strating the existence of the W and Z particles.
Which is "more important"? Both are triumphs of the human intellect.

There is an often-unrecognized diversity within what one normally considers "big science." At one extreme are large groups focused on one problem (or even on a single experiment—*vide* Rubbia and van der Meer). At another extreme are large facilities shared by a number of small-to-medium-sized groups. Such facilities have revolutionized fields traditionally thought of as small science. (One has but to think of the effect of the Glomar Challenger on geology, or the succession of ever larger telescopes on astronomy.) And yet another form of "big science" is the grouping by common consent into a large and diverse enterprise (such as the Joint Institute for Laboratory Astrophysics or the Institute for Theoretical Physics) that by the richness of its internal interactions often sets the pace and standard of quality for a whole field.

These large experiments, facilities or groups are the ones able to open new windows on the unknown and in so doing to lead to the unexpected discoveries that change the course of science. (This has gone on as long as there has been science.[3]) Opening such windows increasingly requires ever larger enterprises. "Big science" is thus simply the next logical step in any field of science. Once made and absorbed it becomes tomorrow's "little science" and is no longer remarked on. ("Little science" is time dependent. Small groups today have more computing power than Los Alamos did when it worked out the first hydrogen bombs.)

The best science is done by allowing scientists to decide what is important and how to do it, not by our telling them. Let me argue for the best science independent of size: It would be a shame if physics were to be decided by formula and not by intellectual challenge.

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Charge-Density Wave Compound Comment

In his December Search and Discovery story (page 17) Anil Khurana surveyed experimental progress toward establishing the existence of the Wigner crystal. One of the key signatures of such a crystal is nonlinear conductance, which presumably arises from the depinning of the crystal from the host lattice. As Khurana pointed out, it may be useful to draw parallels with earlier work on the depinning of the charge-density wave in quasi-one-dimensional solids. However, the compounds in which the charge-density waves may be depinned by a weak electric field were incorrectly identified.

A charge-density wave (a weak periodic modulation of the electron density) is accompanied by a periodic lattice distortion whose wavevector matches the diameter of the Fermi surface. The periodic potential opens up a gap at the Fermi surface. In certain low-dimensional solids, the gain in electronic energy from gap formation offsets the cost in lattice strain energy when the temperature is below a critical value, so that the charge-density wave is stable. The existence of charge-density waves in solids was first demonstrated in the late 1960s by John Wilson, Frank DiSalvo and S. Mahajan.[1] The structural evidence for charge-density wave formation in the transition-metal dichalcogenides ($NbSe_2$ and TaS_2) was carefully argued in their paper, which strongly influenced the work of later investigators, including us. The dichalcogenides are layered compounds with quasi-two-dimensional electronic properties. For reasons that are not completely understood, the charge-density waves are *very strongly pinned* to the host lattice, and there is no evidence (so far) that collective motion of the waves is possible in these layered compounds.

In 1974 Jean Rouxel and coworkers synthesized the trichalcogenide $NbSe_3$. This remarkable compound has a linear-chain morphology and an electronic dispersion that is quasi-one-dimensional. A charge-density wave spontaneously forms in $NbSe_3$ at 142 K, followed by a second one at 59 K. Around this period, we were inspired by a prescient remark by John Bardeen that "sliding Fröhlich" conductivity could exist in quasi-one-dimensional metals. In experiments starting in 1975 we found that at all temperatures below 142 K, the linear conductivity at the microwave frequency 10 GHz is significantly larger than at zero frequency. We also observed that the conductivity increases dramatically in the presence of a weak dc electric field (10 mV/cm). We interpreted these results as reflecting, respectively, collective forced oscillation of the pinned charge-density wave and depinning of the wave from the host lattice.[2]

Khurana also mentioned the phenomenon of noise generation when nonlinear transport occurs. The existence of voltage oscillations ("narrow band noise") accompanying charge-density wave motion in $NbSe_3$ was reported by Robert Fleming and Charles C. Grimes[3] in 1979.

These three unusual transport phenomena—nonlinear conductivity in a weak dc field, excess conductivity at microwave frequencies, and noise generation—are now accepted as the key signatures of charge-density wave motion. To date, all compounds that display these properties [$NbSe_3$, TaS_3, NbS_3, $(TaSe_4)_2I$ and $K_{0.3}MoO_3$] have a linear-chain structure.[4]

In his article in the same issue of PHYSICS TODAY (page 25), Bardeen also referred to the properties of $NbSe_3$. In addition to the quantum tunneling model proposed by him, classical models also have been quite successful in explaining the remarkable transport properties of these solids.[5]

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Europe's Educational Edge

Chiara R. Nappi's comparison of mathematics and science education in the US and Europe (May 1990, page 77) contains many perceptive observations and much valuable analysis. I have recently returned from a visit to the physics and mathematics departments at the University of Rome, Italy, and I can confirm her observation that women are better represented there than in the corresponding departments at American universi-