letters

Beauty and Science

S. Chandrasekhar's article "Beauty and the Quest for Beauty in Science" (July, page 25) expresses a wonderment we all probably have experienced at some time or another but were unable to put into words as he has done.

The idea of the sense of beauty coming from within the beholder rather than from without is a fascinating one, and it has occurred to me that it may be a subtle manifestation of the law of natural selection. To comprehend the world is to survive. Thus, that which gives pleasure is true. One might then regard the scientist and the artist as ones who possess this mechanism in a highly sensitive state. They are "gifted" people. They are in some remarkable sense driven by it.

To be effective, such a mechanism would have to be adaptive—a mechanism that can adapt one's sense of beauty to what a changing world presents. I am sure that we all have had the experience of a work of art "growing" on us. It is as though familiarity breeds a sense of beauty.

This brings us to Chandrasekhar's observations on the different ways in which artists and scientists appear to mature. The young artist who establishes himself is in a position to create beauty. His very reputation as one who generates beauty deems him as one who defines beauty. He becomes a salient part of the very world to which our sense of beauty adapts. His only constraint is that he does not stray too far from the "norm," that is, he must give the beholder time to adapt. The constraint on the scientist, however, is that the theory must work. That is to say that it must predict "facts." This is a severe constraint indeed. The innate sense of beauty as dictated by the postulated mechanism does, of course, tend to drive him toward the "truth" but does not guarantee it. Once the ruthless world rejects the invalid theory, it loses its charm and beauty and we turn away to look elsewhere.

As Einstein once pointed out, the chances of even the most gifted among us of producing a scientific breakthrough are slim. If one does succeed, the world turns to him looking for more but usually in vain.

Thus, it may be true that Keats's equation between truth and beauty is not to be meaningfully judged as being "right" or "wrong" but is to be looked upon as a remarkable manifestation of the law of natural selection.

Perhaps this is why a "correct" theory imparts a feeling of inevitability—a feeling that, somehow, it had to be the way it was. It is as if it were, in some deep and awesome way, a self-fulfilling prophecy.

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7/18/79

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In reference to Chandrasekhar's article on beauty in science, it is interesting to me how scientists frequently confuse and intermix four aspects of scientific thinking/feeling which analysis can distinguish. They are, in no logical order: simplicity, beauty, intuition and creativity. To use Keats's style:

If simplicity does not beauty make
Can creativity from intuition take?

It is impossible in a letter to sort out what aestheticians and historians of (scientific) thought have written about extensively. See Gerald Holton's *Thematic Origins of Scientific Thought: Kepler to Einstein* (Harvard, 1973) for the scientific end, and my *The Science of Art: Cybernetics of Creative Communication* (Day, 1967) for the art end.

I only wish to suggest that "beautiful" scientific thinking also applies to thinking about the beautiful.

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While Chandrasekhar has indeed avoided the "trivial and the banal" in his articles on the quest for beauty in science, one is left with the uncomfortable feeling that important elements of the discussion have been entirely ignored.

The really interesting question is: What human motives drive the development of scientific thought? Surely the quest for beauty, harmony, and a "proper conformity of the parts to one another and to the whole" are important, but my impression is that the persuasive grip of

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a scientific position is also strongly related to sentiments of *power* rather than beauty. We feel that a theorem or an equation is *powerful* if it can be applied to *attack* a broad range of problems. A scientific principle may have a strong or weak statement, such as the Pauli exclusion principle. We are *struck* by the power of Maxwell's equations to give us *useful* insight into electromagnetic phenomena. The seductive aspect of a theory contains elements of strength and power as well as beauty. Science is also pragmatic. Non-relativistic quantum mechanics gained acceptance not because of its beauty but because it worked. At the time of its introduction it was considered an aesthetic outrage. The statistical nature of physical observables and the failure to predict intrinsic spin were two of its most disfiguring features.

Obviously the power and beauty of scientific thought are not unrelated. Power gives beauty an essential fecundity, and since these elements are rooted in the physical universe the pragmatic requirement is inescapable.

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Chandrasekhar's article provides ample proof of his hypothesis that "[a scientist's] early successes are often his last successes." What are we to surmize when we are told that certain mathematical equations thrill G. N. Watson as much as the Medici tombs—was the man a necrophile? His proof that the general theory of relativity is beautiful is about as useful as the Judgment of Paris.

Descriptions of beauty are best left in more capable hands, as Chandrasekhar's final quote from Virginia Woolf demonstrates.

Finally, we question whether PHYSICS TODAY is the appropriate place to publish this essay. A more appropriate vehicle might have been a supplement to the *Oxford Dictionary of Quotations.*

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8/10/79

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As a physicist with an interest in the metaphysics of the East, it strikes me as most curious how the deeper levels of discovery in scientific theory, such as the experiences of Kepler and Pauli reviewed by Chandrasekhar, may involve a distinctly mystical quality. That is, the discovery experiences of Kepler and Pauli included an *experimental* sense that the mind's capacity to recognize and savor the patterned truth/beauty of the external world is due to the inate pre-existence of this same richness of content deep in the mind (or "soul"?) itself.

This is an intriguing and very powerful notion, which could reconcile the scientific and the mystic ways of gaining knowledge. Real truth may be as much to be found in the inner universe as in the outer one, though self-deception may be a greater problem for the inner seeker; perhaps "it is not so much that you are in the universe, as that universe is in you" (Meher Baba).

In any event, what is so very refreshing about Chandrasekhar's article is the clear reminder it gives that the honest roots of scientific pursuit are in the keen longing to somehow find and touch the eternal truth and beauty at the heart of things.

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More on language requirement

Recent issues (November, 1977; June, 1978; July, 1979) contain six letters calling for retention or reinstatement of some form of foreign-language requirement for the PhD in physics or astronomy. In general, the authors point to the importance of language study to the development of a well-rounded scholar and for person-to-person communication within the international scientific community. Curiously, all the letter authors are from the generation of scientists who would be imposing the language requirement. This dissenting letter is from one who would feel the requirement directly: a current graduate student.

Graduate physics study today, even without a language requirement, is a lengthy process. In this department, for example, the average time for a PhD is almost 5½ years, and there are some groups in which even a well-prepared, intelligent, and hard-working student can expect to spend 7 or 8 years. I know of no field where more time is required. Most students accept this as necessary for the acquisition of a wealth of useful skills and the production of high-quality original research, but we resist the imposition of additional requirements unless they can be demonstrated to be truly valuable.

There is a underlying assumption in all the arguments presented calling for language requirements that are incorrect: the idea that all, or even most, current graduate students will go on to join the international scientific community. This may have been true 15 or more years ago, when the authors of the letters got their degrees, but it is certainly false today. The vast majority of current physics PhD students will find permanent employment as computer programmers, teachers in small, nonresearch oriented colleges or researchers and product developers in industries that do not encourage publication of significant results, such as defense industries. For these people, participation in an international conference will remain an unfulfilled dream, and the imposition of a language requirement would be a burdensome waste of time.

One could argue that universities should not be granting PhD's to students who will wind up "misusing" them in the above-mentioned occupations. Even if true, this point should be addressed by considering a major scaling down of the size of all graduate programs, not by introducing requirements based on outdated assumptions. In fact, however, the success physicists have shown in entering these nontraditional fields suggests that the technical skills acquired in connection with the PhD can be transferred successfully to these occupations.

Finally, I would like to make a comment on Bruce Sherwood's proposal (July, page 9) to require all graduate students to study Esperanto. While the presumed goal of conducting international scientific discourse in this universal language is laudable, such a requirement, since it does nothing to educate older, currently active scientists, would accomplish this goal only in the distant future, if at all. It is the most senior members of the physics community who choose conference and journal languages, so, even if Sherwood's proposal were put into effect worldwide tomorrow, it would have little impact beyond a few token demonstrations for perhaps 30 years. Even then, Esperanto would be a long-forgotten skill for the other conference organizers, so its introduction would seem unlikely.

If, on the other hand, Sherwood can come up with a way to get older scientists into an Esperanto classroom right now, his proposed requirement for graduate students would become unnecessary. The day every faculty member begins to make a concerted effort to learn Esperanto, it will become clear to students interested in international physics that such knowledge is going to be useful, and there will not be any way to *stop* them from learning it.

There will always be some graduate students who try to enter traditional areas of employment that lead to international communication, and these students should be encouraged verbally and by example to learn a foreign language. However, since such study would be a needless exercise for most students, making it required for all PhD candidates is inappropriate.

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Although English is now closer than any other to being an international language, Sherwood persuasively describes the