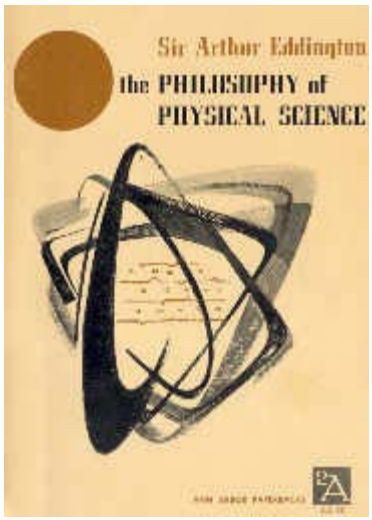

A READER'S TREASURY

The Philosophy of Physical Science
by
Sir Arthur Eddington

Lectures given to Trinity College,
Cambridge, Easter Term 1938
Chapter: Quantum Reality
Published by The University of Michigan Press/MI in 1978

A Book Review by Bobby Matherne ©2006

While it may seem formidable to undertake to read a book on scientific epistemology, I assure you that it will reward you with a better understanding of both physics and philosophy while not overwhelming you in the details of either. This book is rightly considered a classic. You cannot read about Eddington's concept of "catchable fish" without being caught in the shrinkable mesh of the semantic net which Eddington lays out for you.

> **[page 9] Scientific epistemology is the main theme of these lectures. We shall consider it primarily from the scientific aspect. But we shall also at times endeavor to view it in its general setting as a region of overlap of physics and philosophy, and trace its consequences in both fields.**

Rest assured that the book is almost devoid of mathematical formulas, but it is not solely out of consideration of the general reader, Eddington tells us, "but because those whose minds are too much immersed in mathematical formulae are likely to miss what we are here seeking." (Page viii) The mathematicians, he says in effect, will likely slip through his net, uncaught and uncatchable, because of certain dispositions which arise when they encounter mathematical formulas.

For those who have read his earlier book "The Nature of the Physical World" he offers a contrast between that book and this one.

> **[page viii] The starting point in the present [book] is *knowledge*. The title of the earlier book might have been expanded into "the nature of the physical universe, with applications to the theory of physical knowledge"; the corresponding title of the present book would be "the nature of physical knowledge, with applications to the theory of the physical universe."**

Eddington broadens his definition of knowledge to include uncertain knowledge.

> **[page 1] Anything which would be knowledge if we were assured of its truth, is still counted as knowledge (uncertain or false knowledge) if we are not assured.**

Rudolf Steiner often uses the parenthetical phrase "rightly understood" when referring to certain conditions of knowledge, but Eddington actually describes what he means by the equivalent phrase "right-thinking person". He says, in a footnote on page 2, that is "a modest way of referring to oneself."

He defines the physical universe as "the theme of a specified body of knowledge." To avoid any "suspicion of metaphysical contamination" he utilizes the epistemological approach "which takes knowledge as the starting point rather than an existent entity of which we have somehow to obtain knowledge." (Page 3) He refers us to page 159 where he justifies his definition in the face of pure philosophers who would disagree with him. Observe the humor in his objection in this next passage:

> **[page 159] Some of the pure philosophers deny that the scientific description applies to the objects which in ordinary speech are called physical objects. Their opinion is voiced by Prof. Stebbing: "He [the physicist] has never been concerned with *chairs*, and it lies beyond his competence to inform us that the chairs we sit upon are abstract." Physicists are not concerned with chairs! Are we really expected to take this sitting down?**

When we undertake a study of the "nature of physical knowledge", the presence of the word "nature" indicates that we are to study some *process* by which physical knowledge operates, not its *content*(1). When learning something new I say it is best to know all about it before you start(2). Studying the nature of the something new to learn its process is a way of "knowing all about it before you start." I find that a scan of new material is a way of picking up the nature of what it is I'm beginning to study, of knowing all about it before I start. It is the prime utility of what Mortimer Adler calls Inspectional Reading(3) and we would commonly calling scanning.

> **[page 5] We have discovered that *it is actually an aid in the search for knowledge to understand the nature of the knowledge which we seek.*"**

My identification of "nature" as "process" seems consonant with this next passage which would identify scientific epistemology as the process or nature of knowledge of the physical universe.

> **[page 7] Formally we may still recognize a distinction between science, as treating the *content* of knowledge, and scientific epistemology, as treating the *nature* of knowledge of the physical universe. But it is no longer a practical partition; and to conform to the present situation scientific epistemology should be included in science. We do not dispute that it must also be included in philosophy. It is a field in which philosophy and physics overlap.**

The Einsteinian theory of relativity is a scientific theory and can be said to have nothing to do with religion, as Einstein told Archbishop Davidson, but the same cannot be said of the Darwinian theory of evolution, can it? (Page 7) Creationism is an example of religion's rebuttal to Darwinian evolution.

There is much more to chew on in Chapter I, but let's move on to Chapter II where we have bigger fish to fry. Here Eddington introduces his amazing story of what I would call the "semantic net". A fish scientist, an ichthyologist, casts a net into the ocean, brings up the catch, and systematizes its contents. Two generalizations are made about the catch:

> **[page 16]**
> **(1) No sea-creature is less than two inches long.**
> **(2) All sea-creatures have gills.**
>
> **These are both true of his catch, and he assumes tentatively that they will remain true however often he repeats it.**
> **In applying this analogy, the catch stands for the body of knowledge which**

> **constitutes physical science, and the net for the sensory and intellectual equipment which we use in obtaining it. The casting of the net corresponds to observation; for knowledge which has not been or could not be obtained by observation is not admitted into physical science.**

It may occur to you, dear Reader, that there are fishes under two inches in size which escaped the mesh of the net. But the fish scientist would scoff at that idea, saying, "Anything uncatchable by my net is *ipso facto* outside the scope of ichthyological knowledge, and is not part of the kingdom of fishes which has been defined as the theme of ichthyological knowledge. In short, what my net can't catch isn't fish." (Page 17 quote) To operate otherwise would be unscientific. To suggest that there are fishes under two inches would be a guess and add unwelcome "metaphysical contamination" to the fish scientist's work. The fish scientist is only interested in fish that are catchable. Thus we are led by Eddington to the unavoidable conclusion that the realm of sensory observation is identical to the realm of catchable fishes!

If you found yourself thinking of the fishes under two inches, you would be considered as the first onlooker (metaphysician) in the next passage. If you thought about the net's mesh as a determining factor in the minimum size of the fish caught, you would be considered as the second onlooker (epistemologist). The first looks at the *content* of the net and imagines fish not caught; the second looks at the nature of the net itself as a part of specific *process* of catching the fish.

> **[page 18] The first onlooker is a metaphysician who despises physics on account of its limitations; the second onlooker is an epistemologist who can help physics because of its limitations. It is just because of the limited — some might say, the perverted aim — aim of physics that such help is possible. The traditional method of systematic examination of the data furnished by observation is not the only way of reaching the generalizations valued in physical science. Some at least of these generalizations can also be found by examining the sensory and intellectual equipment used in observation. Epistemology thus presents physics with a new method of achieving its aims.**

The epistemologist is the observer who observes the observers. It is an important function to be performed for those intrepid explorers of the physical world we call physicists. Eddington says to add credence to the role of epistemologists, "Generalizations that can be reached epistemologically have a security which is denied to those that can only be reached empirically." (Page 19) Epistemology is a form of second order learning as defined by Gregory Bateson — it is a learning about learning, a knowledge about the structure or nature of knowledge. It is this second order nature of epistemology that gives its generalizations a verity that reasoning from empirical data lacks. After all, the very next experiment one does can to put a lie to the conclusions drawn from all one's previous experiments.

The popular saying "Who polices the police?" is a spin-off from the generic rule, *Quis custodiet ipsos cutodes?* or "Who will observe the observers?" Eddington gives us this terse answer: the epistemologist.

> **[page 21] He watches them to see what they really observe, which is often quite different from what they say they observe. He examines their procedure and the essential limitations of the equipment they bring to their task, and by so doing becomes aware beforehand of limitations to which the results they obtain will have to conform. They, on the other hand, only discover these limitations when they come to examine their results, and, unaware of their subjective origin, hail them as laws of nature. . . . The astronomer observes stars; the epistemologist observes observers. Both are seeking knowledge which rests on observation.**

From my extensive reading of Rudolf Steiner's books and lectures, it is clear to me that his work is that of an epistemologist *vis-à-vis* his comments about the limitations of the physical sciences and the scientists who restrict themselves to sensory observation. He examines their procedure of examining the world and points out how instead of arriving at truth, these scientists of the physical world arrive at what they call

laws of nature. For example in Owen Barfield's Introduction to The Origins of Natural Science [TONS] by Rudolf Steiner, he says about these scientists: "Their basic argument is that modern science, and the scientism based on it, so far from being the only possible 'reality-principle' is merely one way of conceiving the nature of reality; a way moreover that has arisen only recently and which there is no reason to suppose will last forever." One example of what Barfield was referring to can be found in this quote from page 81 shortly after Steiner points out how "any real idea of organisms has been lost to the atomistic approach."

> **[page 81, TONS] Therefore, in spite of its great achievements we can say that science owes its greatness to the fact that it has completely missed the essential nature of man.**

Steiner knows not only the nature of science, but how it evolved over time the way it did and why. Here he explains how science has come to miss the essential nature of man. It demonstrates Steiner's bias as an epistemologist as defined by Eddington.

> **[page 114, TONS] The development towards freedom, for example, would never have occurred had the ancient experience of physics, chemistry, psychology, and pneumatology survived. Man had to lose himself as an elemental being in order to find himself as a free being. He could only do this by withdrawing from himself for a while and paying no attention to himself any longer. . . . During this interim, when man took the time to develop something like the feeling of freedom, he worked out the concepts of science; these concepts that are, in a manner of speaking, so robust that they can grasp nature. Unfortunately, however, they are too coarse for the being of man.**

Observation is knowledge obtained *after the fact*. With physical science, the rule is "It always happens before you know it." [Matherne's Rule # 8] With epistemological study, knowledge may be arrived at *before the fact*. [In the passage below I updated "cost" from sixpence to a hundred dollars and "retailer" from Woolworth's to Walmart for twenty-first century clarity.]

> **[page 24] We may distinguish knowledge of the physical universe derived by study of the results of observation as *a posteriori* knowledge, and knowledge derived by epistemological study of the procedure of observation as *a priori* knowledge. A valuer may arrive at the generalization *a posteriori* that no article in a certain house is worth more than a hundred dollars; the same generalization might also have been reached *a priori* by noticing that the owner furnished it from Walmart's. The observer is called upon to supply the furniture of the mansion of science. The priorist by watching his methods of obtaining the furniture may anticipate some of the conclusions which the posteriorist will reach by inspecting the furniture.**

As a priorist, Eddington examines on pages 35 to 37 how the distance between the two electrons is erroneously treated as if it were possible to distinguish the two electrons by giving the distance between them a positive value if electron A is in front of B and a negative if it is not. Consider observing two identical green Bocce balls rolling on a lawn. Unless one is watching continuously, one could not be sure which ball came closer to the small yellow ball. In physics, observation, especially of electrons, cannot be continuous, and therefore Eddington insists that a directed distance is in fact an unobservable and only an undirected distance (one with no positive or negative values) is observable as the distance between two electrons. Quantum physicists note that there is a difference in the statistics of distinguishable particles and the statistics of indistinguishable particles.

> **[page 37] It is naturally objected that the particles cannot be affected by our inability to distinguish them, and it is absurd to suppose that they modify their behavior on that account. That would be true if we were referring to wholly objective particles and wholly objective behavior. But our generalizations about their behavior — the laws of mechanics — describe properties imposed by our procedure of observation, as the**

> **generalizations about catchable fish were imposed by the structure of the net. The objective particles are unconcerned with our inability to distinguish them; but they are equally unconcerned with the behavior which we attribute to them partly as a consequence of our failure to distinguish them. It is this observable behavior, and not the objective behavior, that *we* are concerned with.**

Our map of the objective world is *not* the objective world, and when the objective world differs from our map of it, *we* are the ones who must change if our maps are to be useful. As Per Holst told me back in 1975, it is written in the Norwegian Boy Scout Handbook in the Map Reading section, "If the terrain differs from the map, believe the terrain."

In describing the scope of the epistemological method in Chapter IV, Eddington summarizes it this way, "The characteristic of epistemological physics is that it directly investigates *knowledge*, whereas classical physics investigated or endeavored to investigate an *entity* (the external world) which the knowledge is said to describe."

In this next passage Eddington could well be talking about Rudolf Steiner as one of those who might reproach the modern physicist, especially those who would reproach Steiner for his claims of knowledge of things that the physicist deems non-existent. But as Eddington shows, it is rather the modern physicist to whom our reproach should be directed, not Steiner.

> **[page 50] The modern physicist is often reproached for assuming that because he has no knowledge of a thing it is non-existent. But this is a misconception; there is no need to make *any* assumption about things of which we have no knowledge direct or indirect, since they cannot appear in an analysis of our knowledge.**

If you, dear Reader, are unsure as to what constitutes an observation in the way a modern physicist means the term, here is a definition from the expert, "A 'good' observation of a quantity, although it does not determine the quantity precisely, narrows down the range in which it is likely to lie. It creates a condensation in the probability distribution of the quantity or, as we usually say, forms a wave packet in it." This condensation is often called a collapse of the wave equation, but Eddington is more precise in his definition of it.

In a dramatic revelation on pages 57 to 58, Eddington claims that the system of fundamental laws and the fundamental constants of nature are wholly subjective. This is a consequence of his belief that their fundamental hypotheses can be replaced by epistemological principles.

> **[page 57] Or to put it equivalently, all the laws of nature that are usually classed as fundamental can be foreseen wholly from epistemological considerations. They correspond to *a priori* knowledge, and are therefore *wholly subjective*. . . .**
>
> **I did not set out with any preconceived idea of the scope of the epistemological method; and the conclusion that the whole of the fundamental laws of nature can be deduced from epistemological considerations was the result of trial.**

Eddington prefigures Kuhn's work on scientific paradigms by some twenty-five years, rightly understood, in his distinguishing a law of Nature (a law emanating from a world-principle outside of us) and a law of nature (a law in current physical practice).

> **[page 67] It will be seen that a law of Nature is a law of the objective universe. But all recognized laws of nature are subjective. We have thus reached the verbal paradox that no known law of nature is a law of Nature. Effectively the terms have become mutually exclusive.**

Having thus established a basis for distinguishing the two types of laws, he points out that the only allowed "laws of nature" are those which fit into our accustomed pattern of thinking or what Kuhn would

call the current scientific paradigm.

> **[page 67] It is true that we have left an opening. A law of Nature is a law of nature if it *would be* (not necessarily if it already *is*) accepted as such in physics. This brings me to a further question, Have we any reason to believe that if a law of Nature — a generalization about the objective world — were to become known to us, it would be accepted by current physics as a law of nature? I think it would only be accepted if it conformed to the pattern of physical law [RJM: i. e., paradigm] that we are accustomed.**

Eddington talks of an "enlarged" physics which includes the objective as well as the subjective world. Steiner makes the same distinction, but calls physics simply "science" and the enlarged part which deals solely with the objective world as "spiritual science." In this next passage, Eddington is talking about the non-physical part of science:

> **[page 68, 69] We should look for it in the part of biology (if any) which is not covered by biophysics; in the part of psychology which is not covered by psychophysics; and perhaps in the part of theology which is not covered by theophysics. The purely objective sources of the objective element in our observational knowledge have already been named; they are *life, consciousness, spirit.***
>
> **We reach then the position of idealist, as opposed to materialist, philosophy. The purely objective world is the spiritual world; and the material world is subjective in the sense of selective subjectivism.**

The above passage gave me this somewhat facetious thought. If the material world is subjective in the sense of selective subjectivism, would not that make Darwin's theory of natural selection the outcome of selective subjectivism? If so, that would make Darwin's theory of natural selection a result of natural selection.

If two people, unbeknownst to each other, view a tree from two different perspectives and then later compare their individual descriptions of the tree, it is unlikely they would reach the conclusion that they were observing the same tree. This nuance of observation is like the five blind men who examine an elephant and each one describes it variously as a vine (its tail), a tree trunk (its leg), a wall (its side), a leaf (its ear), and a snake (its trunk). Steiner describes twelve world perspectives from which one may view a subject, and in his book Philosophy of Freedom writes each chapter from each of the twelve perspectives. It's as though he had a revolving brain which could rotate through each perspective with ease. Each perspective can be thought of as a dummy observer, and Steiner can be seen as identifying himself with each of the twelve possible dummy observers in turn. The use of this tool allowed him to get as close as possible to a non-subjective, but nevertheless observational view of each topic he wrote about. Mathematicians do a similar thing when they use tensors.

> **[page 86, 87] Nature not having endowed us with revolving brains, we appeal to the mathematician to help us. He has invented a transformation process which enables us to pass very quickly from one dummy observer's account to another's. The knowledge is expressed in terms of tensors which have a fixed system of interlocking assigned to them; so that when one tensor is altered all the other tensors are altered, each in a determinate way. By assigning each physical quantity to an appropriate class of tensor, we can arrange that, when one quantity is changed to correspond to the change from one dummy observer A to dummy observer B, all the other quantities change automatically and correctly. We have only to let one item of knowledge run through it changes — to turn one handle — to get in succession the complete observational knowledge of all the dummy observers. . . . A tensor may be said to symbolize absolute knowledge; but that is because it stands for the subjective knowledge of all possible subjects at once.**

If we are only subjective observers of an objective reality, what we observe must change when we change

our subjective laws of nature. Take, for instance, the change which occurs in what constitutes observation for relativity theory versus quantum theory.

> **[page 89] What do we really observe? Relativity theory has returned one answer — we only observe *relations*. Quantum theory returns another answer — we only observe *probabilities.***

In this next passage Eddington puts forth what might be called a "block-head" theory which involves the figure an artist might see in a block of stone, such as Michelangelo who was said to have seen his statue of David inside a huge block of Carrara marble. Matter was once thought to be the ultimate substance, but since Einstein it has been replaced by Energy.

> **[page 110] It is pertinent to remember that the concept of substance has disappeared from fundamental physics; what we ultimately come down to is *form.* Waves! Waves!! Waves!!! Or for a change — if we turn to relativity theory -- curvature! Energy which, since it is conserved, might be looked upon as the modern successor of substance, is in relativity theory a curvature of space-time, and in quantum theory a periodicity of waves. I do not suggest that either the curvature or the waves are to be taken in a literal objective sense; but the two great theories, in their efforts to reduce what is known about energy to a comprehensible picture, both find what they require in a conception of "form".**
>
> **Substance (if it had been possible to retain it as a physical conception) might have offered some resistance to the observer's interference; but form plays into his hands. Suppose an artist puts forward the fantastic theory that the form of a human head exists in a rough-shaped block of marble. All our rational instinct is roused against such an anthropomorphic speculation. It is inconceivable that Nature should have placed such a form inside the block. But the artist proceeds to verify his theory experimentally — with quite rudimentary apparatus too. Merely using a chisel to separate the form for our inspection, he triumphantly proves his theory. Was it in this way that Rutherford rendered concrete the nucleus which his scientific imagination had created? . . . Does the sculptor's procedure differ in any essential way from that of the physicist? The latter has a conception of a harmonic wave form which he sees in the most unlikely places — in irregular white light, for example. With a grating instead of a chisel, he separates it from the rest of the white light and presents it for our inspection. . . . Sometimes the tool slips and carves off an odd-shaped form we had not expected. Then we have a new experimental discovery. . . . the physical analyst is an artist in disguise, weaving his imagination into everything.**

Eddington predicts that artistic physicists will go on to create neutrinos, "little bits of spin-energy that have got detached" — like the chips of Carrara marble from Michelangelo's chisel. Physicists, when they break the rules, are often not penalized, but like "the boy who outrageously breaks the rules of a game . . . may be commemorated as the founder of Rugby football." (Page 113)

Is the bung hole part of the barrel? Eddington takes this question and analyzes it. In a world-view of substance, we can have positive and negative parts, and the bung hole may be viewed simply as a negative part of the barrel — a piece of barrel that is missing. But convert, as we have, to a world-view of wave forms and everything changes. A bung-hole becomes as real as the rest of the barrel is real. A positron is a bung-hole left by removal of an electron from the barrel of atomic substrate.

> **[page 120] When the analysis is not associated with substance (or with a structurally equivalent concept), when for example it is associated with wave form, the restriction cannot be imposed. In optics darkness is considered to be constituted of two interfering light waves; light may be a "part" of darkness.**

When I read this passage on April 22, 1992 I was inspired to write a poem about darkness being composed of light. Here it is:

Darkness and Light

Darkness
is made of light.

Two waves
interfering with
each other

Create a caesura
of light.

As we segue
from light to dark
and back to light

Let us remember
that God is light
and we are light —

That we exist in darkness
only by interfering with
God's will,
up until now.

[page 120] A positron is a hole from which an electron has been removed; it is a bung-hole which would be evened up with its surroundings if an electron were inserted. But it would be out of the question nowadays to define "part" in such a way that electrons are parts of a physical system but positrons are not.

As mentioned above, when we reach the point of analysis at which everything becomes identical "green balls" and therefore indistinguishable from each other, we are completely stymied — we can no longer determine if a particle has deviated from its expected position because it encountered a force or whether the particle is really another particle we have mistaken for it.

[page 129] If the aim of analysis is to separate, it must stop short of the ultimate structural units; because when the parts become so simple that they are indistinguishable, their indistinguishability confuses them in our observational knowledge and, in a sense, undoes the separation which the analysis has effected.

In the summary Eddington gives of his chapter "The Concept of Analysis" I'd like to highlight item (5) for your attention. It points to the physicist as a sculptor who approaches his particular block of Carrara marble like Michelangelo — with a certain conception of what is inside of it — and lo, and behold! when the dust settles, the figure of David appears. For the physicist, the equivalent figure of David is the sum total of all that can discovered of the world using one's sensory apparatus, and nothing more. And yet, we must admit that there is more to the world than what can be discovered in our sensory apparatus just as there can be other figures in the block of marble. (Page 135, 136)

In his chapter "The Concept of Existence", Eddington asks us to consider whether an overdraft in a bank accounts exists or not. My banker certainly would attest to its existence by charging me $20 for an overdraft. Are not overdrafts like a bunghole in a bank account? Let's listen in on Eddington as he explains why this question is important.

> **[page 154, 155] If the question were put to the vote, I think some would say that its existence must be accepted as a grim reality, and others would consider it illogical to concede existence to what is intrinsically a negation. But what divides the two parties is no more than a question of words. It would be absurd to divide mankind into two sects, the one believing in the existence of overdrafts and the other denying their existence. The division is a question of classification, not of belief. If you tell me your own answer, I shall not learn anything new about the nature or properties of an overdraft; but I shall learn something about your usage of the term "exists" — what category of things you intent to cover.**

For example, do chairs exist? Some philosophers claim that when we give a scientific description of a chair, we are *not* describing the object in everyday life we call a chair. This is the point when Eddington ask the question, "Are we really expected to take this sitting down?" (Page 159)

Eddington asks a question about the name "I" and approaches the concept that Rudolf Steiner gives it, which is the name that no one can use but the one who owns it. I cannot use "I" to refer to you, only to myself. The "I" is the concept of the "I Am" encountered by Moses in a time when the idea of an individual consciousness of self was so new that only a few courageous souls would even discuss it publicly and then only in the act of attributing it to God. Moses asked whom to say sent me and was told to tell them, "The I Am sent me" — this marked the beginning of humankind's awareness of the I Am inside individual human being. When Eddington calls "I" a label or pointer-word, he is correct, but misses the larger picture which includes the awareness of self, the unity that cannot be split into parts, cannot be analyzed; it is the glue which only sticks to itself — the unity we call "I".

> **[page 206] In the subject-object description of self-consciousness "I am aware of 'I'", the second "I" stands for the unity of consciousness. Distinguishing it as I_2, I_2 is what is left if you imagine me without any of the feelings, thoughts, etc., inventoried by the concept of analysis. These inventoried contents can be varied without modifying the essential "I" associated with them. It may perhaps be objected that this description of I_2 precisely fits the "I" who was fast asleep a few hours ago — which seems to lead to the *reductio ad absudum* that it is in sleep that the essential "I" emerges from the swarm of thoughts and emotions that ordinarily obscures it. But that is like arguing that the essential qualities of glue are best displayed when it does not contaminate itself by sticking to anything. To obtain the I_2, of which we are aware in self-consciousness, thoughts and feelings must be abstracted, not eliminated. The unity of consciousness is manifest *because* there are parts for it to unite.**
>
> **To sum up: "I" is first a label or pointer-word attached to a particular consciousness, and consequentially to the sensations, emotions, etc. into which the consciousness is divided by the concept of analysis.**

In what Benjamin Lee Whorf called the Standard Average European language which epitomizes most languages of the Western civilization (outside of various native languages) the world is chopped up or analyzed grammatically into process and content, action and passivity, verbs and nouns. In this next passage Eddington talks of a paucity of verbs and demonstrates it with verbs for manipulating numbers. What's interesting to me in his presentation is that it closely matches the process for teaching numbers that Steiner recommends for educating our children which involves not teaching numbers as things which are added on to each other like 1+1 =2, 2+1=3, but instead teaching the process of dividing a bunch of apples into groups(4). First have the child share with another child so each has the same amount. Then share with two other children. By starting with division concepts first, division will be easiest of the four processes of instead of the hardest when it is taught last in the usual pedagogical approach of teaching arithmetic in this order: addition, subtraction, multiplication, and division. Who among you had the least problem with division out of the four arithmetic operations? Who found long division fun?

> **[page 213] The view that activity (expressed by verbs and gerunds) is of a few simple kinds and that variety resides in passivity (expressed by nouns) has purely linguistic origin. The paucity of verb forms is familiar to mathematicians as a difficulty of ordinary speech easily surmounted in their own symbolic language. Thus it is possible to speak of duplicating, triplicating, sesquiduplicating, etc., but this mode of expressing variety of operations is soon abandoned; we use instead one verb-form "multiplying" and transfer all the variety to noun-forms called numbers. Then perhaps it will be said "It is clear that whenever anything is multiplied it must be multiplied by *something*, and this something, e.g. two, is not itself a multiplying but an independent entity, exactly the same when it is a multiplier as when it is not a multiplier". The argument would not have arisen if we had stuck to the terms duplicating, triplicating, etc.: for one does not duplicate by anything.**

When one starts with addition and moves to multiplication, one must somehow communicate the very abstract concepts which Eddington describes so clearly above — this is, however, the language of adults *not* of children. Children are not ready to deal with the abstract concepts such as "independent entity" and no amount of repetition will help them to comprehend it, only the wisdom of years will manage the feat, and by then those taught too early using abstract entities will hate arithmetic, algebra, and all forms of mathematics. They will join in unison with Kathleen Turner in "Peggy Sue Got Married" when she goes back in time 30 years to high school and tells her math teacher, "I assure you that I will *never* use algebra as an adult!" Never use it because she never got it in the first place, never got it, because arithmetic was presented to her as a child using abstract concepts in the early grades beginning with addition instead of division by sharing.

Eddington's conclusions presented in this final lecture "The Synthesis of Knowledge" are dramatic. He says that physics has no laws which apply to the underlying reality, the objective content of the world. This thought should sober up any physicists or other scientists who are deeply intoxicated with the intricacies and beauty of their fields of endeavor.

> **[page 217] But according to our conclusions, the laws of physics are a property of the frame of thought in which we represent our knowledge of the objective content, and thus far physics has been unable to discover any laws applying to the objective content itself.**

"The danger of a broad view is that it is often a shallow view," Eddington says on page 223, but claims that the epistemological approach "gives to the scientist a view broader than his traditional view without sacrificing depth." Yet the banquet table of the objective world remains untouched by physical scientists — they must be content to nibble the menus on which they have described the banquet of the world, unable ever to ingest the objective food spread on the banquet table before them.

---------------------------- *Footnotes* ---

> **Footnote 1.**
> My distinction between *content* and *process* is explained in Matherne's Rule #26: Every word has two types of meanings: a content meaning and a process meaning. It even happens (v. — process) to "happen" (n. -- content). See its explanation here: http://www.doyletics.com/mrules.htm#mrn26
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> Return to text directly before Footnote 1.
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> **Footnote 2.**
> This is Matherne's Rule #23: When learning a new subject, it's best to know all about it before you start. See its explanation here: http://www.doyletics.com/mrules.htm#mrn23

Return to text directly before Footnote 2.

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Footnote 3.
See Mortimer Adler's book, How to Read a Book, for his exposition on four types of reading. He gives the best description of the process of reading in its many forms that I have found.

Return to text directly before Footnote 3.

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Footnote 4.
See Soul Economy — Body, Soul, and Spirit in Waldorf Education, a series of lectures by Rudolf Steiner for more details on how this teaching process works.

Return to text directly before Footnote 4.

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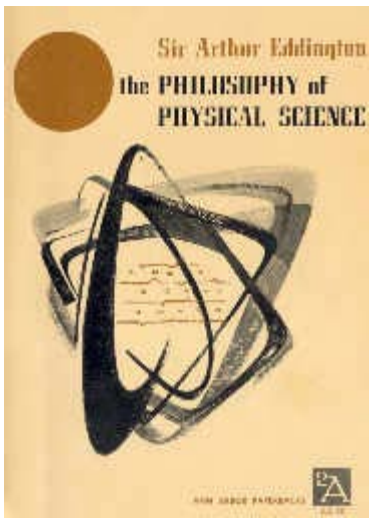
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