major increase. If faculty take advantage of collaborative efforts, modest college research need not be expensive. We agree that there are tradeoffs, but money is less a problem than time for most of us.

We certainly agree with Walstad on the importance of providing high-quality educational experiences for students not intending to major in physics. However, the topic of the June issue of PHYSICS TODAY was the education of professional *physicists*, and that is the reason for our emphasis. Our experience has been that many physicists and administrators are skeptical about the possibilities for doing successful research in colleges. This deters physicists who enjoy both research and teaching (and can pursue both with distinction) from applying for faculty positions in colleges. By providing concrete evidence for the existence of successful college research programs, we hoped to modify this prejudice.

Walstad implies that our case is substantially based on the existence of a correlation between the PhD productivity of colleges and their success in research as measured either by publications or by grant-getting. We made no such claim (though we think that there may be a correlation) because there does not appear to be valid quantitative evidence on which to base it. (We dispute Walstad's claim that data from our reference 6 may be used to show the absence of a correlation. The number of institutions is small, they were preselected for inclusion, and the data for PhD productivity and research success are for different periods.) Our argument that research activities are useful educational experiences for undergraduates does not depend on whether they choose the PhD path or not. However, we personally know many students who chose graduate study after a successful college research experience.

We would like to correct two errors in our article: We regret the omission of an award to Connecticut College from the list of Research Corporation grants. The grant is for studies of photon emission from collisional excitation of N_2O, NO_2 and SF_6. An error also appeared in the profile of Robert Warner of Oberlin College, whose research has received continuous outside support from the NSF since 1965 (not 1985).

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I was pleased that PHYSICS TODAY invited college teachers Jerry Gollub and Neal Abraham to write an article on the important role of college research in both fundamental physics and the education of scientists. Other readers who found the article interesting should be aware of the Council on Undergraduate Research, to which both authors belong, and of whose Physics Council I am president. It is an organization of college faculty who have joined together to encourage research efforts in the undergraduate environment. The directory *Research in Physics and Astronomy at Private Undergraduate Institutions*, referred to in their article, is available from Brian Andreen, Editor, 6840 East Broadway Boulevard, Tucson AZ 85710, for $25 prepaid or $30 charged. It provides useful information about the major private-college physics departments for use by graduate departments, employers, funding agencies, other colleges or high schools.

The CUR also publishes a thrice-yearly newsletter to share ideas about college research efforts, including funding information and case studies. Subscriptions ($22/year) may be ordered from Michael P. Doyle, Newsletter Editor, Council on Undergraduate Research, Department of Chemistry, Trinity University, San Antonio TX 78284.

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Calibrating with bubbles

If the large-scale distribution of galaxies resembles the disposition of soap films in "the suds in the kitchen sink," as is compellingly indicated by Valerie de Lapparent, Margaret Geller and John Huchra's recent redshift survey (PHYSICS TODAY, May, page 17), we may eventually be afforded new handles on the old cosmological problems of the distance scale, expansion rate and global curvature of the universe.

Attempts to infer the cosmological distances of remote objects from their brightnesses or redshifts have remained uncertain owing to the possibility that the distribution of luminosities of objects or the rate of global expansion may have varied with the age of the universe. (What we see at great distances are necessarily in the remote past.) However, if we make the usual cosmological assumption that the Earth does not occupy a privileged position, then the sharply bounded cells or "bubbles" within which luminous galaxies are virtually absent should not on the average be elongated in directions that are systematically oriented with respect to their direction from the Earth. By fitting ellipsoids (or, in two-dimensional slices, ellipses) to the boundaries of apparently empty cells in surveys of the sort reported by de Lapparent, Geller and Huchra, we should eventually be able to use any systematic elongations or compressions along radial directions from the Earth to determine what correction of the distance scale, if any, is needed at each redshift to render the principal axes of the ellipsoids equal or, at least, uncorrelated with radial direction from the Earth.

Any residual dependence on distance of the average size of the cells would then furnish evidence concerning secular trends in the sizes of these cells over cosmological time.

Finally, for all cells within a given range of redshifts, the extent to which the average number of cells sharing a boundary with each individual cell deviates below or above 12 (the close packing number for Euclidean space) would indicate the extent to which the global curvature of the universe at the corresponding temporal epoch was positive or negative, respectively.

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That ol' dark matter

The news story on the "bubbly universe" (May, page 17) needs some additional clarification. Three primary theories are discussed in trying to account for this structure: primordial explosions, cold dark matter and hot dark matter (also called the "pancake theory"). Unfortunately, the interviews included in the theoretical section of the story quoted only proponents of the first two models. This may be related to the fact that Yakov Zel'dovich's group in the USSR is primarily associated with the third model, which is an appropriate one if any of the three(?) neutrinos has a small but finite mass.

Such models are often studied by numerical simulation. It is unknown whether such large voids as the bubbly universe appears to contain can form in the primordial explosion model by propagating explosions. The cold dark matter model does not produce large voids naturally. It is possible to reinterpret the model so as to cause some voids to appear; they of course must appear extremely commonly, as they seem to in the observational data. Note

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that one is now treading on very subjective ground, as it is possible to search a multitude of interpretations of a numerical model until one is found that fits the data.

It is not true that none of these models anticipated the existence of such large voids. In fact, they are a natural outcome of the hot dark matter model, and have been extensively studied as such.[1] The news story misses the point that not only are such voids a generic prediction of models of this type, but that their size is precisely what is expected for reasonable values of the Hubble constant and the density of matter in the universe in such models. The study quotes objections to the hot dark matter model by proponents of the cold dark matter idea, primarily the excessively large autocorrelation length. That objection has been questioned in a variety of ways. It is based on equating the autocorrelation lengths of particles interacting purely gravitationally in a model in which hydrodynamic processes are known to be quite important. More generally, it is based on a reinterpretation of the model, in which galaxies form only in the collapsed pancakes; this increases the correlation strength. If one relaxes the assumption that mass traces light, one must be prepared to do so in a complicated way. It is easy to write a biasing prescription that reduces the amplitude again by judiciously choosing galaxy masses.

It is also not correct that the first structures form too late in hot dark matter models. The first nonlinearities appear at a redshift of 4 relative to the moment I describe above,[2] which is about the same as that of the first known quasistellar objects, the most ancient known nonlinearities.

I do not wish to appear to be an advocate of hot dark matter. In fact I think the question is open. All the models have positive and negative features when compared with the data and with "reasonable" theoretical interpretations. The exclusion of this model from serious discussion in your story seems to be based largely on the sociological phenomenon that it is not popular in North America. The numerical simulations can be more and more reliably interpreted when we concentrate on large-scale features, which we can be more confident are based purely on gravity. It is an objective fact that the hot dark matter model is the only one that predicted the existence of such voids. [See also the article on page 28.]

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Memories of Wheatley

Some time ago we received the sad news: John Wheatley was dead [see PHYSICS TODAY, September, page 73]. First the telegram from a former student, later the phone call from Los Alamos, and then the confusion between space and time came to my mind. I saw John, Martha and the children near the fire, Martha waiting for the bus in a cold winter, a long trip through Patagonia on a lonely dirt road, John planning one week's work for the lab—but let me put some order in this story.

Many people will be able to talk about the relevant scientific contributions made by Wheatley, and most of them will be better able than I to explain how his scientific and technical contributions have been crucial to the modern understanding of condensed matter. However, very few are in a position to talk about the Patagonian adventure in which Wheatley took the leading part.

In August 1955 a young Argentinian theoretical physicist, Jose Antonio Balseiro, supported by the Argentine Atomic Energy Commission, started a new teaching and research institute in Argentina with a small group of collaborators and students. They came to Bariloche, a small town 1100 miles from Buenos Aires at 41° latitude in a beautiful national park. Two flights and three trains per week and an almost useless dirt road were the only connections with the civilized world. Why a research and teaching institution was started in such isolation belongs to Argentinian history and is not the subject of this letter. What is important to point out is that Balseiro had a strong and clear commitment to build a research center based on experimental physics. Such a decision, which might seem trivial to people in industrialized countries, is by no means a simple task in ours. Balseiro asked for the support of Argentinian and international funding agencies. The first result of their positive response was a continuous flow of visiting professors teaching courses and advising on research projects.

In 1958, Jim Daniels came from Vancouver offering his collaboration in