Discrete Degrees Within and Between Nature and Mind[1]

Ian J. Thompson
Department of Physics, University of Surrey, Guildford GU2 7XH, U.K.
I.Thompson@surrey.ac.uk

To be published by

Lexington Books, 4501 Forbes Blvd., Suite 200, Lanham, MD 20706, USA.
Tel 301.459.3366, fax 301.429.5749

Examining the role of dispositions (potentials and propensities) in both physics and psychology reveals that they are commonly derivative dispositions, so called because they derive from other dispositions. Furthermore, when they act, they produce further propensities. Together, therefore, they appear to form discrete degrees within a structure of multiple generative levels. It is then constructively hypothesized that minds and physical nature are themselves discrete degrees within some more universal structure. This gives rise to an effective dualism of mind and nature, but one according to which they are still constantly related by causal connections. I suggest a few of the unified principles of operation of this more complicated but universal structure.

Introduction

Questions about the nature and interaction of mind or soul and body have been much debated since Plato, who argued that the soul cannot be the 'harmony of the body', but must have its own existence. In the seventeenth century, this commonly held view was articulated and codified by Descartes, who proclaimed that there were two kinds of substances: thinking substances which are our souls, and extended substances which constitute the physical world. Since then, some kind of dualism has been almost universally assumed in folk psychology, morality and religion, while at the same time almost universally condemned in cognitive psychology, philosophy and neurobiology. Modern philosophers tend to ritually deny dualism, and use Descartes' formulation as a convenient target for their discontent. To rationalise their dissatisfaction, a variety of questions have been asked and arguments presented.

Some of the questions raised against dualism are based on empiricism: that we never see minds in nature, and science has no need for non-material causes. Some object from methodology that modern science must assume all causes are part of nature, and that in any case physics can be defined as the basic science of all causes. Others are puzzled when trying to understand dualism: how can there be a non-substantial substance, how do (can?) mind and body interact? Some want to keep everything unified, and say that there must be unity at the heart of nature, not an irreducible multiplicity, and that we do not want to fragment our 'person' into multiple parts: we are a whole! Does not Descartes relegate our body to be mind-less, feeling-less?

Of course, there are equal or greater problems with materialism that led us into the whole discussion, since our minds seem so obvious to us, but so obscure to science. What is mind? − that is the perennial debate. In the last decade there has been renewed interest in consciousness, but very often with the contexts of functionalism, supervenience, or 'non-reductive physicalism', so that the causal closure of the physical world is maintained. Many problems then arise as to how our ideas, decisions, affections have *any* influence in the world.

[1] Draft chapter for the book 'Psycho-Physical Dualism Today. An Interdisciplinary Approach', edited by Alessandro Antonietti and Antonella Corradini.

The challenge I want to meet in this paper, is to conceive coherently of multiple kinds of substances existing, so they can interact with each other, yet without all these kinds being reduced or conflated into one kind. How is this possible? Is it possible for mind and body to be of such multiple kinds? Could minds and bodies conceived like this be in general agreement with the assumptions of folk psychology as well as of neurobiology?

My proposed answers will depend on developing the concept of multiple generative levels of dispositions, and then showing that there are many kinds of linked dualisms or discrete degrees within physical nature, possibly also within minds, and then plausibly *between* nature and minds. The links will arise from causation as more generally conceived, but this causation will not look more like collisions of billiard balls, more like non-local 'resonances' or 'correspondences' as I will explain.

Many people have noted that there are several aspects of quantum mechanics which are reminiscent of mental properties. Quantum processes are indeterministic, nonlocal, and consciousness could have a role in initiating measurements. Walker (1970) and later Eccles (1977, 1989) have suggested that mental events influence or bias at least some physical outcomes within the range allowed by quantum mechanics. However, quantum mechanics makes *very precise predictions* for the probabilities of those outcomes, and, furthermore, the evolution of these probability distributions is completely deterministic. If there were external mental input, it would have to change the probabilities of different outcomes (Saunders, 2000 and Brecha, 2002), and hence change the probability rules of quantum physics. Other scientists and philosophers (e.g. Wigner (1962), Popper (1977), Faber (1986), Toben (1974), Squires (1990), Donald (1990), Stapp (1977), among others) have believed that the problem of *measurement* can only be solved by introducing some basic notion of an *observer*, presumably a conscious observer, and that this indicates an essential role of consciousness in the physical world. Since however the 'measurement problem' can perhaps be solved within physics, by theories of decoherence (Giulini, 2003) or of propensities (Maxwell, 1988), the role of consciousness in measurement has little direct bearing on the problem of how the mind and brain *function* together. Finally, Marshall (1989) and Clarke (2006) think that the *non-locality* of for example Bose-Einstein condensates is suggestive of mentality, and therefore these condensates could *be* the carrier of consciousness. However, all psychological details of mental structure and operations would then be derived from this quantum structure, so that all human life (from mathematics and logic to arts to psychopathology) would have to be implicit in Schrödinger's equation. Personally, I find it extremely implausible that the quantum mechanics of patterns of excitations of Bose-Einstein condensates exactly and mechanically determines the interaction patterns of ideas, images and meanings in the human mind.

Despite the shortcomings of these theories of quantum effects in the brain, I still believe that quantum physics is important in our understanding of its function. To show this, I am going to take a different approach, and develop a dualism that is non-reductionist, as Eccles and others do, so that the mind is (in some way) distinct from the brain. But I want to then see how they could be intimately connected (still). Psychologists and neuroscientists are aware of the close functional dependence of minds and brains, that physiological changes very readily affect the mind in many ways, and that mental intentions and attitudes affect both the normal and abnormal functioning of the nervous system. A good theory ought to be based on sound principles, cast light on the above phenomena, and contribute constructively to psychology.

Dispositions

We need therefore to go back to basics, and consider some rather fundamental questions about dispositions and causation in the sciences. I will be using the terms 'power', 'potential', 'capability', 'capacity', 'propensity' and 'cause' as examples within the category of 'dispositional properties of objects'.

It is a common belief that modern science does away with those obscure notions of 'disposition' and 'potentiality', in favour of an analysis of the component structure of the things concerned and their functional relationships, but many philosophers (Molnar, 2004) have realised that the truth is quite different. As explained in

Thompson (1988), dispositional properties can only be explained or reduced to other dispositions, *not* to entirely static or structural properties. That is, dispositions have a 'categorical irreducibility', as it is impossible to explain them away in terms of other categories such as space, time, form, process, material, property etc. For suppose that the exact shape and size of an object were known, the shapes and sizes of all its constituents, along with a list of these facts at every time. We would still not know enough about how or why the object would *change* over time or on interactions. Still less could we predict how it would respond to a new experimental test. There seems no way to avoid some kind of irreducibly dispositional properties of physical objects. In psychology, much theorizing is done using functionalist explanations, but Klein (2004) shows that the realistic interpretation of any functions must be in terms of dispositions.

Ontology of Dispositions

We next consider a kind of 'ontology of dispositions', where what is necessary and sufficient for the dispositional causation of events is interpreted realistically, and postulated to exist. Thompson (2005) shows how this leads to a concept of 'generic substance' (Aristotle's underlying 'matter') as being constituted by dispositions, not just being the 'bare subject' for those dispositions. That is, the substance of an object is constituted by the set of underlying dispositions or propensities for how it can act or interact.

If furthermore we describe the forms of objects according their spatiotemporal range, then this form is best viewed as a *field*, and substances themselves are best conceived as 'fields of propensity'. I have described elsewhere (Thompson, 2005) that then we can try to understand some of the more mysterious quantum features of nature, such as the nature of measurement interactions and non-localities, and as well as the duality of wave and particle descriptions.

How dispositions change

Most examples of dispositions in philosophical discussions are those, like fragility, solubility, radioactive instability, whose effects (if manifested) are events. If a glass exercises its fragility, it breaks. If salt shows its solubility, it dissolves, and the manifestation of radioactive instability would be a decay event detected with a geiger counter. However, physicists want to know not merely that these events occur, but also how the dispositions themselves may change after the manifestation event.

In the cases above, the fragility of the parts or the stability of the nuclei may change as a result of the manifestation events, and it is an important part of physics to describe the new (changed) dispositions as accurately as possible. Sometimes, new dispositions may be ascribable after an event which could not have been ascribed before the event. The fragments of a broken glass may be able to refract light in a way that the intact glass could not. The existence of some of these new dispositions may perhaps be successfully explained as the rearrangement of the internal structures of the objects under discussion, when these are composite objects. The refraction by pieces of broken glass, in contrast to the original smooth glass, has obvious explanations in terms of the shapes of the new fragments. Science is largely successful in explaining such dynamical evolutions of empirical dispositions of natural objects: it bases its explanations in terms of changes in their structural shapes and arrangements of their parts, along with the fixed underlying dispositions or propensities of these parts. It is from the dispositions of these parts that, according the structure, all their observed dispositions and causal properties may be explained. The existence of new dispositions by rearrangement of the parts of an object may be taken as non-controversial. However, it appears that not all dynamical changes of dispositions occur by rearrangements of parts, and these are what in this paper I want to call 'derivative dispositions'.

Derivative dispositions in physics

There are some cases, to be listed below, where new dispositions come into existence without there being any known parts whose rearrangement could explain the changes. The next section gives some examples of what appear to be such derivative dispositions, and this is followed by a more general analysis of how these might work. If there turns out to be a sequence of derivative dispositions, then the combined structure will be termed a set of 'multiple generative levels', as will be illustrated.

Energy and force

If we look at physics, and at what physics regards as part of its central understanding, one extremely important idea is that of *energy*. Physics talks about kinetic energy as energy to do with motion, and potential energy as to do with what motion would happen if the circumstances were right. More specifically, if we look at definitions of force and energy which are commonly used to introduce these concepts, we find definitions like

- *force:* the tendency F to accelerate a mass m with acceleration F/m.
- *energy:* the capacity E to do work, which is the action of a force F over a distance d,
- *potential energy field:* the field potential $V(x)$ to exert a force $F = -dV/dx$ if a test particle is present.

As Cartwright (1983) points out, force is *not identical* to the product ma, because it is only the *net* force at a point which can have an effect. An individual force is only by itself a tendency which may or may not be manifested. It is a *disposition*, as is energy generically, as well as potential energy.

Furthermore, we may see a pattern here:

- *potential energy field:* the *disposition* to generate a *force*, and
- *force:* the *disposition* to accelerate a mass, and
- *acceleration:* the final result.

I would like to take this as an example of two successive *derivative dispositions*, where the effect of one disposition's operation is the generation of another. An electrostatic field potential is a disposition, for example, the manifestation of which—when a charge is present—is not itself motion, but is the presence now of a derivative disposition, namely a force. The manifestation of a force—when acting on a mass—may or may not occur as motion, as that depends on what other forces are also operating on the mass.

The production of a force by a field potential does not appear to be something that occurs by means of the rearrangements of microscopic parts, but appears to be more fundamental, and almost *sui generis*. It appears that field potentials, force and action form a set of multiple generative levels, and this situation is clearly in need of philosophical inspection. Admittedly, many physicists and philosophers often manifest here a tendency to say that only potential energy is 'real', or conversely perhaps that 'only forces are real', or even that 'only motion is real', and that in each case the other physical quantities are only 'calculational devices' for predicting whichever is declared to be real. Please for a while apply a contrary tendency to resist any of these reductive conclusions.

Hamiltonians, Wave Functions And Measurements

In quantum physics, energy (the total of the kinetic and potential energies) is represented by the Hamiltonian operator $\hat{H}$. This operator enters into the Schrödinger wave equation $\hat{H}\Psi(x,t)=i\hbar\partial\Psi(x,t)/\partial t$, which governs all quantum wave forms $\Psi(x,t)$. It thus generates all time evolution, and hence all fields of probabilities for measurement outcomes. The principal dynamics in quantum physics are specified by knowing what the initial state is, and what the Hamiltonian operator is. These remarks apply to quantum mechanics as it is practised, by using Born's statistical interpretation and then naively saying that the quantum state changes after a measurement to one of the eigenstates of the measurement operator. (This is the much discussed 'reduction of the wave packet', which we may agree at least *appears* to occur.)

We may therefore consider quantum physics in the following 'realistic' way. We have the Hamiltonian which is to do with total energy, which is somehow 'active' since it is an *operator* which operates on the wave function and changes it. The Schrödinger equation is the rule for how the Hamiltonian operator produces the wave function, which is a probabilistic disposition (a propensity) for action. This wave function (in fact its squared modulus) gives a probability for different of macroscopic outcomes of experiments, and the wave function changes according to the specific outcome. Such is the structure of quantum physics as it is practised, and we may observe a sequence of derivative dispositions in operation:

- *Hamiltonian operator*: the fixed disposition to generate the wave function by evolving it in time,
- *wave function*: the probabilistic disposition (a 'propensity wave') for selecting measurement outcomes, and
- *measurement outcome:* the final result.

It appears again that we have multiple generative levels, with the set of {Hamiltonian $\rightarrow$ wave function $\rightarrow$ selection event}. Note here also that the final result is not a disposition, but the last of a sequence of derivative dispositions. For completeness, therefore, we have included such a 'bottom line' within the concept of multiple generative levels. Admittedly, again, reductionist tendencies may be applied here as well. Most commonly, it may be denied that there are distinct measurement outcomes in any ontological sense, and that they may only be approximately defined within a coarse-grained 'decoherent history'. Advocates of the Many Worlds Interpretation, or of Decoherence theories, take this view. Others such as Bohr take the opposite view, and hold that only the measurement outcome is real, and that the Hamiltonian and wave function are calculational devices and nothing real. These views in tension will be discussed later.

Virtual and actual processes

Taking a broader view of contemporary physics and its frontiers, we may further say that the 'Hamiltonians, wave functions and measurements' of above describe just the dispositions for a class of 'actual processes'. The Hamiltonian is the operator for the total energy, containing both kinetic and potential energy terms. However, we know from Quantum Field Theory (QFT) that, for example, the Coulomb potential is composed 'in some way' by the exchange of virtual photons. Similarly, we also know from QFT that the mass in the kinetic energy part is not a 'bare mass', but is a 'dressed mass' also arising (in some way) from many virtual processes. This again suggests the theme of my paper: that the Hamiltonian is not a 'simple disposition', but in fact is itself derivative from some prior generative level. In this case the needed generative level could be called that of 'virtual processes', in contrast to that of 'actual processes'. The class of virtual processes, as described by QFT, have many properties that are opposite to those of actual processes of measurement outcomes. Virtual events are at points (not selections between macroscopic alternatives), are interactions (not selections), are continuous (not discrete), are deterministic (not probabilistic), and have intrinsic group structures (e.g. gauge invariance, renormalisation) as distinct from the branching tree structure of actual outcomes. All these contrasts suggest that virtual processes should be distinguished from actual events. The guiding principles have different forms: virtual processes are most commonly described by a Lagrangian subject to a variational principle in a Fock space of variable particle numbers, whereas actual processes, as discussed above, deal with the energies of specific observable objects leading to definite measurement outcomes.

Pregeometry and the generation of spacetime

Field theories such as QFT still use a geometric background of spacetime, and there is currently much speculative work in quantum gravity research to determine how this spacetime might arise. Wheeler started interest in 'pregeometry': the attempt to formulate theories of causal processes which do not presuppose a differentiable manifold for spacetime. Rather, his aim was to encourage speculation as to how spacetime might arise. Most commonly, the task has been taken as showing how spacetime may turn out to be a 'statistical approximation' in some limit of large numbers of hypothetical pregeometric processes. Proposals have involved spinors by Penrose (1987); 'loop quantum gravity' as described for example in Rovelli (1998); and 'causal sets' according to Brightwell et al (2003). If some pregeometry could be identified, I would speculate that a good way of seeing this would be as a distinct pregeometric level within a structure of derivative dispositions. That is, instead of spacetime being a statistical approximation (in the way thermodynamics is a statistical approximation to molecular gas theories), it should be better imagined that spacetime is an aspect of derivative dispositions that have been generated by 'prior' pregeometric dispositions. This is admittedly speculative, but it does follow the pattern of some current research, so I use it as an example of how the philosophical analysis of dispositions may yet interact fruitfully with modern physics. This appears to be useful particularly since the very aim of 'deriving spacetime' has itself been called into question by Meschini (2005).

TABLE 1 NEAR HERE

Summary of physical discrete degrees

Table 1Table 2 collects and collates the discrete degrees that have been discerned so far in physics. The degrees appear to be in groups of three. The lowest (1–3) describe the operation of 'actual processes' as in non-relativistic quantum mechanics governed by the Schrödinger equation with its Hamiltonian, its wave function and boundary conditions, and the actual selection of alternatives after measurements or decoherence. The next triple (4–6) describes analogous functions, now with virtual rather than actual particles. There is a governing variational principle, now the Lagrangian, there are fields describing virtual particles, and there are interaction vertices when virtual particles are produced or absorbed. The similarity of corresponding 1–3 and 4–6 triples will be discussed later in the section on correspondences. Finally, it is now frequently speculated that there is another degree of pregeometric processes of some kind, but no-one is sure what they consist of. Using the logic of discrete degrees, I would imagine that they are an internal triple (7–9) with again analogous internal structures.

Psychology

Levels of causal influence

There are many examples of apparent derivative dispositions in everyday life, in psychology, in particular in cognitive processes. Such dispositions are involved whenever the accomplishment of a given disposition requires the operation of successive steps of kinds different from the overall step. The original disposition on its operation therefore generates the 'derived dispositions' for the intermediate steps, which are means to the original end. An original 'disposition to learn', for example, can generate the derived 'disposition to read books', which can generate further 'dispositions to search for books'. These dispositions would then generate dispositions to move one's body, which in turn lead ultimately to one's limbs having (physical) dispositions to move. These successively generated dispositions are all derived from the original disposition to learn, according to the specific situations. Another example of sequential and derivative dispositions is the ability to learn. To say that someone is easy to teach, or that they are musical, for example, does not mean that there is any specific action that they are capable of doing. Rather, it means that they well disposed to learn new skills (whether of a musical or general kind), and that it is these new skills which are the dispositions that lead to specific actions.

In this I follow Broad (1925): that there are 'levels' of causal influence. We might allow that particular dispositions or intentions are best regarded not as the most fundamental causes, but as 'intermediate stages' in the operation of more persistent 'desires' and 'motivations'. The intention to find a book, for example, could be the product or derivative of some more persistent 'desire for reading', and need only be produced in the appropriate circumstances. Broad would say that the derived dispositions were the realisation of the underlying dispositions.

The pattern of 'underlying propensity / distribution / result' for 'mental sub-degrees' shows the steps by which deep motivational principles (purposes) in an 'interior mind' lead to action. These purposes come to fruition by means of discursive investigation of ideas, plans and alternatives in what can be called a more exterior 'scientific discursive mind', as constrained by existing intellectual abilities. The actions by the sensorimotor mind select one outcome among many, as constrained by bodily conditions. Moreover, psychologists who have investigated perceptive and executive processes within the sensorimotor stage realise that these are far from simple. What we see, for example, is very much influenced by our expectations and desires, as well as being constrained, of course, by what is in front of our eyes. They would agree that there are subsidiary degrees of expectation, presentation of alternatives and resolution even during 'simple' sensations.

Piaget's cognitive stages

In attempting to describe the phenomena of mental development in children, Piaget (1926, 1962) has distinguished five broad stages. These, as shown in Table 2, are first the sensorimotor stage (ages 0 − 1), followed by the preconceptual (2 − 3 yrs) and intuitive (4 − 6 yrs) stages. (The preconceptual and intuitive stages together are called the 'preoperational' stage.) Then come the operational (7 − 11 yrs) and formal (12 − 16 yrs) stages, while the 'creative stage' (ages 17 −) is a sixth stage postulated by Gowan (1972) as an extension of Piagetian theory. We may very briefly summarise these stages as follows:

Sensorimotor Stage: The sensorimotor stage consists of the 12 or 18 months before the stage '1' structures can be properly constructed and manipulated. At the end of this time, the child has a mental map of objects and his place among them, but this map only includes what he sees.

Preconceptual Stage: These years involve building up concepts at stage 2 representing events and episodes as single entities. Procedures are built up to recognise such events while observing successive positions of objects (at stage 1), and to use subject-object sentences to express these features linguistically.

Intuitive Stage: In this second half of the preoperational stage, the child begins to see relations between objects, and can use categorising words (such as colours, shapes etc.) though *not* systematically. The child still can only imagine one relation at a time, so she cannot examine her own consistency over time, cannot see one-to-one correspondences, and cannot see a series as a whole.

Operational Stage: The child can now imagine reversible operations, 1:1 correspondences, and series of relations, so he or she can come proficient in operations with group structures (such as rotations, reflections), matter conservation properties, classes according to property abstractions related as elements in a lattice, and numbers.

Formal & Creative Stages: The final stages 5 and 6 were designed to correlate with Piaget's 'formal' stage, and with Gowan's (1972) proposed continuation with a further 'creative' stage, but the details here become less specific. What is known can be summarised by postulating first a distinct stage 5 in which whole sequences of abstract plans can be formulated and explored. Gowan's extension calls for a stage with the ability to formulate meta-theoretic notions, to think *about* theories, create them, and discuss the meaning, interpretation and application of formal theories as if they were individual cognitive entities in an additional stage '6'. Such processes would enable us to formulate and implement life-long goals.

TABLE 2 NEAR HERE

Developmental stages as discrete degrees

A good understanding of the cognitive dynamics underlying Piagetian stages is still being sought, but the logical structures are becoming clearer (Commons, 2002). Thompson (1990) proposed a multilayer network architecture in which there are links within discrete parts of the network as in connectionist theories, but in addition that there pattern-directed rules combining the distinct network 'layers'. Piaget's developmental psychology was used to suggest specific semantic contents for the individual layers, along the lines suggested in Table 2. This layered structure of cognitive network stages allows the separate layers to function simultaneously, so that the stages themselves can be well described as partially independent *discrete degrees* of cognitive activities. We must insist that the stages are not merely 'structures', as they are not merely mathematical, but structures *of* something substantial. So we should postulate that they are different kinds of dispositional substances identified naturally by the different dispositions for change at each stage.

Stages as derivative dispositions in reverse order

The above series of stages is generally thought of according to their order of cognitive development during childhood. It is now fruitful to turn the order around, and look at the series of stages starting with the top 'creative' or 'goal oriented' stage. Given this stage, carrying out a certain goal first requires entertaining plans in abstraction for possible sequences of acts. Usually, we think and make plans before we act. Then, having made a plan, we need to formulate the individual operations, and apply our abstract arguments to specific problems and situations. This is to use concepts at the operational stage. Then, given an operational formulation, we need to think of causal sequences of events (preoperational thought), which in turn we use to produce real actions by close-coupled feedback loops at the sensorimotor stage.

If we use the criteria above, when we discussed levels of causal influence, this view of Piagetian stages suggests that the stages, from the top down, should therefore themselves be regarded as discrete degrees which are the forms of operation of *successive derivative dispositions*. We next investigate the general form that these might take.

Logic of discrete degrees

Generative sequences

We now consider the concept of 'multiple generative levels' more generally from a philosophical standpoint. The first general idea is that they are a sequence $\{A \to B \to C \to ..\}$ in which A 'generates' or 'produces' new forms of B using the present form of B as a precondition. We say that B derives from A as its manifestation. Then B generates C in the same way. This sequence may perhaps continue until an end Z, say, where nothing is active. This rough scheme does not tell us, however, how A, B, etc might be changed as a result of their operation. This appears to occur often, as for example according naive quantum theory when a wave function is changed after it generates a particular measurement outcome. It would be good if we had the philosophical principles for a general scheme which might explain the (apparently mysterious) logic of the 'reduction of the wave packet'. In order to formulate such a general scheme, let us extract some guidelines from our example derivative dispositions listed above. To do this, we will need to first distinguish the concepts of principal from instrumental and occasional causes.

Principal, Instrumental and Occasional causes

In the present paper, I want to allow both dispositions and previous events to be causes, although in different senses. Thus I recommend that distinctions ought to be made between all of the following:

- the 'Principal Cause': that disposition which operates,
- the 'Occasional Cause': that circumstance according to which dispositions operate,
- the 'Instrumental Cause': the origin of the occasional cause. The instrumental cause is thus a previous cause, and is that by means of which the Principal Cause operates.

The overall pattern is therefore that "Principal causes operate according to occasional causes, which arise from instrumental causes." All three kinds of causes appear to be necessary for any event in nature, for example, when a stone is let fall: the principal cause is the earth's gravitational attraction, the occasional cause is our act of letting go, and instrumental cause is the muscle movements in our finger releasing the stone. Its hitting the ground is thus caused by our letting go, but only as an instrumental and then occasional cause. Many common uses of 'cause' (including that of Davidson (1967)) refer to occasional causes rather than principal causes, as it is only in the 'occasional' sense that *events* can be said to be causes. Previous events cannot be efficacious causes, Emmet (1984) points out, in the sense of 'producing' or 'giving rise to' their effects, since events *per se* are not themselves powers. The instrumental cause is a genuine causal contributor, and may be said to 'set the stage', by creating suitable conditions (namely, the occasional cause) for the operation of the principal cause.

Whenever any potentiality is exercised to produce a particular outcome, future potentialities must depend on the detailed outcome. Suppose for example that at the moment, I have the potentialities of moving left or right; if I actually move left, say, then this influences (by restriction to a fixed history) of what I can do from now on. This implies not that actual outcomes are dispositions to change causes, but, on the view above, that they are simply the occasional causes for the future operation of causal influences.

Causal sequences in physics

Consider now a electron of fixed charge and mass moving in an electrostatic potential, according to classical electrostatics. At a given place x, the derivative of the potential $V(x)$ gives the force, and the force gives acceleration which in turn changes the velocity of electron, and it moves to a new place. In our framework of derivative dispositions, we see that the potential is one disposition which generates another disposition, namely the force. It does so, moreover, according to the place of the electron. The electrostatic potential is therefore the principal cause of the force, and the place of the electron is the occasional cause. A place by itself is never an efficacious cause, but it can be said to be the circumstance by means of which the potential generates the force. Note that we never have forces causing potentials to exist where they did not before, and (again) places are never themselves dispositional. Let us generalise by surmising the set of generative levels *Potential* $\rightarrow$ *Force* $\rightarrow$ *Places*, such that the principal causation is always in the direction of the arrow, and the only apparent 'backward' causation is with the occasional cause. The only feedback 'back up the sequence' is with the conditional aspect of certain occasions, and how the operation of prior dispositions somehow still depends on particular occasions as preconditions.

Consider secondly the quantum mechanical evolution of a system from time t_0 that is subject to measurement selections at various later times t_1, t_2 etc. The quantum mechanical story is as follows. The initial quantum state $\Psi(t_0)$ is evolved according to the Schrödinger equation by the Hamiltonian $\hat{H}$ for $t<t_1$. Consider the measurement for operator $\hat{A}$ occurring at $t=t_1$, the operator having an eigen-expansion $\hat{A}u_\lambda=a_\lambda u_\lambda$. In practical quantum mechanics, the quantum state changes to $\Psi(t_1^+) = u_\lambda$ if the result of the measurement is the eigenvalue a_λ, which occurs with probability $p_\lambda = |< u_\lambda \mid \Psi(t_1) >|^2$. The new state $\Psi(t_1^+)$ is then evolved similarly for $t<t_2$, the time of the next measurement. Seen in terms of derivative dispositions, the Hamiltonian is the disposition to evolve an initial state $\Psi(t_0)$ to new times t, generating $\Psi(t) = \exp(-i\hat{H}t / \hbar)\Psi(t_0)$. A new $\Psi(t)$ is itself another disposition, namely a propensity to produce measurement outcomes with the various probabilities $p_\lambda = |< u_\lambda \mid \Psi(t) >|^2$. The final results are the discrete selection events at the times of measurement. These discrete events have themselves only a residual causal power, that to definitely influence the future evolution of the wave function. In that sense, they are 'occasional causes' according to which other dispositions may operate. The principal dispositions are first the Hamiltonian operator that starts the whole process, and then the wave functions considered as fields of propensity for different selection events.

Summarising the quantum mechanical case, we see that here again, the principal causes act 'forwards' down a set of multiple generative levels, yet act conditionally on certain events. These events thereby become occasional causes. Because the wave functions before a measurement event are the cause of that event, those wave functions are thereby the instrumental cause of the new wave functions after the measurement.

Conditional Forward Causation

From our examples, we may generalise that all principal causation is ‘down’ the sequence of multiple generative levels $\{A \rightarrow B \rightarrow ...\}$, and that the only effect back up the sequence is the way principal causes somehow still depend on certain occasions in order to operate. Let us adopt as universal this asymmetric relationship between multiple generative levels: that dispositions act forwards in a way conditional on certain things already existing at the later levels. The only power that later stages have is to restrict the earlier stages in this way.

We regard this as a simple initial hypothesis, and will have to observe whether all dispositions taken as existing in nature follow this pattern. We may therefore surmise that *A*, the first in the sequence, is the ‘deepest underlying principle’, ‘source’, or ‘power’ that is fixed through all the subsequent changes to *B, C*, etc. Conditional forward causation, the pattern we saw from physics, would imply that changes to *B*, for example, come from *subsequent* operations of *A*, and not from *C, D*,.. acting in ‘reverse’ up the chain. We would surmise, rather, that the *subsequent* operations of *A* are now conditioned on the *results* in *B, C, D*, etc. The operations of *A* are therefore the *principal causes*, whereas the dependence of those operations on the previous state of *B* is via *instrumental causation*, and the dependence on the results in *C*, *D*,... is via *occasional causation*. I would like to suggest that this is a universal pattern for the operation of a class of dispositions in nature, namely those that do not follow from the rearrangement of parts of an aggegrate object.

Reductionism and dispositional ontologies

In all the apparent examples of multiple generative levels given here, many physicists and philosophers of physics will often want to assert the particular ‘reality’ of one of the levels, and say that the prior levels are ‘merely calculational devices’ for the behaviour of their chosen ‘real’ level. For example, some assert in electromagnetic theory that only the field tensors (incorporating the electric and magnetic vector fields) are ‘real’, and that the vector potential (incorporating the electrostatic potential) is a calculational device with no reality. To this end, they note the gauge uncertainties in the vector potential, which for electrostatics is the arbitrariness in setting the level of zero potential energy. Against this, many have noticed that the scattering of electrons in the Bohm-Aharonov experiment is most succintly explained in terms of the vector potential, not the field tensor. It turns out that it is loop integrals of the vector potential which carry physical significance. I conclude that there are non-trivial physical and philosophical questions about the relative ‘reality’ of potentials and forces, questions which require not immediate preferences but considered responses.

We also saw how reductionist tendencies may be manifest in quantum theories. ‘Decoherent history’ accounts of quantum mechanics want to keep the wave function according to the Schrödinger equation, and deny that macroscopic outcomes occur in a reality, and only allow them to be approximate appearances. The founders of quantum theory such as Bohr and Wheeler, however, took the opposite view, that an electron is only ‘real’ when it is being observed—when it makes the flash of light at a particular place—not while it is travelling. In their opposite view, the Hamiltonian and wave function are calculational devices and nothing real, having only mathematical reality as portrayed by the mathematical name ‘wave function’.

The views which make prior or later levels into ‘mere’ calculational devices can be critiqued from the point of view of dispositional ontology. This view encourages us in general to not invoke arbitrarily mathematical rules for the laws of nature, but, as Mumford (2005) suggests, replace the role of laws by that of the dispositional properties of particular objects.

For now, this paper simply explores the theories which result if all the stages of operation of derivative dispositions are given whatever kind of own existence is necessary for realistic interpretations. That is, just as in quantum mechanics we argue that the world must have propensities, wave functions, energies, and virtual process *all existing in some manner*, so we assume in general that members of a set of discrete degrees all exist in their own right.

Correspondences between degrees

Note that there are detailed constituent events in both of any pair of prior and produced degrees. Because of all these microscopic events, we should expect that there will be successive principal causations from the prior degree reciprocating with sequential constraints by the produced degree. This gives rise to an alternation of principal and occasional causes that will repeat itself longest if the *patterns* of the constituent events are most similar in the two degrees, and they do not get out of step. By a sort of survival of the fittest, this in the long term gives rise to *correspondences of function* between adjacent degrees. We may conversely say that the functions in distinct degrees sustain each other in a kind of 'resonance' when they are most similar in the patterns of their constituent events. There is much detail here to be learned by theorising and observing. Discrete degrees are not of a continuous substance with each other, but, we see, have therefore functional relations that make them 'contiguously intertwined' at all stages, and at many levels of detail at each stage.

Some of these corresponding structures have been seen already, where similarities in the internal structures of actual and virtual processes were noted.

Mind and nature as discrete degrees?

In previous sections I have argued that there are discrete degrees of derivative dispositions within both the physical and mental realms. The next hypothesis to consider is that the physical and psychological are *themselves* discrete degrees, so that physical dispositions as a whole are derivative from mental dispositions, at least within living and/or thinking organisms. That is, we entertain the view that the *dualism* of mind and body is not an *ad hoc* division, but one that logically follows from the kinds of causation that exists within a universe in which there are both minds and bodies as distinct ontological substances connected as derivative dispositions.

To see whether this works in practice, we have to consider the detailed requirements of any theory of psychology. At the simplest level of generalisation, in order for people to have functioning minds connected at least with their brains, minds must be able to

- implement intended functions by feeling and thinking, then using motor areas,
- establish permanent memories, presumably by means of permanent physiological changes,
- form perceptions using information from the visual & auditory (etc.) cortexes,
- be able to follow 'internal' trains of thought/feeling/imagining without necessarily having any external effects.

One way that these requirements can be most simply accomplished is by means of the ideas presented so far, formulated in the following three principles:

I. Some physical/physiological potentialities (both deterministic or indeterministic according to quantum physics) are derived dispositions from minds as their principal cause. That is, minds predispose the dynamical properties of some physical objects.
II. That the dispositional capacities of the mind are consequentially restricted (and hence conditioned) by their actual physical effects, by means of occasional causation.
III. That the pattern of I and II is repeated for individual stages of more complex processes.

These principles together give what has been called Conditional Forward Causation, or 'top-down causation'. Note that we do *not* have a fourth 'bottom-up' principle that neural events directly cause events to occur in the mind. We do not have general matter → mind causation, although something resembling this does arise, namely selection. This is not causation in the sense of principal causation as producing or generating the effect, but is occasional causation as being a necessary prerequisite.

A strong argument for these three principles is that they are already similar to what is known already to happen in physics. According to quantum field theory, for example, we saw how virtual events predispose the ordinary quantum wave function. These virtual events operate deterministically, and describe the operation of the electric, magnetic, nuclear and gravitational forces. They are not the actual events of quantum mechanics, as those are the definite outcomes of events like observations. Rather, they are a 'prior level' of 'implicit events' whose operation is needed in order to derive or produce the potentialities for events like observations. The principle (I) states the analogical result that mental events themselves are a 'prior level' of 'implicit events' whose operation is needed in order to produce the potentialities for physical events.

The argument for the principle (II) is more general. This principle can also be seen as the law according to which your future life is restricted and influenced by your past actions (by selection). Physical events are in this way the necessary foundations for permanent mental history and structure.

Principle (III) has an important corollary connected with the observations of the above section on correspondences:

IV. That the mind predisposes the brain to carry out those functions which 'mirror' or 'correspond to' the mind's own functions.

This is because mental functions involve intermediate steps, and these intermediate mental steps predispose suitable intermediate physical steps (by I), and are in turn conditioned or confirmed by them (by II). Thus the sequence of physical steps should follow the sequence of mental steps, and the overall function of the physical process will be analogous (in some sense) to the overall function of the mental process.

Examples of this 'mirroring' or 'corresponding' can be illustrated by the similarities between minds and physics already seen in the previous sections. If we compare Tables 1 and 2, we see considerable structural similarities in the way they have internal discrete degrees.

Table 3 brings together these similarities, and we see that the order of the columns is the same in the mental and physical cases. I claim that just such similarities should be expected by the principles of correspondences, if indeed minds and nature are individual discrete degrees within a broader structure of multiple generative levels. According to those principles, we should expect that at each stage the mental derivative dispositions (i.e. the particular ideas) have similar functional relations among themselves as do the corresponding physical derivative dispositions. Such functional relations should be a fruitful source of scientific predictions that may be investigated experimentally.

TABLE 3 NEAR HERE

Let us then see how these principles enable the mind and brain to function together:

- The particular functions selected by the mind to be carried out by the brain will be the establishment of spatiotemporal patterns of neural activity that may then be 'decoded' in the motor cortex to lead to the desired activities, by the principle (I). Principle (IV) establishes a criterion for the overall functioning of this decoding.
- Permanent physiological changes lead to permanent memories in the mind, by the principle (II). (It is an empirical question, *which* physiological changes are relevant, but principle (IV) will be a guide.)
- Perceptions are formed by the sensory cortex areas deterministically forming particular patterns of neural activity, so that these physiological effects can select the subsequent perceptual content of the mind. The process here is rather subtle. The mind must have a 'general disposition' to see/imagine any of its possible percepts; the role of the sensory cortex is to *select* the particular content, by means of principle (II). Thus we have the general psychological observation that 'we see only what we are capable of and disposed to see'.
- To be able to follow 'internal' trains of thought / feeling / imagining without necessarily having any external effects, the mind must be able to produce physiological effects which do not have significant behavioural consequences. Presumably, much of the cerebral cortex can function in a way 'loosely connected' with the motor areas, in order to provide the foundation for a set of permanent mental structures capable of 'internal thought'.

This theory of mind and brain connection establishes an intimate relation between them. It is not a relation of identity, or a relation of aspects or points of view. It is more a relation of inner and outer, or cause and effect: propensities in the brain are the causal product of mental actions. As Bowden (1947) wrote: 'the role of the psychical in relation to the physical (in the living organism) is essentially the relation of the potential or incipient to kinetic or overt action'.

Replies to common arguments against dualism

The assumption of naturalism

Let us next see how we can reply to some of the early questions often raised against dualism. The first set of questions from empiricism are that 'we never see minds in nature, and science has no need for non-material causes'. However, the meaning of 'non-material' has changed considerably over the last century, to the extent that Clarke (1995) claims that no idea of 'material' is present in modern physics. Certainly, the successive ideas of electromagnetic fields (Pockett, 2000 and McFadden, 2002), wave functions (Eddington), virtual fields (Jibu, 1995) and zero-point motion (Lazslo, 1993) have become progressively less material, and each of these has its advocates being the carrier of consciousness. However, according to the physics view of above, these are sub-degrees still *within* the physical. To find minds, we have to go further back in the causal analysis.

Some today object from methodology, that modern science must assume all causes are part of nature, and that in any case physics can be defined as the basic science of all causes. This is the oft-quoted 'presumption of naturalism'. However, modern science is quite capable of postulating and understanding that which it cannot see or feel, as long as it has a rigorous intellectual structure that enables us to make deductions, and eventual partial testing. Many scientists say that they will follow 'wherever science leads them', and that 'perhaps we will gradually get used to the weird ways of our cosmos and find its strangeness to be part of its charm' (Tegmark, 2003). If we are to have a unified account of discrete degrees that brings together theories of mind and physics, then there will definitely be predictive power and testable consequences. The fact that there is no fully-fledged scientific account including dualism, tells us merely that we lack the imagination to make even a possible such theory. We thus need a specific theory: one that could be verified or refuted like other scientific theories, and fail or prevail. A theory would link disparate pieces of evidence together, and then scientists think they can begin to properly understand.

Rather than asserting that there are non-substantial substances (a contradiction in terms), we now rather hold that there are different *kinds* of substances, with rather different properties and capabilities. Only if all substances are taken to be necessarily those of contemporary physics would we find contradiction in the substantiality of minds. This 'mental substantiality' is simply the statement that minds exist as individual beings in some world of similar beings, at least for a while, and that other aspects of mind or thought are properties or modes of action of these substances.

The biggest puzzle for everybody is how can mind and body interact, or at least influence each other in some way, in agreement with our obvious abilities to perceive and act in the world. Here, we explain the connection between mind and body in terms of correspondences, which are similarities of functional forms. These correspondences are not magic, but each must have an explanation in terms of the constituent processes in each of successive discrete degrees, one producing the next. There is much detail yet to understand here, of how there are asymmetric links of 'downward' production and 'upward' constraint, but the principles of these features should already be discoverable within physics and psychology. Our challenge today is to formulate a theory of discrete degrees so that they may be recognised in detail.

Are minds in space?

Objections are often formulated as to *where* minds might be in space? Descartes went so far as to say that they are completely unextended, as the opposite of extended physical matter, but does that mean they are unextended like a point? Where is that point— in the pineal gland? Most of us would naively say that location does not apply to thoughts, but how is this possible, and, if so, how can they affect physical objects which do have locations?

The lesson to learn from physics, however, is that our best description of physical process is getting less and less localised. The successive discrete degrees in physics as summarized above are at one end completely definite measurements at specific locations, and further up Table 1 become more and more non-local. The non-locality of the wave function is now well known, and quantified. Energy is global property. Virtual processes do not have specific locations or times, since they contribute to potentialities which may never actualise. Then the pregeometric processes themselves are clearly not localised, since they are themselves responsible for in some way 'generating' space time. My proposal about the duality of minds is that they are discrete degree 'beyond' or 'above' such pregeometric degrees. Such a proposal is not inherently absurd, but follows the pattern we see beginning in modern physics. Thus, minds are not in space, but are part of what produces the degree that generates space. These connections of 'produce' and 'generate' are clearly linked in the end with specific physical objects, and it is by means of such a generative chain that minds not in space are connected with material objects that are in space.

Conservation laws and closure

It is generally taken as a strong indication against dualism that the physical world appears to be causally closed. This is taken from the fact that the total of energy and total momentum appear to be accurately conserved whenever they have been measured in modern physics. These conservation laws do not seem to allow any room for minds to make any difference to evolution of the physical world. We should first note, with Meixner (2005), that there is little or no experimental evidence just where it is needed, namely within living bodies and especially within brains, so the universal application of conservation laws is an *assumption* of the physical sciences, *not* a *result* as it is commonly presented. Various general philosophical arguments for causal closure have been presented, but they all depend on some assumption that is almost identical to the result to be proved.

Suppose that physicists found that conservation laws in a object were not conserved in some instances. How would they react? First, they would note that the laws apply only to *isolated* systems, so they would examine whether the object really was isolated or not, and whether they should look for something further (like a hidden planet) that was producing the effects. Secondly, they could generalise the conservation laws so the new law was satisfied but not the old one. It used to be thought, for example, that total mass and total energy were separately conserved, but, after many subatomic experiments showing the annihilation and creation of massive particles, those separate laws were quietly dropped in favour of a general law of conservation of mass-energy in combination. Note that this example is directly related to having a virtual as well as a 'actual' degree in physics. A further 'pregeometric' degree would force a further generalisation of the conservation laws. At present, energy and momentum conservation are typically 'derived' from the invariance of the underlying Lagrangian under small time and spatial translations respectively. If spacetime were curved, or was being dynamically generated in some way, this invariance would not hold, but physicists would soon come up with a 'generalised mass-energy' measure that was still conserved. If, therefore, the non-conservation of energy and/or momentum were found in certain biological or psychological processes, science as we know it would not collapse. Either the influence from other kinds of beings would be ascertained, or a further generalisation of the conservation laws would be sought. The only novelty in the proposals here, is that these 'other kinds of beings' would not be 'physical' in the traditional way. I remark that the generalised conservation laws (beyond the pregeometric degree) to take into account these new substances will still be recognisably rational.

Conclusion

By reconsidering the basic metaphysics of dispositions and propensities, we see how to formulate a 'dispositional ontology'. After seeing how 'derivative dispositions' commonly form discrete degrees in both physics and psychology, we try to see such ontologies as 'multiple generative levels', each discrete degree of which exists in its own manner.

Given such a multiple-level ontology, it is then argued that mind and nature are plausibly themselves discrete degrees that are linked together by the same general principles. Thus we have an ontology of multiple kinds of substances that yet operates by unified and universal principles. In this ontology, mind and physical nature are not reduced or conflated, but exist alongside each other in deeply intertwined causal relations. This is effectively a dualism of mind and nature, but in fact they are both part of a more complicated structure that the scientists have already begun to investigate in detail even though they have not yet seen the whole picture.

Bibliography

Bawden, H.H. 'The Psychical as a Biological Directive', *Philos. Science*, 14:56-67, 1947.

Brecha, R. 'Schrödinger's Cat and Divine Action', *Zygon* 37:909-924, 2002.

Brightwell, G., F. Dowker, R.S. García, J. Henson, and R.D. Sorkin, "Observables" in causal set cosmology, *Physical Review D* 67:084031, 1-8, 2003.

Broad, C.D. *Mind and Its Place in Nature*, London: Routledge and Kegan Paul, 1925.

Cartwright, N. *How the Laws of Physics Lie*, Clarendon, 1983.

Clarke, C.J.S. 'The role of quantum physics in the theory of subjective consciousness', <www.scispirit.com/Role_of_QT.pdf>, 2006.

Clarke, C.J.S. *Reality Through the Looking Glass*, Floris, 1995.

Commons M.L. and F.A. Richards, 'Organizing Components into Combinations: How Stage Transition Works', *Jnl of Adult Development*, 9:159-177, 2002.

Davidson, D. Causal Relations, *Jnl of Philosophy* 64: 691-703, 1967.

Donald, M.J. 'Quantum Theory and the Brain', *Proc. R. Soc. Lond*, A 427:43-93, 1990.

Eccles J. and K.R. Popper, *The Self and Its Brain*, Springer, 1977.

Eccles, J., *Evolution of the Brain: Creation of the Self*, Routledge, 1989.

Emmet, D. *The Effectiveness of Causes*, New York: State University of New York Press, 1984.

Faber, R.J. *Clockwork Garden*, University of Massachusetts Press, 1986.

Giulini, D., E. Joos, C.Kiefer, J. Kupsch, I.-O. Stamatescu and H.D. Zeh, *Decoherence and the Appearance of a Classical World in Quantum Theory*, Springer, 2nd Ed, 2003.

Gowan, J.C. *Development of the Creative Individual*, R.K. Knapp, San Diego, 1972.

Jibu M. and K. Yasue, *Quantum Brain Dynamics and Consciousness, An introduction*, Benjamin, 1995.

Klein, C. 'Functions as Dispositions', <www.princeton.edu/~cvklein/papers/dispfunct2De1.pdf> , 2004,

Laszlo, E. *The Creative Cosmos*, Floris Books, 1993.

Marshall, I.N. 'Consciousness and Bose-Einstein Condensates', *New Ideas in Psychology*, 7:73-83, 1989.

Maxwell, N. 'Quantum Propensiton Theory', *Brit. Jnl Phil. Science*, 39:1-50, 1988.

McFadden. J. 'The conscious electromagnetic field theory: the Hard Problem made easy', *Jnl of Consciousness Studies* 9:45-60, 2002.

Meixner, U. 'Physicalism, Dualism and Intellectual Honesty'. *Dualism Review* 1:1-20, 2005.

Meschini, D., M. Lehto, J. Piilonen, "Geometry, pregeometry and beyond", *Stud. Hist. Philos. Mod. Phys*. 36: 435-464, 2005.

Molnar, G. *Powers*, Oxford: Oxford University Press, 2004.

Mumford, S. 'Laws and Lawlessness', *Synthese* 144: 397-413, 2005.

Penrose, R.. *Spinors and Space-Time: Volume 1, Two-Spinor Calculus and Relativistic Fields*, Cambridge: Cambridge University Press, 1987.

Piaget, J. *Play, Dreams, and Imitation in Childhood*, Norton, 1962.

— *The Language and Thought of the Child*, Harcourt, Brace & World, 1926.

Pockett, S. *The Nature of Consciousness: A Hypothesis*, iUniverse, 2000.

Rovelli, C. ‘Loop Quantum Gravity’, *Living Rev. Relativity* 1: 1. <www.livingreviews.org/lrr-1998-1>, 1998.
Saunders, N.T. ‘Does God Cheat at Dice? Divine Action and Quantum Possibilities’, *Zygon*, 35:517, 2000.
Squires, E.J. ‘An Attempt to Understand the Many-worlds Interpretation of Quantum Theory’, in *Quantum Theory without Reduction*, ed. Cini and Levy-Blond, Adam Hilger, 1990, 151-160.
Stapp, H.P. ‘Theory of Reality’, *Foundations of Physics*, 7:313-323, 1977.
Tegmark, M., ‘Parallel Universes’, *Scientific American*, 288:40-51, May 2003.
Thompson, I.J. ‘Layered Cognitive Networks’, <www.generativescience.org/ps-papers/layer7.html>, 1990.
— ‘Pragmatic Ontology I: Identifying Propensity as Substance’, <www.generativescience.org/ph-papers/pragmatic_substance.htm> , 2005.
— ‘Real Dispositions in the Physical World’, *Brit. Jnl Phil. Science*, 39:67-79, 1988.
Toben, B. *Space-Time and Beyond*, Dutton, 1974.
Walker, E.H., ‘The Nature of Consciousness’, *Mathematical Biosciences*, 7:131-178, 1970.
Wigner, E. ‘Remarks on the Mind-Body Question’, in *The Scientist Speculates*, I.J. Good, ed: Basic Books, N.Y., 1962, 284-302

TABLES IN MICROSOFT WORD FORMAT

Discrete Discrete n	**Derivative Disposition for producing *n*–1 degree**	**Physical Process**	
7-9	Pregeometric?	spinor loops?	Pregeometry?
6	variational principle	Lagrangian	
5	virtual particles	field propagators	Virtual processes
4	virtual events	field interaction vertices	
3	energy	Hamiltonian	
2	quantum objects	wave function	Actual processes
1	events (the end)	measurement selection	

Table 1: Relation between discrete degrees and physical processes. In each degree, the second column gives the derivative disposition that is operating to produce the dispositions of the next degree down in the sequence. The pregeometric degrees are speculative, but are widely believed to be necessary in some form.

Discrete Stage *n*	**Cognitive Structures forming *n* by relating n−1**	**Developed in Piaget/Gowan Stage**	**During ages**
6	meta-theories, paradigms	creative	17−
5	plans, models, formalisms	formal	12−16
4	classes, series, numbers	operational	7−11
3	single relations	intuitive	4 − 6
2	sentences	preconceptual	2 − 3
1	objects	sensorimotor	0 − 1
0	sensory and motor systems	(initial biology)	− 0

Table 2: Relation between Discrete Degrees and Piagetian Stages. During each stage *n*, at the approximate ages shown, the child is learning to relate the concepts listed in the row *n*-1 below, and is constructing the concepts in a given discrete stage *n*.

	Corresponding Derivative Dispositions	
Discrete Degree	Mental	Physical
6	Creative	variational principle as Lagrangian
5	Formal	virtual particles as field propagators
4	Operational	virtual events as field interaction vertices
3	Intuitive	energy as Hamiltonian
2	Preconceptual	quantum objects as wave function
1	Sensorimotor	events as measurement selection

Table 3: Hypothesis of similarities between the discrete degrees within mental and physical processes. The order of the columns is the same in the mental and physical cases. And on each row, the mental derivative dispositions (i.e. the particular ideas) are claimed to have similar functional relations among themselves as do the given physical derivative dispositions.

TABLES IN TABBED FORMAT

Discrete Discrete n	**Derivative Disposition for producing *n*–1 degree**	**Physical Process**	
7-9	Pregeometric?	spinor loops?	Pregeometry?
6	variational principle	Lagrangian	Virtual processes
5	virtual particles	field propagators	
4	virtual events	field interaction vertices	
3	energy	Hamiltonian	Actual processes
2	quantum objects	wave function	
1	events (the end)	measurement selection	

Table 1: Relation between discrete degrees and physical processes. In each degree, the second column gives the derivative disposition that is operating to produce the dispositions of the next degree down in the sequence. The pregeometric degrees are speculative, but are widely believed to be necessary in some form.

Discrete Stage *n*	**Cognitive Structures forming *n* by relating n–1**		**Developed in**
Piaget/Gowan Stage		**During ages**	
6	meta-theories, paradigms	creative	17−
5	plans, models, formalisms	formal	12−16
4	classes, series, numbers	operational	7−11
3	single relations	intuitive	4 − 6
2	sentences	preconceptual	2 − 3
1	objects	sensorimotor	0 − 1
0	sensory and motor systems	(initial biology)	− 0

Table 2: Relation between Discrete Degrees and Piagetian Stages. During each stage *n*, at the approximate ages shown, the child is learning to relate the concepts listed in the row *n*-1 below, and is constructing the concepts in a given discrete stage *n*.

	Corresponding Derivative Dispositions	
Discrete Degree	Mental	Physical
6	Creative	variational principle as Lagrangian
5	Formal	virtual particles as field propagators
4	Operational	virtual events as field interaction vertices
3	Intuitive	energy as Hamiltonian
2	Preconceptual	quantum objects as wave function
1	Sensorimotor	events as measurement selection

Table 3: Hypothesis of similarities between the discrete degrees within mental and physical processes. The order of the columns is the same in the mental and physical cases. And on each row, the mental derivative dispositions (i.e. the particular ideas) are claimed to have similar functional relations among themselves as do the given physical derivative dispositions.