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implies that many research organizations are already too large, and that therefore they should budget not just their costs but also their staff sizes. This would cause some of the author's complaints to be minimized.

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Solitary Wave Preoccupations

James Krumhansl (March, page 33) credits D. J. Korteweg and G. de-Vries[1] with the resolution of the conflict between J. Scott Russell's observation of the solitary wave and G. B. Airy's claim that such a wave could not exist. Russell discovered and named the solitary wave in 1834, carried out laboratory experiments in 1834 and 1835, and reported his investigations[2] at the British Association meeting of 1837. The contradiction with Airy's prediction (on the basis of his shallow-water equations, which neglect dispersion) that a wave of finite amplitude cannot propagate without change of form was resolved independently by Joseph Boussinesq[3] (1871) and Lord Rayleigh[4] (1876), who showed that the increase in local wave speed associated with finite amplitude is balanced by the decrease associated with dispersion. The seminal contribution of Korteweg and deVries was to combine the assumptions of weak nonlinearity and weak dispersion with that of unidirectional propagation to obtain the nonlinear partial differential equation that today bears their name. Their work may fairly be said to have stimulated the present-day interest in solitary waves and other localized, coherent structures.

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KRUMHANSL REPLIES: I thank John Miles for calling attention to several significant 19th-century contributions to the understanding of solitary waves that neither space nor the context of my retiring APS presidential address (on which my March article was based) allowed me to discuss in detail. The references he provides may be found discussed at further length in the books named in reference 2 of my article, particularly the volume by M. Ablowitz and H. Segur. Further amplification is to be found in the historical discussion by Alan C. Newell.[1] Certainly Joseph Boussinesq[2] made important contributions to this topic, including discovering several new conserved quantities that we now recognize as an essential feature of integrable soliton-bearing equations (which have an infinite number of conserved quantities—that is, constants of integration). However, Newell points out that Boussinesq's solution still suffered from being bidirectional, whereas the Korteweg–deVries analysis finally provided an integrable nonlinear equation that had the key properties we now associate both theoretically and experimentally with solitons.

At the same time, it is important not to leave the impression that the competition between nonlinearity and dispersion in a wave excitation is either an essential or a necessarily useful way to think about solitons in general. In any case it is limited to small-amplitude nonlinear perturbations. There is a large class of problems, namely those defining topological solitons, as in the Sine Gordon equation, whose solutions may be entirely static (not wave-like at all) and must have only discrete amplitudes. These appear prominently in quantum field theory, condensed matter physics and structural phase transitions. In spite of the fact that they are completely different in physical nature from water waves, the general soliton analyses apply.

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Socratic Pedagogy in Introductory Physics

In his thoughtful review (December 1990, page 67) of Arnold Arons's book *A Guide to Introductory Physics Teaching*, Charles Holbrow raises a few good questions: "The book is eye opening and informative, but is its program for improving the teaching of introductory physics feasible? . . . How much time is available for Socratic questioning of students? . . . Is this an approach that can be used in a course of 100 students—let alone 1000 students? . . . How worthwhile is the investment of these resources in generating understanding? . . . How much coverage are you trading for how much understanding?"

Our four years of experience[1] in using the method Arons advocates shows not only that it is feasible, but that it is extremely successful in promoting students' conceptual understanding of Newtonian mechanics as measured by the Halloun–Hestenes test.[2] At Indiana University we bring Arons to the masses in large, non-calculus-based classes for science (but not physics) majors, including prospective high school and middle school teachers, primarily by means of Socratic Dialogue Inducing laboratories. These labs emphasize interactive engagement with simple concrete experiments and promote conceptual change through "disequilibration," collaborative learning, extensive diagramming and Socratic dialogue. For the spring 1990 class of about 100 students this required an extra resource expenditure of about 6 professor-contact-hours per week averaged over the course of the semester. How much coverage did we trade? In that course we sacrificed coverage of waves and special relativity, treating only mechanics and thermodynamics in the first semester.

How worthwhile is the investment of resources? From the standpoint of most research universities it is not at all worthwhile, especially for a class of nonphysics majors. But perhaps research universities need to reexamine their priorities.[3] As Arons has written, "Were more of us willing to relearn our physics through the dialogue and listening process I have described, we would see a discontinuous upward shift in the quality of physics teaching."[4]

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