Contingency and the Order of Nature

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PART I SETTING THINGS UP

Introduction

This is a paper in defence of radical contingency in Nature, radical contingency despite the pockets of rough order we observe in our daily lives and of precise order we report in our modern sciences. But, are contingency and order not in opposition? Yes, I think they are.... if the view of Nature and science that has dominated since the Scientific Revolution is correct, that order arises from the rule of universal laws, laws that hold everywhere and everywhen and that dictate all aspects of what happens. But they are not in conflict if the source of order in Nature is not laws but powers and mechanisms.

I have been arguing for the importance of powers (which I have called *capacities*) and mechanisms (which I have called *nomological machines*) for a long time and I have my own slant on just how to describe them. But these are both central topics in philosophy now, powers primarily for the metaphysicians and mechanisms in the philosophy of science, and there are a variety of different accounts available. No matter. Almost any of the variations can be adapted to the image of Nature where laws play a minimal role, powers rule, physics is incomplete, the future is open and what occurs in Nature can be a matter of mere hap.

I have argued against universal laws as the correct way to reconstruct our impressive body of knowledge in modern science and in favour of powers instead in a number of different ways. The basic attitude behind all the arguments is a metaphysical modesty: postulate what is needed and don't make grand gestures beyond this. Powers make sense of the practices of much modern science and of its impressive empirical successes. They allow us to account for any order that we have actually observed or established without signing up to faith that all is ordered everywhere and that physics is Queen of all of Nature. Finally, powers allow for a this-worldly metaphysics in which Nature, once created, moves forward of its own accord; what happens next is governed from within Nature and not by some mysterious laws that dwell outside and operate by some extra-natural force.

In this paper I shall argue that embracing contingency and deriving order from powers and mechanisms resolves 3 distinct kinds of problems in one fell swoop: ontological, theological and epistemological. The theological is in honour of our conference organiser, Peter Harrison, whose work provides the starting point for it. The ontological problem is one adumbrated before and the dimensions of it will be familiar to all here. But the epistemological problem is, I believe, relatively unfamiliar. I take it from the recently deceased German philosopher of physics and friend, Erhard Scheibe.

I begin by outlining the view about powers, mechanisms and contingency that I maintain will solve the three problems I will describe.

Powers and mechanisms

So, what's a power? I don't think the lens of modern science is strong enough to show an answer, which I take it is why contemporary metaphysics has taken up that job. Happily for present purposes it is enough just to note a handful of features that I argue we had best ascribe to powers and their mode of operation if we are to account for at least a large swathe of the practices and impressive empirical successes of our modern sciences.

1. Powers are identified by a canonical operation. For example gravity is the power to attract objects of mass m a distance r away with a force Gm/r^2.

2. Our modern sciences have empirically established a very great number of powers. Some are the result of stable arrangements of components with other powers: e.g. the power of objects identifiable as toasters to brown bread depends on the arrangement and familiar powers of its parts. But we cannot assume that all powers 'reduce' to arrangements of some basic set. Each science produces knowledge of myriads of special powers that relate in complicated ways to other powers. And where reductions are possible, the lessons of the 'mechanists' in contemporary philosophy of causation (like Bechtel and Machamer, Darden and Craver) must be heeded: arrangements matter, not just the powers of the parts.

3. Modern sciences also have empirically established a myriad of reliable indicators of powers: Any system with a gravitational mass has the power of gravitational attraction; experts can tell a barley seed from rye and oat by their visible characteristics; I know the object in the box in the shop will brown bread because it is labelled 'toaster'. (The metaphysical relation between the indicators and the powers is a matter of current controversy.)

4. What happens when a power operates in its canonical manner depends on the arrangement of circumstances: When the earth exerts its gravitational power on a compact unsupported object in a vacuum, the object falls at 32 ft/sec/sec; when (to use an example of Otto Neurath) it exerts its gravitational attraction on a 1000 mark note dropped on a windy day in St Stephen's square, the bill blows all over the place; when it exerts it on a glass sitting on a table, the glass sits still.

5. Some arrangements of circumstances fix what will result when the components exercise their powers in consort. Successful design will engineer these arrangements to produce the kinds of results we want. Some arrangements of the right sort to fix results occur naturally and these are the sources of predictability in Nature. In other cases we have no guarantee that the results are fixed.

6. The impressive precise predictive success of modern physics as well as the phenomenal technological advances that physics has aided can (as I shall describe in more detail in Part IV) be accounted for by 'local mechanisms' without resort to universal laws that fix all of the effects in physics' domain.

7. The possibilities for new reliably predictable behaviours by engineering new mechanisms are endless.

This last is what is so exhilarating about replacing the rule of universal law with a power/mechanism ontology if correct. Nothing in our future is set irredeemably by what happened at the Big Bang or at some hyper-surface in space time. What happens can depends on how we arrange things to exploit the powers of their parts.

The place for radical contingency is found in number 5. It is here that others adopt a faith in determinism whereas I urge we remain agnostic, putting into Nature only what we need in order to account for what we know to be the case. I say that *some* arrangements fix what happens. We have strong empirical evidence for this much at least. Moreover in different fields of knowledge we can say quite a lot about what the arrangements are like that provide fixed outcomes that we know, at least roughly, how to predict. But the empirical evidence stops far short of the stronger conclusion of determinism: that every arrangement has a fixed outcome. (Or, with quantum mechanics in view, a fixed outcome space with fixed probabilities across it.) Some things just happen. Powers operate in their usual way but circumstances are not right for a fixed outcome.

This is how Nature appears to us much of the time, especially Nature in the wild, outside of our technologies, our societies and our laboratories, and it is how it continues in some cases to appear despite our best scientific efforts to uncover the hidden rules we take to be fixing its every outcome. What happens may be constrained in ways we have come to learn about -- it is fairly certain that the thousand mark note in St Stephen's Square will not suddenly turn into a giraffe. But the evidence that secures that prediction does not go far enough to assure that just where the bill lands is fixed by law given the circumstances. You may if you wish have faith in determinism just as I have a strong aesthetic preference for a dappled and open-ended world. But in either case it would be a mistake to maintain that the evidence selects one view over the other. At least the dappled, open-ended world where powers, not laws, operate, has this in its favour: It involves less metaphysical commitment and the metaphysics it does embrace is this-worldly, and, if I am right in my arguments here, it provides as side benefits help on pressing problems in theology, ontology and the epistemology of science.

PART II SOME ONTOLOGICAL ADVANTAGES

The usual story has it not only that Nature is ruled by universal laws but that these laws govern only a special set of basic features. These features and laws are the special domain of physics. What then of all the other features we find in the world around us, from the central theoretical quantities studied in other disciplines to the everyday features by which we organise our lives?

Philosophers nowadays offer two accounts. One, which is very visible in the literature on mind-body relations, involves supervenience and multiple realisability. The microphysical state of the universe determines all the other features that hold in the sense that were the microphysical states different, these other features would have to differ as well. The reverse though is not the case. The same set of non-physics feature can be realised by a variety of different physics states.

The other, which I think is preferable for reasons I shall explain, proposes that there are what philosophers of science call 'reductions': There is a physics state to correspond to certain other stable features of Nature and the laws that govern the basic features of physics explain why these other features exhibit whatever regular behaviour they do exhibit.

We are told that modern physics provides empirical support for the metaphysical claim I question, that the non-physics features and regularities of Nature are fixed by law once the initial physics features are laid down. Yet physics does not provide even a rough sketch, let alone a proper account, of how this works for any features at all. But there are those who are committed to the effort, for instance the physicist turned philosopher of physics David Albert, who says of himself: 'My research is focused mainly on questions of whether and how physics might amount to a fundamental and universal account of the entirety of nature.'[1]

Much of the effort in this regard by Albert and other physicists and philosophers focuses on reconciling the second law of thermodynamics, whereby systems evolve towards 'equilibrium' – heat flows from hot to cold, gases expand throughout their available volume – with the fact that for any sequence of states that the basic laws of physics allow, they allow the sequence in reverse temporal order as well. The conventional manoeuvre here is first, following the ideas of Ludwig Boltzmann, to make some probability assumptions whereby the set of microstates evolving towards macroscopic equilibrium is far more probable than the set evolving away from equilibrium, and second, to postulate – note, postulate, not discover – a very special starting state of very 'low entropy', i.e. very far away from equilibrium. How far away? As Craig Callender remarks: 'How low would the entropy have to be? *Real* low: low enough to make thermodynamic generalizations applicable for the roughly 15 billion years we think these generalizations held.'[2]

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[1] http://philocosmology.rutgers.edu/who-we-are/david-albert Published on 07 February 2012

[2] **Measures, Explanations and the Past: Should "Special" Initial Conditions Be Explained?**

That's about as good as it gets when it comes to detailed models of how the regular behaviours of other features in Nature come about from the initial physics features of the universe: We can give a transcendental argument about what the initial conditions must have been if the special feature 'entropy' is to behave as we observe it to behave. And even this claim is way overstated. Even if successful, all these arguments do is to show that the entropy of the universe as a whole goes in the right direction. But what we observe is not the whole but a very great many of the parts. In each of these local systems we observe, from our coffee cooling in our cups to the gas escaping from the punctured balloon, entropy increases. It is perfectly compatible with the global entropy going up that all the subsystems on Earth have their entropy go down.

This issue links with Scheibe's worries about coherence and generality that I discuss in Part IV. As Calendar remarks in personal correspondence:[3] 'One gets pushed "global" by backward time evolving the particles making up your coffee and the probability distribution over them. Those guys came from the water from the tap, which came from the lake, which came from....the formation of oxygen and hydrogen... So the transcendental argument pushes one not just all the way back but all the way "wide." Make that global posit. Nothing in particular follows about that coffee cup. Or at least, one needs to wave one's hands a lot making various huge controversial and unverifiable assumptions about the dynamics for anything to follow at all.' In Part IV I explain why we needn't get pushed global in our laws just because the water comes from the tap that comes from the lake.... since little of this history happens in the context of a mechanism in which the laws can take control and dictate outcomes.

We do enormously better though when it comes to providing local physics substructures that explain particular kinds of regular behaviours, what I above called 'reductions'. This is why I prefer reduction to supervenience. 'I believe it when I see it' and urge the same for you. And there are lots of empirically well-supported reductions (but see my caveats on this below) of particular special features to be seen in the natural sciences. One I have studied is provided by the BCS theory of superconductivity. The BCS theory proposes that superconductors are materials in which a sea of electrons float in a certain kind of lattice structure. The theory then deploys a combination of quantum and classical mechanics to show that materials with this structure will exhibit the two central characterising behaviours of a superconductor: They expel magnetic fields and they allow for the flow of DC electricity without resistance.

Providing this explanation is an enormous achievement. But it is a very very long way from showing how each expulsion of the magnetic field by an operating superconductor was destined by the initial conditions of the universe. I have no doubt that there are good historical explanations to be had, and

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Craig Callender
[3] 31 July 2013

similar ones at that probably, about how each and every sample of lead or cadmium or zinc comes to be the way it is, e.g. how zinc sulphides in Lisheen, county Tipperary, Ireland, in which the zinc will have what is called a 'body centred cubic' lattice structure, resulted from mineralogical changes in the host lime mud limestones. But this kind of explanation will involve local arrangements of a mix of causes, including geological forces, that act in cooperation with the microstructures of the more original materials from which the sulphides formed.

There are three points I want to make from this discussion. First, the BCS theory helps provide a good explanation[4] of a new feature – being a superconductor – and of its regular behaviour – when cooled below the transition temperature a superconductor expels magnetic fields and allows for resistanceless flow of DC electricity – that involves features of fundamental physics and their known behaviours. But the explanation does not involve deriving those regular behaviours from the state of physics features at the start of the universe. The explanation is given by describing a mechanism: an arrangement of parts with powers that can be taken to constitute a new feature – being a superconductor – that exhibits regular behaviour.

I say that the parts have powers that, when exercised in consort in the specific arrangement described in the theory, produce the two effects regularly associated with being a superconductor. I suppose many would accept that the explanation proceeds by describing a mechanism but insist that the operation of the mechanism depends on laws not powers. This is of course a matter of reconstruction: Which is the better metaphysics to describe the knowledge used in these accounts and what counts as 'better'? For me a 'good' metaphysics for the job will be this-worldly; it will have solid empirical warrant; and it will not stretch its neck out much farther than necessary. That's why I choose powers.

I also think, as I argue in Part IV following Erhard Scheibe, that there are consistency problems about these laws given what we know of how interactive the systems in Nature are. I picture our knowledge of how charges repel and attract each other, which is central to the explanation for superconducting regularities, as knowledge about the canonical operation of the powers to repel and attract that charged objects have. If it is instead to be cast as knowledge of laws, just what do the laws say, and how do you show that what they dictate is consistent with what is dictated by law from the initial conditions of the universe?

Second, although for the sake of illustration I have talked as if the BCS theory reduces superconducting materials and their behaviour to some set of fundamental physics features, I have never seen a serious model that accounts in this way for real phenomena that take place at a specific place and time. All the models I know that describe and predict the behaviours of real objects,

[4] Though there is some question whether it is the 'right' explanation since it does not extend to high temperature superconductivity, for which we are having a hard time finding a good theory.

from superconductors to lasers to gyroscopes testing the general theory of relativity (GTR), involve a host of features not in this privileged set and not otherwise reduced to them. The BCS theory looks as if it does because it is an abstract model; it is a template that we deploy as a central part, but only part, of detailed models of mechanisms that we use to make real empirical predictions. This kind of template is not what we use for the precise on-the-ground predictions about real systems that make credible the knowledge claims of modern physics. Rather we use a model that deploys a very rich set of concepts that allows us to describe and make predictions about a real material sunk into a real dewar to cool it below the transition temperature to employ, say, as part of a SQUID (a superconducting quantum interference device) to help measure the precession of a fused quartz sphere that will serve as a 'gyroscope' used to test GTR.

The lesson is two-fold. All the models I know that produce the kinds of precise empirical predictions that give us well-grounded faith in physics' knowledge look like detailed descriptions of mechanisms and they use a host of features of various kinds at various 'levels' related in diverse and complicated ways. If we take seriously that we should accept into our ontology what we use in our best empirically predictive models, we will end up with a rich ontology of features and not the sparse set of special quantities that physics specialises in.

Third, we are also able in modern science to explain the appearance of features and behaviours, even microphysical features – like the formation lattices in zinc sulphides in Lisheen – that don't come close to looking like reductions to physics, though physics may play a role in the account. As I noted above, these explanations look like descriptions of mechanisms, and in these cases even more so than in those that approach reductions, if we read our ontology from our explanatory and predictive success, it will look nothing like an ontology of physics features.

A metaphysics of powers and mechanisms will thus allow us a world rich in features that relate in just the ways we see them relate in our successful predictive and explanatory models, features that do not have to be accounted for in models that we don't have even sample of by the laws of physics evolving the initial conditions of the universe.

PART III A THEOLOGICAL ADVANTAGE

Peter Harrison has argued that historically the doctrine of the universal rule of Nature and all within it by immutable law that has dominated since the Scientific Revolution made the secularisation of Nature easier. On the dominant view God laid down the laws and the initial circumstances of the world and, supposing the laws are obeyed, all else follows. There is recurring debate about whether God is needed to keep reaffirming the entire set up to keep it in existence but if He is not needed, there is no role for God once the world has been created. But then, why suppose there is a God to create it? God is an unexplained explainer. Why not just stop one step sooner: The laws themselves and the initial state are together the final unexplained explainer. So the rule of universal law makes God appear unnecessary.

I would like to suggest that, equally, it makes God appear unattractive, indeed sinister. Logically it is a short step from universal determinism to the denial of free will for humans and the Calvinist doctrine of predestination. The argument about free will is familiar to us all. All that happens in Nature -- including all our actions and their consequences -- are dictated by the rule of immutable law from the initial state in which the world began. If so, it seems not only unjust but cruel to punish us for our failings.

Some thinkers, like the English Anglican Puritan, Thomas Beard, who taught Oliver Cromwell, have argued that God foreordained everything including the fall of human kind. (See his 'Theatre of God's Judgments'). Others give humanity more responsibility. *We* are responsible for our fall from grace but God foreordained everything after the fall, including people's actions and lives and ultimately then heaven and hell for each of us. In the first model, God still reacts to circumstance, in the second he does not. Scholars disagree about which of these Calvin himself believed. Whichever was Calvin's own view the first model got gradually replaced by the second over the early modern period, essentially because of a following through on the logic of divine sovereignty. People start out thinking about predestination in the context of questions about salvation but then it becomes our familiar cosmological question.

We can see the difference by looking at descriptions of predestination in different Calvinist statements of faith. For instance, compare

> <u>Belgic Confession of Faith 1561</u>
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> 'We believe that all the posterity of Adam, **being thus fallen into perdition and ruin by the sin of our first parents, God then** did manifest himself such as he is; that is to say, merciful and just: *Merciful*, since he delivers and preserves from this perdition all whom he, in his eternal and unchangeable council, of mere goodness hath elected in Christ Jesus our Lord, without respect to their works: *Just*, in leaving others in the fall and perdition wherein they have involved themselves.' (Art. XVI)

with

> <u>The Westminster Confession of Faith (1643)</u>
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> '**God from all eternity did by the most wise and holy counsel of his own will, freely and unchangeably ordain whatsoever comes to pass**; yet so as thereby neither is God the author of sin; nor is violence offered to the will of the creatures, nor is the liberty or contingency of second causes taken away, but rather established.

> By the decree of God, for the manifestation of his glory, some men and angels are predestinated unto everlasting life, and others foreordained to everlasting death.
>
> As God hath appointed the elect unto glory, so hath He, by the eternal and most free purpose of His will, foreordained all the means thereunto. Wherefore, they who are elected . . . are effectually called unto faith in Christ by His Spirit working in due season, are justified, adopted, sanctified, and kept by His power. through faith, unto salvation. Neither are any other redeemed by Christ, effectually called, justified, adopted, sanctified, and saved, but the elect only.
>
> The rest of mankind God was pleased, according to the unsearchable counsel of His own will, whereby He extendeth or withholdeth mercy, as He pleaseth, for the glory of His Sovereign power over His creatures, to pass by; and to ordain them to dishonour and wrath for their sin, to the praise of His glorious justice.' (Chap. III — Articles I, III, VI and VII)

When it comes to thinking about the character of God, the differences here can seem minor, almost insulting. Am I supposed to be comforted and convinced of God's beneficence and justness by the reassurance that I am not damned from the start for doing what I have no choice in but rather damned for doing what I have no choice in on account of the foolish or wicked behaviour of Adam and Eve?

As with our contemporary attempts to reconcile free will with the universal and fundamental rule of the laws of physics and the assumption that all that happens in Nature supervenes on what happens in physics, there has been a lot of fancy footwork to try to explain just how it can be that everything is determined by the laws and initial conditions that God laid down but still 'neither is God the author of sin; nor is violence offered to the will of the creatures, nor is the liberty or contingency of second causes taken away, but rather established.'

Nor is the theological problem just that God seems to allow us to be punished for what we did not genuinely do. Indeed even if one believes in universal salvation, the problem of human freedom still stands in the same relation to God’s will as in a picture where some are predestined to heaven, others to hell. Given the universal rule of law, we cannot do anything; we have no role to play in how the world unfolds. We are like the hammer that strikes the nail: We have no choice of which nail to strike, or to strike or not, let alone about whether we want to be a hammer or not.

A more attractive God is the God of the 4th century Pelagius, defender of what came to be labelled the 'Pelagian heresy’, or the rather different God of the earlier Irenaeus. Both of these thinkers, in their different ways, give us resources for thinking about a God who not only leaves space for us to do things but encourages us to do our best. Pelagius admitted God’s sovereignty

in the world as it unfolds but argued that it is sovereignty as potentiality in the sense that God *can* make his will occur, but he might not. God might want something to happen but nevertheless it may not because we don't make it happen. And Irenaeus, though a firm defender of divine sovereignty over creation, urged that people's actions have to come from themselves in order to be genuinely moral acts and he insisted that we progress towards perfection. Admittedly both of these ideas can be found in a wide variety of patristic authors in some guise. However, for Irenaeus, they are both especially emphatic and especially calculated to draw out the importance of human agency.
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The contingency of events that can be allowed once the universal rule of law is rejected can leave space for us to play an active role in what the world will come to be like. It is not of course enough by itself. If what happens just happens we have no more control than we do if all is fixed forever from the start. Powers too by themselves do not solve the problem. We may indeed have a myriad of powers but if they exercise themselves willy-nilly when the occasion is ripe, again we have no control. So it looks as if we need in addition some kind of doctrine of agency, like the one Tim Mawson among others defends: We are agents endowed not only with a variety of powers but also with the ability to exercise them to change arrangements in the world and to invent and set-up new arrangements with new previously undreamt of outcomes.

This kind of doctrine is notoriously difficult to get right and I shall not make any attempt at it. My contribution here is to provide independent motivation for two of the three chief ingredients that allow us to play an active role in shaping Nature and in moulding the societies in which we live, by setting these problems in the philosophy of science, in the context of the attempt to provide a reasonable and not inflated this-worldly reconstruction of the scientific world image. In this context powers are widespread, they are not peculiar to human beings, and contingency is not motivated by the free will problem but rather it serves to avoid making grander metaphysical commitments than we need to account for the evidence about Nature provided by the empirical successes of our modern sciences.

PART IV AN EPISTEMOLOGICAL ADVANTAGE[6]

Erhard Scheibe argues that the more general our physical laws are, the less coherent or interconnected is the world that our theories picture. There is a 'mutual exclusion "by degrees"' between generality and coherence.[7]

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[5] Reference to Mawson's recent book

[6] Thanks to Tom Bunce who is responsible for the exegesis of Scheibe's views. More details can be found in xx [Scheibe paper with TB]

[7] ref

Consider what a law of physics says. The law claims that all physical systems described by it behave in a certain manner – that described in the law. All hydrogen atoms, for example, behave in accordance with the Schrödinger equation with a Coulomb potential. By putting laws in this form we see that they have two components: 1) the content of the law, and 2) its universal form.

The content of the law, according to Scheibe 'is what physicists have to find out by exploring nature'. It tells us about each individual system; the actual claim of the law -- its concrete content -- is different in the different cases that the law applies to. The universal form bestows onto a law the generality that makes it a law. The problem is that these two parts of a law work against each other. The generality of a law implies a certain kind of independence between the systems in the domain of its quantifier. Each of them individually should satisfy the law regardless of the state or situation of the others. This independence between instances limits the establishment of lawlike connections/interactions between the physical systems in the domain of the law. Conversely the content of a theory can produce a connection among systems in the world of a strength that it disallows independence and universality. The kinds of interactions pictured in the theory might lead to an extreme coherence in which everything is related to everything else in such a way that no natural laws for the separate systems involved can be admitted.

What then, is the coherence of a physical system like? The picture of how the world operates presented in both classical and quantum physics introduces dependencies between otherwise independent subsets. Consider the contrast between the world in which there is no true reduction of a quantum wave-packet – a world in which things have no individual state once they have interacted – and the world of logical atomism (as pictured for example in Wittgenstein's *Tractatus*)– a world in which each proposition can be true or false independently of any of the others. The former is maximally coherent; the latter minimally so. In the no-collapse quantum world there is only one state – the state of the entire world. In the Tractarian world each and every constituent part has a state of its own independent of all of the other constituent parts and so coherence is minimized.

Coherence has a different nature in classical physics since in classical physics each distinct system does have its own state despite interaction. But as soon as gravitational interaction is admitted the states do not evolve separately but only the entire collection at once. So again generality is completely lost. We can put a universal quantifier in front if we want. So we can SAY of the temporal evolution of the state S of a physical system, 'For all x, dS(x)/dt = ….'. But there is really only one 'x' that this law governs.

But that is not how we use our laws. We do picture the world as highly coherent: full of connections and interactions. Yet we apply our laws to sundry individual systems. Often this is defended with the excuse that we are merely *idelaising* in a harmless way. Scheibe notes that as a consequence of this kind idealisation, there is a 'radical and inevitable fictionalism' at work in physics – we abstract almost everything about the real world. This is inevitable, he argues. Otherwise it seems we would have to jump straight from knowing nothing to knowing everything.

But this is not a trivial fact. It imposes on the world and our theories of it the requirement that the behaviours that our theories predict to be physically possible should, even though viewed as different possible worlds, be realized in THIS world with sufficient accuracy and in sufficient numbers despite the fact that this world is full of interactions that destroy the requisite independence. Now this seems to be the case. We would not, Scheibe points out, have physics without it. The epistemological problem would be insurmountable.

It is though a truly remarkable fact: If anything like our current understanding is correct, our world is highly coherent. So coherent that there may be only one system for the laws of evolution to govern. How do we learn this law, or confirm it? For sure it is not by looking at the only state the evolutionary laws care about – the state of the entire universe -- at different times. We learn the law of the whole by generalising the behaviour of the parts. For this to be possible the very laws – totally non-general laws -- that describe the behaviour of the whole must also describe the behaviours of the components in good approximation. How can that be so? This is the big question that Scheibe’s lessons about coherence and generality raise.

How did we get so lucky? For the kind of fictionalising Scheibe describes to work, the fundamental law of evolution of the universe – the one true law, the only one there is – must have very special characteristics. Without it we couldn’t look at how the parts behave in certain peculiar circumstances – when they are ‘nearly isolated’ – and find the same regular behaviours and then extrapolate the behaviours we regularly see for the parts to be the law of the whole. In fact, there’s no reason even to think there would be any regular behaviour to be observed, even in ‘isolated’ parts.

Let me give a simple diagrammatic example. Consider gravitational attraction as we understand it in classical mechanics: Any mass M attracts any other mass m with force GMm/r^2, where r is the separation between the centres of mass of the two. We learned this in part from observing the effect of the sun on the earth. But the earth is made up of myriad small morsels of mass. If the formula is true for all masses, as it is supposed to be, then each of these must be attracted to the sun with a force given by the same formula. In that case the earth as a whole must move as the motions of these morsels dictate and so, in train, must its centre of mass. Why should that result in a motion for the earth that looks anything like one in which the centre of mass of the earth is attracted to the sun by a force GMm/r^2? The motion of the whole must follow willy-nilly from the motion of its parts and any force that we read out of that for the attraction between masses need look nothing at all like the true one that is at work. Yet we did look at the motion of the whole and read back a correct force both for it and for all its parts. How is this possible?

Answer: We are lucky, and on two counts. The distribution of matter making up the earth is very nearly spherically homogeneous and the force of gravitational attraction is a $1/r^2$ force. That's terrific because for $1/r^2$ forces, if each morsel of a spherically homogeneous body is attracted to a spot with that force, so the centre of mass of the whole will also be attracted by the same force. Moreover, $1/r^2$ is the only form for which that is true.

We must suppose the same kind of luck for the forms of the laws of the universe if we are to read these laws off from what we observe about the separate parts when their interaction is minimalized. Or beyond luck – a miraculous gift.

The trade-off between coherence and generality that Scheibe highlights makes the possibility of our doing physics seem a miracle. The laws of the evolution of the universe must have a very special form indeed if we are to learn them in the way we do and if we are to use them in the way we do. But with a metaphysics of powers and mechanisms, we don't need this miracle after all. There are no laws for the universe as a whole with which the laws of its parts must be reconciled. There are just the parts of Nature. The parts have powers and when parts with suitable powers are arranged in suitable ways – i.e. they constitute a mechanism -- outcomes may be fixed. This gives rise to a host of local necessities but there is no natural source of inconsistency among them.

In defence of these claims I shall first review how we acquire knowledge of the physics of Nature on the powers/mechanisms account and how we use it, then make some brief remarks on Scheibe's picture of the coherent universe.

Sometimes we are able to study mechanisms – arrangements of parts -- in which a particular powers acts more or less on its own, so that we can see its canonical exercise directly in what happens. That's what Galileo did in his rolling ball experiments to study the power of gravitational attraction exerted by the earth. He honed the plane to be as smooth as possible before he rolled the balls down it so that the earth's power to attract the balls would not be adulterated by the power of friction to slow them down. The mechanism he devised allowed him to see the power's canonical operation directly in the effect that actually happened.

What Galileo learned would not be very interesting if the attraction of the earth on his rolling balls was not the operation of a power that recurs regularly in Nature, indeed in this case a power that we suppose that a system will have so long as it has a (gravitational) mass. We express our commitment to the universal association between the power of gravitational attraction and the independently identifiable feature of having a gravitational mass in what is called 'the law of gravity': Any object with a gravitational mass, say M, will attract another object with gravitational mass m a distance r away with a force GMm/r^2. Having a universal law like this does not, however, commit us to the kinds of laws that start from the initial state of the world and fix everything in train. Even if the earth always pulls things down to it, we can fly our planes in the air and affix magnets to our fridges by building the right kinds of mechanisms in which the effects of gravity are circumvented.

It is important to note that Galileo's rolling ball experiments allowed him only to observe the effects of the earth's power of gravity acting on those balls. They did not provide him much evidence that the earth has had this power for a very long time and will continue to have it in the future, nor that the power affects not just balls but any massive object, nor any object with a mass can be relied on to possess this power. These grander conclusions get their support from a vast web of experience, experiment and theorizing. I do not have any special thoughts about the usual histories of how this knowledge got stabilized except to urge that in appreciating the results we have been able to create and predict we not lose site of the mechanisms that make predictability possible, from the planetary system which gives rise to Kepler's laws for the orbits of the planets to the intricate experimental arrangements that have recently been used to test the inverse square law of gravitational attraction at length scales shorter than a few millimetres, spurred on in part by the desire to look for quantum gravitational effects, which would only be significant over incredibly short distance scales.[8]

Galileo worked hard to study the power of gravitational attraction acting on its own but often we can only manage to study what happens when powers act in consort. Then the job of inferring the canonical operation of any one of the powers is harder. But there's no grand constraint of consistency here as there is when we try to read the laws of the universe from the regular behaviours of the parts. We can gain knowledge in physics in just the way we do and use it in just the way we do and no miracle form-matching is required.

Powers affect what happens. Mechanisms make what happens predictable. And where we can't predict, it may be no fault of our own. The setting just may not have the right structure to fix an outcome to predict; i.e., the setting may not constitute a nomological machine – an arrangement sufficient to fix what will happen.[9] The earth will surely exert its gravitational pull on the 1000 mark note blown by the wind around St Stephen's Square. That is certainly not enough to allow us to predict where the bill will go. Can God or Laplace's demon predict it? One may postulate that the demon need only consult those universal laws and the precise initial conditions and then he will know what will happen to the bill. The more modest metaphysics of powers and mechanisms allows that even Laplace's demon cannot predict what we cannot predict in this case since it allows that there may be no pre-set fact to predict. The power of

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[8] For a review of these cf "Tests of the Gravitational Inverse Square Law", E.G. Adelberger, B.R. Heckel and A.E. Nelson, Ann. Rev. Nucl. Part. Sci. **53**, 77 (2003). (hep-ph/0307284)

[9] This possibility may not be allowed on every account of powers. Some for instance individuate powers by assuming that each power has a different complete profile of what will result from pairing it with any situation. This is not at all a necessary way to view powers. (Cf **Causal laws, policy predictions and the need for genuine powers** Nancy Cartwright plus the slightly modified account in **Aristotelian powers: Without them, what would modern science do? Nancy Cartwright and John Pemberton**)

gravity is acting in a situation where there are no rules for how powers in that set-up combine.[10]

Of course there are cases, many many cases, where accurate predictions are possible. It doesn't even take Laplace's Demon. We can do it. Most impressively we can use our laws of physics to make very precise predictions that are regularly borne out and to build very precise instruments that work as we expect (like lasers to operate on our eyes). It is these astounding predictions that provide our best reason to take our laws to be correct, or correct enough. Does this not argue for the universal rule of the laws we use to make these predictions?[11]

No. Because the arrangements where the laws of a physics theory are seen to hold almost without adjustment are very special. They are mechanisms, arrangements of systems in which the following special condition holds:

> All the causes of the predicted effect are in the theory's domain.

So there are no causes of effect that we don't know how to label within the theory. That I claim is how we should read the theoretical claims if we are to have solid empirical support for them, and without commitment to the far stronger claim that for every effect there is, at least in God's great book if not in any of ours, some theory or set of theories that provides appropriate descriptions of all the causes of that effect, which can be plugged into laws to predict it. After all, we cannot test the predictions of a theory by looking at situations where we have no idea of how to provide descriptions in the language of the theory for some significant causes since in that case we would not know what the theory should predict for those situations.

One may object to this line of argument that I am too Positivistic, confusing truth with testability: I take the range across which a physics claim is true to be the range across which it can be tested. Yes, one of the reasons in favour of adopting this view is epistemic caution. It is all we need to account for the impressive successes of modern physics; why leap to believe in more? But it also has metaphysical modesty in its favour. If we can account for our empirical successes in physics with the constrained metaphysics of powers and mechanisms, why resort to a grandiose vision of a world of universal laws, total determination and predestination?

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[10] This will of course not be the case if we insist that all the causes of the bill's motion in that set-up are genuine instances of forces and that forces always combine by vector addition. My argument here depends on this assumption: We can SAY that anything that pushes the bill around is a force and even assign that force a value by back calculation of what it 'must' be from the bill's motion, having subtracted out the properly identified forces (like the pull of gravity). But that claim is not justified until we can assign the back-calculated force to otherwise identified features of the situation by one of the properly evidenced bridge principle of mechanics (like the bridge principle that says that when another mass of size M is located a distance r from it, a mass of size m will experience a force GMm/r^2 or the principle that says a charge q_1 a distance r from a second charge q_2 will experience a force $\varepsilon q_1 q_2/r^2$). For the most part we cannot do this. This is a case of the kind described in the next paragraph of the text where not all the causes of a given effect (motion) which effect is in the domain of a theory are instances of causes assignable in the theory.

[11] I am here setting aside the usual anti-realists worries since they are well rehearsed and generally orthogonal to the issue here of the range of governance of the laws.

Turn now to what coherence looks like on the powers/mechanism ontology I urge. Consider first the story about quantum physics. Every system eventually is in interaction with every other to some extent. Once two systems have interacted, barring genuine (not merely apparent) reduction of the wave packet neither will ever have a state of its own again. This leaves one big quantum state for the universe, to be evolved by whatever turns out to be the correct law of evolution.

This presupposes that all these systems have quantum sates to begin with. But what about the view of Willis Lamb, who won the Nobel prize for discovering and explaining the Lamb shift and who also made considerable contributions to quantum optics and the theory of the laser? Lamb explained that it is very difficult to get a system into a quantum state.[12] Of course Lamb could have meant a 'known' quantum state. But I doubt that. Lamb paid a great deal of attention to *how* to get systems into quantum states – using techniques backed up not primarily by quantum theory but by a hodge-podge of knowledge from various branches of classical physics, engineering and materials science. This fits with the ontology I urge of a great host of features in Nature associated with a great number of powers, many studied by our many different branches of learning, that relate to each other and interact in a great many different ways. Some especially nice arrangements of these will fix as an effect a quantum state. Most will not.

As to the classical coherence I used as a second example, let us suppose that all systems with masses have the power to attract each other and exercise that power continuously. And let us suppose what seems to be the case from observing a host of successful predictions, that there are many arrangements in which we can predict, say, the acceleration of a system – maybe a cannonball or an electron – by combining the power of gravity with others that we have proper labels for (like the Coulomb power that charges have to attract and repel each other) using the laws of classical physics. We can allow that for very precise predictions it may be necessary to include the pull of the distant planets in the description of the mechanism that fixes the motion of the electron or the cannonball. But this will not generate one big system that is forced forward through time by the laws of motion, at least if I am right about the correct way to think of the range of our laws.

Most of the systems that exert forces on our cannonball or electron are not themselves in the fortuitous kinds of arrangements where their own behaviours can be fixed by the laws of classical physics: A great many of the causes of their motion are not in the domain of those laws. The laws have no idea what to do in response to these causes. Our cannonball and our electron, being massive objects, do pull on these systems so that what these systems do is different from what they otherwise would – that's a result of allowing the power of gravitational attraction to be associated with all masses and to exercise at all times without interference. But what the systems actually do

[12] Ref to his LSE lectures. Theer may be a ref in one of my books which are on my shelf.

may not be fixed. Once we countenance the modest metaphysics of powers and mechanisms, genuine contingency is possible in our world.

PART V CONCLUSION

Maybe what happens in Nature can all be explained by universal laws evolving the world from its initial conditions. But it would be very good luck to end up with the rich diverse partly ordered, partly dishevelled world that appears to us. The initial conditions would have to be very special and so too would the form of the laws.

We can account for the successes of modern science with the far less sweeping metaphysics of powers and mechanisms, and as side benefit make inroads on some problems in theology, ontology and the epistemology of science as well. With this kind of metaphysics we can embrace contingency and take responsibility for creating a better order.