Q will result in an instantiation of P. Now, if we created this long bridge law for each Q_i that is a type in psychology, then we would have all of the bridge laws that one would need to make the reduction from FP to Psychology. More generally, if such a bridge law could be constructed it would mean that each fundamental type in a SS is co-extensive with a restricted fundamental type from FP.

How does this relate to the structure of an intertheoretic reduction outlined at the beginning of Part IIIi? Well, that structure seemed to be bi-directional, so that Psychology should reduce FP and FP should reduce Psychology. With the bridge law stated above, we do not necessarily get this, but we get something close. We can reduce Psychology by FP, we did this just above, but we can also reduce FP by Psychology for only a select few entities or situations; namely the entities that would be in the extension of some P_i *and* satisfy each of the conditions

present in the conjunctive bridge laws that relate Q_i to P_i . So, if we started with the statements of psychology and wished to add in each of the bridge laws that we spent so much time constructing, we actually could, but the entire reduction would only be true for *some* instantiations of P_i . This is both a concession to Fodor and a statement that the method of intertheoretic reduction developed in this paper more closely captures our intuitions on the subject; namely that each thing that satisfies a type from psychology will satisfy a type from FP, but that not all things that satisfy a type from FP will ultimately satisfy a type from psychology. Similar arguments can in principle be made for any SS.

The goal has hopefully been reached. Starting from Nagel's definition of an intertheoretic reduction, we defined and explored the two different types, *homogenous* and *inhomogenous*. The difficulties of the inhomogenous reduction forced us to consider in what ways that fundamental predicates of an older or more specific SS relate to those from a newer or more inclusive SS. In doing so, we discovered that the bridge laws could be used to relate the extensions of one predicate to another other through the subclass relation. Taking this idea further, we argued that any fundamental predicate from a SS would end up being embedded in a predicate from FP by taking advantage of the transitivity of the subclass relation. Once this transitive chain of subclasses is established we could create a bridge law that relates any predicate from a SS to a predicate from FP by creating a large conjunctive bridge law whose conjuncts are each bridge law used to create the subclass chain from the extension of that predicate from the SS to the predicate from FP. So long as we included the initial conditions that determine the restrictions placed on each of the predicates that were being embedded in so that their extension exactly matched the predicate that was being embedded in them, this bridge law would be biconditional. With these biconditional bridge laws for each fundamental predicate

from a SS to a fundamental predicate from FP, we could start with the statements of FP and add in the bridge laws to create an argument that would yield the statements of any SS. Thus, if such a structure could be made, which rests on increased empirical investigation, that structure can be used to show that FP reduces any SS.

Notes:

1. I should also point out that the bridge laws that state the identity of two extensions of predicates satisfy the subclass relation because any class is a subclass of itself (i.e., the subclass relation is reflexive). The reflexivity of the subclass relation will be important for bridge laws that assert the identity of the extension of two or more SS predicates. This will allow us to continue linking the extensions of SS predicates in the transitive subclass chain even if we have two extensions that are found to be the same through empirical enquiry.
2. [Rothbard, Murray, Commodity Money in Colonial America, LewRockwell.com](#)

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