Holism and Reductionism in the Entwined History of Light and Mind

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The history of light is not only concerned with the discovery of increasingly subtle features of our physical universe, but it is also a history of the methods of inquiry and the modes of imagination used by scientists. When in 1300 B.C., the anonymous Egyptian scribe of the Turin papyrus penned the words of Ra, "I am the being who opens his eyes, and there is light; I am the being who shuts his eyes, and darkness falls,[1]" he recorded an experience of light utterly different from that of modern physicists. For the ancient Egyptian, as well as for many other contemporary cultures, light was directly related to the gods and their activity. From the above passage we learn that, for the Egyptian, light was the sight of Ra. It was their god seeing. To stand in the daylight was then to stand within the sight of Ra. The moral and spiritual significance of this view is still palpable.

The intervening years reduced light to mechanical undulations in a hypothetical luminiferous ether, or alternatively to corpuscular emissions careening through space like so many atoms in the void. By the mid-19th century at the hands of Michael Faraday and James Clerk Maxwell the "mechanical philosophy" of their predecessors was losing ground. The electromagnetic view they espoused seemed to require no material basis. Instead of an "ontology of matter" light seemed to suggest an "ontology of force." Physicists such as Hendrik Lorentz suggested that not only light, but perhaps everything should be understood in a manner analogous to light, that is to say, electromagnetically. The long and apparently relentless reduction of light from the activity of the gods to a mechanism in a materialistically-conceived universe, hit an inflection point at this point in time. Brute materialism came under scrutiny. At the dawn of the 20th century two new strands in the story of light emerged, and they both – in different ways – reasserted holism over reductionism. While Max Planck was lecturing at the Kaiser Wilhelm Institute in Berlin, not far away Rudolf Steiner was lecturing at the *Architektenhaus*. These two figures can symbolize for us the two strands of holism that appeared around 1900, which I will term "quantum holism" and "phenomenal holism." It will be important for our considerations to understand each and differentiate between them.

Quantum Holism

Early in the history of quantum mechanics, Erwin Schrödinger pointed to a single novelty as "*the"* distinguishing feature of quantum physics. It was a property he termed

[1] E.A. Wallis Budge, *Legends of the Gods* (New York: Cosimo Classics, 2010), 51

Verschränkung, translated into English as "entanglement."[2] Quantum holism, as a precisely formulated physical and mathematical concept, rests on this feature. The experimental evidence in support of entanglement seems now to place it beyond doubt as a feature of our universe. Thus quantum holism is a well-accepted if poorly understood fact of life in quantum physics today. It is important to understand this feature of our physical world because it can help guide our thinking as we consider what exactly holism is and what difference it can make in the world we inhabit. In my opinion, holism is often used in vague ways usually in opposition to mechanism and somehow in alliance with organism, but no clear concept of holism is offered. By contrast in quantum holism we have a clear concept which, when fully developed, has wide-ranging implications for our understanding of phenomena around us and for new technologies that rely on quantum holism. In the last few years entanglement or quantum holism has been termed a "resource," that has been neglected until now, and which can be used in communication and computation to great effect. What is entanglement and how does it show itself?

I will make use of an analogy. Let's begin with an empty library bookshelf. The system we will consider is comprised of the books on the shelf. We begin with a single volume, call it A. Next to it we place a second book B. Each additional book can be labeled in sequence. The arrangement of books is simple juxtaposition: one beside the other, A to the left of B. We can denote this as AB. Alternatively the two books might be in reverse order: BA. Since the Greek atomists Democritus and Lucretius, we have imagined the microscopic world of atoms is similarly arranged with one atom beside the other. In a dynamic model the atoms also move, but this is an insignificant modification for our purposes. Reductionism of the variety familiar to us from classical physics views *everything* as capable of being modeled by theories of juxtaposition and lawful movement. The mechanical clock, as Lewis Mumford once declared, is the perfect metaphor for this manner of understanding the world. In this way the universe became a clockwork mechanism.

From the fourteenth century when the clock was invented to the eighteenth century Enlightenment, this view gained ground. At first the human being eluded the grasp of mechanistic reductionism. Even René Descartes reserved for the human being a special cognitive nature: *res cogitans*. But this distinction was short-lived and by the height of the Enlightenment the human was considered a clockwork mechanism like everything else, as evidenced by Julien Offray de la Mettrie's infamous book *Man a Machine* (1748).

Simultaneous with this development, subjective experiences such as color and taste were declared to be "secondary qualities" only and not appropriate as primitives for scientific analysis. Only position, extension, velocity, mass and the like were real or primary qualities. These became the aspects of the world to which science would reduce everything. Colors, warmth, fragrance, and so on were merely derivatives of the primary features in interaction with the human sense system. As science shunned lived experience

[2] Erwin Schroedinger, *What is Life? and Other Scientific Essays* (Garden City, NY: Doubleday, 1956), 161-162

for experiment and instrumentation, all explanations of phenomena were in terms of a tiny set of fundamental attributes of matter and the forces between them.

Quantum physics takes the mechanical view it inherited and inserts a new kind of order into it which results in a reconceptualization of matter, specifically the rejection of simply juxtaposition as the way matter is organized. In terms of books on a shelf, the new principle maintains "superpositions" are possible. Thus a perfectly good state of the shelf might be (AB + BA)/2, that is book A to the left of B plus its complement. I divide by 2 to normalize the number of books to two. Such states are non-classical (and difficult to imagine!), and were termed *entangled* by Schrödinger because one cannot reduce the state to simple juxtaposition of one book next to the other. In its mathematical representation AB is the simple product of A with B. Since the order is crucial we <u>cannot</u> rewrite the entangled state equation as (AB + AB)/2, which would obviously reduce to AB. Therefore in the entangled state, two books form a single entity mathematically characterized by (AB + BA)/2. No longer is it possible to think of one set of features on the left and another distinct set on the right since we find both A and B on the left and on the right. Rather the two entities together have aggregate properties. Only upon measurement do distinct properties manifest on the left and right. This is the so-called "collapse of the wave function."

The evidence in support of this strange state of affairs has grown to become compelling. Attempts to account for experiments in terms of conventional reductionist theories (so-called local hidden variable theories) have consistently failed. Einstein himself resisted this view of the world and proposed an experimental refutation. Ironically in the intervening decades variations of Einstein's experiment have been done repeatedly and now are used as the primary evidence against his view of the world.[3] In addition new technological developments are being successfully made that utilize the "resource" of quantum entanglement. The most dramatic is the quantum computer. We can understand how it uses quantum holism to advantage by reverting to the book shelf analogy once again but with a small twist.

Suppose that we have two copies of each book, i.e. four books total. However imagine that only two can go on the shelf at once. Four combinations are possible: AA, AB, BA and BB. Now consider a 2-bit computer register. Like the bookshelf its states can be: 00, 01, 10 and 11. In a conventional computer (or for a conventional shelf) we simply must have one instantiation of the four possibilities. The world makes sense, classically-speaking, only when we have particular objects in particular places. Quantum mechanically the situation is quite different. By suitably interacting the two bits with each other they can be put into a entangled state of all four values: 00+01+10+11. In this way a single 2-bit quantum computer can do the work of four. If we scale the register up to n-bits then the starting state is equivalent to 2^n bits. One can construct entangled states quite easily, although they are extremely fragile and difficult to sustain. Certain important classes of mathematical problems (such as searching and factoring algorithms) can in

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[3] George Greenstein and Arthur Zajonc, *The Quantum Challenge* (Sudbury, MA: Jones and Bartlett, 1997).

principle be solved much, much faster using a quantum computer than a classical computer of the type now available. The reason for the speedup is quantum holism.

In order to get a clearer idea of what quantum holism entails I would like to give one example in quantum computation, perhaps the simplest I know of. It reveals certain features of quantum holism. Consider a coin, which may be a fair or unfair coin. An unfair coin has two sides the same: heads-heads (HH) or tails-tails(TT). Obviously a fair coin has two sides that are opposite. If we wish to determine whether a coin is fair or unfair, classically one must look at both sides. You cannot tell from one side alone whether it is fair or unfair. This means there are two measurement that need to be made. Physicists Deutsch and Jozsa have shown that there is a quantum procedure to determine the fairness of the coin with a single measurement.[4] The quantum algorithm does not examine the sides separately but only their relationship. If the sides are the same, then the quantum device gives one result. If they sides are opposite, it give a different result. In fact the quantum device cannot tell whether the unfair coin is TT or HH. It only signals unfair. In this way it is sensitive to the whole, to a set of relations without breaking the system down into parts.

We habitually think of attributes as built up from atomic parts. Here we see that this habit is a block to understanding how global or collective properties can be present without instantiation through a particular form or realization. This point is driven home by the experiment proposed by Einstein, Podolsky and Rosen in 1935[5] and realized today in many laboratories. These experiments demonstrate that no account of the phenomena is possible that conceives of the system in terms of parts. Quantum holism is a must.

An important question of interpretation remains. Quantum holism can be an attribute of matter. That is, matter itself may be viewed as entangled and as possessing "nonlocal" properties. This is the majority view today. David Bohm rejected this view and developed an interpretation in which particles behave in ways quite like the ways they always have, traveling well-defined paths, even through double-slit experiments. However, these quasi-classical particles are guided by a radically non-local new quantum potential. All the weirdness of quantum mechanics is in the quantum potential. Whereas the world of substance displays an "explicate order" the quantum potential possesses a novel "implicate order." In his view, quantum holism is located with the quantum potential. His view keeps the two domains of order distinct from one another. His theory gives identical predictions to that of conventional quantum theory so there is no basis for experimental tests to distinguish one from the other.[6]

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[4] David Deutsch and Richard Jozsa, "Rapid Solution of Problems by Quantum Computation," *Proceedings: Mathematical and Physical Sciences,* vol. 439, Issue 1907 (1992), 553-58.

[5]A.Aspect, et al., "Experimental realization of Einstein-Podolsky-Rosen-Bohm *Gedankenexperiment*: A new niolation of Bell's inequalities," *Physical Review Letters,* vol. 49 (1982) 91-94; and "Experimental test of Bell's inequalities using time-varying analyzers," 1804-07.

[6] David Bohm, *Wholeness and the Implicate Order,* (New York: Ark Paperbacks, 1987)

As we complete or considerations of quantum holism I wish to stress that quantum mechanics is still "mechanics." The field has been forced to embrace a form of holism, and to develop exact mathematical methods for handling this holism. Yet for all this it remains an abstract view far distant from the secondary qualities of human experience. No colors or scents waft through the *sensorium* of the quantum physicist, or if they do they are accounted for in a manner analogous to that of the classical physicist. In order to reach beyond the limited holism of quantum physics to an full holism we must find a way to retrieve experience. For this reason I think it essential to develop a science that is based in phenomena. Goethe has been an important guide for me concerning the possibility of a phenomenal holism.

Phenomenal Holism

In 1851, the American naturalist Henry David Thoreau stood on a hillside viewing the sunset. It was Christmas evening. And he writes in his journal:

> "I, standing twenty miles on, see a crimson cloud on the horizon. You tell me it is a mass of vapors which absorbs all other rays and reflects the red. But that is nothing to the purpose. What sort of science is that which enriches the understanding, but robs the imagination? If we knew all things thus mechanically merely, should we know anything really?"[7]

Here Thoreau alerts us to a major tension, a contrast he describes as holding between "understanding and imagination". At stake here is the difference between a form of understanding which he calls 'mechanically merely,' and what it would be to comprehend something incisively and satisfactorily. Thoreau seeks more than just to know via a narrow preoccupation with the models and postulated mechanisms of physics, that is via reductionism. He wants also to know through what, in the parlance of his time, he calls the faculty of imagination.

The "imagination" that Thoreau so prized—and which he claims might reveal the sunset to him more fully than a mechanical account by itself—certainly also has a central and active place in the life and practice of a scientist. By clarifying this faculty's nature, scientific role and relation to the world, we may establish that science can do more than proffer merely mechanical accounts. Thoreau's friend and mentor R. W. Emerson raises the challenge succinctly: "never did any science originate but by a poetic perception."[8]

Despite the great difficulties involved in defending such an assertion, I think what's at stake is so important that we must reopen the inquiry—how might Emerson have been right? Note that what lies behind his point applies to commonplace insights and sensibilities, ethical, spiritual and aesthetic responses, philosophy, and to the practice of science. Much has changed since the romantic philosophical vision of Emerson and Thoreau. And of course our contemporary view of nature and science cannot possibly be

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[7] Henry David Thoreau, *The Journals of Henry D. Thoreau,* ed. Francis H. Allen and Bradford Torrey (Boston: Houghton Mifflin Co., 1906), vol. III, 155-6.
[8] Emerson, *The Complete Works,* vol. 8, 365.

traded away for a return to those 19th century yearnings. But still, Thoreau and Emerson also offer us glimmerings of a critical and timeless issue.

We find related clues in other authors, cultures and periods. Thoreau and Emerson struggled to articulate and defend a point that for them and many others over the centuries has remained inchoate, an awkward fledgling. Now its explication must be made more mature, and integrated more fully into our modern understanding. Much new work is needed, but it should not be undertaken without acknowledging the early but extremely provocative attempt by Johann Wolfgang von Goethe.[9]

Goethe was a genius of an unusual kind, who sought a harmony of view concerning the scientific, poetic and human domains. He made a remarkably concerted attempt to engage the question—how we can understand science and the knowledge project in general, in ways that would also be open to the spiritual dimensions of our lives? Like Thoreau and Emerson, Goethe saw this as not only desirable, but essential.

First of all, Goethe was critical of the model-building enterprise as an end in itself. He said:

> "The investigator of nature should take heed not to reduce observation to mere notion, to substitute words for this notion and to use and deal with these words as if they were things."[10]

And also:

> "A false hypothesis is better than none at all. The fact that it is false does not matter so much. However, if it takes root, if it is generally assumed, if it becomes a kind of credo admitting no doubt or scrutiny this is the real evil, one which has endured through the centuries."[11]

In the terms of our example, we're standing there on the hill in the early evening, immersed in our experience of the sunset, but we unconsciously drift from its vibrant presence to words, notions, concepts. And then we deal with those concepts and words as if they were the thing itself. So in fact, we've stopped looking. Unless we're aware of these concepts' limits and their source in our capacity for insight, and are careful to note ways they may aid our direct participation and enlarge our discernment … we're effectively not there anymore.

The same dislocation and truncation of appreciation can occur in many other domains, even the interpersonal sphere. When looking at one another, we sometimes see another person only in terms of social conventions, memories and descriptions, words and

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[9] For a fuller account see: *Goethe's Way of Science*, ed. by David Seamon and Arthur Zajonc (Albany, NY: State University of New York Press, 1998).

[10] J.W. von Goethe, *Theory of Colours* trans. by C.L. Eastlake (Cambridge, MA: MIT Press, 1970), 283

[11] J.W. von Goethe, *Goethe's Botanical Writings* trans. by B. Mueller (Honolulu: University of Hawaii Press, 1952), 239

concepts, and perhaps ideas drawn from psychology, politics or medicine or a hundred other disciplines. We meet, understand and interact with each other in a way that's very complex, but remains "mechanically merely," as opposed to *really*.

Over the course of his life, Goethe went to great pains to explain why, both as scientists and as human beings, we must avoid this mistake. From his standpoint, the problem is not that we use a description, convention, model, or hypothesis, but rather that it acquires a dominating force.

> "Hypotheses are like the scaffolding erected in front of a building, to be dismantled when the building is completed. To the worker the scaffolding is indispensable, but he must not confuse it with the building itself."[12]

Models and hypotheses are like scaffolding … don't confuse the scaffolding with the building itself. Once we've succeeded in raising the mature insight, we must take down the scaffolding so we may see the building directly. Doubtless we need stepping stones, intermediate stages, conceptual aids, in order to gain a fuller and more direct view, a direct engagement with the building. But we shouldn't confuse the latter with any of the former.

Here Goethe uses a wonderful German word, '*das Wesen'*. He says:

> "Yet how difficult it is not to put the sign in place of the thing. How difficult to keep the being (ed. *das Wesen*) always livingly before one, and not slay it with the word."[13]

We must gain and retain access to what he calls *das Wesen*, the being, the building itself, whose character is reflected in the theory or scaffolding, but should not be equated with the latter at all, and is thus not limited to the narrow, antiseptic version of what we moderns typically consider a "phenomenon." So I honor theory and the theoretical enterprise of normal science, but at the same time I don't want to adopt a fundamentalist attitude toward that science. I don't want to interpret *knowing* and *knowledge* of a thing as being equivalent to our possessing a scientific model of it.

I seek an approach to science that is honest about its nature and sufficiently respectful of the world being studied that it can accommodate more of the phenomenon's actual character. Granted, this agenda is both complex and problematical, possessing many controversial points. But these difficulties should not intimidate us into settling for less without even considering the possibilities. And by this commitment, spirituality may also be accommodated—not as involving only faith, but as part of the knowledge project, as relevant to true knowing.

Goethe's own work contains some useful hints about how this might be achieved. In addition to being a great romantic poet, Goethe also made many significant contributions to the study of color, plant morphology and human anatomy. His approach to these

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[12] J.W. von Goethe, *Goethe's Werke, Hamburger Ausgabe (HA),* (Munich: C.H. Beck Verlag, 1981) 432.
[13] Goethe, *HA,* 452

apparently quite disparate fields exhibits a vision which was clearly indebted to his study of novelistic technique. Drawing upon that experience, he says that attempting to formally define the inner nature of a thing is not the only or best option.

> "What we perceive are effects, and a complete record of these effects ought to encompass this inner nature. We labor in vain to describe a person's character, but when we draw together his actions, his deeds, a picture of his character will emerge."[14]

Goethe, the novelist and playwright, knows one doesn't capture and convey a person's character by trying to define it, but rather by *showing* it, enabling the reader to directly apprehend that person's actions and responses to life. Confronting first the effects or actions, we readers can eventually come to see more, the person. Turning his attention towards Nature, Goethe retains this same conviction. A person must do her job as an observer, as an empiricist, and one could say, as an experiencer, knowing that she can't just open her eyelids and let the whole world flood in and be known. One must engage the world actively and systematically, seeking out its effects, and then the phenomenon will begin to reveal itself more completely and coherently. Its nature will shine through its effects. Attaining a more full and incisive cognizance of these effects is the goal of applying the scientific method.

In dozens of treatises and also in his correspondence with Friedrich Schiller and others, Goethe explored this view's application to science. While modern science and philosophy obviously supercede much of that 18th century account, we think Goethe saw and emphasized an important point that nowadays tends to be lost.

> "There is a delicate empiricism that makes itself utterly identical with the object, thereby becoming true theory. But this enhancement of our mental powers belongs to a highly evolved age."[15]

This is an extremely condensed statement of many of Goethe's ideas about science. "A delicate empiricism"—there's a way of engaging the world of phenomena, the world of experience, which is both fully active and delicate. We thereby make ourselves "utterly identical with the object" of study, we move into the phenomenon, we don't stand off at arm's length. We maintain the best kind of objectivity when we engage and become identical with the phenomenon. And thus we "become true theory." What could Goethe possibly mean by being identical with the object, by becoming true theory? Aren't we separate from the objects of our knowing? Isn't a theory just a formal statement, a generalization, an abstraction?

Goethe says that true theory, true knowledge, arises for us in that moment and through that delicate empiricism, because by staying with the phenomenon, insight into its fundamental nature may arise. This more participatory form of insight is what he calls "the aperçu." And then he cautions, "But this enhancement of our mental powers belongs

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[14] J.W. von Goethe, *Scientific Studies,* ed. and trans. by Douglas Miller [Goethe Edition, vol. 12] (New York: Suhrkamp Publishers, 1988) 158

[15] J.W. von Goethe, *Maximen und Reflexionen,* no. 509, *HA,* XII-435

to a highly evolved age." A person can't just passively acquire the aperçu. First we must work to enhance our powers of discernment. As a physicist struggling with a scientific challenge, or as a person seeking maturity or moral integrity, we must evolve, developing new capacities of insight so we may integrate more fully with the phenomena of life as they actually present themselves.

This very brief account of an alternate view of the knowledge project posits that knowing is more capable of refinement and discernment with respect to the phenomena than is usually supposed, and thus need not be set altogether apart from more spiritual forms of beholding. Applied to science, this view does not overemphasize theoretical models, but rather respects the cognitive source that gives rise to them and also, in the end, completes them.

Conclusion

Quantum holism demonstrates to us the essential holism that pervades our world. This is not merely a philosophical viewpoint or Romantic desire, but rather a hard-won experimental deduction about the nature of our universe. Physicists now work actively to understand this holism more thoroughly and billions of dollars in research has and will be spent trying to harness this new resource in quantum computation, cryptography and communication.

But quantum holism only gets us half way to true holism. It does not speak to the holism of human experience. For this we need a new method, one that appreciates the role of models and theories of science but does not fall into idolatry, worshiping them and putting them in place of the direct experience, of the aperçu, or of genuine insight. Goethe was a pioneer in the development of a phenomenal holism. Through a science that grounds itself on his phenomenological methodology we can find ways of not only thinking wholes but of perceiving them. In my view it will only be through phenomenal holism that we can hope to make real contact with the aesthetic, moral and spiritual dimensions of life. Only in this way will science find its right relationship to civilization.