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*Amazing Light —
Visions for Discovery*

*An International Symposium In Honor of the
90th Birthday Year of Charles Townes
October 6–8, 2005, UC Berkeley*

Thirty years ago I questioned the adequacy of quantum theory to explain my daily conscious experiences and specifically my observations on the absorption spectra of Promethium. I presented this opinion during my doctoral thesis presentation and was promptly flunked by the chairman of the physics department at the University of California at Berkeley. Thankfully, Charles Townes, winner of the Nobel Prize for his invention of the laser and a member of my thesis committee, intervened. As penance I was asked to read a text, which claimed in its introduction that quantum theory was only a few decimal points away from explaining everything we know of the physical world. Confronted with the potential loss of my four-year doctoral investment I took the cowards' way out and confessed to the error of my ways during several private sessions with the chairman. He thereafter took a delight in the case of this returned prodigal son, and I sailed through the remainder of my thesis work in record time. I promptly turned to computer graphics, still nursing a private desire to find the explanation of my every day experience in the bowels of Silicon Valley commercialism.

It was therefore with great interest and curiosity that I received an invitation to attend the Amazing Light Symposium In Honor of the 90th Birthday Year of Charles Townes earlier this year.

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The programme was divided into three one-day sessions. The first day was devoted to great unknowns in physics and cosmology, the second to possibilities in innovative technologies, and the third to questions about the boundaries of science. This last day included sessions with provocative titles such as ‘Consciousness and Free Will’ and ‘Mind, Matter, Mathematics — The Nature of Ultimate Reality’. I decided to attend because I was curious to see how far physics had progressed and to pay tribute to a man I owe a personal debt of gratitude.

The symposium exceeded my expectations, not so much because of what was ultimately said but because eighteen Nobel laureates and another dozen potential candidates openly entertained the possibility that the explanations for life and consciousness might not be found in the next ‘few’ or even the next ten decimal points of physics experiments. Such an admission is especially noteworthy because the need for funding requires a tight phalanx of agreement, regarding the next critical questions and the experiments to best answer these questions, within the scientific community. If our understanding of the origin of the universe, life, and consciousness cannot be advanced with a simple, clean story, it will be very hard to convince the general public to finance such endeavours. Honestly admitting to difficulties confronting one’s own discipline is both necessary to make progress and the potential kiss of death to one’s career and historical significance. It takes great courage for physicists to participate in such discussions, and I believe I have witnessed a landmark event in the history of science.

The situation in cosmology was most poignantly exemplified by a question asked by a young teenage boy during the Friday evening session, ‘The Challenge of Supertelescopes in Search of Extraterrestrial Life’, with Geoffrey Marcy, Reinhard Genzel and Antoine Labeyrei. He asked, ‘First you need dark matter to make the Universe expand slower, then you need dark energy to make it expand faster, which is it?’ Dark matter is hidden material not detectable from radiation in stars or from absorption by interstellar dust. It is required to prevent the Universe from expanding forever. Dark energy was introduced as a concept in the late 1990s when astronomers discovered the Universe was expanding faster during an earlier expansion phase than was possible without such energy. Together they comprise some ninety-six percent of all mass and energy, but nobody knows what either is. The young man was told that this was a very good question and that if he studied hard he might be able to join the team of scientists looking for answers.

The team represented by Reinhard Genzel, Scientific Director at the Max Planck Institute for Extraterrestrial Physics, hoped to build a series of twenty-five metre-diameter telescopes with adaptive optics to resolve planets capable of sustaining life in distant solar systems. His lecture was the culmination of a day of presentations from young (under 40 years of age) scientists presenting advanced research in quantum theory, astrophysics, and technological innovations. These presentations left me with a feeling of awe and humility. These individuals have the ability to devise instruments and theories that measure time more accurately, see farther, achieve lower temperatures, compute faster, and control smaller particles than can be currently achieved, by several orders of magnitude.

Though their technical achievements, both already realized and planned, were generally noteworthy, I would like to mention in particular a presentation by Bruce O. Knuteson from MIT, which impressed me for its unique philosophical implications. Knuteson recognized that the normal methodology for particle accelerator experiments was to look for specific detector events predicted by theories. This often involves sorting through thousands of events to find one that verifies the existence of a new particle or interaction. Finding such rare events can lead to publications, Nobel Prize candidacy, and is otherwise very important. Knuteson, however, asked about all the events that have been discarded. Are we theory blind? Is there no information to be found in results we discard because we do not know what question to ask? To explore this issue he and his team devised a data-mining system, which would sort through all the data from particle collider experiments and attempt to automatically match them up with theoretical explanations. Such an approach might identify new phenomena waiting to be explained, rather than explanations waiting to be verified.

If successful, Knuteson's currently unique effort may signal the return of a positivist approach in high energy physics. Positivists, inspired by Ernst Mach, paved the way for an experimental observation first and theory second philosophy that supported the acceptance of both relativity and quantum theory during the first part of the twentieth century. Peter Galison's lecture, 'Innovation and Invention', traced the impact of Positivism on science and pointed out that anti-positivism has dominated scientific thinking since the Second World War. Theory-guided development reduces cost and risk but also eliminates unexpected experimental results from consideration. The origins of life and consciousness are certainly areas of research that abound in data that is often discarded for lack of an acceptable

theory. A positivist view may encourage theoretical speculation that is unacceptable today but necessary for progress and innovation.

Steven Chu, director of the Lawrence Berkeley National Laboratory, delivered a lecture titled 'Is Life Based on the Laws of Physics?', which addressed head on the inadequacy of current physical theories. Chu examined the recent advances in single-molecule biology that have allowed us to see biological processes in physical terms. Though cautious and non-committal, his viewpoint was captured in a quote he read from Erwin Schrödinger:

From all we have learnt about the structure of living matter, we must be prepared to find it working in a manner that cannot be reduced to ordinary laws of physics [not because] there is any new force, but because the construction is different from anything we have yet tested in the physical laboratory (*What is Life*, Cambridge University Press, 1945).

On the third and final day issues related to consciousness, life, and social significance became central topic of the presentations. David Gross (2004 Nobel Laureate for his discovery of asymptotic freedom in the theory of strong interactions) commented on emergent patterns rather than reductionism as a guiding principle for addressing big questions. I felt this theme characterized the underlying sentiments of the day. Freeman Dyson delivered a very upbeat and entertaining lecture predicting personal biotech kits and games to eliminate the fear of genetic engineering, much the same as personal computers eliminated the fear of robots. However, he concluded that the 'big problems — the evolution of the universe as a whole, the origin of life, the nature of human consciousness, and the evolution of the earth's climate — cannot be understood by reducing them to elementary particles and molecules. New ways of thinking and new databases will be needed.'

Next, John Searle, chair of the philosophy segment of a session entitled 'Consciousness and Free Will' argued strongly for the existence of free will, citing that he was once asked, 'If someone could unequivocally prove determinism, would you accept it?' to which he answered, 'Are you asking me to freely accept or reject such a proposition?' During this session Robert Bishop argued that though physics is governed by deterministic (or deterministic probability) laws, the experimenter is assumed to stand outside these laws, which leads to a dilemma. 'At best,' he said, 'the laws of physics do not globally determine what experimentalists can do, but rather provide limits on the space of possibilities for their choices and actions.' Nancy Cartwright, professor of philosophy at UC San Diego, argued for a 'narrow self-closure of physics' reiterating this theme. As an example she

pointed out that the invention of the laser might be considered a verification of quantum theory but to actually explain the functioning of a laser requires that quantum physics be combined with a huge amount of auxiliary information — classical physics, knowledge of material, clever design — none of which is describable in the language of quantum theory.

Nancey Murphy presented 'Free Will and Downward Causation' and introduced the need for emergent properties. The parts do not dictate the behaviour of the whole. The atoms of a wheel do not explain its rolling downhill. The eleven-second half-life of a free neutrino does not explain its near total stability when bound in nucleus. The whole provides a context and even changes the behaviour of the parts. Thus consciousness cannot be explained from the independent properties of elementary particles, but must emerge instead from the organization of those parts.

Opposed to this point of view was Christof Koch, one of the members of the neurophysiologist panel. His 'give us some time' argument points out that doubters have always existed before a new discovery proves them wrong. Koch, whose former collaborator, the late Francis Crick, was credited for the discovery of the structure of DNA, is following an empirical program to discover and characterize the neural correlates of consciousness. This is the minimum set of neural events that leads to conscious perception. He states, 'This program assumes that consciousness is a distinct ontological entity, distinct from its physical correlates, and that it can be explained within the existing physical framework'. Koch's fellow panelists William Newsom and Gerald Edelman were not as emphatic about the prospect of explaining consciousness within the current understanding of neurophysiology, but admitted that questioning the adequacy of underlying physics was at best a rare and unpopular topic among their colleagues.

As might be expected, physicists who agreed to serve on a panel to discuss consciousness were in a better position to question the foundations of physics than the neurophysiologists who depend on chemistry (and, in turn on physics) to supply the context for their work. George Ellis, co-author with Stephen Hawking of *The Large Scale Structure of Space Time*, presented the physical hierarchy of scientific fields of study starting with physics at the foundation and ending with sociology at the top. Each discipline depends upon the one below for component behaviour and adds new rules for emergent behaviour as layers are added. He was the only speaker to mention the 'hard problem' of consciousness and admitted, 'We do not know the answer; indeed do

not even know the questions to ask...’ However this was the only time this logical bombshell was mentioned during the symposium.

Hans Halvorson of Princeton University reviewed the implications of quantum theory on the problems of consciousness and free will. He pointed out that Wigner, who won the Nobel Prize in physics in 1963, believed consciousness provides the final choice forcing the collapse of the wave function. He was careful not to give credence to any theories but simply pointed out that quantum mechanics, to the extent that it is governed by Schrödinger’s wave equation, is also deterministic and therefore its probabilities cannot be cited as a *carte blanche* rationale for introducing free will. Anton Zeilinger, Institute Director at the Experimental Physics Department of the University of Vienna, analysed quantum teleportation experiments through entangled states, of interest in sending crypto codes, and concluded that if a sender’s decision about which information to send were not free it may be possible to send messages faster than the speed of light. ‘It is therefore suggested that the randomness of quantum measurement might be an indication of the existence of free will.’

During the panel discussion following these presentations on consciousness and free will a member of the audience asked anyone believing in pure determinism to raise his or her hand. None of the eleven-member panel did. The resulting discussion led to the inevitable, ‘Well then how does the brain do it?’ question. All the panelists dismissed the possibility that the brain is a quantum computer, as promoted by Hameroff and Penrose. Several panelists cited that de-coherence times of 10^{-21} seconds eliminated such possibility. One joked that he does not think that fast. Christof Koch observed that microbes had been grown with deuterium instead of normal hydrogen and this should certainly interfere with normal quantum operation if the brain acted like a quantum computer below the neuron level. However, no such deviant behaviour was observed. I felt this discussion was a perfect example of the anti-positivist stance, which so easily dismisses possibilities on the grounds that they do not fit into established theories. Only Anton Zeilinger said, meekly, that perhaps — just perhaps — we should leave the door open for this possibility.

In my opinion, the take-away consensus at the end of the day was that reductionism alone would not suffice to explain the evolution of the universe, life, and consciousness. Some additional emergent property or ‘Metaphysical Selection Process’, as it was called by Paul Davis (winner of the 2002 Faraday Prize for his contributions to the deeper implications of science), would be necessary. Though this

opinion was sharply criticized by some voices, it was shared by most of the participants and the audience.

I should apologize for the large numbers of presenters I have not mentioned in this report. The quality, pertinence, and clarity of the presentations were outstanding. As mentioned at the outset, little new information was presented, and I believe this was not the time for potentially contentious alternative view points. Much more important is the fact that consciousness can now be discussed as a legitimate topic among a gathering of physical scientists. I found out later that it was Charles Townes himself who requested this topic to be included in these celebrations. Though no one can dispute the importance of his discovery of the laser, his contribution to the legitimization of the study of consciousness in the physical sciences may very well be of greater significance in the long run.

Thank you and happy birthday.