lity it was trying to express. The rest of us, whether believers or not, have abandoned the old imagery without being able to find a convincing new one. Thus, not surprisingly, we have no words with which to talk about the ineffable. Yet surely the wonder at, and curiosity about, the universe that led most of us to take up scientific careers is not so very different from the attitude behind the first chapter of *Genesis*; and if the writer of that was more interested in the final cause than we are, can we say that our different ideas about efficient causes prove him wrong on what to him was the greater concern?

ALAN H. BATTEN
National Research Council
11/82 *Victoria, British Columbia*

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I cannot help feeling that the whole debate as published in your columns, interesting as it is, misses a major point that is a central issue in the relation of science to theology.

The correspondence focuses on the issue of the nature of the creation of the world and the Universe. However, if one accepts the idea of creation through the agency of some God, the *mode* of that creation ("Big Bang," "Steady State," or any other proposal) is really irrelevant to the theological discussion. Why any particular mode of creation should be considered more "Christian" than others is something of a mystery; as your correspondents have noted, the Bible offers several contradictory creation options, all of which a mature view will interpret as symbolic rather than factual. Major scientific figures (such as Lemaitre, Eddington and Jeans) have had no difficulty in reconciling versions of the usual scientific view with a Christian understanding.

In my view, the area where physical science impinges much more directly on theological issues is via the vexed question of free will. Presumably the brain is controlled by the laws of physics. The usual physical view must surely be that it is *completely* controlled by these laws—there are no biological factors not determined by physical laws. Classically, this prevents the existence of free will—the ability to make responsible choices. Given an initial state of the brain, the final state is determined by the laws of physics, and any apparent choice is an illusion. Quantum mechanics worsens the situation—probability replaces determinacy, and the illusion of free will is the reflection of chance events. Either view challenges the notion of responsibility, and hence the basis of ethics. I know of no satisfactory resolution of this question (which poses a major problem for humanism just as it does for theology).

This relates back to the issue of creation in the following way: the concept of creation inevitably has an element of continuation, because one of the fundamental questions (posed, for example, by John Wheeler) is why one particular set of laws of physics controls and continues to determine events in the universe. What dictates that *they* should become and remain the controlling feature? For it is these laws that enable the body and the brain to function as they do, and therefore gives us either free will or at least the illusion of free choice. Thus, as significant as the question of how the Universe came into being is the question of why it maintains its functional basis in a particular set of physical laws. This question relates, of course, to the "Anthropic" principle that has been the basis of much fascinating speculation in recent times.[1]

Reference

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GEORGE F. R. ELLIS
University of Cape Town
2/83 *Rondebosch, South Africa*

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Science deserves every whack it gets from the so-called creationists, for a charge of puritanical posture belongs as much to one side as to the other.

Ultimately, those who presume to engage in intellectual rather than emotional debate must first inform themselves of their subject—both sides, that is. And to any scientist who takes the trouble to expand his mental horizon beyond the strict confines of his profession, inquiring with free and properly open mind into the nature and reaches of the religious experiences marking both current and historic humanity, prolongation of the 19th century contest between science and religion into the 20th would only be viewed as ridiculous were it not so serious. For if those engaged with the various pursuits of the intellectual life, and in sufficient number rather than the typical individual oddity, had only prepared themselves properly for the subject they now find thrown back at them, this foolish contest over what to teach our children in public schools could never have arisen. The fact that it has arisen therefore stands as a direct and censuring measure of both a closed and an insufficiently informed attitude among scientists themselves.

For all one needs in rebuttal of the fundamentalist proposition is to ask this simple question: Which religious teaching? Which "creationism"?

Purely through circumstance, this loud cry for teaching a particular religious tradition along with the scientific paradigm has been allowed to arise from a mere minority within a minority, which happens at a particular time and place to be a local majority. For not only is the Judeo-Christian stream a minority among world religions, but fundamentalism is a minority in turn within it. Of some four billion inhabitants currently occupying this interesting planet, far less than half belong to the Judeo-Christian persuasion. And of these, the fundamentalist represents a fraction of very trivial proportions, were it to be measured arithmetically rather than acoustically. Has any one heard the great Roman or Greek Orthodox churches, or indeed the majority of the larger Protestant branches of Christianity, either issue a proclamation or take a public stand against the basic tenets of science since they made that now-admitted massive mistake of the Inquisition?

To repeat: Which "creationism" should be taught in our schools to balance the alleged and possibly real materialistic threat of science? The Hindu's? The Buddhist's? Shamanism? Taoism? Jainism? Shinto? The fascinating Nana Bozho constructions of the Ojibwe Indians? . . .

CARL A. ZAPFFE
12/82 *Baltimore, Maryland*

Liquid crystal priorities

It was with keen anticipation that I was reading the special issue of PHYSICS TODAY on liquid crystals (May 1982). In this field, as in most fields of science, the work done by a number of scientists and laboratories all over the world contributes to the progress. However, if there are scientists whose original work can unambiguously be shown to have initiated the development of a new technology such as the LCD technology with which we are familiar today, I believe we should give proper credit to these persons. It was therefore with considerable astonishment and disappointment that I read in David Litster's article (page 26) that the twisted nematic display (TN-LCD) was invented in the US. An equal surprise was his statement that liquid crystal materials that made TN-LCDs practicable were developed in Great Britain.

It is well known and generally accepted by the scientific community (see, for instance, reference 1) that the twisted nematic effect was discovered by Martin Schadt and Wolfgang Helfrich[2] at the Hoffmann-La Roche Re-

search Laboratories in Basel, Switzerland. Shortly after its publication, Japanese laboratories especially became strongly interested in the practical potential of the new electro-optical field effect, whereas in Europe and in the US almost all laboratories continued to work on dynamic scattering LCDs discovered by Heilmeier and collaborators[3] at RCA in 1968.

Since hardly any liquid crystals with positive dielectric anisotropy were known at the time Schadt and Helfrich published their effect, novel liquid crystals that could be used to demonstrate the commerical applicability of TN-LCDs had to be developed. This was achieved for the first time in 1972 by A. Boller and collaborators[4], who published the first low-voltage nematic mixture (Schiff bases) for TN-LCDs which is still today used by some companies; these compounds were described 2 years before George Gray of Hull University, England, published the biphenyls[5] referred to by Frederic Kahn and Litster. It is correct that biphenyls, which do not hydrolize like Schiff bases, are more practical to handle. Therefore, biphenyls became commercially much more important after Japanese scientists managed to replace the early glass frit seals in TN-LCDs by plastic seals, using new production technologies. However, besides Schiffs and biphenyls, a number of other LC-classes and mixtures with novel electro-optical properties that open up new applications for LCDs were—and still are—developed mainly by the Merck group[6] in Germany, at Hull University in England and by F. Hoffmann-La Roche in Switzerland.

There exists a US patent on TN-LCDs obtained by Fergason. However, his filing date is two months later than the filing date of Schadt and Helfrich. Fergason obtained a US patent despite the earlier priority by Schadt and Helfrich because of the US patent law gives preference to US inventors.

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C. von Planta

11/83 *Biel-Benken, Switzerland*

THE AUTHOR COMMENTS: Introducing the May 1982 issue of PHYSICS TODAY, I briefly remarked on the significance of some events of the past 15 years. This was dangerous, since we all view our activities and those of our close colleagues differently than the community at large does. I have undoubtedly disappointed others besides von Planta, and I apologize to them, too.

My remarks on the twisted nematic (TN) display came from my recollection of events and not from Fred Kahn's article. As I recall it, James Fergason conceived of the TN device in Kent, Ohio, in late 1969 and reduced it to practice in early 1970. Wolfgang Helfrich and Martin Schadt applied for a Swiss patent on the same device in December 1970. I believe that they and Fergason independently and approximately simultaneously conceived of the idea; therefore, credit for this scientific discovery should be shared by all three scientists. I am happy to add that Helfrich has made several contributions of equal or greater importance to liquid-crystal physics. Legally, as von Planta reminds us, the invention was assigned to Jim Fergason.

Von Planta incorrectly quotes my remark about materials. As Fergason, Helfrich, and Schadt demonstrated, TN devices were practicable in 1970. However, I regard the cyano biphenyls synthesized by George Gray's group as a genuine breakthrough and the first materials to make TN displays practical.

Finally, my remarks on TN-LCDs were intended not to offend, but to call attention to Fred Kahn's point that attempts to compete technologically by restricting the flow of basic knowledge will ultimately fail. The historical details given by von Planta strongly reinforce this view. The answer, clearly, is to stay ahead in basic research and discovery and then not to abandon the commercial development to others.

J. David Litster

Massachusetts Institute of Technology

11/83 *Cambridge, Massachusetts*

THE AUTHOR COMMENTS: As pointed out in my article, "The spectacular growth in LCDs over the past 14 years has been made possible by the efforts of physicists, chemists, and engineers exchanging materials and technology relatively freely across international borders." The Swiss company F. Hoffmann-La Roche and its scientists, including Schadt, Helfrich, and Boller cited in von Planta's letter, certainly played a significant role in this growth. Many others not cited in my article also made significant contributions. Unfortunately, it would have been virtually impossible in an article of the length publishable in PHYSICS TODAY to recognize all those efforts and materials in perspective and still convey to the reader the important physical principles underlying those developments. The latter was the object of my article and I hope all those not cited will understand.

Nevertheless, I stand by my statement that "the first truly reliable and stable liquid crystal materials useful for devices" were synthesized by George Gray and his coworkers at Hull University in England. I believe this development of stable liquid crystals suitable for use in relatively low-cost, plastic-sealed TN-LCDs was the primary materials development underlying today's widespred use of TN-LCDs.

As to who invented the TN-LCD, a topic not addressed in my article, von Planta accurately points out that James Fergason is recognized in the US as the inventor of the TN-LCD. Fergason published the first description of a twisted-nematic, electric-field effect device in January 1970.[1]

The TN-LCD was apparently invented independently by several different workers in different parts of the world. The first time I learned of the TN-LCD electric field effect was in 1970. I was at Harvard University to present a seminar on electric field effects in liquid crystals and was told privately by Robert Meyer, then at Harvard, of his epxeriments demonstrating this effect. He neither published nor patented this work. In May 1971 I attended the International Symposium of the Society for Information Display in Philadelphia. James Fergason showed me privately a TN-LCD numeric display operating at room temperature and with good viewing angle. About the same time, the *Applied Physics Letter* of W. Helfrich and M. Schadt,[2] the first detailed description of this effect was being read throughout the world. Schadt and Helfrich are widely recognized by the scientific community for discovery of the TN-LCD on the basis of this publication and by the foreign legal and business communities on the basis of their filing date for the TN-LCD patent. Due credit should go to all these workers for their independent research and discoveries. Credit should also go to BDH, E. Merck, F. Hoffmann-La Roche, and other chemical companies for providing high-quality liquid crystals for research and manufacturing.

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Frederic J. Kahn

Hewlett-Packard Laboratories

11/82 *Palo Alto, California*

Chinese vs. Japanese

With reference to the inverted photo of Yukawa and Feynman in April 1982