proof came in early 1924 when he determined that the so-called "Andromeda Nebula" was a separate galaxy far beyond the Milky Way.

So Shapley's universe was profoundly smaller than the one Hubble revealed as an emerging cosmos—though the general applications of Shapley's work deserve all the credit of astronomical history.

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A Brief History Lesson in Deep Ice Core Drilling

In his article on rapid climate change (PHYSICS TODAY, August 2003, page 30), Spencer Weart incorrectly credits Willi Dansgaard's Danish team for augering the first deep ice core to reach the bottom of an active ice sheet from Camp Century, Greenland. This honor rests with B. Lyle Hansen and associates Herbert Ueda and Donald Garfield from the US Army Corps of Engineers' Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire. In July 1966, after a five-year field effort, they reached a depth of 1387 meters.[1] One of us (Langway) was responsible for developing the international study program for the Camp Century ice core.[2]

The Hansen crew also drilled the second ice core ever to reach bottom ice, in January 1968, at a depth of 2164 meters, from Byrd Station, Antarctica.[1] Both core drillings were extensions of the successful US International Geophysical Year projects in Greenland and Antarctica (1957–58) to deep-core drill into polar ice sheets for scientific purposes.[3] The IGY studies were proposed, initiated, and led by Henri Bader, chief scientist, under an interagency agreement with NSF.

It was data obtained in these early drilling projects that ultimately led to the discovery of rapid climate changes and served as the foundation and justification for the follow-up international, multidisciplinary Greenland Ice Sheet Program by researchers from the US, Denmark, and Switzerland.[4,5] It was also during the final three years (1979–81) of the GISP 10-year field and laboratory investigation that Danish drilling participants, led by Niels Gunderstrup and Sigfus Johnson, augered the 2037-meter-deep third ice core to reach the bottom of the ice sheet at Dye-3, in August 1981.

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Weart replies: Historians should work hard to be accurate, and the same applies to those who would criticize historians. What I actually wrote, and which is true, was that in the 1970s the most convincing evidence for rapid climate change came from an ice core drilled by Willi Dansgaard's Danish group in cooperation with Americans led by Chester Langway Jr. I never said that theirs was the first deep core. The constraints of a brief article, which attempted to cover a great deal of ground, left no space to describe how the drilling campaign was but one stage in a prolonged effort of heroic proportions—an effort that began in the 1950s and continues today. (Attentive readers might have noticed brief mentions in my photo captions.) I have written more about the drilling campaign in the essay cited in the article, available at http://www.aip.org/history/climate/rapid.htm. Those interested in ice drilling history are also urged to review and contribute to the additional but fragmentary information collected at http://www.aip.org/history/sloan/icedrill.

I am glad that Langway and Johannes Weertman have taken the trouble to draw attention to early deep ice drilling developments. Those named in their letter, and the many other institutions and people who contributed to that important task, deserve more recognition than they have received.

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Mixing the Practical and the Scholarly in Physics Education

John Neumann's letter calling for inclusion of fluid mechanics in the physics curriculum (PHYSICS TODAY, June 2004, page 14) is quite interesting. I suggest, however, that mechanical engineers are generally better trained in computational methods than physicists are, and it is this training, rather than an academic course in fluid dynamics, which gives them an edge in applied problems.

I like the fundamental approach of the physics curriculum. In fact, I would argue for the reestablishment of professorships of natural philosophy and physics. Today's graduate training seems to suffer from a fissure between course work on the one hand and, on the other, research in which professors and students are overly dependent on the tools of the trade—for example, canned computer codes for theoretical studies. That situation in turn leads to the stifling of really innovative and trenchant work.

Clearly there is a danger that an overemphasis on practical training and technical skills could shift the physics curriculum toward a course of study expected for a certificate from a vocational-technical institute rather than for a PhD from a major university. I have always found that the chemistry curriculum tends to have an orientation that emphasizes the practical rather than the scholarly, such that the poor physical chemist, for example, is offered no courses in optics, no classical or quantum electrodynamics, and just enough quantum mechanics so that the student can make sense of spectroscopy for chemical analysis. It seems to me that the American Chemical Society is minimalist in acknowledging the existence of quantum or theoretical chemistry, notwithstanding all the good theoretical work performed in chemistry departments roughly since the publication of the distinguished text in 1935 by Linus Pauling and E. Bright Wilson, *Introduction to Quantum Mechanics: With Applications to Chemistry* (McGraw-Hill).

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Historical Notes on Feshbach and Shape Resonances

In his interesting Reference Frame piece (PHYSICS TODAY, August 2004, page 12), Daniel Kleppner relates Herman Feshbach's reaction to the term "Feshbach resonance" and gives a capsule account of the topical and vital role this phenomenon plays in today's explorations of cold collisions of fermions and bosons, and of condensates of atoms and molecules. Readers may be interested in the earlier history and why atomic physicists began to use a term that Feshbach himself dismissed as jargon.

In the Los Alamos experiment of Howard Bryant's group on photoabsorption by the negative ion of hydrogen, two prominent resonances were seen at photon energies of about 10.95 eV. This energy marks the position of the first excited state of the hydrogen atom above the single bound state of the negative ion.

One narrow resonance occurs just below the threshold of that excitation, whereas the second, broad one occurs just above. Their physical mechanisms are different and, following the paradigm set by that historic experiment, it has become customary to refer to the two types of resonance, both common in atomic and molecular physics, as Feshbach and shape resonance, respectively. That is, a resonant coupling just below the relevant threshold, leading to narrow profiles, is distinguished from those lying just above the threshold to which they are most strongly coupled, and typically broad.

The two types of resonances are most naturally viewed in state and coordinate space, respectively. Feshbach resonances are thought of in terms of the superposition of two quantum states, one with discrete and one with continuum character, leading to a temporary quasi-bound state that manifests itself as a resonance in that continuum channel. The independent and almost simultaneous work in nuclear physics by Feshbach using the language of projection operators and in atomic physics by Ugo Fano using the language of superposition of wave functions serves for their technical description.

Shape resonances, on the other hand, may be associated with the shape of a trapping potential in real, coordinate space. Most often, the trapping potential is an angular momentum potential that combines with the internal one to create intervening barriers to low-energy particles. The resulting pictures often display "two-valley" potentials. In the case of the negative ion of hydrogen, such a barrier has been described in terms of the hyperspherical coordinates of that three-body system. Examples of such shape resonances abound in low-energy scattering of electrons from molecules.

For more discussion and references, including to recent applications in mesoscopic condensed matter systems, see my pedagogical mini-review in *Physica Scripta*, volume 69, page C10, 2004.

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