letters

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tering of thermal neutrons might, *in principle*, be used to resolve the individual atoms in a molecule without seriously affecting its biological functioning in a thermal environment.

The other issues mentioned by the authors are more technical and can be dealt with more appropriately elsewhere.

GEORGE T. TRAMMELL
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7/12/76

THE AUTHORS COMMENT: George Trammell asserts that we have given a false impression in our article (June, 1975, page 40) and letter (July, page 57) regarding the usefulness of x-ray lasers for the study of biological molecules. We do not believe that this second letter of Trammell's makes any worthwhile new points.

His point that Compton scattering (rather than the photoelectric effect) is the fundamental—rather than merely practical—constraint when discussing limitations on the things one can do with an x-ray microscope was already mentioned in the first paragraph of our earlier letter. His assertion is simply incorrect that one cannot effectively image the atoms in a biological macromolecule because the ratio of x-ray inelastic to elastic cross sections is never less than 10. Apparently Trammell is unaware of the variety of techniques one can employ to record Angstrom-scale images with Compton-scattered x-rays, either conventionally or holographically.

It is also curious that Trammell asserts that the fundamental limitations imposed on an x-ray microscope by Compton scattering are not directly related to the uncertainty principle, since Heisenberg's original description of the uncertainty principle made use of a thought experiment involving the imaging of an electron with an x-ray microscope (see Heisenberg's *Physical Principles of Quantum Theory*).

GEORGE CHAPLINE
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10/20/76

Humanity of physics

In his characteristically beautiful article in your June issue (page 23), Victor Weisskopf made an excellent statement of "Why physics is human," but regrettably failed to put forward any arguments in defense of the mathematical content of physics. Since I once had the honor to be addressed as a "horrible mathematician" by Weisskopf himself, (on the occasion of an after-dinner graduate-student discussion when I made a presentation on SU(3) in 1969) perhaps I could remedy the situation on Weisskopf's behalf.

At the outset I feel that we should remember that mathematics is an essential part of physics at all levels, and that of all the four complaints in Weisskopf's article the second hits closest to the essence of physics. We need only recall Lord Kelvin's famous remark to the effect that when he could measure or quantify a concept, it became much more understandable to him. If, even in the nineteenth century, numbers and mathematics were central to a physicist's view of the world, how much more true this is of the twentieth century.

As Weisskopf points out in his case for his points 1 and 3, nature exhibits form, structure, and patterns of symmetry, and these have fascinated Man from the earliest times. It is here that we can start our apology for mathematics. From the ancient Greeks we have inherited a tradition of investigating the order and beauty in the world. Even before the ascendency of Athens two great themes of nature were recognised: first, that nature exhibits order—in the sense of patterns of events that are not totally random or chaotic, as exemplified by the progression of the seasons and the motions of the plants—and second, that the essence of this order is to be found in mathematics. At Plato's Academy, appreciation and understanding of the beauty of such patterns exhibited by the natural world were regarded as among the loftiest ideals to which a man could aspire, and in his curriculum for the education of philosopher-kings, Plato placed mathematics at a central point. In view of these facts surely we should not feel apologetic for mathematic's role in today's physical sciences. We only need a contemporary statement of the same themes to justify it.

Firstly, we can state that the most esthetic aspect of modern scientific endeavor is to give a clear and concise description of the patterns of symmetry and order in nature and of the mechanics underlying them. Secondly, the clearest and most concise statements of symmetry and order, and therefore the ones that are most elegant and esthetically appealing, are those made in terms of mathematics.

At Maharishi International University in Fairfield, Iowa, concepts similar to these have been used as a central part of extremely popular courses in physics and other sciences (and arts), and it is noteworthy that the four complaints enumerated by Weisskopf have been almost unheard of.

In conclusion I suggest that the best defense of the mathematical content of physics may be made on artistic, and therefore more directly human, grounds rather than by appealing to the intellect and pure reason. I would also suggest that your readers might well find it profitable to look further into the methods used at Maharishi International University.

A. M. A. HANKEY
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8/10/76

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Victor Weisskopf's article "Is physics human?" disturbed me as a physicist very much. I thought it was too defensive. More importantly, I thought it was *itself* an example of the approach that is largely responsible for the real problem: the "aversions to physics" among laypeople.

Obviously physics, and physicists, are "human." Why doubt it or defend it? A musician would not defend the humanity of composing in some musical mode, however "contrived, mathematical, abstract, and distant" it might seem. Would the question even occur to someone who likes that music? For me, the "humanity" of physics resides with my own humanity. Physics is not revealed, it is developed by people, like myself, whose awareness of the world is nourished in turn by physics. Physics is human because I am human and not because it has something "to do with human relations."

The question "Is physics human?" presents the world as somehow divided into Man and Nature, Logic and Beauty, etc. The same division is implied in variations such as "Does physics exclude an essential part of Nature?" I don't think this duality exists; furthermore, I think introducing it turns many people off to physics. Some people reject the dichotomy outright, and doubt the relevance of a discipline that assumes it. More often people disbelieve the conclusion—any conclusion—of an argument based on that dichotomy. Justifications of physics based on any conclusion are not persuasive to them, because ultimately they are also uncomfortable with the assumption. For instance, Weisskopf's article suggests Goethe was contemptuous of physics because he thought "the methods of physics somehow exclude some essential part of Nature . . . ." The thrust of the article is to clear up this misunderstanding. On the contrary, perhaps Goethe and Whitman *were* told physics excluded no essential part of Nature, and they just refused to believe that stars could be essentially reduced to "figures . . . ranged in columns," or that poetry was a branch of inclusive physics. Whichever way physics was presented they could raise objections, because each way assumes the same divided world view.

Enthusiasm generated in the article's approach sometimes leads to a second source of unpopularity: arrogance. To excerpt from many similar examples in the article, physics provides "a true insight into the workings of Nature," deals with "fundamental problems of human existence", and is "an expression of the most significant relations between Man and Nature." In addition, scientists themselves are able to "approach sensitive [political] questions with greater ease and lesser danger of misunderstandings . . ." than other people. I disagree with these statements and I doubt they would persuade anyone that physics is "human." The final paragraphs concede, ". . . the scientific explanation of a human experience does not necessarily touch all aspects of this experience." This disclaimer is too little and too late. The implications should be the crux of the discussion, not the afterthought.

I would restate the basic question as, "Why are some people turned off to physics?" I believe that by-and-large the answer is: they are turned off by approach, and *not* by subject matter. To turn people on to physics, or at least to help them appreciate its immediacy, I try to begin at the source of its strength and weakness—people in the world. I present physics as being founded in our experience, constructed through our interpretations, and directed by our interests. This approach sometimes stimulates disagreement, but even the argument leads to a better appreciation of physics; it certainly increases interest in concrete examples.

An approach that divides the world into Man and Nature can also lead a physicist to treat his listeners like objects and overlook both their humanity and his own. This situation is less likely to arise if physics is presented as derived from interactions within the world. In this latter case, sensitivity to the humanity of an audience includes the recognition that teaching is not like programming, because it allows a speaker to spread his enthusiasm and an audience to respond with their perspectives. Sensitivity to one's own humanity includes the admission that physicists are not less subjective, apolitical, or fallible—"human"—than other people, nor are they closer to the Truth. Finally, this point of view accepts that not everyone will be convinced, because relevancy cannot be proven.

HOWARD SMITH
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8/23/76

No practical physics

In his letter to the editor (September, page 88) David Lazarus made a strong appeal to let the "practical" physicists return to full membership in the physics department, so that students could see them as role models and be exposed to such specializations as possible career choices. On the contrary, I would like to argue for a more distinct separation of physics into two fields, "physistry" and