Physics, Metaphysics, and a Whiteheadian Interpretation of Quantum Mechanics:

An Exploration

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Introduction

All physical theory contains, either implicitly or explicitly, metaphysical components. No theory that concerns itself with the physical world--its forms, properties, interactions, or changes--can exist without including, on a fundamental but often tacit level, one or more purely metaphysical assumptions. In the contemporary world physics is often thought to be the hardest of the 'hard' sciences, which is another way of saying that physics is that discipline most rigorously concerned with understanding the physical truths of the universe. This, along with the consistent validation of physical truths in their applied form ("technology"), easily leads to the conception that physics has some particularly authoritative claim to insight concerning the ontology of the universe.

Nevertheless, a close examination of any physical theory, no matter how "proven" or "tested" will yield various underlying assumptions that can only be described as metaphysical. "Gravity"[1] is a perfect example: ask any physicist if gravity exists, and the answer will be affirmative; ask what gravity is, and suddenly the responses become much stranger. Some might relate that gravity is an inherent property of mass, a "field" with attractive properties whose intensity decreases in exact proportion to the square of the distance from the center of the object of mass; others might mention space-time and the General Theory of Relativity and how mass distorts space-time to create something that looks like a "force". When pressed, however, it is mildly shocking to discover that, although the actual existence of gravity is entirely unquestioned, its particular ontology is quite mysterious. We don't really know *what* gravity is--in fact, Einstein showed that gravitational frames and accelerated frames can be treated identically (the math is the same in both cases).

Gravity is an old theory created as an explanation for otherwise unexplained phenomena (for example the observation that if one drops an object, it will always fall towards the Earth and not into the sky or parallel to the ground). We assume that something is happening in the universe to create these peculiar events, and we call it "gravity". Unfortunately, the creation of the term in conjunction with its subsequent widespread usage has resulted in the popular reification of gravity--it has been promoted from a concept to an actually existing force in the universe.

In general it would seem that in order to retain explanatory power a concept must have an ontological status that is more fundamental than the phenomena it explains. This is true not necessarily because of any logical rules, but because of the particular constitution of those that require explanation: namely, humans. The argument may be something like: "because it is obvious that objects *actually* fall towards the Earth, gravity too, must actually exist, because isn't that what causes the objects to fall towards the Earth? And besides, if gravity did not exist, then what would explain this phenomenon?". The incompleteness of the logic is glaring, but it can slide by unnoticed due to the unquestioning acceptance of the existence of "gravity". When examined critically, the theory of gravity remains metaphysical--its status cannot exceed that of an explanatory concept--one that can be more or less useful, to be sure, but a concept nonetheless.

The answer to the question "...isn't that what causes the objects to fall towards the Earth?" is negative. That objects fall towards the Earth is an empirical observation; the theory of gravity began as an attempt to provide an explanation of *why* this is so. Unfortunately, to have the concept of gravity does not necessarily result in the *fact* of gravity; rather, it placates those people who ask the question "Why do objects fall towards the Earth?" by posing as a valid, ontological "reason" for the observed events. Yet we still do not know what gravity *is*, only that in order to explain certain phenomena, it is valuable to posit *something* like what we know of now as "gravity".

Once the concept of gravity exists, it becomes possible to test its applicability in various ways, and through a careful process, the idea can be refined. New observations are made, which are subsequently compared with and related to older observations, and depending upon the specifics, the idea of gravity is modified to fit the new observations (for example that massless particles are affected by the 'attractive' properties that were thought only to apply to other bodies of mass).

It is often assumed (by physicists and philosophers alike) that physics poses only "What?" and "How?" questions, and in fact physics, abstracted from its existence as a human creation, does relate to physical truths in this manner. But physics as a discipline *cannot* be completely abstracted in this way, and when placed in its context as a human discipline, the fundamental motive for physical theory is seen to arise not from "What?" or "How?" but from the question "Why?".

To continually search for answers to this most difficult of queries inevitably leads beyond the conservative boundaries of physics and into the speculative realm of metaphysics, which also asks "Why?" In fact, metaphysics can be seen as an attempt to create a framework in which the question "Why?" can be answered directly, through the establishment of some sort of 'ultimate' upon which all explanation can and must finally rest. Still, as a general rule, an adequate metaphysical scheme must be able to take into account what we know about reality through physics; if it does not, then the scheme is inadequate and must be rejected or revised.

Whitehead knew this, and when he brought his metaphysics into clear formulation in the late 1920's, he made a remarkable effort to include what he knew from the developing field of physics. Between then and now, however, such significant advances in physics have taken place that it seems that Whitehead has been left entirely in the subatomic dust. In particular significant advances have occurred in the highly non-intuitive and extremely complex field of quantum mechanics--one of the most metaphysical realms in all of modern science and therefore one quite congenially related to Whitehead's own temperament.

Quantum Mechanics

Although quantum mechanics burst onto the scientific scene in the mid 1920's, the theory was not considered 'complete' until after World War II, [2] and Whitehead had at his disposal only information about quantum mechanics in its infancy. Yet it is the highly metaphysical consequences of modern quantum mechanics that Whitehead would most readily engage with today, were he here. This paper explores what would happen if Whitehead were to appear today and find out that his metaphysical theory was quite 'out of date', and in need of rethinking. This is no small task by any means, and thus I will focus mainly on the consequences of the crucial experiment performed recently by A. Aspect which violates the Bell Inequality before considering a few features of the 'standard' interpretation of quantum mechanics and the ways in which Whitehead might be able to deal with them. I hope to bring to light some aspects of the symbiotic nature of the relationship between physics and metaphysics by examining quantum mechanics in the context of Whitehead's metaphysical scheme--an approach that at least provides an interesting way in which to scrutinize the problems of quantum mechanics, even if it is sure that Whitehead will not be able to *solve* any of the problems (the reasons for this shall become apparent). In order to make it slightly less taxing to the reader unfamiliar with quantum mechanics, some explanatory background material is provided, but by no means do I present a complete introduction, as a sufficient literature exists for this particular purpose. However, I do assume that the reader has at least a basic understanding of Whitehead's metaphysical scheme.

Background to Bell's Theorem

In 1935, Einstein, Podolsky, and Rosen published a paper in the *Physical Review* which questioned the completeness of quantum mechanics. It seems that if one accepts that there can be no action-at-a-distance (i.e. no signal or information that can travel faster than light), and that properties of any physical system exist independently of our choice to observe them (both of which are plausible assumptions), then quantum mechanics *is* actually incomplete--it does not make predictions that are in accord with our observation of physical facts. Einstein, Podolsky, and Rosen (EPR) formulated a clever thought experiment[3] which showed that quantum mechanics would predict results which could not be explained if the assumptions of locality (no action-at-a-distance) and reality (the definiteness of properties of a quantum object regardless of experimental apparatus or individual measurements of such properties) were accepted.

A reply to this claim of incompleteness was quickly offered by Neils Bohr, the prime defender of quantum mechanics at the time. Most physicists accepted Bohr's refutation of the EPR argument (the specifics of which are not important here), but debate continued. However, what debate that did exist remained entirely theoretical, and as a result of the general acceptance of Bohr's ideas along with this inability to form physical experiments that could test the theories, the issue was placed on the back burner--until further notice.

Further notice came in 1965, when John Bell provided the possibility for experimentally testing the arguments of the EPR thought experiment. Bell determined a limit for certain kinds of empirical predictions made by any theory that accepts the assumptions 'locality' and 'reality', and from this formulated an inequality[4] that he subsequently showed *all* 'locally real' theories are absolutely required to obey. In particular, and for the purposes of this paper, this means that in certain experiments where measurements of a property of a quantum system (like spin or polarization) are correlated with each other, all locally real theories must predict correlations that fall within certain well defined limits--an upper limit of possible correlation between empirical measurements of properties of a quantum system is established. Since I deal with the idea of locally real theories throughout this paper, allow me to briefly summarize their major characteristics. First, such theories assume that physical phenomenon are produced by interactions between physical entities which have definite properties at all times, and which are independent of our knowledge of them. Thus, when the tree falls in the forest and there is no one around to hear, it *does* make a sound. Second, such theories assume that there is always *some* sort of definite physical property that can account for any observed phenomenon. This results in the assumption that a complete state-description of a system consists in the accurate specification of the physical properties that make up the system (what is physically the case). Lastly, it is assumed that there is no possibility for faster than light signaling, a principle central to relativity theory. Although such locally real theories do not necessarily require a deterministic universe, the derivation of such a universe is quite natural given these basic assumptions.

Quantum mechanics, however, does *not* satisfy Bell's Inequality[5]; it predicts correlations that cross the boundaries delineated by the structure of the inequality. It has long been known that quantum mechanics predicts 'strange' correlations that seem to defy a common, classical[6] conception of reality, and in fact it is for basically this type of reason that Einstein, Podolsky, and Rosen argued in 1935 that it was incomplete. The formulation of Bell's Inequality, however, allowed the possibility for determining, *experimentally*, who was right: quantum mechanics or a locally real theory of the sort Einstein postulated, because it stated what must be the case in our experiments if a locally real theory is correct.

It is important to note that Bell's Theorem does not in any way depend upon quantum mechanics itself, but instead arises from a set of logical premises independent of any physical theory. This is crucial because in effect it allowed Bell to set up a situation in which the *entire class* of 'locally real' theories could be tested, without having to consider each 'locally real' theory individually. This type of phenomenon has been accurately dubbed 'experimental metaphysics' and is significant in that a set of metaphysical assumptions can be adequately tested through experiments that fall entirely in the realm of physics.

Aspect's Experiment

The experiment that is generally regarded as the most successful test of Bell's Inequality was conducted by A. Aspect, J. Dalibard, and G. Roger in 1982. In the experiment an 'excited' atom decays and emits two photons in opposite directions. Detectors placed on opposite sides of the room then record the polarization of the photons. There are two detectors on each side, one of which detects for polarization in one direction (say +45 degrees from horizontal), and another which detects for polarization in another direction (say -45 degrees from horizontal). The photon is directed to either of the two detectors by a switch through which the photon must pass. The experimenters can change at random how the switch is set, and therefore to which detector a photon will go, and therefore what type of measurement will be made in a particular run of the experiment (+45 or -45 polarization).

Interestingly, however, the setting of the switch, and thus the subsequent path of the photons, can be left until *just* before the photon arrives at the switch, long after the photons have been emitted. This feature is extremely significant, because it is impossible for a signal, even a signal traveling at the speed of light, to travel from one side of the experiment to the other (conceivably in order to 'tell' the other photon how the switch was set across the room) before the switch could be changed.

Einstein, Podolsky, and Rosen argued that quantum mechanics requires that a property, like polarization of the photon (P1) in a certain direction, could be measured at a distance by measuring the polarization of another photon (P2) that had previously interacted with it--that is, quantum mechanics predicts that there will be a certain level of correlation between the measurements of the polarization of the two photons. They argued that since it is impossible for the measurement of P2 to actually interfere with P1 (no action-at-a-distance), it follows that P1 must have had its particular polarization *before* the measurement of P2 was taken, and that our measurement is merely conforming with the independent and enduring reality of the actual polarization of P1.

This idea is strengthened by the fact that because the particular direction of polarization being measured can be changed by the experimenter *after* the photons are long separated (we can switch the setup of our apparatus *just* before the photon arrives and instead measure for polarization in a different direction), it *must* be the case that *all* properties must be 'real' *b□□efore* they are measured, for otherwise the measurement itself (and by implication the experimenter's choice of what property to measure) must have some impact on the determination of the property of a quantum system.[7]

Aspect's experiment is important in the sense that it does much more than just resolve a technical point between two contending theories; it forces us to reconsider our conception of the structure of the universe and the nature of reality--it leads us into metaphysics. Before the advent of quantum mechanics, most scientists believed that objects had an independent existence, that things (tables, chairs, your mother-in-law) existed 'out there' whether or not anyone observed them. It was also thought that each object enjoyed a *complete* set of attributes, such as position, momentum, energy, and spin both before and after our observation of it. According to this conception, atoms and electrons (little things) would differ from bowling balls and watermelons (big things) only in *scale* and not in *kind*.

When Aspect's experiment was performed, the results were clear: Bell's Inequality was violated--the correlations exceeded the limits set by the inequality. Physicists expected this result, for otherwise the most successful theory in scientific history would be wrong! However, even though it was known that quantum mechanics disagreed with the common sense, Newtonian view of reality, Aspect's experiment has definitely and completely confirmed this in a repeatable experimental situation--to the best of our knowledge quantum mechanics remains a perfectly good theory, just as it is.

The problem is that quantum mechanics doesn't provide its own interpretation. As a theory, quantum mechanics is essentially a number crunching exercise: plug a few numbers into some equations and other numbers result, and it just so happens that the resulting numbers always seem to fit with actual observations of the world. Various theories try to explain what is 'actually happening' in the universe such that these particular numbers, and not other numbers result, but they do not originate in quantum mechanical theory itself, but instead exist in the form of supplementary, essentially *ad hoc* explanations.

Today, much of the debate about quantum mechanics is not about quantum mechanical theory as much as it is about the theory of quantum mechanics, or rather, the *philosophy of quantum mechanics*: what must be the case metaphysically assuming quantum mechanics is "correct". There exist many different "interpretations" of quantum theory, which provide explanations of one sort or another for observed phenomenon. Unfortunately, *all* these metaphysical theories are in perfect agreement with the predictions of quantum mechanics--each theory gives the same observed results! Their differences lie in the way in which they answer the question: "What must be the case metaphysically in order to satisfactorily account for observed phenomenon?". Note that the question is *not* "What must be the case metaphysically in order to account for observed phenomenon?". The key lies in the word "satisfactorily"--if physicists were only concerned about the probability of predicting any particular quantum event, then all questioning ceases, as this is exactly what quantum mechanics does best;[8] but if physicists question *why* it is that our universe seems to be one in which quantum mechanics is a good theory, suddenly metaphysics enters the scene, center stage. Most contemporary debate concerning quantum theory tends to focus on the relative advantages and disadvantages of competing interpretations.[9] However, since they are all equal in the realm of prediction, it is impossible to determine which theory is "right". Aspect's experiment is one (rare!) instance in which definitive metaphysical consequences arise from an entirely physical experiment.

Consequences of Aspect's Experiment and the Violation of Bell's Inequality

The most immediate and important consequence of the violation of Bell's Inequality is the seemingly final rejection of all locally real theories. Even though it was known that quantum mechanics was basically incompatible with a locally real view of reality since the 1920's, the major evidence for this rested only in the awesome predictive power of quantum mechanics--the fact that it just seemed to work. The locally real Newtonian view, dominant among scientists[10] in the pre-quantum mechanical era, although discredited, was not actually *disproved*, and many scientists (Einstein among them) tried desperately to find a way to save what their common sense intuition knew to be true about reality.

The rejection of locally real theories means that at least one of the assumptions of the Bell Inequality must be false. As discussed above, Bell's initial assumptions were 'reality' and 'locality', but later it was shown by J. Jarrett that the assumption of 'locality' is really a combination of two other assumptions. He called these premises 'locality' and 'completeness', but I shall adopt Shimony's terminology and use 'parameter independence' and 'outcome independence' instead, so as not to confuse Bell's assumption of locality with Jarrett's slightly different version. Parameter independence states that the probability of an outcome of an observation on one particle is independent of the parameter chosen for the analyzer of the other particle. In terms of the Aspect experiment, this merely means that the particular direction of polarization that we set up the apparatus to detect on one side of the room can in no way effect the actual outcome of the measurement of the polarization of the photon on the other side of the room. Outcome independence states that the probability of an outcome of an observation on one particle is independent of the outcome of the observation of the other particle. Which is to say in our example that the fact of detecting the polarization of one photon to be +45 on one side of the room can in no way influence the actual outcome of the measurement of the photon on the other side of the room.

We now have a few options: we can get rid of any one of these three assumptions[11], or any two, or perhaps even all three. No matter which assumption we throw out, however, our view of reality must change significantly. If we abolish parameter independence, then it seems that the mere fact of the experimenter's choice to detect for polarization in a certain direction on one side of the room will effect the actual outcome of the measurement occurring on the other side of the room. This fact is too bizarre for all but a few physicists to accept--most feel that parameter independence seems to be an important feature of reality.

Getting rid of the reality assumption flies in the face of all common sense, for the answer to the 'tree question' would then be that no, when a tree falls in the forest and there's no one around to hear it, it *doesn't* make a sound. This question, however, brings up an important point, the elucidation of which has allowed the majority of physicists today to accept that reality is not a necessary assumption.

In the tree example, the objects (the tree, the forest, even the vibrations of the air caused by the falling tree) are all 'macroscopic'. That is, it seems to be a definite feature of reality that objects of sufficient size can be treated classically (with standard, locally real Newtonian mechanics), and that quantum mechanical effects on such objects are statistically negligible and can be ignored. Apparently the strange properties predicted by quantum mechanics only take noticeable effect when the systems considered are small enough. Thus, both locality and reality can be said to exist simultaneously for non-quantum systems in a perfectly ordinary way that corresponds to our common sense intuition. The problem is that on a quantum level, these effects still do exist even in large objects. Therefore, it can be said of the Moon, for example, that it can be treated as actually existing when we are not looking, even though its quantum constituents cannot individually be said to exist (in the full sense of the term)! How could an actually existing object like the Moon be built up out of objects in a quantum realm that have no reality apart from our observation of them? Yet this is one consequence of rejecting the reality assumption, and thus is one of the major issues which physicists are trying to come to grips with today.

Our last choice is to discard outcome independence. It is generally agreed among physicists that this is the best candidate for rejection, but getting rid of this assumption has its own problems. To reject outcome independence means that even though the configuration of the distant apparatus cannot affect the outcome of a measurement here, there still exists a strange type of correlation between the results that physicists are hard pressed to explain. It seems that somehow the actual outcome of the measurement here can effect the outcome of the measurement across the room.

Interestingly, the most commonly accepted view of quantum mechanics (called the Copenhagen interpretation after the city in which its inventor, Neils Bohr, worked) rejects both outcome independence *and reality*. For Bohr, the only way to obtain information about a quantum system is to measure it, but the act of measurement always has some sort of effect on the system being measured. It is therefore pointless to think of an isolated quantum system as having definite properties, because we can never know what these properties are without measurement. But since the act of measurement turns the system into a non-isolated one that includes the measuring devices themselves, it seems that we must determine that definite physical properties are possessed only by the combination of the system *plus* the measuring apparatus. Until we have measured some property of a quantum object, it is meaningless to even talk about the independent existence of that object. When a measurement has been made, however, it *is* meaningful to talk about the quantum object with the measured property as a real phenomenon. Bohr's interpretation thus rejects the assumption that objectively real phenomena exist apart from a measurement situation, and correlatively, that this results in the rejection of outcome independence, which can hold true only if the entities in question are considered objectively separated. In the case of Aspect's experiment, the Copenhagen Interpretation states that it is *not* correct to say that two photons are emitted from a source and travel to the two separated detectors where they are measured, but rather that *only* when the measurement takes place can we speak of two separated photons. Before the measurement occurs, it is incorrect to assume that two separate photons exist--in effect the measurement *causes* the separation. This counter-intuitive interpretation is actually the standard way of thinking about quantum mechanics today, and although it seems to solve some theoretical problems of quantum mechanics, it introduces entirely new ones at the same time.

The assumption that there can be no faster-than-light signaling is quite secure, because it is a major assumption of relativity theory, which is independently well confirmed. However there is a substantial minority who wish to get rid of Bell's locality assumption in order to keep the assumption that quantum objects are independently real apart from our observation of them, and in fact the major debate at present is between those who wish to keep reality and those who find it better to keep locality. Unfortunately, there is no clear answer as to who may be right, and the debate moves on. Whitehead, however, can provide an alternate way of thinking about these quantum dilemmas that may be useful, if we take him as a 'metaphysical counselor' and not a scientist.

Whitehead and Bell's Inequality

How would Whitehead respond to Aspect's experiment and the violation of Bell's Inequality? At first it would appear that Whitehead's theory of actual entities (I will refer to them as actual occasions from here on, as 'occasion' is more accurate than 'entity' in nearly all senses) is doomed to failure because of its inherent realism, and its seeming inability to account for the strange quantum effects that are observed in modern experiments. But the problem of bringing Whitehead up to date with the modern physical situation may really be more a question of adapting our own understanding to that of Whitehead's in order to see how his metaphysics might apply.

One of the central problems that physicists deal with is the temptation to hold onto a view of the world that can be squared with our common sense perception of it. Therefore it seems reasonable, for example, to attribute definite properties to objects even while they are unobserved. One way in which physicists are able to explain the strange quantum correlations is to say that there is some way in which the two correlated measurements had a certain cause in their past which brought about the effect of a correlation (essentially saying that the photons were correlated *before* the measurements). Most physicists will agree that this is a *possible* explanation--that the rules of the universe as we know them do not prohibit this type of phenomenon. However, it appears that if this explanation is taken, the result is that science itself becomes impossible.

This is so because the explanation that the state of a phenomenon can be explained by a common cause *somewhere* in the past (however distant) seems to say that we cannot fully explain a phenomenon by examining only its *immediate* past. It is as if we must give up all certainty in science in order to explain a few details (*interpretational* details at that!) of quantum mechanics, because we could never know for sure what distant cause could be producing this particular present phenomenon. For this reason, physicists reject this explanation out of hand as quite absurd.

If we take into account Whitehead's view of physics, however, this view deserves a second glance. The important point to consider is what Whitehead calls the "Ontological Principle", which merely states that *all* phenomena can be traced back to actual occasions themselves and no further--any reason for anything must ultimately and finally rest upon actual occasions and the interactions between them (which is really just to say the actual occasions themselves, since an actual occasion consists almost entirely of *relations*).

As a result of the Ontological Principle, we must radically change our common conception that space and time are separate, objective 'dimensions' in which all events take place. Rather, space and time are properties of the relations between actual occasions. This is point is absolutely crucial. For Whitehead, the past is defined relatively for every actual occasion and is not defined by a blind linear progression through time from the past, through the present, to the future. The past for *this* actual occasion *is* just those actual occasions that contribute to its process of concrescence. Thus, the resulting objective datum that is positively prehended from each already satisfied actual occasion in the initial datum by a particular actual occasion *becomes* the past for that actual occasion.[12] Similarly, the future is defined as just those actual occasions that *will* prehend *this* concrescing actual occasion. Time in this sense can be seen as the result of a type of *causal link* between individual actual occasions. Thus, there is no past that is more or less distant, because the past arises relatively for each actual occasion in its process of concrescence.

In Aspect's experiment, the photons would be considered enduring objects (objects consisting of actual occasions that exist in a particular type of simple relationship). They would be enduring objects that, although spatially separated, were part of a larger society. Following from the Copenhagen interpretation, the society in which the enduring objects exist as a sub-society is the 'measurement situation' itself, where it would be incorrect to abstract the particular photons from the entire society in which they are a part. (To assume that these particular photons will behave exactly like every other photon, even like ones not in the experiment, is a good example of what Whitehead calls the 'fallacy of misplaced concreteness'.)

Saying that the photons are part of a larger society is actually to say nothing other than that the past for each actual occasion in each enduring object is similar, to the point at which there exists a common cause for the particular behaviour of the photons. This common cause is just the fact that the photons are part of the society of the measurement situation from which they cannot be isolated. The past, being just those prehensions that contribute to the satisfaction of an actual occasion, is highly influential upon the final outcome of that actual occasion. By looking at an actual occasion's past, we examine *reasons* for why that actual occasion came to its particular satisfaction. An enduring object, because it has very little freedom, is extremely influenced by its past, to the point at which it seems to act in a determinate manner (more on this below). Thus the past for an enduring object (the photon) that is part of a larger society (the measurement situation) is intimately entangled with the past of the entire society itself. The actual occasions of the enduring object take into account (prehend) an objective datum consisting mostly of other satisfied actual occasions which are part of the larger society, whose influence causes the enduring objects to behave in a correlated manner. The correlations occur because of laws internal to the society, which arise from the relations between the actual occasions in the society itself.

One reason that physicists are so worried about the possibility that there might be some sort of faster-than-light signaling taking place behind the scenes arises from an innate (and highly classical) propensity to consider the photons as separate and individual phenomenon. Given this type of conception, it appears that the photons must be 'communicating' in some way if we are to explain the correlation. Neils Bohr took a step in the right direction when he determined that the photons couldn't really be considered individual photons unless they were part of a measurement situation set up to detect this property (of individuality). As related above, Bohr noted that rather than conceiving of some sort of connection between two individual and spatially separated photons, it would be more accurate to think about the photons as part of a larger situation which included the measuring apparatus, and that no property of a quantum system was definite and real unless it was itself part of such a larger system. In this instance the possibility for faster-than-light signaling need not take place, because it is the situation of the entire measurement (including the measurement of both photons) that gives rise to the correlation. If only one photon is measured, the correlations do not occur.

Then how can Whitehead deal with the claim that to explain the correlations by attributing to them a certain type of past results in the death of all possible prediction? This critique, arising from the search for an explanation of the violation of Bell's Inequality, is also aimed at Whitehead more generally by all sciences concerned with certain prediction.

The problem arises because for Whitehead, there are no unchangeable and immutable laws of physics that must be obeyed by actual occasions. According to the Ontological Principle, it is in fact just the reverse: the laws of physics arise from the actual occasions themselves, just as space-time (and everything else) does. This in conjunction with the idea that actual occasions are not fully determinate, but have some level of freedom, results in the fact that the laws of physics are not constant but rather evolutionary, in the sense that they *evolve*--they are part of the changing process, which is the reality.

This fact directly results in another critique of similar spirit from a slightly different angle: in the scientific realm it is an advantage for a theory to have predictive powers. If a theory cannot add something to our knowledge of the future, then it is powerless and can serve no purpose. Yet Whitehead's metaphysical scheme is exactly that which cannot take part in the realm of prediction. For Whitehead, a metaphysical scheme must, *in principle*, be able to account for *both* all of actual experience, *and* all of *possible* experience. Because of this, and as a consequence of its very nature, a metaphysical scheme cannot be predictive, but must function only in an explanatory capacity. "Metaphysics is nothing but the description of the generalities which apply to all the details of practice." (Process and Reality:13)

For those who are accustomed to the ways of methodological science, this would appear to be a grave fault. It would seem that any theory that disclaimed in principle all predictive power should be given up immediately, as it would be utterly useless--but useless only to physicists who are preoccupied with definite prediction and measurement. Metaphysics provides us with an ability to understand the physics *in relation* to other types of knowledge, and perhaps more importantly, other types of experience. The need for this type of *relation* (that metaphysics provides) is obvious today merely from the fact that the major debates surrounding quantum mechanics in the present (and for the past 50 years) are all basically metaphysical in character, if not explicitly so in substance. Even though metaphysics doesn't necessarily add anything to our knowledge of the future, it does contribute much to our knowledge of the *present*. Far from being vestigial, Whitehead would argue that metaphysics is actually quite necessary for a complete understanding of experience (more on this in my conclusion).

It seems then that Whitehead would give up the assumption of parameter independence, while keeping reality and a version of locality. Or rather, Whitehead never would have assumed parameter independence to begin with. Because space is a consequence of the relations between actual occasions, Whitehead is able to keep locality in the sense that in our present epoch, it just so happens that space is constructed in certain ways (i.e. has a definite relation to time, can be 'warped', etc.), and that one of the ways in which it is constructed has as a consequence a definite non-relative speed for light. In our present epoch, Bell's assumption of locality (no faster-than-light signaling) seems to be a good assumption, but due to the fact that actual occasions are not fully bound by any external environment (since they themselves create that environment), this will not always necessarily be the case.

This conclusion presents a big problem for physicists who depend upon the fact that the laws of the universe remain constant. The entire validity of scientific progress rests upon the assumption that results of a particular experiment, if set up with sufficient attention to detail, will not vary through time. This assumption is not generated from within science, but rather is a principle that allows science to exist in the first place. It arises not *a priori*, but from the simple observation of its truth as manifested in the actual world: if we set up an experiment to detect the speed of light today, its value will be exactly the same as it was last week, or even last century. If there is any change in physical law, it is because we become more accurate in our experiments and are able to see reality more clearly, not because the laws themselves are subject to change.

Yet if Whitehead's scheme were correct, it would seem plausible that we could, by performing an experiment at *t*1, and later at *t*2, detect some difference that would correspond to the change in physical law over (Delta*t*. Yet it seems to be a fact of nature that whenever we perform the same experiments, no matter when or where (again provided we set up the experiment with sufficient attention to each of its elements), the same results occur. Whitehead, however, does appear to be able to deal with this dilemma.

Physical laws are a consequence of the interactions between actual occasions, which is to say that they are a consequence of the prehensions of actual occasions. Whitehead would argue that what we observe to be physical laws are almost entirely due to the way in which certain actual occasions which form enduring objects prehend each other. The mode of the prehension in these instances can be characterized by an inertial power, in fact a *tradition*,[13] from one actual occasion to another. The propensity for any actual entity to either follow the tradition or not is directly proportional to its level of freedom (here referring to the occasion's propensity or ability for novelty). In the case of systems with very low levels of complexity, such as enduring objects, this freedom is negligible. For this reason, the tradition is almost always accepted, as there is insufficient complexity in the string of actual occasions that constitute the enduring object to allow for the realization of possibilities outside of those presented by the actual occasion's objective datum.

For example, an electron (an enduring object) *always* has a negative charge which is quite invariant. The actual occasions that constitute the electron are in a sense overwhelmed by the sheer inertial power of the particular objective datum (which can be characterized as electronic in the present epoch) which it prehends, and is essentially forced to follow the rules of the tradition that already exists.

Subatomic particles, like electrons, have as constituents only actual occasions that are already easily subject to traditional forms (in the sense of electronic or protonic forms of behaviour--particular types of physical law). A highly complex actual occasion would almost never become part of a traditional chain (an enduring object), because it is, by the fact of its complexity, not as impressionable as actual occasions of a more simple type, and therefore not as subject to the certain laws which pervade such traditions. The majority of actual occasions are of the simple, traditional type, and thus obey the laws of physics--although it is more correct to say that enduring objects are just those in which the laws of the tradition are realized.

Of course the laws of the tradition need not always be obeyed. If an actual occasion in an enduring object broke the tradition, some sort of radical change in the enduring object could be expected. In modern high-energy physics this might be analogous to particle creation and destruction.

Supplementally, Whitehead relates that God's placement of the subjective aim into each actual occasion is a principled one. Novelty arises principally in organisms of high complexity, which have as constituents sub-societies and sub-sub-societies, all the way down to the simple enduring objects. Such complexity is built from the bottom up, in the sense that complex organisms presuppose the existence of the simpler societies (the reverse is not true, however). Because God has as a goal the expansion of novelty, and because novelty has a much higher possibility for realization in complex organisms that require the existence of simple societies and enduring objects, it seems reasonable to assume that God would willingly place into simpler actual occasions (like the kind that form enduring objects) subjective aims that were designed not for the maximization of novelty on the simple level, but rather for the maximization of novelty on more complex levels. It is a question of harmony: in order to have intense forms of novelty and experience on one level, such novelty must be sacrificed on another level. Thus there would be an advantage for God to place subjective aims into certain actual occasions such that something like 'laws of the universe' exist and exhibit the seemingly immutable character presently observed.

It is clear that for Whitehead the laws of physics are *not* constant, but the relative degree and severity of their change remains undefined. It is quite possible that the basic laws of physics change only very slowly, as they can be seen to be more 'entrenched', while, for example, biological laws would have a tendency to shift more readily, as they exist only in reference to more complex systems which are more capable of novelty and freedom. And because the Ontological Principle states that all things, including such laws, are due to actual occasions and their interactions, a derivative statement results to the effect that when laws exist for certain types of systems of actual occasions, the degree of constancy in the particular tradition (the sheer inertial power of the objective datum) *decreases* in proportion to the level of complexity (and hence propensity for novelty) achieved in that particular system of actual occasions.

Whitehead and the Copenhagen Interpretation

Because most physicists accept the Copenhagen interpretation of quantum mechanics, it is important for Whitehead to be able to account for its major features, since supposedly this interpretation is our best understanding of 'the way things are'. The issues dealt with here are realism, indeterminacy, complementarity and the measurement problem, but it will be apparent that only one small conceptual change need be made in order for Whitehead to deal successfully with *all* of these phenomenon. We begin with the problem of the rejection of realism.

Realism

When Whitehead talks about the concrescence of an actual occasion, he makes it very clear that the satisfaction is real in the fullest sense of the term. How is it, then, that Whitehead can retain his form of metaphysical realism, which is an essential feature of his whole scheme, if rejecting the objective reality of quantum objects makes the most sense given experiments like Aspect's?

A proposal by Shimony provides one way out. Rather than postulate that actual occasions are the *final* real constituents of the universe, Shimony toys with the idea that there is a more general form of ultimate reality underlying the existence of actual occasions. He proposes that this more general reality might be a type of "'field' of diffused primitive feeling, of which the actual occasions are 'quanta' "existing whenever there are individual loci of feeling." (1993:305) In this conception, actual occasions are not the ultimate real things of the universe, but rather *special cases* of the more basic reality of the field of feeling.

To Whitehead this sort of solution would be unacceptable. It is imperative that a real universe has as its final constituents *real* entities.[14] But quantum mechanics treats quantum objects not as independently real entities, but rather as *probability fields* which establish the possibility of obtaining any particular result in the measurement of a quantum system. The actual properties of the quantum system have only secondary reality, and are not the most fundamental constituents of the universe.

However, by modifying the conception of the actual occasion only very slightly, it seems that Whitehead may be able to stay afloat. In the actual occasion are multiple sub-processes (the prehensions) which lead the actual occasion to its satisfaction. None of these sub-processes can be said to be real in an objective sense, as they are only *derivatively* real in relation to the satisfaction of the actual occasion. The probability field of quantum mechanics is none other than a description of a complex interaction between certain of these indefinite sub-processes. In fact it can be said that the probability field is just the combination of the phases of concrescence abstracted from the satisfaction. Of course these phases of concrescence cannot be fully abstracted from the satisfaction itself,[15] and it is exactly for this reason that such an abstraction is inherently indeterminate--it is itself merely probabilities for a certain satisfaction.

Whitehead is able to maintain that actual occasions are, in the final analysis, *the* ultimately real constituents of reality. The satisfaction of an actual occasion is the culmination of the indefinite sub-processes (the phases of concrescence) into one definite, and hence *objective* unified feeling. Abstraction of sub-processes from the satisfaction is always just that--abstraction. This is why the phases of concrescence are said to have only *derivative* reality. Let me explain how this thesis is in accord with modern quantum theory.

Indeterminacy

It is a consequence of the fact that quantum mechanics deals fundamentally with probabilities that it is impossible to ever know in advance the exact outcome of an experiment. This has been confirmed extensively in various experimental situations and forces us to conclude that it is a fundamental fact that the universe is not deterministic in the Newtonian sense. Whitehead would joyfully accept this premise, as it conforms perfectly with his idea of the intrinsic freedom of actual occasions.

When we perform a measurement of the polarization of a photon, we cannot say whether a particular photon will be either passed or blocked by the polarization filter. The best that we can do is calculate the probability that in any given instance a photon will pass or not. In such cases (which apply to all measurements of quantum properties) our certainty of what will happen is never complete, although *in general* we can say what will happen. When the polarization measurement has been made, however, we can definitely say that the particular photon *really is* polarized in such a way. If the photon passes through a +45 degree polarization filter, then at any time in the future (assuming that the photon is not disturbed) we can perform another polarization test, and we will always find that it is polarized at +45 degrees.

For Whitehead, this indeterminacy is due to the fact that each actual occasion has at least some level of individual freedom, and in fact can never be predicted in a complete sense. As discussed above, quantum objects have very little freedom, and are very much bound up in their tradition. Consequently, our measurements of a property of a quantum system always seem to fall within certain limits (defined by quantum mechanics which is itself defined by the actual occasions themselves); there are only certain values that are possible for any given experiment measuring a quantum property. Within a tradition there are only certain 'occupations'[16] that are acceptable (the details are provided by the laws of the tradition), and any actual occasion that is a part of the tradition must choose one of the available occupations if it is to remain a part of the society of which the tradition is an integral component. The actual occasion *can* in principle choose any path, but this would mean that it could not be a part of the society whose laws require certain types of behaviour.[17] The fact that we cannot tell what any one property of a quantum object will be with complete certainty is a testimonial to the freedom inherent in the natural world.

Complementarity

The most interesting and important conceptual tenet of the Copenhagen interpretation is that of complementarity. The most easily grasped manifestation of complementarity is in the Heisenberg Uncertainty Principle, which states that the position and momentum of a particle cannot be measured simultaneously--the two properties, position and momentum, are complementary.[18]

In the Copenhagen interpretation, this uncertainty arises not from the inadequacy of our ability to measure the properties, but from the nature of reality itself. It is actually that both a definite position and a definite momentum *do not exist simultaneously* in a particular measurement situation. It is important to note that this does *not* mean that position and momentum do not exist *generally* at the same instant, but that the more exactly we define the position of a quantum object, the more uncertain its momentum becomes. If we only define the position of a particle with a moderate degree of uncertainty, then we can also define the momentum of the particle with a moderate degree of certainty.

The Copenhagen interpretation states that if we define the position of a quantum object *exactly*, then it would be meaningless to even talk at all about the momentum of the object (even if it was just to say that the momentum doesn't exist!). Thus it is correct to say that in such a situation the position exists definitely (exactly), but it is *not* correct to say in the same instance that because of this the momentum *does not exist*--rather we cannot say in this case *anything* meaningful about the existence or nonexistence of the momentum of the quantum object. This point is very important and is often missed except in the most complete accounts of the Copenhagen interpretation: the fact that the statement "a definite position and a definite momentum cannot exist simultaneously in the same quantum object" is true *does not* necessarily result in the statement that "if the position of a quantum object is defined exactly then the momentum does not simultaneously exist", but rather results in a statement like "if the position of a quantum object is defined exactly then we cannot say anything about its momentum, including statements referring to the existence or nonexistence of this property". The key is that we are speaking of uncertainty-if we defined the position of a particle exactly, and then said that therefore the particle had no momentum, then essentially we are saying that its momentum is zero, which is another way of saying that we know *exactly* what the particle's momentum is, namely, zero! On the contrary, because of the Heisenberg Uncertainty Principle, in this case we must say not that the momentum is exactly zero, but that it is 100% *uncertain*--the only statement we can correctly make concerning the particle's momentum is an epistemological one: that we cannot make any correct statements concerning the ontology of the particle's momentum.[19] The natural response from the philosophy of organism to the idea of complementarity[20] is to say that such properties cannot exist simultaneously in the satisfaction of an actual occasion, but that they do exist as potentials in the actual occasion's abstracted phases of concrescence. These phases, as we have seen, are only derivatively real and correspond to the quantum idea of probability fields. Just as there appears to be an upper limit to the possibility of knowledge of the entire state of a quantum object, so there is an upper limit to the possibility of knowledge of the phases of concrescence in an actual occasion. In the phases of concrescence, a potential exists for the realization in the satisfaction of *both* properties in a complementary duality--the actual occasion *could* have an exact position by sacrificing the possibility for an exact momentum (or vice versa), or it *could* have a general position *as well as* a general momentum.

To say that complementary properties exist in the phases of concrescence is to say that complementary properties exist (in the sense of having derivative but not independent reality) as prehensions in the actual occasion. The properties are only *real* when they become incorporated into the final complex feeling which is the satisfaction. The derivative reality of the prehensions in an actual occasion is exactly analogous to the superposition of states in a quantum system: the wave-function of a quantum system is said to collapse when its superposition ends and one possibility becomes real, just as an actual occasion is said to be real in its culmination in a satisfaction. In other words, *the satisfaction of an actual occasion is the collapse of the quantum mechanical wave function*. This statement has very important implications, and provides a way of dealing with one of the major areas of debate in quantum mechanics today--the measurement problem.

The Measurement Problem

In the Copenhagen interpretation, it is meaningless to speak of the existence of a property (such as polarization) of a quantum object unless it is measured. Fine and good--but what exactly constitutes a measurement? The example of Schrödinger's Cat has served to explain the measurement problem for decades, and remains the easiest way to conceptualize the phenomenon. In Schrödinger's own words:

> A cat is penned up in a steel chamber, along with the following

> diabolical device (which must be secured against direct interference by the cat): in a Geiger counter there is a tiny bit of radioactive substance, so small that perhaps in the course of one hour one of the atoms decays, but also with equal probability, perhaps none; if it happens, the counter tube discharges and through a relay releases a hammer which shatters a small flask of hydrocyanic acid. If one has left this system to itself for an hour, one would say that the cat lives if meanwhile no atom has decayed. The first atomic decay would have poisoned it.

It seems clear that the cat is, at any given time, either quite alive or quite dead. Quantum mechanics, however, states that this is not the case, and that actually the total system within the box is in a superposition of two states, one with a live cat and one with a dead cat. But of course that seems absurd because how can the cat be both dead *and* alive at the same time? According to quantum mechanics, this superposition of two states collapses into one definite state (where the cat is either alive or dead), when a measurement takes place, but it does not say what constitutes a measurement.

Bohr dealt with this by stating that a measurement was an 'irreversible act of amplification'--that somewhere between the quantum world of atoms and the classical world of Geiger counters and cats, quantum physics 'turns into' classical physics, in which the cat is definitely either alive or dead. It seems clear that such an irreversible act of amplification must occur somewhere in between the quantum and classical worlds, and it also seems clear that this measurement takes place because of the coupling of a quantum system with a macroscopic measuring apparatus (in this case the Geiger counter).

The problem arises because the measuring apparatus, although macroscopic, is itself made up of atoms and so is subject to the rules of quantum mechanics. If quantum mechanics is to remain a consistent theory, then quantum effects must be present in the measuring apparatus, no matter how large it may be. Consequently, we can consider the measuring apparatus plus the measured object as a single large quantum system. Yet this presents a problem: if the system can be considered isolated from yet larger systems, the same rules of quantum mechanics still apply such that the entire system including the measuring apparatus exists in a superposition of states which requires a further measurement to occur in order to collapse into one reality.

Whitehead can avoid this type of von Neumann regress by defining the collapse of the wave function to be the concrescence of each actual occasion. Thus the 'irreversible act of amplification' is just the bringing into final reality the complex unification of feelings of the actual occasion in its satisfaction. According to Whitehead, "the subject completes itself during the process of concrescence by a self-criticism of its own incomplete phases."[21] (Process and Reality:244) The process of self-criticism is the way in which an actual occasion determines its own final qualities--the measurement situation is provided by the satisfaction itself and is the satisfaction itself.

For this reason, the strange properties of quantum systems (the actual occasions) like complementarity, can be seen as applicable *only* to quantum systems. Medium and large-scale objects may be treated normally (classically) for all practical purposes. Thus locality and reality can be said to exist for objects of sufficient size, even if on the quantum level they cannot, because societies have their own laws which are not necessarily applicable to all other types of systems. For example, the laws of very complex societies (those described by the science of biology) follow laws that simpler societies (those described by the laws of physics) do not, although the laws of biology presuppose the laws of physics.

The laws that apply to quantum systems cease to have effects on medium and large objects because the level of complexity is sufficiently increased by the sheer number of actual entities involved in the society to allow for a new set of (classical-looking) rules to take over. Quantum mechanics can in principle talk of macroscopic systems as if they were merely large quantum systems. Whitehead, however, would call this an instance of the 'fallacy of misplaced concreteness', because quantum laws (which apply to quantum systems, which in this case means just actual occasions themselves) are applied to classical systems, for which different rules apply. *Even though* the classical rules rest upon the foundation of quantum systems which follow quantum rules, classical systems cannot be explained *merely* in terms of quantum rules, just as postulates of biology cannot be exactly reconstructed using *only* the laws of physics, even if biological rules necessarily require physical laws in order to exist.

The Rejection of Parameter Independence

Whitehead rejects the assumption of reality along with the Copenhagen interpretation, but at the same time he avoids the strange metaphysical consequences that the Copenhagen interpretation must deal with by keeping entities that are definitely real. Whitehead would also reject parameter independence as we have seen, but this rejection seems to have serious implications that conflict with much of modern physical theory.

The crucial point is that for Whitehead, time and space (or space-time, if you are so inclined) are not initial properties of a world in which actual occasions happen to find themselves, but are actually properties of the interactions between the actual occasions. Time and space are relative in the strict sense of the term--there is no such thing as an absolute frame of reference. We have seen that the laws of physics for Whitehead arise from the actual occasions themselves--so it is with space and time as well.

Thus, in a certain sense, there is a sort of initial nonlocality and atemporal form to the indefinite phases of concrescence of an actual occasion. Locality and temporality exist in the strong sense of the word only in the final satisfaction of the actual occasion and not before. By concrescing, an actual occasion becomes real and attains its *place* and its *time*. The occasion's place and time are relative to the other actual entities which it prehends. It is simultaneous with all those other actual entities with which no prehensions (positive or negative) are shared--all those actual occasions which are not prehended by the one actual occasion, and which do not contribute to the satisfaction of the one actual occasion are considered simultaneous.

The fact of selective simultaneity is what allows for differentiation in an actual occasion; the character of an actual occasion arises in large part from the selective process culminating in the delegation of the entire 'field' of satisfied actual occasions (the initial datum) into either the past, the future, or the simultaneous 'present'. The term 'present' is misleading; two actual occasions are simultaneous when they have no causal interaction of any sort (although in principle they always *could* have such interaction)--*simultaneity does not necessarily mean contemporaneity*.

Because the prehensions of an actual occasion are nonlocal and atemporal, an actual occasion can have as its past *any* other satisfied actual occasion, which is to say that the initial datum of an actual occasion is limited only by the number of satisfied occasions (the finitude or infinitude of which is undetermined probably approaching infinity). The question is: what makes an actual occasion prehend the objective datum it does, rather than any other set of objective data? The actual occasion is not bound by eternal, objective laws of nature which dictate what initial datum any particular actual occasion may have, but there *are* laws which the actual occasions themselves create and follow which determine to a high degree what particular satisfied actual occasions any given concrescing actual occasion will take as objective datum from the entire set of objective, real, and satisfied actual occasions. To state it simply, an actual occasion *can* prehend any other satisfied actual occasion (regardless of the *derivatively* real properties of space and time), but this potential prehension of other satisfied actual occasions is limited by the actual occasion's initial choice of 'environment' which is closely related to its subjective aim. Its initial choice actually sets up the environment, including the laws of the environment, which then further determine what that actual occasion will prehend.

Such a statement results in a radical departure from the rule-governed universe which physicists (as the extreme example) think we inhabit. In Whitehead's universe there is almost nothing that is *in principle* impossible, given enough novelty and freedom. *Any* sort of physical law has potential to exist in actuality, including laws that would seem to result in heavy paradoxes, such as the ability to travel into the past or teleport across the universe in an instant.

Despite this, however, order does exist in the universe, and Whitehead provides an explanation for why that is so: God's contribution of the subjective aim into each actual occasion, and the formulation of inter- and intra-societal laws in the form of tradition are two such reasons. His scheme, although formulated to be able to accommodate all of experience, remains highly coherent.[22] Whitehead's theory cannot be disproved, even in principle, as it is a metaphysical scheme not partaking in the realm of predictive results that can be experimentally determined to be incorrect. However, the explanatory power of Whitehead's metaphysics does provide a mode in which to understand the universe-its correctness is not at stake in the particular, but in the general success of the theory.

Conclusion

Metaphysics

Metaphysics is a discipline of boundaries and horizons, and as such it is continually involved in complementary processes of self-destruction and re-creation. Two major forces are at work within this cycle: one, the Question, strives to break down the present boundaries in order to glimpse a distant horizon, while the other, the Answer, seeks to construct boundaries out of an horizon through a process of solidification and stabilization. Each force has its own creative and destructive properties, and when combined result in a movement of metaphysics within and beyond itself.

To build a boundary is to create a place at which travel must cease. Metaphysics establishes boundaries of knowledge beyond which questions cannot pass--they are interrupted and rendered void. The creation of such boundaries is the translation of the unknown into the familiar. A home is created in the construction of boundaries that define inside from outside, and while the territory within becomes familiar, the territory outside is forgotten, or rather, slowly erased. By taking a horizon of knowledge and solidifying it in this way, metaphysics provides a framework within which questions can be replaced by Answers--answers of ultimate and final authority.

At the same time, the construction of a boundary of knowledge by metaphysics through a structuring of Answers gives rise to the possibility for the asking of Questions--questions posed directly to the present boundary of knowledge which are designed to pull it down *from the outside*. The construction of a boundary is never complete, and Questions seek out the inconsistencies inherent in Answers in order to re-mystify and challenge the authority of the Answers by liquifying their foundation. Once a boundary has been infiltrated, a horizon of knowledge becomes apparent.

A horizon is an ever-receding line stretched between the knowable (but not necessarily known) and the unknowable, which cannot be either encompassed or reached. Uncircumscribable by knowledge, it is itself that which ultimately circumscribes knowledge. A horizon, however, is not a boundary, as it does not limit or even delineate; rather, it is the vanishing point for knowledge that calls forth Questioning. It is the formulation of Questions that eventually leads to the creation of Answers and the darkening of the horizon into a boundary. The constancy of metaphysics lies in its Answers, while its movement and self-reflection stem from its Questions. As a discipline encompassing both its own consolidation and alienation, metaphysics is unique: it can never stand still, even though it continually creates platforms of knowledge upon which stillness is possible.

Physics and Metaphysics

The word "metaphysics" is almost taboo for some modern physicists. As a close synonym for "unfounded explanation", it is used as a last resort in the formation of a physical theory that does not obviously square with the hard facts of physical reality. In general, physicists wish to render metaphysics unnecessary--to make all of what now falls under the heading "metaphysics" explainable entirely in terms of physical theory without appealing to concepts that do not have a clear basis in observed fact. To the extent that this is true physicists become allied with the force of the Answer, and seek to construct and maintain boundaries of knowledge within which questions are not only meaningful but answerable.

But as we have seen, physics and metaphysics are not so separate as some philosophers and physicists indicate, and in fact are in a sense symbiotic. Physics cannot exist without metaphysical postulates upon which it can rest its own theories, while metaphysics can in turn be directly influenced by physical experiments.

Ideally one could create physical experiments that tested metaphysical assumptions just as one creates physical experiments that test physical assumptions. Unfortunately, "experimental metaphysics" is not so easy, due to the fact that metaphysical theories are often formulated in such a way as to make direct experimentation impossible (and in fact this is one of the primary reasons for the avoidance or rejection of metaphysics by physicists, who rely heavily upon physical experiments). Usually this is a result of the sometimes excessive generality of metaphysical theories--they are loosely structured and can accommodate almost any new observations without detriment to their primary principles. The above analysis of Whitehead's metaphysics is a perfect example of how a tightly knit metaphysical scheme can adapt to new information without needing to be entirely re-formulated.

However, the physical testing of Bell's Inequality in Aspect's experiment shows that, despite the general malleability of metaphysics, something like experimental metaphysics is possible. The uniqueness of this particular situation stems from Bell's creation of the inequality; by restructuring metaphysical assumptions according to logical rules, he was able to formulate a set of propositions that could be tested in physical experiments. The peculiar difficulty of the work lies in the translation of metaphysical postulates into physical consequences that are testable in controlled conditions.

This type of work must almost necessarily fall to the physicists and those philosophers, logicians, and metaphysicians with scientific sensibilities, or ideally all of these in cooperation. The goal of metaphysics, however, is not merely to provide metaphysical principles that are able to be translated into physical situations, but to search for the *proper* first principles upon which all further explanation must rest as well. As a human discipline subject to human limitations (and human wonder), the claims made by metaphysics are necessarily biased in some form or another, but this does not detract from its importance as a background field upon which phenomena (be they physical, mental, or other) are seen to occur. If physics tells us what we *can* say about reality, then in one sense metaphysics tells us what we *might be able* to say about reality--but in another sense it tells us what we *must* say about reality at any given time. The former statement concerns the field of experimental metaphysics, while the latter concerns metaphysics in its broader, human context as a discipline that serves as the starting, or rather finishing point for explanation.

The search for truths in metaphysics should be supplemented by progress and advances that occur in physics, while physics should regard itself as being able to provide not *final* truths about reality, but truths that are dependent upon a more general metaphysical scheme. If metaphysics rejects physics as a valid partner in the search for truth, then its explanations can be valid to those who need final and ultimate answers, but the goal of metaphysics should not be to pose as any arbiter, but as the one that provides the best final and ultimate answers. If metaphysics limited itself to making the people that asked metaphysical questions feel better by giving them absolute answers, then there would be no need for any distinct metaphysical theory--any scheme would do that could provide this service. But metaphysics, although existing for this purpose, also exists as a discipline that seeks particular and unique explanations--namely, the best explanations, and the best explanations are likely to be those that correspond with what we know about reality through physics. But because metaphysics is a human discipline existing for human purposes, the best explanations will also likely be in accord with discoveries of other fields such as human psychology, biology, and ecology, to name just a few.

Of course the claims to truth made by metaphysics are questionable--this is in fact one of its greatest assets. We should not judge metaphysical schemes solely on the grounds of "correctness" alone (a problematic concept) but also by criterion of usefulness, application, and consequences. This is not to say that metaphysics must ultimately relinquish all claims concerning the ultimate nature of reality. On the contrary, by maintaining a certain level of self-criticism and humility, metaphysics can create for itself the possibility to transcend its own delusions. An answer to the question of whether or not there is one unique set of metaphysical principles that is "right" is itself a metaphysical question subject to all the limitations of metaphysical inquiry and understanding. Claims to knowledge are always conditional, and metaphysics, even as it creates its Answers simultaneously allows them to be destroyed. "Truth" then becomes both opaque and translucent, settled and unsettled.

If metaphysics does provide the decisive point at which explanation ceases, a place where the question "Why?" can no longer be asked, then it can be dangerous. The formulation of first principles in a metaphysical scheme is a delicate matter with profound implications that ultimately affect not just ethics but even the everyday modes in which we view and interact with the world.[23] Because of this it is important for metaphysics to nurture an intimate relation with physics while not limiting itself by this relation. To formulate first principles that are not only in accord with physics but also with ethics is one of metaphysics' greatest tasks.

The question "Why?" can always be asked again, whether of physics, metaphysics, or any other discipline, but the ultimate goal of the question is common: to grasp truth. But "Truth" does not merely exist; it creates. Metaphysics is the only discipline which can undertake the examination of "Truth" in reference to both its existence and its self-creation, and as such it is indispensable.

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Footnotes

1. "Energy is another example. Most physicists will initially define energy in terms of its relations to other physical concepts, for instance rest mass and the velocity of light (e=mc2), or Planck's constant and frequency (e=h(). Yet even though the existence of energy is accepted, we don't really know what it is. A signal of the problematic nature of the concept of energy is apparent in the fact that the definitions that do exist are usually framed in such a way as to be tautologies cloaked in equivocatory language, essentially reducing to a statement like "energy is the thing we call 'energy'". Back

2. Actually quantum theory is not considered 'complete' in the strong sense of the word even today. Quantum mechanics, as it is presently, makes certain predictions about the

results of experiments. To date, there has been no strong evidence disconfirming quantum theory, as experimental results are always in excellent agreement with theory. This does not necessarily mean that quantum theory is complete, and in fact many would argue the reverse. The work in quantum cosmology and quantum gravity are two examples of areas in which physicists feel that quantum theory needs supplementation. Back

3. Explained later in this paper in its modern form as A. Aspect's experiment. Back

4. For example, -1<0><3 is an inequality. >Back

5. Others have since proven similar theorems using slightly different assumptions that result in slightly different inequalities. Inequalities of this type are called "Bell inequalities", and the theorems proving them "Bell theorems". Back

6. The classical conception of reality is essentially Newtonian, and besides being itself a 'locally real' theory, it agrees extremely well with common sense experience. It is because of its seemingly intuitively obvious principles that the classical conception of reality has such staying power, even in light of the fact that both relativity theory and quantum theory (each independently formulated and independently confirmed) prove the invalidity of Newtonian mechanics and the world it implies. Back

7. In effect Bohr agrees with this, stating that the two photons of the above example cannot be considered separate entities until after a measurement has been made to separate them. The measurement itself actually causes the separation. Back

8. One particular interpretation of quantum mechanics, often called the ensemble interpretation, assumes that ontology of probabilities present in quantum mechanics is the end of the line, and that almost no other questions remain to be asked about the nature of the universe on this level. Back

9. Of course this is not the bulk of the work done with or in quantum mechanics, which, far from theoretical, is characterized more by examining possible technological applications of quantum mechanics. Back

10. The Newtonian type of view, because it is so compatible with common sense, and because the ideas of quantum mechanics are not terribly accessible to the average populace, still seems to be dominant among non-scientists, although there is a growing set of layman's books that are beginning to change this. Back

11. There are actually more than just these three assumptions that can result in a Bell inequality, but it is generally agreed that parameter independence, outcome independence, and 'reality' are the most likely candidates for rejection. Linda Wessels has done particularly detailed work examining these various assumptions. Back

12. The initial datum for an actual occasion consists of every already satisfied actual occasion. The objective datum for an actual occasion consists of those already satisfied

actual occasions that it positively prehends. A prehension can be thought of as a bringing from the past (as defined above) into the present (of the concrescing actual occasion in question) by a process of perception-Whitehead speaks of a prehension as a 'feeling'. The satisfaction of an actual occasion is the culmination of the occasion's multiple prehensions into one unified feeling; the actual occasion becomes part of the initial datum, loses its ability to prehend, and can now itself be prehended. Back

13. The word "tradition" is my own term, not employed by Whitehead. Back

14. Otherwise one is committing a 'fallacy of misplaced abstractness'! Back

15. An interesting quote from a modern textbook on quantum mechanics may give some force to the idea of the universe as inherently interconnecting processes that cannot be completely abstracted from the whole: "As a practical matter, therefore, it's okay to pretend that electrons with nonoverlapping wave functions are indistinguishable. (Indeed, this is the only thing that allows physicists and chemists to proceed at all, for in principle every electron in the universe is linked to every other one via the antisymmetrization of their wave functions, and if this really mattered, you wouldn't be able to talk about any one electron until you were prepared to deal with them all!)" Griffiths:1995 p.184 Back

16. Again this is my terminology, not Whitehead's. Back

17. This can explain why, for example, electrons always occupy very particular 'orbits' when they are part of an atomic system (the 'quantum leap' phenomenon). Back

18. The relationship is expressed as p > h/4, where x is the uncertainty in position, p is the uncertainty in momentum, and h is Planck's constant. It is easy to see that decreasing the uncertainty of position necessarily increases the uncertainty of momentum, and vice versa. Back

19. This strange thesis of the Copenhagen interpretation stems from Bohr's idea that physics tells us not what is, but what we can say about the world. Back

20. Several properties are complementary besides position and momentum: wave-ness and particle-ness are complementary, as are time and energy. Back

21. This could be taken to mean that each actual occasion is philosophical! Back

22. Although not completely so-for example, how is it that an actual occasion can possibly begin? That is to say, what allows the actual occasion to begin its process in the first place? Back

23. The eventual worldwide impact of the settling of Cartesian metaphysics in the Western mind is one example. Back