



Aspirations in Science and Civics

From the carbon-nanotube lab to the corridors of Washington power, Mildred S. Dresselhaus has followed a career that combines scientific research with public service

By David Appell



MILDRED S. DRESSELHAUS: INDEFATIGABLE

- Married to M.I.T. physicist Gene F. Dresselhaus; four children; son Peter is a physicist at the National Institute of Standards and Technology.
- Avid violinist and violist; member of Amateur Chamber Music Society in New York City.
- National Medal of Science, 1990; president, American Association for the Advancement of Science, 1997-1998; 17 honorary doctorates.

Standing in a well-worn hallway of Building 13 of the Massachusetts Institute of Technology, Mildred S. Dresselhaus is quietly but firmly directing the show. She answers questions from a member of her lab group and, in the next sentence, asks another if he is free to pick up a visitor at the airport that afternoon.

Next, she moves on to me and says, correctly, "You look like you're looking for me." We find an empty conference room "away from the phone," and immediately I have her full attention. It is, I learn later from her friends and colleagues, "typical Millie." "She has these fantastic personal skills and inexhaustible energy," says M.I.T. colleague physicist Daniel Kleppner. "She manages to do two or three things at once and do them well. She's never sitting idle."

Indeed, the scope of Dresselhaus's career is imposingly impressive: a leader in carbon research for 40 years; author or co-author of nearly 1,000 scientific papers, articles and reviews; adviser to more than 60 doctoral students; national officeholder in several professional science associations; and past director in the U.S. Department of Energy's Office of Science, one of the largest funders of basic research. To top it off, she has 17 honorary doctorates and was awarded the National Medal of Science in 1990.

All this, begun at a time when professional currents pushed much harder against her gender than they do today. "We didn't think we had a career in physics," she says of women physicists of her generation. "We were just doing it because we were interested and hoping we could do some kind of research." But she got lucky and found herself under the tutelage of past and future Nobel Prize winners. In 1951 she graduated with a physics

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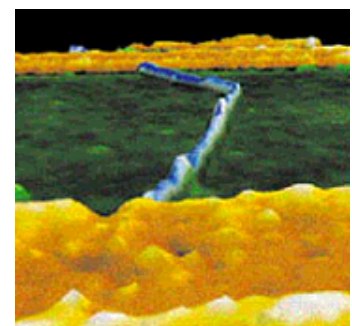
degree from Hunter College, where one of her mentors was medical physicist Rosalyn S. Yalow. After a year at the University of Cambridge on a Fulbright fellowship, she received her master's degree from Harvard University, where her adviser was physicist Norman F. Ramsey. She completed her Ph.D. in solid-state physics at the University of Chicago, where she took classes from Enrico Fermi. "I learned a lot from him about teaching methods, how it's important to get things simple," she recalls. "If you can't explain it simply, Fermi wasn't really that interested in it."

At Chicago in 1956, she met her husband, solid-state physicist Gene F. Dresselhaus. Four years later the Dresselhauses had found themselves posts at M.I.T.'s Lincoln Labs. It was a great place to work, she recounts, "but it had only one drawback--they expected me to start the job at eight o'clock in the morning," which wasn't always possible once they'd had four children. After many reprimands, she found refuge in a visiting professorship in the electrical department, which turned her post into a tenured position a year later. In 1985 M.I.T. granted her an Institute Professorship, its highest academic honor; only about a dozen such posts exist.

Dresselhaus has made her name in the field of carbon physics. Early in her career she unveiled the mysteries of the way electrons are organized in graphite (technically, its electronic band structure). She discovered that the identification of electrons and holes (positive charges created by the absence of electrons) in the material had been interchanged, thus answering a variety of previously open questions. She was among the first to utilize lasers for magneto-optics experiments, and she was a pioneer in determining how certain semimetals, including vanadium and niobium, transport heat and electricity. Dresselhaus also did founding work in intercalation physics, the determination of the properties of materials that are interlaced with other materials, such as graphite with alkali metal layers.

Over the past decade Dresselhaus has focused on the burgeoning field of carbon nanotubes, which in the last year has seen a doubling of published papers, to an annual output of more than 1,500. In 1992 she predicted with her husband and Riichiro Saito from the University of Electro-Communications in Tokyo that carbon nanotubes could be either semiconducting or metallic depending on their geometric characteristics-- an extraordinary hypothesis borne out by experiment in 1998. "The science is booming right now," Dresselhaus says, and the potential applications for it are diverse, including flat-panel displays, hydrogen energy storage, building construction and drug delivery. Nanotubes hold great promise as well for electronics, portending a drastic shrinkage of wires and electronic devices, with a concomitant increase in speed [see "Nanotubes for Electronics," by Philip G. Collins and Phaedon Avouris, *Scientific American*; December 2000].

Even as she was helping to lay the foundation for a nanotube future, Dresselhaus kept in mind the service side of science. "My own undergraduate education at Hunter College cost me \$5 per semester, which covered tuition, laboratory charges and textbooks on loan," she noted in 1997 while president of the American Association for the Advancement of Science (AAAS). "The taxpayers invested in me." Her decision to tackle the administration of science was prompted, she elaborates now, by her election to the National Academy of Engineering in 1974. She has been president of the American Physical Society and treasurer



CARBON NANOTUBES are

of the National Academy of Sciences, just two of the many posts from which she has been able to give back to taxpayers, to her discipline and to science at large. Name a committee, and Dresselhaus has been on it--and was probably its chair.

Her last public appointment began in August 2000 and effectively ended in November, with the presidential election. Energy Secretary Bill Richardson had asked her to direct the Department of Energy's Office of Science, overseeing a \$3.1-billion budget (placing it among the largest federal supporters of science) and five national laboratories. Dresselhaus agreed, even though it was at the tail end of the Clinton administration. "Then came a confirmation process that was very, very discouraging," she says: it was drawn out over 10 months while legislators played political football. She can't pinpoint the reasons for the delay. "It had nothing to do with me, nothing to do with my post, nothing to do with science. It's the way politics is done," she observes.

CARBON NANOTUBES are promising in part because they can have various electrical properties, Dresselhaus found. Here a tube (*blue*) acts as a nanometer-wide wire connecting two electrodes (*yellow*).

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Late in his term President Bill Clinton became particularly interested in science, she says: "He saw the connection between science and the economy." But Dresselhaus is disappointed in the present administration's attitude. "The president personally has not much interest in it, and he doesn't have people around him with much interest." The Bush administration did not even respond to her offer to stay on at the DOE until the next appointment was made, and ultimately she simply packed up and left. (In December, President George W. Bush announced his intention to nominate Raymond L. Orbach, now chancellor of the University of California at Riverside.)

Noted ecologist Peter H. Raven calls Dresselhaus a "foremost role model." Director of the Missouri Botanical Garden and current president of the AAAS, Raven was secretary of the National Academy when Dresselhaus was treasurer. He praises her for being firmly anchored in family life while forging ahead with contributions as a scientist. In a scientific life that has been remarkably broad in scope, Mildred Dresselhaus has not forgotten to go deep as well.

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