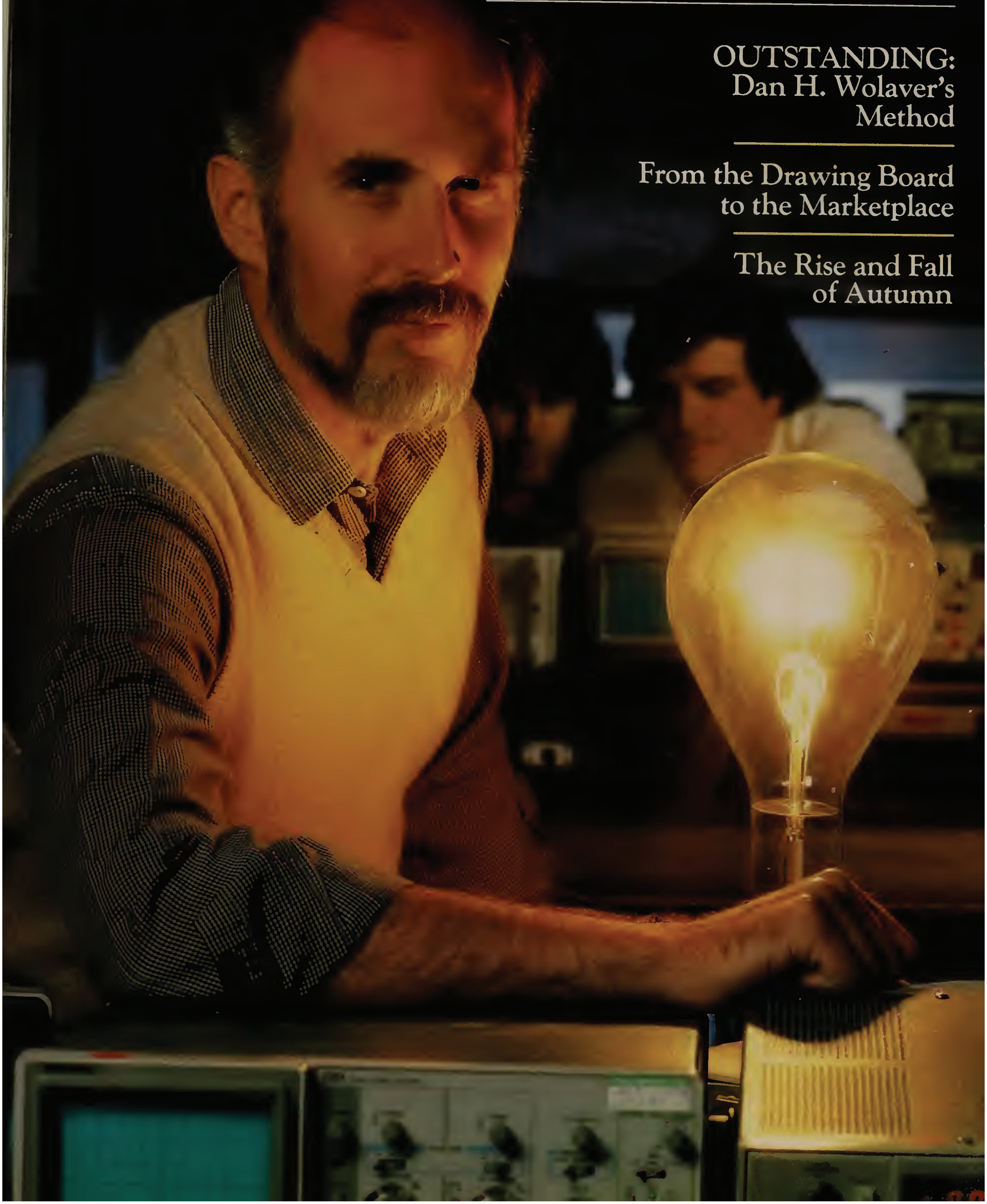
WPI Journal

WORCESTER POLYTECHNIC INSTITUTE FALL 1986

OUTSTANDING: Dan H. Wolaver's Method

From the Drawing Board to the Marketplace

The Rise and Fall of Autumn



A Special Message to WPI Alumni, Parents, and Friends

Over the past few weeks, a few of us here in University Relations have been at work preparing brief biographical sketches on those individuals who have contributed to the endowment of WPI over these past 12 decades of our history. The first such donor, of course, was John Boynton, who anonymously provided the challenge to "the citizens of Worcester": If they would construct a building for the new school, he would endow the college with much of his lifetime savings. In 1865, that amount—$100,000—was a handsome sum, for at that time the barter system served as the means of exchange for most families.

Those sketches tell a wonderful story of the history of WPI, one different from the usual "college history"—the study of presidents, the development of academic departments, and the evolution of the campus. In a sense, these essays on many of WPI's benefactors recount the real outcomes of the WPI experiment. That experiment—*Lehr und Kunst*, teaching and skilled art—has come to serve so well so many of us during our lifetimes.

Many of those donors provided gifts of consequence that resulted from highly successful careers. Some donors had little direct connection with WPI. And with special poignancy, many wives left much of what remained of their inheritances (some large, some small) from their "Tech men" to the institution for which their husbands had had a special affection.

Equally striking to me were endowments that came from individuals who had had comparatively modest careers and who, by frugality and at times self-denial, returned to WPI something of what they felt the college had meant to them. This history of WPI, *In the Founders' Footsteps,* will be published in late November. I hope many of you will be interested enough to write to me for a copy. A good story of American science and technology will be contained within its covers, as well as a special human history of the builders of today's WPI.

Since the very first day of classes on November 10, 1868, WPI has quietly gone about the business of educating young men (and since 1968, young men *and* young women), preparing individuals for careers of economic worth and social value. Some 118 years ago this month, that first class of 32 students faced a barren hillside with two lonely sentinels—Boynton Hall (dedicated on November 11, 1868) and Washburn Shops—on the outskirts of what was to become the second-largest city in New England. But as the years ticked by, each successive freshman class found a campus steadily enriched with new resources: a growing faculty, better equipment, new buildings and playing fields, more books, a wider variety of student activities, *and* more scholarship and financial support.

Whenever each of us may have passed through what Richard W. Lyman, our 1986 Commencement speaker, referred to as "our pleasant hilltop campus," we benefited, albeit sometimes unknowingly, from the beneficence of those who passed before us. Over the years, what the school has become is due in no small measure to the support that had been provided by the countless other believers in John Boynton's challenge. Today, as our history demonstrates, if an institution is to grow in strength and stature, it must continue to attract resources, both material and human. And in the domain of science and technological education, the Institute had better not stand still!

Very shortly, our alumni and friends will be hearing about a major campaign for support as WPI prepares for its 125th anniversary in 1990. This campaign will seek the resources required to make WPI—today a very *good* institution—into an *excellent* one, the goal articulated by President Jon C. Strauss in his inaugural address last May. Thus we have launched the "Campaign for Excellence." Between now and 1990, we will be seeking $52.245 million, no mean sum.

We begin this effort on a very solid foundation. WPI's budgets have been balanced for 11 consecutive years. And with periodic surpluses, the Institute has been able to acquire property along its borders for future expansion, especially for student residences, and to keep deferred maintenance on our physical plant to a minimum.

This fall, we welcomed an oversubscribed freshman class—740 strong. In academic achievement, it is the strongest in at least a generation. More than 60 percent of these young men and women came to WPI because financial aid was provided. Some 20 new faculty, a full 10 percent of their total numbers, were recruited in the past year, six in electrical engineering alone. And fully refurbished outdoor athletic and recreation facilities are now available to a college community that is perhaps more fitness-conscious than ever before.

This foundation is the legacy of our past support: donors to the Annual Alumni Fund; individual gifts; planned gifts and bequests from alumni, parents, and friends; and grants provided to us by local, regional, and national businesses, corporations, and philanthropic foundations.

What WPI can become in 1990—our next historic milestone—depends upon you. If WPI means as much to you as it has meant to those represented throughout *In the Founders' Footsteps,* it will leave me in great confidence that the Campaign for Excellence will succeed, ensuring that WPI will continue to be the vital, progressive institution that we are today.

All of us are going to be asked to pull hard on the oars!

Best wishes to all our readers for a year-end holiday season filled with life's rich blessings.

Donald F. Berth

Donald F. Berth '57
Vice President for University Relations

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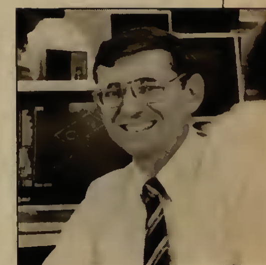
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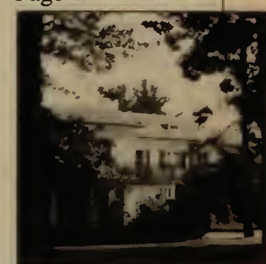
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Cover: Electrical Engineering Professor Dan H. Wolaver has been honored with the 1986 WPI Board of Trustees' Award for Outstanding Teaching. Story on page 35. Photo by Michael Carroll.

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The Importance of Private Higher Education

Michael Carroll

Recently, I had the opportunity to speak with a prospective trustee of WPI about why he should take on the responsibilities that membership on the Board involves. I spoke, of course, of the excitement I found at WPI, and of the rewards of service to young adults and the community.

I also emphasized the importance of private higher education in the United States and its contributions to our nation's acknowledged worldwide leadership in post-secondary education. Without our independent colleges and universities, I postulated, higher education as well as the nation itself would *never* have developed as rapidly as it has.

As Harvard University, the nation's first college, recently celebrated its 350th anniversary, it and our 1,800 other independent colleges and universities can be proud indeed of the leadership they have provided. For at private institutions such as WPI, it is merit alone, unfettered by the bureaucracy of government, that decides the fate of curriculum content and process, scholarly research, and insti-

"Private colleges are free to pursue educational goals in an environment that brings together the best that free enterprise and healthy competition have to offer."

By Jon C. Strauss

tutional administration. We are able to pursue educational goals in an environment that can be characterized as the best that free enterprise and healthy competition offer.

Most experts agree that, were it not for the quality standards set by private institutions of the caliber of Harvard or Stanford, the nation's premier public institutions, like the University of California or the University of Wisconsin, would be mere shadows of their present forms.

Moreover, those same experts would affirm that the Massachusetts Institute of Technology, WPI, and our peer institutions provide educational innovation and quality that serve as models for distinguished engineering schools at public institutions such as the Universities of Massachusetts or Illinois.

Here at WPI, the Plan is a good example of the creative power of private education. Emphasizing outcomes rather than just the process or content of education—real-world problem solving rather than lock-step curricula—the Plan serves as proof of principle for engineering and science education the world over.

Understandably, implementation and, more recently, enhancement of the Plan have required what accompanies any new venture: a willingness by its creators to take risks, together with the commitment of time, personal sacrifice, and financial resources needed to make the change viable. It is unlikely that this sort of innovation could have occurred in the typically more conservative realm of public higher education. The costs would be too high, the changes too severe. But at WPI, as in business, we encourage prudent risk taking and successful innovation in the pursuit of knowledge.

> "The continuing success of our public colleges and universities depends on enhancing the quality of our private institutions."

Some will argue that what appear to be significantly lower costs of public higher education portend the ultimate demise of our private institutions. Yet this view ignores respected studies indicating that the publics are often *less* cost efficient than the privates.

The costs of tuition and room and board may appear significantly lower at public institutions, but this is due largely to the substantial subsidies which publics derive from taxpayer "contributions." Still, colleges such as WPI cannot ignore the dynamics of the marketplace, especially in these days of dramatic reductions in the number of high school seniors nationwide. [You may be interested in turning to page I, for a story entitled "Higher and Higher Education," which addresses the issue in some detail.]

Let's examine the scenario in which U.S. higher education is influenced by private institutions. We can gain some insight into this situation by looking at the history of educational systems that have not benefited as directly from private institutions.

Europe is a good example. The great public universities—The Sorbonne and Heidelberg, for instance—while known for their extraordinary scholarship, have been far less influential in the societies they serve than have U.S. universities. In fact, many observers contend that U.S. universities are having a greater impact on Europe than many of Europe's own institutions.

Similarly, universities in Japan and other Eastern nations seem to have remarkably little impact on the societies and the commerce they serve. This situation cannot be fully ascribed to the absence of a healthy private higher education sector in Europe and the Far East, but that absence is certainly a contributing factor.

Typically, governments—state or federal—are too cumbersome and too far removed from the needs of academia to be permitted to be solely responsible for standards of higher education. Less influence on education by the public sector leads to more effective responses to society's needs.

Higher education's public sector, however, is far from an intellectual wasteland. Many of the publics enjoy hard-earned reputations for excellence in teaching and research. For the sake of the nation and the world, they had better: public colleges and universities educate more than 80 percent of the nation's undergraduate students and perform over 50 percent of federally sponsored research. To extend the argument offered above, the continuing success of these institutions depends in no small measure on enhancing the quality and vitality of our private institutions.

As we face this challenge, it is vitally important that every member of the WPI community—trustees, faculty, students, staff, alumni, and friends—recognizes the special trust and responsibilities thrust upon each of us as members of private higher education.

And, oh yes, the prospective trustee with whom I discussed what I've shared with you is now the newest member of the Board. As such, he has accepted the responsibilities of helping the Institute evolve and prosper for the years and generations ahead—for the benefit of WPI and all of society, at home *and* abroad.

"In our schools and colleges, the aim should be to train the mind rather than to impart technical information."
It was in 1915 that L.B. Stillwell, former president of the American Institute of Electrical Engineers, made that remark. Seventy-one years later, Stillwell's belief that engineers must learn how to think, not just how to do, remains a challenge to engineering educators—the central theme in a pedagogic debate that has spanned decades.
But accomplishing this balance, at a time when innovations in science and technology can become obsolete in just months, calls upon educators to be inventive themselves. And while much has changed in technological education, some things have not.

In the 30 years since the Soviets launched Sputnik and spawned the space race, technological development has intensified to the point that innovation is commonplace. Engineering students who toil four and sometimes five years to master a body of rapidly changing knowledge often find their training outdated soon after graduation. The dilemma for engineering schools is twofold: how to stay abreast of new developments without becoming mired in soon-to-be obsolete technology—and how to turn out engineers and scientists who are able to keep current long after they graduate.

For WPI, meeting the challenges of the post-Sputnik era has meant renewed attention to the values L.B. Stillwell expressed at the turn of the century, when satellites, robotics, and genetically engineered organisms were still the dreams of science fiction writers.

"We've moved a long way from a 'how to' orientation toward a focus on *why* things happen," says William R. Grogan, dean of undergraduate studies. A member of the Class of 1946 who returned as an electrical engineering instructor after World War II, Grogan became involved in efforts to adapt WPI's curriculum as the space race triggered a shift in priorities from techniques to engineering science.

"During the '50s we had many, many courses that were handbook oriented," recalls Grogan. "There was a great deal of drill and repetition. A lot of the labs were simply boring—'do this, do that, verify the principle.' There wasn't much creativity involved, and reports were often copied from fraternity files. Students did a great deal of analysis, but very little synthesis."

After Sputnik, however, intensified research efforts created a "knowledge explosion" which Grogan says made it impossible for students to remain abreast of the latest generation of technologies and techniques. "Practice became a moving target," he says. "The only things that remained stable were the fundamentals."

A deep shift in classroom instruction and laboratory projects from current practice to underlying principles resulted. But even as the revised approach enabled engineers to function better in a rapidly changing technological environment, Grogan says it also created frustration and confusion. "There was a much longer period of time before students saw the fruits of their efforts," he explains. "Under the old system, they could design things quickly. Now it took longer to understand subjects like physics and mathematics. That was very frustrating for some students, especially if they had been drawn to engineering for the hands-on gratification."

To restore that lost sense of progress and tangible outcomes, Grogan says the WPI Plan, instituted in the early 1970s, introduced the Interactive Qualifying Project and Major Qualifying Project as degree requirements. "The projects have been extremely effective, both in enabling students to synthesize ideas and in aiding their personal growth," says Grogan, who discovered the motivational value of projects in his own classroom as early as the 1950s.

In 1973, WPI introduced another change in curriculum structure. Seven-

Tech 101: The New Curricula

By Evelyn Herwitz

week terms replaced 15-week semesters, and student course loads shifted from a half-dozen classes per semester to three per term. The idea, says Grogan, was to help students concentrate on a few subjects at a time, rather than "just go from course to course." But even as the four-term structure better enables students to focus their attention, Grogan admits it is still an imperfect solution to an age-old pedagogic problem.

"We have always tried to teach too much in too short a period of time, and we always will," says Grogan, "because I think students have an enormous capacity to learn that is not often tapped. But sometimes we delude ourselves into thinking that if we've covered something in class, the students understand it. You can cover a barn with a thin coat of paint—but will it last through the winter?"

How to explain fundamental, abstract concepts within a tight time frame is of particular concern to the Physics Department faculty. Though the basic subject matter in freshman physics has not changed dramatically since the 1930s, a renewed emphasis on concepts has intensified the challenge of explaining ideas that contradict intuition.

"In the late 1960s, the introductory physics courses were far and away the most hated courses on campus," says associate professor Van Bluemel. Along with professor Thomas H. Keil, Bluemel is teaching freshman physics this year. "When we came here in the mid-'60s, the courses were very drill oriented," says Keil. "Since then, we've been trying to place greater emphasis on concepts and ideas, rather than just plugging in variables to set problems."

That shift to an even more abstract focus, however, has not necessarily increased enthusiasm for freshman physics. "Students often come into freshman physics with the same conceptual biases as Aristotle," says Bluemel. "To really understand the discipline, each person must go through an intellectual transition similar to the historical development of classical physics."

The basic dilemma can be illustrated with a simple example: "Imagine you are sitting in a car that suddenly starts moving forward," explains Department Head Stephen N. Jasperson. "You feel as though a force is pushing you back against the seat. But actually, what you experience is a force moving you forward, when your body wants to stay at rest. That's why Newtonian physics seems strange—because the principles seem contrary to expectations based on your experience of the world."

Even more alien are the concepts underlying Einstein's theory of relativity, first published in the early 1900s. "Of all the material presented in introductory courses," says Jasperson, "relativity is probably the most unsettling because it's so obviously at odds with experience. If two events happen simultaneously for one person, we're accustomed to believing the same is true for everyone else. But not according to relativity."

Although these contradictions have been plaguing students and professors for nearly a century, pedagogic approaches to them have only recently come under close scrutiny. So strong are

In the Solid State Physics Lab, this student built a capacitive dilatometer capable of taking experimental measurements at extremely low temperatures. Using advanced technology gives students a better feel for the abstract concepts of physics.

Michael Carroll

Michael Carroll

Computers have reduced part of the detailed analytical work of freshman chemistry to split-second tasks, freeing up time to study such fields as quantum mechanics and thermodynamics. Learning other lessons, however, still requires goggles and flasks.

student preconceptions about the physical world, reports recent research in the *American Journal of Physics*, that conventional instruction, regardless of teaching method, typically fails.

"Learning physics is a lot like mastering a foreign language," says Keil. "Not only do you need to understand English terms that are used in a very different, specific way than you're accustomed to, but you also need to understand mathematics and graphics. We tend to translate quite freely among the three, but most freshmen can't."

Hoping to bridge that conceptual barrier, Keil has developed the first in a planned series of computer modules for freshman physics. "It's designed to create a kind of play space where students can experiment with physical concepts," he explains. "The module starts with a projectile on top of a cliff. Students can adjust factors like height and speed, and the computer records the trajectory and other data about the projectile's motion. It's a way of giving students a world more like the one we're trying to teach them about."

Unlike the world of physics, the world of chemistry is readily observable. Lab experiments are replete with bright colors, strong odors, occasional loud noises and often unintended, but equally instructive lessons in phenomena such as the effect of acid on denim jeans.

But in keeping with the trend among all sciences since the 1950s, chemistry as a discipline has become more quantitative. At the freshmen level, what was once a course in descriptive inorganic chemistry now includes a heavy dose of physical chemistry.

Subjects such as quantum mechanics and thermodynamics, which provide the theoretical structure for analyzing physical properties of chemicals and chemical reactions, are now central to a curriculum that once emphasized memorization of formulas.

"We used to focus on problems like what a substance looks like, what reacts with what, and the characteristics of the reaction," says Nicholas K. Kildahl, associate professor of chemistry, who this year is teaching the freshman course. "Now we ask questions like how much energy is released during a particular reaction, rather than focusing on the reaction itself. Quantum mechanics has enabled us to look deeper, beneath the phenomenologic observation, to explain why things happen."

The shift away from descriptive chemistry, however, has sparked some criticisms. "Presumably, the theoretical approach gives you a background for meeting new situations and gives you a basis for understanding new developments as they come along," says Wilbur B. Bridgman, professor emeritus and a physical chemist. "On the other hand, theory can't explain all chemistry yet. One simply has to learn some facts as facts." That concern, shared by many

"Thirty years ago, many labs simply bored students: Do this, do that, verify the principle. Lots of analysis but little synthesis."

chemists who fear that students are learning theory at the expense of mastering the language of chemistry, is, according to Kildahl, prompting a "big move" to return to descriptive chemistry.

Nonetheless, powerful analytical tools such as quantum mechanics are now an accepted part of any freshman chemistry course.

Labs, too, have become more quantitative. And the demand for more detailed data observations has prompted development of a whole new generation of instrumentation that has revolutionized the chemistry lab. In upperclass and graduate analytic chemistry, for example, the spectrometer, which reveals the identity of chemical components by analyzing how much light a solution absorbs, has replaced laborious, "wet" techniques for isolating substances.

Freshmen also benefit from instruments such as electronic balances. "Thirty years ago, it took a long time to weigh things," says Professor Ladislav H. Berka. "Then, you'd record the scale reading each time the needle stopped swinging on either side of the zero. Adjustments with weights would be made until the initial average with empty pans was again obtained. You could take as many as eight averages in one weighing.

"Now it takes about two seconds to put your sample on an electronic balance and simply read the weight. You can get a lot more accomplished."

William Denison

Michael Carroll

Veteran ME Lab Technician John "Joe" Gale shows his welding techniques. Below left: In 1915, in PC (Pre-Computer) days, this was the scene in drafting rooms. Right: Now, PCs hold sway in the engineering design graphics course taught by John J. Titus (l) and George Y. Jumper, Jr.

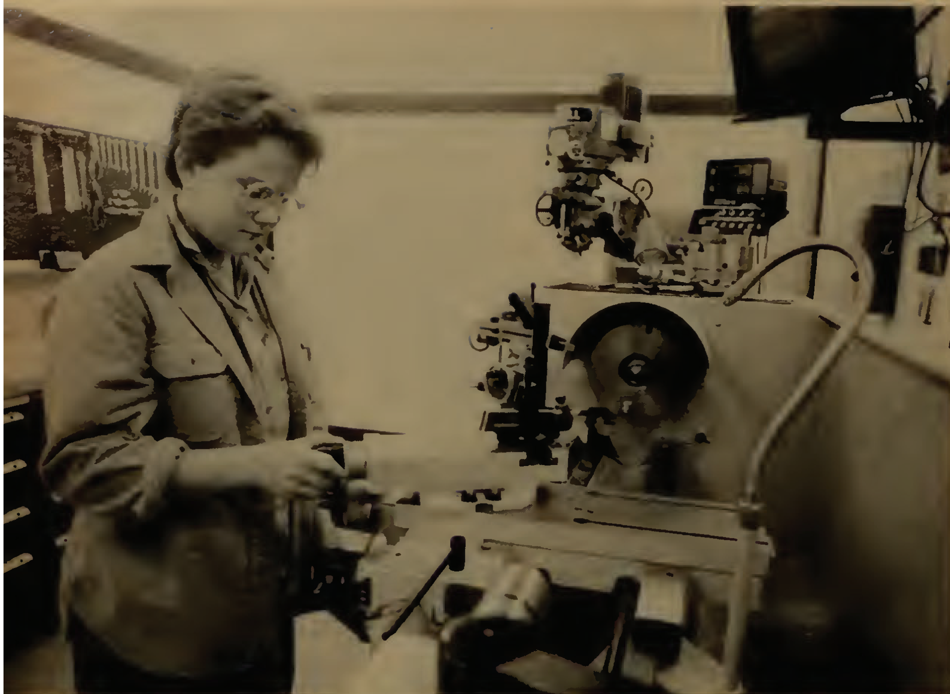
Much as the tools of the chemistry lab have changed in the past three decades, no less dramatic has been the transformation in the drafting classroom of WPI's Mechanical Engineering Department. Once filled with rows of drafting desks, the large room in Higgins Laboratories now houses dozens of computer work stations. In front stands a blackboard-sized screen that projects a view of the instructor's video display.

Demonstrating how the system works, Associate Professor George Y. Jumper, Jr. instructs the computer to recall a simple drawing of a square with a diagonal line across the upper right corner. As he types on the keyboard, the square rotates through different planes, revealing the object's true identity: a cube with one corner sliced away.

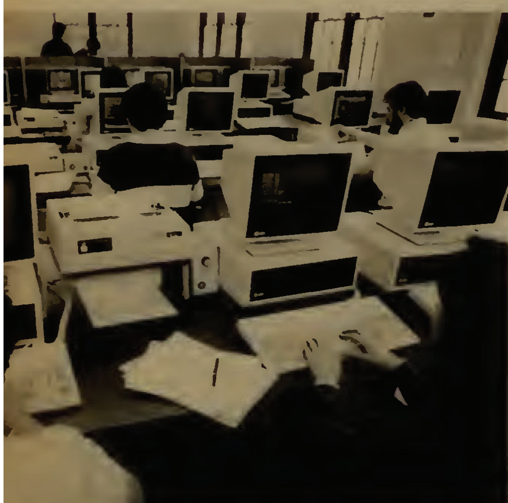
"The student creates a three-dimensional mathematical model of the object, and then the computer does a two-dimensional representation in any view the student selects," explains Jumper. "The results are very professional. At the end of seven weeks, everyone can make a fantastic, polished drawing."

Evidence of the computer's power lines the classroom walls. Prominently displayed is a student's detailed wire frame drawing of a can crusher; nearby, for inspiration, an intricate illustration supplied by Wyman-Gordon Company of a forging that resembles a topographical map.

Initiated last fall, the micro-CADD lab (short for microcomputer aided design drafting) has transformed engineering



William Denison



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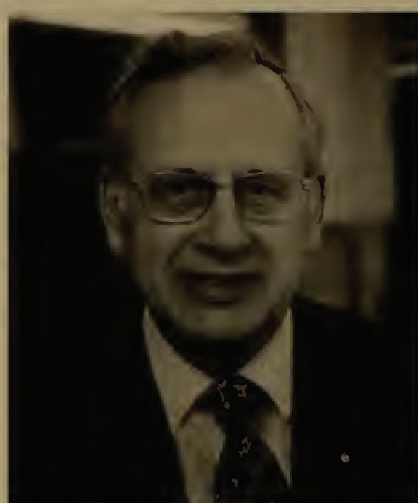


Chuck Kidd

design graphics from a course that most students tried to avoid to one of the department's most popular offerings. "They're having a ball, making these drawings," says Jumper, as he deftly instructs the computer to turn a point at the tip of an abstract figure into a red sphere. "The computer eliminates a lot of the tedium."

While students still study basic sketching techniques and design standards, much of their class work involves learning how to create and manipulate engineering designs on the computer. "Drawings are an important way that engineers communicate with each other," says Jumper. "If used properly, the computer can do the dog work of drafting while the students learn to address the tough conceptual questions. And it allows them to put their learning into practice the way it's done in industry."

That strategy of using state-of-the-art technology to increase student mastery of fundamental concepts is central to the mechanical engineering curriculum. As in other scientific and engineering disciplines, the trend has shifted away from what Department Head Donald N. Zwiep calls "information transfer" toward mastery of principles basic to all engineering problems. Modern computational tools like CADD encourage that learning process by increasing the student's ability to tackle in-depth problems.

But Zwiep's basic advice to new ME majors is the same as it was when he joined the faculty 30 years ago: Develop a strong background in basic math and science, a working knowledge of engineering science and design, and an understanding of the humanities and social sciences.

"Though necessary, information transfer must be combined with the ability to learn on a 'need to know' basis in a professional atmosphere," says Zwiep. "Then the half-life of the engineering graduate becomes infinite because learning becomes a continuous rather than a finite process.

"Engineering involves a lifetime of learning. Anyone not willing to dedicate himself to that is dead in the water."

Washburn Shops features state-of-the-art machining tools and video systems. Center left: The PC labs in Higgins are usually full. Right: ME Department Head Donald N. Zwiep urges learning on a "need to know" basis.

Of all the engineering disciplines, one of the most dramatically affected by recent technological developments is electrical engineering. With the invention of the transistor in 1948, ever smaller and more efficient electronic circuits have become possible. Every decade has brought major technological breakthroughs: digital computers in the 1950s, integrated circuits in the '60s, microprocessors in the '70s, and very large scale integrated (VLSI) circuits in the 1980s.

In the EE lab, computer work stations have replaced benches littered with wires, electronic components and soldering irons. With a few keystrokes, students can design schematic diagrams of integrated circuits on a color monitor. Once their designs are complete, they can test them on the computer using simulation tools. The debugged design, recorded on disk, can then be sent to a chip manufacturer for production.

Beginning this fall, partly in conjunction with Westboro-based Massachusetts Microelectronic Center (M^2C), students learning the basics of VLSI design will have access to an even more convenient way of making chips. Called electrically programmed logic devices—EPLD—the technology uses "small" chips, containing 2,000 to 3,000 transistors (in contrast with the 50,000 to 500,000 transistors found in microprocessors), unconnected by any wiring.

"You plug the chip into a programming board connected to a personal computer," explains Professor Wilhelm Eggimann. "You can then program the chip to do what you want. Then you simply unplug the chip and try it out."

The Challenge of Faculty Recruitment

Recruiting engineering school faculty in the post-Sputnik era has often proved as challenging as striking the right pedagogic balance between principles and applications.

In recent years, competition for science and engineering Ph.D.s has intensified, as high-technology firms siphon graduates away from academia. In addition, says Richard H. Gallagher, vice president and dean of the faculty, there has been a "doubling of output" from engineering colleges, increasing competition among universities for a limited supply of qualified faculty members.

"Fifteen years ago, 40,000 students graduated from engineering schools in the United States," says Gallagher. "Today, the figure is somewhere between 80,000 and 90,000." In part, he says, those figures represent general demographic shifts. But the increase in engineering students also reflects the drawing power of a high-tech career and the influx of women to engineering colleges.

With more students to teach, the search for qualified faculty has intensified. "It has always been difficult attracting individuals who are excellent teachers with some commitment to research," says Gallagher. "But I think the WPI record shows we've been very successful." —EH

Like an audio cassette that continues to play a message until erased with a magnet, the chip will retain the programmed circuits until it is passed under ultraviolet light. "If the program works, you can make a dozen chips by just plugging them into the program," says Eggimann. "Instead of waiting two months for your chips to be manufactured, you wait just two seconds."

But even as students, anxious to learn the latest in chip design, flock to take courses in what is now WPI's largest department, EE faculty members share their colleagues' pedagogic priorities. "The technological applications change about every 10 years," says EE Professor Harit Majmudar. "We choose different problems. But the principles remain the same."

Like ME's Zwiep, Majmudar stresses the need for engineering students to master fundamentals, rather than get caught up in the complexities of current applications: "Physics and math are technology-neutral, as are the basic principles of engineering analysis and problem solving. The good engineers and scientists who will do research and be leaders have to excel in thought processes and problem solving."

Evelyn Herwitz is a free-lance writer living in Worcester.

Michael Carroll

Left: Wilhelm H. Eggimann, EE associate professor, shown with colleague Ronald J. Juels (r), teaches VLSI circuit design. Right: Professor Harit Majmudar sums up that EE's fundamentals remain the same.

DRURY LANE AT REGENT STREET

There was no question now. As soon as they were "settled," they must engage a maid. A real maid. Not a hired-girl, nor an oafish Mrs. Lundstrom. Something to match the house. A black uniform and white apron for dinner. And dinner would be at night—not at noon.

—Esther Forbes, *Miss Marvel*

They were still newcomers, by Worcester standards. Neither descendants of Revolutionary War heroes nor city founders, they hadn't been in town long enough to join the high-society families over on Elm and Cedar Streets. But they had been in town long enough to make more money in a year than most of their neighbors would earn in a lifetime.

Men with a knack for turning inventions into marketable products, they were Worcester's rising industrial elite. Their fortunes were built on grinding wheels, forging, drawn wire, and textiles. And they intended that their homes would reflect their accomplishments.

So in 1899, when Worcester partriarch Stephen Salisbury III—a WPI trustee and son and namesake of the WPI founder who gave the land on which the college is built—decided to subdivide his land on the hillside west of Park Avenue, these up-and-coming families were among the first in line for parcels.

Most of the lots along newly named Massachusetts Avenue, Drury Lane, and Regent Street were small—an acre or less—and expensive by turn-of-the-century standards. Parcels sold between 1899 and 1901 went for $3,000 to $11,000, depending on lot size.

But the houses were at least as large as the owner's budget could allow—and sometimes larger. Servants' quarters were considered a necessity, and the latest innovations, such as central vacuuming systems, were touted features.

It was a lifestyle far removed from the factory floors that made all this possible. As families like the Jeppsons, Stoddards, and Fullers moved in, the elegant hillside neighborhood behind the newly constructed American Antiquarian Society building soon replaced Elm and Cedar Streets, a half-mile to the south, as the nucleus of Worcester's upper-class establishment.

Although the lifestyles of their owners may have changed, the 19 homes built between 1899 and 1919 in what is now Worcester's only local historic district retain the grace and charm of that pre-World War I era. And at least three of the homes have been preserved in much the same style as they were built. Owned by WPI, the Jeppson House at 1 Drury Lane, Hughes House at 15 Regent Street, and Thayer House at 4 Regent Street are now home to the Institute's president, vice president and dean of faculty, and vice president of student affairs, respectively. The three "executive residences" are among 16 off-campus buildings owned by the college.

Donated by WPI trustee George N. Jeppson and his wife, Selma, in 1941, 1 Drury Lane was the first of the Institute's three acquisitions west of Park Avenue. Now home to Jon and Jean Strauss, the former Jeppson residence was a later addition to the Massachusetts Avenue neighborhood.

Though the Jeppson family lived in the house for many years, the original owner was Frank O. Woodland. A Swedish immigrant, Woodland bought the one-acre tract from Stephen Salisbury's heir, the Worcester Art Museum, in 1912. Worcester architect Lucius Briggs, who

The Institute's three homes recall the spoils of Worcester's early industrial growth. They are among our most handsome and heavily used facilities.

By Evelyn Herwitz
Photos by Michael Carroll

helped design the Worcester Auditorium and War Memorial, drew the blueprints, and contractor E.J. Cross built the two-storied, stuccoed, Georgian Revival mansion.

Woodland lived in the house for only a few short years. Not long after he built his home, the story goes, Woodland suffered a major financial loss and committed suicide. His estate sold the house to Julia C. Brown in 1916, who in turn sold it to Thilda A. Jeppson two years later. Thilda was the wife of John Jeppson, George's father. As was the custom of the times, title to real property was often placed in the wife's name.

"There was a crack in the tile in the downstairs bathroom," recalls John Jeppson, son of George and Selma, of visits to his grandparents' house. "As children, that's where we thought the bullet went!" Further speculation about the

Opposite page: This solarium, one of two in Jeppson House, offers an informal flavor to the otherwise public feel of the main floor of the house. Right: To the left of the main staircase in this executive mansion stands a door to the dining room.

The Strausses are the seventh WPI first family to live at 1 Drury Lane, donated by the grandparents of John Jeppson (left). Opposite: the living room.

demise of the home's unfortunate first owner was "not encouraged," however, adds Mr. Jeppson. Still, there was plenty to do and explore in the 16-room home at 1 Drury. "We had great visits at my grandparents' every weekend," says Mr. Jeppson, past president of Norton Company, who retired in 1984 as the company's honorary chairman. "My grandmother was very solicitous. She used to feed us too much and take us for rides in their Pierce-Arrow."

The elder John Jeppson, a potter by trade, together with Milton P. Higgins, first superintendent of the Washburn Shops, Professor George I. Alden, and others, founded Norton Company. Jeppson died when young John was only five. "He worked beautifully with his hands," says the younger Jeppson, who describes his grandfather as a "bearded patriarch" who kept a potter's wheel in his Norton office to make mugs and vases for friends on special occasions.

When Thilda died in 1925, a few years after her husband, Mr. Jeppson's father, George, inherited the estate and moved in with his wife and three children. For young John and his sisters, Britta and Betty, nearby Bancroft Tower Park soon became a favorite place to play. And John found his own special spot on the Drury Lane grounds: a stone post that proved the perfect perch for watching WPI baseball games.

The house itself had lots of doors and corridors to inspect and an attic playroom. There were other interesting features too, like the huge dryer in the basement, with its six-foot racks that slid in and out of a giant, gas-heated frame. And the north and south porches had heating pipes running under the ceramic tile floors, "so your feet would stay warm even in the winter," says Jeppson.

For the most part, George and Selma Jeppson made only minor changes, splitting one upstairs bedroom into two, and adding a poolroom in the cellar. An avid gardener, Selma Jeppson created a formal garden off the south porch and built a terrace to the east of the garden.

"The house was very Swedish—very light and neat and airy," says Margaret Erskine, who grew up around the corner at 8 Massachusetts Avenue and was a schoolmate of Betty Jeppson. A full compliment of Swedish servants discouraged any kind of horseplay, she recalls. "You always behaved very properly there. It was a pretty posh existence."

Her mother-in-law, Katharine Erskine, also recalls visiting the Jeppson home. A member of the Bancroft School's board of trustees, which George Jeppson chaired, she was once invited to 1 Drury for a smorgasbord breakfast. "The house looked very much as it does today," says Mrs. Erskine, who can remember walking with her sister, author Esther Forbes, through the fields that became 1 Drury Lane. "It was a very handsome home. We always looked up to it as an outstanding, attractive addition to the hillside."

Bancroft School trustees were just some of the many guests whom the Jeppsons welcomed. Undoubtedly their most notable visitor was Crown Prince Gustaf Adolf of Sweden. "Worcester was one of the centers of Swedish activity in this country, and he was making his rounds," says John Jeppson, who was about 10 at the time. "He was a tall, dark-haired, good-looking guy. My parents had a tent set up on the Park Avenue side of the house, and we had invited him for lunch." Other than that impression, Mr. Jeppson's most salient memory of the Crown Prince's visit was being "very upset at having to wear a sailor suit!"

The Jeppsons continued to prosper during the 1930s, and enlarged a country home they kept in Brookfield, MA. They also acquired a house in Florida, where George Jeppson had hoped to retire.

A trustee of WPI, George Jeppson decided to donate the Drury Lane home to the Institute in 1941. At the time, the assessed value of house and property was $46,000. But John Jeppson believes the market value was actually closer to $60,000. Today, estimates David Lloyd, former WPI treasurer and vice president for business affairs, the estate is worth nearly three-quarters of a million dollars.

Despite his plans for retirement, however, George Jeppson stayed on at Norton longer than he'd intended. Having already given up the Drury Lane home, and not wanting to commute from the country house in Brookfield, George Jeppson found an apartment in Worcester. Eventually he bought another house in the city, which he sold after the Second World War ended.

The center of Jeppson family activities is now their Brookfield country home. And the house once visited by the crown prince of Sweden now welcomes WPI faculty, staff, students, and out-of-town guests.

Following a tradition established by Admiral Wat Tyler Cluverius, the Strausses are the seventh presidential family to reside at 1 Drury Lane.

The once ivy-cloaked, stuccoed facade, with its broad porte cochere on the west side, is now painted a light gray with striking maroon trim. Inside, light grays and pastels dominate, recreating the airy feeling that once characterized the Jeppson home.

A panelled study to the left of the foyer provides a refuge for President Strauss—his "brainstorming room," according to his wife, Jean. For her, the cozy study is also a favorite place to "curl up with a good book" in front of the fireplace.

The foyer opens onto a large living room with its own black marble fireplace. On the mantel is a trombone, one of several antique brass instruments displayed throughout the room. Other personal touches include a small Shaker desk in the foyer that stands next to a skulling trophy won by George Alden's grandson.

Borrowed from WPI's archives, the trophy has special significance to Jean Strauss, a former national singles rowing champion who finished eighth in the 1980 Olympic team trials for skulling. Today, she and the president keep in shape by rowing on Lake Quinsigamond. In fact, she says, "It was Jon's interest in learning to row, while we were both living in the Los Angeles area, that helped bring us together."

Enjoying her new home for its "coziness" in spite of its size, Jean says she especially likes the twin solaria, one at either end of the house. Both decorated in white wicker and cool pastels, the green-tiled north patio and blue-tiled south patio provide relaxing, intimate spaces that balance the more formal central living and dining rooms.

The south patio, she says, with its sunny bay window and view of a walled-in garden, is her favorite room—"a great place to enjoy a morning cup of coffee." The bay window is also a favorite perch for one of the Strausses' pets, L.A. Alley Cat, who revels in a good stretch in the morning sunshine. Meanwhile, the couple's two dogs, George and Gracie, make themselves at home in the terrace beyond

the walled garden.

Back through the foyer and up the curving front staircase, past an antique grandfather clock presented as a gift from alumni to WPI, is the master bedroom suite. There, a cozy living room with a white marble fireplace opens onto a bedroom with private bath. "Sometimes living in this house feels like living in a fishbowl. It's not difficult, but it's different," says Mrs. Strauss. "This suite is our private place."

Of the remaining eight bedrooms, the Strausses have combined three to create a suite for a caretaker who watches the house and animals when they are away.

With its spacious yet comfortable main rooms, inviting patios, and gracious grounds, 1 Drury Lane has all the elements for a variety of social gatherings. More than 3,000 guests, including members of the senior class, faculty, staff, and alumni, have visited with the Strausses during their first year at WPI. "I love entertaining here," says Jean Strauss.

Just across the street from the Strausses' home, at 15 Regent Street, proudly sits the Hughes House. Now home to WPI Vice President and Dean of the Faculty Richard H. Gallagher and his wife, Therese, the two-storied brick house was donated to the Institute in 1959 by Earl C. Hughes '14 and his wife, Mary.

Built in 1919 on land purchased from the Worcester Art Museum by a Mr. Batchelder in 1917, the house was the last to be constructed in the neighborhood. Also designed by architect Lucius Briggs, the home is believed to have been constructed by E.J. Cross. With its hipped roof and balanced chimneys over a central, symmetrical section, the house exemplifies the Regency Revival style popular at the time. Other features then in vogue were the small portico supported by Ionic columns and dentilled cornice.

In 1922, Batchelder sold the house to John F. Tinsley, vice president and general manager of Crompton and Knowles,

At 15 Regent Street, Dick and Terry Gallagher stand beside the foyer staircase that curves up two flights (far left). The Regency Revival style home (right) was a gift to WPI from Earl C. Hughes '14 and his wife, Mary. The house features at the rear a latticed entryway and garden fence.

and his wife, Helen. The Tinsleys lived at 15 Regent Street until 1954, when the home was sold to Earl Hughes, then vice president and later president of Bay State Abrasives.

"Mother fell madly in love with the Tinsley house," recalls Emma King Hughes Peterson. Daughter of Mary Hughes and step-daughter of Earl Hughes, Mrs. Peterson was already married by the time her parents moved to Regent Street from the house they'd built in 1927 on Salisbury Street. With only her youngest brother, Earl Jr., still living at home, Mrs. Peterson says her parents wanted a smaller place than their six-bedroom Salisbury Street house. (That home is now the Petersons'.) Their new residence, which at the time contained two bedrooms, better suited their needs, she says, and was also more accessible by car in the winter.

"It was a gracious, lovely, comfortable home for entertaining," says Mrs. Peterson. "Mother especially loved the staircase that curved up two stories over the front door. She wanted everyone to be married there."

Other favorite places were the panelled library/living room, and, to the rear of the house, a sunny music room where Mrs. Hughes used to keep both an organ and a piano. On the sun porch to the right of the music room, Mrs. Peterson recalls her mother's card room, which was always set up with card table and chairs. To the left of the music room was a bar which opened onto a formal dining room.

"She did a lot of entertaining there and loved it," says Mrs. Peterson. "They thought they'd be there forever." But as things turned out, Mr. Hughes's health necessitated a move to Florida. An "ardent supporter of WPI," Mrs. Peterson remembers, Earl Hughes decided to donate his home to his alma mater. In January of 1959, when the Hugheses presented their home and 40,000 square feet of land to the Institute, its assessed value was $29,500. For gift purposes, however, David Lloyd says the house was valued at $75,000. Today, he places the property's worth at nearly a half-million dollars.

For about a year after the Hugheses moved to Florida, a minister from All Saints Episcopal Church occupied the home. Then T.W. Van Arsdale Jr. became the first WPI vice president to live at 15 Regent Street.

The Gallaghers are the fifth WPI family to reside in the Hughes House. Having lived there for the past two years, Terry Gallagher enjoys her home as much as did her predecessor, Mary Hughes.

"It's large enough to entertain in, but small enough to feel like home," says Mrs. Gallagher. The formal dining room, with its intricate floral scrollwork over door and fireplace, and the mahogany-panelled library are spacious but not overwhelming. What was once Mrs. Hughes's music room is now the Gallaghers' living room; the sunny card room, a television room; and the bar, Dean Gallagher's study.

Upstairs, the large master suite features a tiled shower with nine nozzles. "You can really get a good spray!" notes Mrs. Gallagher. Two other bedrooms share a connecting bath, while what were once the maid's quarters over the kitchen today provide a spare room and extra study.

Avid travellers who have visited 54 countries on six continents, the Gallaghers have personalized their home with treasures from their trips. A collection of Japanese Hakata dolls is displayed beneath a glass coffee table in the living room, and glass shelves are filled with articles as varied as a stuffed bird from China, a carved wood zebra from Africa, and an ostrich egg fragment.

"We've blended a lot of modernism with the older furniture that belongs here," says Mrs. Gallagher. "It's a grand old house. We're so proud of it."

A few houses down on the other side of the street, 4 Regent is the third executive residence acquired by WPI. Purchased in 1966 for use by the vice president for student affairs, the nine-room house and 8,000 square feet of land sold for $22,000.

Now worth around $400,000, the two-and-a-half-storied, stuccoed house was built in 1916 on land purchased from the Worcester Art Museum by Earl Thayer.

Designed by architect Edward Topanelian, son of a prominent Armenian community leader, the Georgian bungaloid house is distinguished by first-floor palladian windows and a heavy, hipped roof with a pedimented dormer. Mission influence is evidenced in such exterior features as the triple double-hung windows above the first floor, and the deep roof eaves with exposed outriggers.

According to Frances Thayer Chapman, oldest daughter of Earl and Rosa Thayer, the interior of the house was in large part a mirror image of the house Topanelian designed for her aunt.

About five years old when she moved into the house with her parents and younger sister, Eleanor, Mrs. Chapman remembers the home for its circular front

Bernie and Gayle Brown share the Thayer House with their three teenagers, Matthew and twins Jody (left) and Tara (right). A sunroom, situated off the formal dining room, is a highlight of the stuccoed Georgian bungaloid, purchased by the Institute in 1966.

Thayer's detailed woodwork graces the main staircase and living room.

stairway, mahogany-panelled living and dining rooms with their built-in, leaded-glass shelves, and, best of all, the third-floor play room. "We had a doll house there with all the fixings," she recalls.

Initially, she believes, the sun room was an open porch which her parents later had enclosed and heated. Though the grounds were small, there was always the Antiquarian Society across the street. "We used to play hide and seek there," says Mrs. Chapman.

After her husband's death, Rosa Thayer remained in the house until she died in 1965. At that point, Mrs. Chapman says she and her sister decided to sell the house to WPI. "The college seemed to want it very badly, and we knew it would go into the right hands and be well maintained," she says.

First home to Dean of Students Martin VandeVisse, the Thayer House recently became the residence of its fourth WPI family, Vice President for Student Affairs Bernard H. Brown; his wife, Gayle; and their three children.

Brown's predecessor, Robert F. Reeves, remembers 4 Regent Street as "a very comfortable house" with beautifully crafted interior woodwork. He also appreciated some of the antiquated, but intriguing, features of the place. "It had a central vacuum system, which they used to activate by hauling buckets of water to a tub in the attic," explains Reeves. "They poured the water into an airtight container. As the water flowed out, it would create a vacuum." Wands attached to holes in the walls of each room would suck dirt into a collection chamber in the cellar.

That vacuum system hasn't been used for years. But other features of all three houses have kept WPI's physical plant staff busy. As in any old home, problems such as corroded pipes, basement flooding, and worn gutters have required attention. Of 4 Regent Street, for example, WPI College Engineer Anthony J. Ruksnaitis says, simply, "Murphy's Law has presided in that home since the first day we bought it." Of the three homes, Ruksnaitis says 15 Regent is the most solidly built, and has required the least work.

Though disasters tend to strike at the most inopportune moments—a pipe broke in honor of the Strausses' first Christmas Eve—the residents have high praise for WPI's maintenance staff. Of both WPI's plant services department and security force, Terry Gallagher says, "We feel very much protected."

And despite any maintenance difficulties, all three houses are valuable and valued acquisitions. Generous gifts or prudent investments that have enabled several members of the Institute's leadership to live in style and to enhance campus social life, these magnificent residences stand as reminders of a significant period in Worcester's economic and architectural development.

Higher and higher education

Paying for private college in the 1980s brings up the issues of higher costs, bigger debts, threatened cuts in aid, and the search for a good return on investment.

Photographs courtesy Chronicle of Higher Education

By Donna Shoemaker

Rob Ruth's story seems almost a vignette from America's past. From the 8th grade on, he helped his parents on the family dairy farm in Telford, Pa. Rob banked on receiving the reward for his labor much later, in the form of college tuition for his pre-veterinary studies. Rob and his sister both chose to attend the same private college, Franklin and Marshall. The Ruths sold a tract of land to developers to help pay for eight consecutive years of hefty college bills. At F&M, Rob found a new interest, in human medicine, and this fall, he's at Harvard Medical School. "I won't be taking over the farm," he says.

"My family and I have followed the philosophy that we try not to borrow more than we have to," Rob explains. But it's here that his story takes a contemporary twist. Despite his own labors and his family's foresight, Rob has already accumulated almost $10,000 in debt for student loans and undoubtedly will owe far more before becoming Dr. Ruth. But he's willing to accept that responsibility. Adds his father, Merrill Ruth, "If Robert wants to do it, we're going to get him through one way or another. He's always really hung in there." Both father and son are sensitive to the long haul ahead. "My parents are looking toward retirement. I hate to have to see my father continue to work," Rob adds.

His undergraduate debts are about on par with the national median debt level ($9,000) for 1986 graduates who borrowed for college. In the 1980s, for the Ruths and for other families with children in college, the rules of financial survival have been changing as the cost of a college education—particularly at independent institutions—has far outstripped inflation. With four years at a prestigious private college now costing about $65,000, has the price surpassed the ability of a middle-income family to pay? On whom has the burden fallen the hardest? For years the specter of "creeping careerism" has loomed over the liberal arts: Do heavier student loan debts tend to herd young people into the more lucrative professions? Whose responsibility is it to pay for the education of the next generation?

In these and other questions—about access, about the competition between publics and privates, about the long-term effect of a "fly now pay later" approach—can be found a core concern: People want assurance that the big-ticket purchase of a private college education still carries a tacit guarantee of value and lasting worth.

In private colleges, to provide the small classes, the first-rate faculty, the latest equipment, and the finest facilities that the public has come to expect, there seems to be no obvious stopping point where spending won't have a return in quality. In that quest for excellence, influence, and prestige, colleges can spend a limitless amount "for seemingly fruitful educational ends," noted Howard Bowen, one of higher education's best-known observers, in his seminal report for the Carnegie Commission (*The Costs of Higher Education,* 1980).

"You never have enough money. You always know what to do with the money you bring in. So we bust a gut to go out and raise a little more," adds Michael Hooker. That's true for public or private institutions, he believes. He has experienced both worlds: Since July, Hooker has been chancellor of the University of Maryland Baltimore County campus and formerly was president of the nation's most expensive college—Bennington—where this year's tuition, room, and board run $16,950. He sees how educational costs keep spiraling upward. The funds aren't used to lower tuition but for such things as recruiting and retaining good faculty, decreasing course loads and class sizes, stocking laboratories and libraries, and supporting faculty travel and development programs.

"There is a crunch now," Hooker adds. "The publics are faced with the same motivation to improve their quality that the privates face, and they're not getting enough resources either, so they are turning to private sources. I understand the resentment the privates feel at this because I felt it myself at Bennington."

He says his favorite argument when he was there was that "private education is as cheap as public education—the per-student cost is no greater. But in the private sector, you've got to charge students more." He kids, "I always cringed when I said that because I wasn't sure I was telling the truth," although he did feel Bennington delivered "quality for the price" and provided generous financial aid. Sighs Hooker, "The sad fact of life is that there is more quality to be had than we have the capacity to pay for."

In 1950, one-half of the nation's 2.3 million college students attended private colleges and universities. Today, with almost five times that many college students, only two out of 10 are enrolled in independent institutions. Since the 1950s, public universities have been riding the crest of the G.I. Bill, the baby boom, and the Sputnik-inspired drive to expand and to improve education, all of which swung open the door to the democratization of higher education. Public colleges and universities thus have dramatically grown in their percentage of the market, in enrollments, and in quality as well. A college education is no longer a luxury but a necessity required by the business world even for most entry-level positions.

From the 1920s to the 1960s, both public and private higher education wended their way with relatively stable tuition, adjusted for inflation. Tuition in the early '70s at private institutions more or less kept pace with the rise in the per-capita disposable personal income. Tuition and fees at public colleges and universities, then on the average one-fifth the price of the privates, rose more slowly.

During the latter part of the '70s, college students, whether they realized it or not, were getting somewhat of a bargain. The federal government significantly expanded financial aid for middle-income families; in 10 years alone, federal loans swelled from $1.8-billion to $10-billion in 1986. It was also a time when inflation deflated faculty paychecks and maintenance projects were deferred for lack of funds. Retrenchment—achieved through cutting back on such expansionist staples as an ever-larger freshman class, new programs, and tenured positions—became an unwelcomed ritual in academe.

Meanwhile, the traditional pool of college students—the 18-year-olds—was beginning its projected decline. (The demographic reality is that, between 1979 and 1992, the pool will shrink by 25 percent.) The decrease is expected to hit hardest in the 13 states where 51 percent of the private four-year colleges are located and will be felt most deeply by those liberal arts colleges drawing upon their home states to fill the beds. For such institutions, 75 percent of whose operating budgets are funded through tuition, losing too many potential students to the competition could turn the belt-tightening into tourniquet time.

The federal aid designed to ease the "middle-class squeeze," some critics say, has instead subsidized even higher tuition. And now real and threatened cuts in federal aid are particularly alarming to private institutions. The 1980s ushered in four years of double-digit tuition increases at the privates; in 1982–83, some colleges even announced increases of 20 percent. The past two years have brought more modest increases (6 to 8 percent), still well ahead of the rate of inflation. The 1986–87 tuition and fee increases for public four-year colleges averaged 6 percent. At a public four-year college, the current average tuition and fees are $1,337 (and a total cost of $5,604 for resident students). At a private, four-year college, tuition and fees average $5,793 (with a total cost of $10,199 for resident students), reports the College Board.

In the 1980s, people are asking if private, liberal arts colleges are pricing themselves out of the market. When that question had occasionally come up before, noted Thomas E. Wenzlau (in *The Crisis in Higher Education*), judging from the tuition hikes the trustees approved, the answer was No. However

Eric Poggenpohl

"The publics are faced with the same motivation to improve their quality that the privates face."

much the institutions believe the increases are justified, at times the public rebels. You hear complaints about the "Ivy-League" cartels controlling prices or claims that college is affordable now only for the affluent.

"When perceptions become accepted as reality, it does not really matter what the data show," observed Terry W. Hartle, a resident fellow at the American Enterprise Institute. His report, released last summer, takes exception to the perception that college costs have been skyrocketing. He found considerable stability in the cost of college over the past decade or so, at least for families with students in college—a group usually at the peak earning power and higher income level. Analyzing data from the U.S. Census Bureau, he concluded, "the bottom line is that for most median-income families with a child enrolled in college, higher education does not require a significantly greater share of family income than it did 10 years ago. The exception is at selective private colleges and universities, where price increases are quite pronounced."

You can see that jump in the figures he cited: In the past 12 years, when the consumer price index rose by 142 percent, private four-year college charges rose by 179 percent, private universities by 199 percent, public four-year colleges by 149 percent, and public universities by 143 percent.

Since 1980, Hartle added, the gap between family income of those with children in college and those whose children do not attend has become wider. But the data he used don't tell precisely how many of those students have had to forego college or attend a less expensive institution because of high costs.

Private colleges traditionally have had special appeal for people willing and able to pay a premium for excellence. The same holds true for institutions educating students for the careers most in demand. Thus, for the nation's top tiers of private colleges and universities, the more they charge, the more attractive they become. "Frankly, we haven't had to do a lot of justifying" to parents about why tuition keeps going up, states Robert Voss, executive director of admissions and financial aid at Worcester Polytechnic Institute (WPI). And at F&M, adds Donald Marsh, associate director of admissions, parents "don't see much difference between institutions in terms of costs" as they and their offspring look for a quality education.

Not only does the "prestige" factor push up college costs, but an economic irony seems to be at work as well. The greatest increases ever in college costs are coming right in the midst of this ballyhooed post-baby-boom drop in the number of 18-year-olds and a constrained era in higher education in general, in which the weakest liberal arts colleges may not survive. And yet quite a few colleges (generally the more selective ones) are finding that freshman applications, acceptances, and aptitudes (based on SAT scores) are on the rise. "Many colleges have had one of the best years yet in admissions," says Rob Ruth, who worked in F&M's admissions office this past summer. That gave him a sense of confidence—at least a short-term one—that F&M and its liberal arts peers face little danger of overpricing themselves.

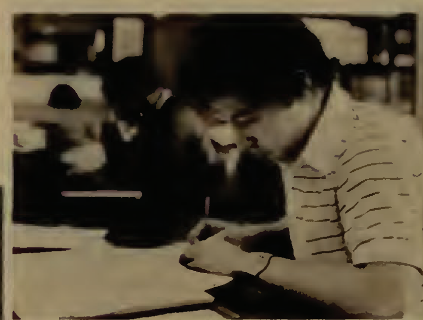
"We're swimming in success," beams Donald Berth, vice president for university relations at WPI. WPI had expected a freshman class of 640 this fall; instead 740 showed up for orientation, or "100 more than we can comfortably handle. It's the relative attractiveness of science and engineering in this age," explains Berth. Villanova University closed its admissions earlier than usual last year (in February), swamped with 8,000 applications for 1,500 spaces, says W. Arthur Switzer, associate director of financial aid. Adds Villanova's dean of admissions, the Rev. Harry J. Erdlen, O.S.A., "I'm beginning my 11th year in this position. Ever since I've been here, I've been told the '80s were going to be the dark days." Instead, there's a silver lining in the gloomy predictions. Applications increased from 5,600 to 8,600 over the past 10 years, and, Father Erdlen adds, "the quality of the applications has increased significantly with us, especially last year."

Faced with a struggle for the survival of the fittest (and fattest-coffered), it's no wonder that there is jubilation among the private colleges experiencing red-letter days in admissions—and even some cheers among those simply holding steady in the level of applications. Amid this encouraging supply of prospective freshmen, it seems there would be little reason to cry wolf.

But the evidence is increasing that the wolf is at the door. Some would slyly suggest that he comes disguised as President Reagan's secretary of Education, William Bennett, a vociferous foe both of what he perceives as abuses in federal financial aid and the deteriorating quality of education at all levels. Others might say the wolf is dressed in sheepskin's clothing: They foresee students flocking away from privates to the best publics to earn their degrees, in search of the green pastures of high quality at a lower price. A recent Carnegie Foundation survey of high school seniors showed 80 percent of the respondents thought the high cost of college was "outrageous."

"We in higher education should be concerned. The tendency to push the market as hard as we can, albeit for noble ends, is gradually and undesirably altering the character of higher education," warned Michael O'Keefe, president of the Consortium for the Advancement of Private Higher Education, in a hard-hitting article in *Change* magazine (May-June). He took colleges to task for tuition increases double—and occasionally triple—the rate of inflation. He urged the privates to show restraint and not to take "excessive advantage of the tendency of parents and students to equate higher prices with higher quality."

College benefits both society and the individual. Who should pay to educate the next generation while it prepares for the future?



Beverly Taylor

Others on campuses have been issuing warnings as well. "I cannot justify the way tuition has increased. When inflation has gone up 4 percent, you can't justify an 8-9 percent increase in tuition. It will backfire on us and we'll reach a point of no return," states an East Coast university admissions official. A financial aid expert adds that he sees this concern over costs showing up "in the expressions of distress from students and parents, guidance counselors, and many others. You see it in the level and volume of unpaid bills—there's an increased pressure on the bursar to go out and *collect* college bills. We have to tell too many students to make some arrange-

ment to pay your bills or you're going to be dropped from classes."

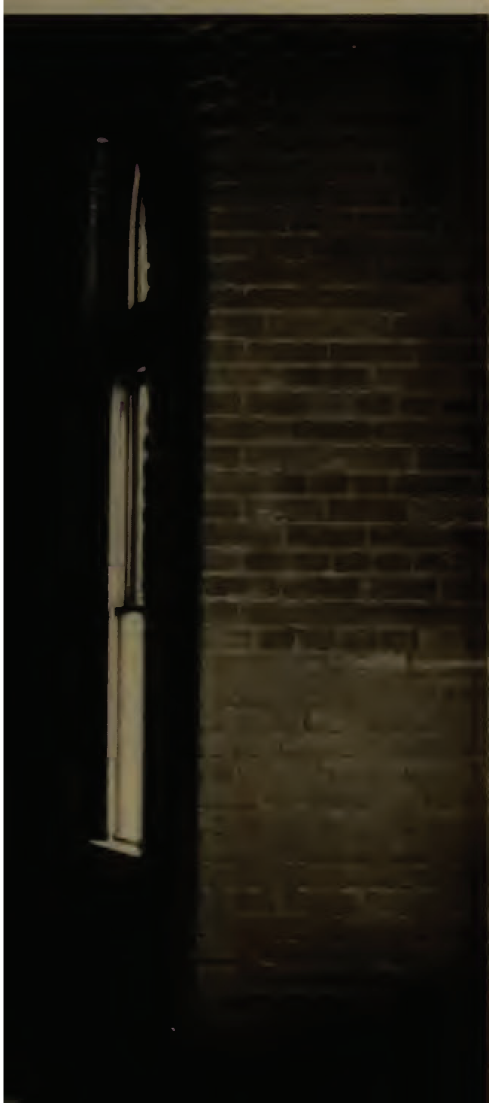
The rhetoric—and reality—of cost containment and quality control have been making themselves known in higher education. The nation seems awash in a rising tide of studies probing why Johnny and Jane can't read, write, and think—or afford college. Secretary Bennett lost no time in cautioning students and their parents "to kick the tires and look under the hood of higher education." His *caveat emptor* to college-goers has been heeded as a caveat in at least a few ivy towers, too.

In response to the continuing challenge to make higher education more affordable, several institutions have launched unusual consumer-oriented pricing policies. Among them is Duquesne University's "zero-coupon education." Parents can purchase for their infants four years of a Duquesne education at today's price, saving thousands of dollars in the long run (if their child opts to go to another college, Mom and Dad will recoup only their initial investment, without accrued interest). Southern Methodist University last year announced a plan to finance four years of a set rate of tuition over a 10-year period, with either a fixed or variable interest rate. Williams College has a popular 10-month installment plan for tuition payments. In spirit at least, such plans have much appeal, even if most institutions haven't jumped on the bandwagon yet. Notes Villanova's Father Erdlen, "I would personally like to say to freshmen, 'This will be your cost, and we will hold that for four years.'" A few institutions have already put that promise into practice.

"The biography of an American family is written in its cancelled checks," is how Howard Bowen so aptly began his book on the costs of college. Today, the collective checkbooks of the families of 12 million college students tell tales of change, challenge, and stress. On one page we read biographies of parents whose own parents put them through college but who now ask their own offspring to pay their way by taking out large loans. On another page we read of the incredible wealth to be found in the upper echelons of American society. Turn the page, and we read the troubling stories of college students forced out because they can't afford to pay.

The stories have a common theme, of coming to terms with just who should assume the responsibility for supporting the next generation while it devotes four years to preparing for a personal and societal future. More and more nontraditional students, among them adults, are going to college, thus adding other complexities to the picture: What about the 30-year-old single mother, trying to meld part-time parenting, studies, and employment into a full life? Who picks up her college tab when financial aid is so limited for continuing education?

Don Berth at WPI points out that, over the past 20 years, the ethic of parents assuming the responsibility of paying for their children's education has generally been abandoned, and not always out of financial exigency. Depriving oneself of consumer pleasures isn't very much in vogue. In years past, he explains, a family would have had almost "a sense of



John C. Phillips

As private colleges become more expensive, their newly won diversity may disappear

"We've simply brought the country club to the campus," says a parent and professor convinced he doesn't like what he sees. David McKeith has taught American history for 25 years at SUNY-Cortland, at Elmira College, and currently, at Ithaca College. He criticizes what he believes are the "excessive expenses" of private education, pricing it out of the reach of the middle-class and "accentuating the lack of sensitivity of people who have money and power for those who don't," he says.

The 1970s, says McKeith, brought a greater diversity of students into the colleges—among them inner-city youths, a wider range of middle-income students, and more minorities—who expanded the collegiate experience for all groups. But he sees such diversity disappearing at private schools, a victim of too little financial aid, as the privates once again become the preserves of the rich. "For all their problems of huge classes, public universities have a much more sensible balance in the classroom," McKeith believes. "So much of this country has been built on middle-class values," he goes on. But those values are becoming scarcer in private schools. "To talk about America's heritage of living on the land and loving it, the rural life, the frontiers, is like talking about some kibbutz in Israel. They've never lived it."

Yet he seeks to preserve the essence of what often distinguishes a private from a public college. He and his wife invite students to their home. He has long office hours. He carries a student load of 85 and refuses to lecture to a class larger than 35. Both he and his wife were educated at private colleges (Colby and Wellesley); their three college-age children have chosen privates as well. Son John graduated from Hartwick College in 1983, some $6,000 to $10,000 in debt, which he pays off in his job of producing videos for high schools. Anticipating $40,000 to $60,000 in expenses to send a fourth child, now 15, to school, McKeith salts away a considerable amount of money each month. "I don't anticipate any help. I'm glad to do something for my kids, but I can't do it all."

gratitude to a college" for providing a quality education. Now, says Berth, prospective students come to college asking, in effect, "What are you going to provide me in financial support if I come here?"

The pages of that American family biography now attracting the most attention are those spelling out danger signals. High debt levels are alarming many in academe—and in the public. Cutbacks in direct grants hamper the educational futures of students. The doors are closing on those unable to pay for a college degree. Having to work at several jobs to earn money is creating a new category of "invisible drop-outs"—students who get less than they should out of college. Minority enrollments are decreasing at the prestigious private colleges; in general, the number of black students going on to college has dropped 11 percent from its peak in 1976 even though 30 percent more now are graduating from high schools.

More and more, colleges have had to infuse operating budgets with large amounts of scholarship aid; the higher the tuition, the more aid is required, and the more they have to charge full-paying students. Most institutions offer packages of loans, work/study jobs, and outright grants. Villanova, for example, requires students receiving financial aid to contribute $1,200 from a summer job and to work during the school year. Switzer points out that putting in that extra 10 to 30 hours a week, on top of a full academic schedule, "is not something to be taken lightly. There is a point beyond which they should not go."

Tales are rife of the labyrinthine formulas for awarding financial aid. Parents are expected to divulge all of their assets and liabilities—even as far as submitting income-tax forms—when their children apply for financial aid. Explains Berth, "When you look at the parent's confidential statement (a required form for financial aid), it's no question that the parent who is frugal and puts the money into the bank or insurance policy to assure that Suzie or Johnny has the means for college is penalized, versus the parent who has a seaside cottage, is mortgaged to the hilt, has two high-quality cars, and no liquid assets. There are too many abuses of that sort in the system."

The burgeoning rise in scholarships at private colleges has even caused some institutions privately, if not publicly, to ask themselves if those funds could not be invested in more productive ways. WPI is one of only a few private institutions that can still hold to an "aid-blind" policy of admitting undergraduates regardless of their finances. Berth observes that this means the Institute each year must come up with $6.5-million in financial aid. He wonders whether $1-million or so of that could better be spent on recruiting top faculty and otherwise improving quality. He fears: "We may have become more generous than we can fundamentally afford."

The rapid growth in the student loan debt has educators most concerned. Switzer gives as an example a common occurrence at Villanova: a graduate who goes on to law school might come out owing $50,000 in loans. Should she marry someone in similar circumstances, the couple would have "$100,000 in debt before they've earned their first professional dollar." Notes Rob Ruth, the F&M graduate, "I have some friends who have graduated and are very worried about paying off debts. But down the road, they will be glad they struggled."

Others are not so sure. Nationally and internationally, the debt burden "is one of the biggest issues facing us now," Chancellor Hooker states. In 1984, 30 percent of all undergraduates borrowed money for their education; nine years previously, only 11 percent had. A study conducted by the Carnegie Foundation for the Advancement of Teaching found the amount borrowed had increased by 300 percent in that period (in constant 1975 dollars). Colleges and universities, says Hooker, are "turning out students shackled with these enormous debts." Undergraduates, now, for instance, can borrow $2,500 a year under the Guaranteed Student Loan program. Hooker adds that students often have little idea of the responsibility they are taking on by borrowing thousands in loans each year. However, "for the colleges, this poses a moral problem because we know what's happening."

It also poses a philosophical concern. As *Change* magazine put it, loans reinforce self-interest values rather than the concept of education as a public resource, intrinsically worthwhile to society. With heavy debts, this college generation, already more preoccupied than previous ones with earning high salaries in their careers, is looking for tangible returns on the investment in education. In decades past, young men and women might have felt more free to study British poetry, European history, Greek philosophy, or anything else that held a fascination in the world of ideas. They accepted that education had a non-trade value: It encouraged one to become a better citizen and it enhanced our civilization. Explains WPI's Robert Voss, "They used to assume that, if they went to college, of course they'd be part of the elite, managerial class. Now they want to see what's in it for me." Voss's colleague, Don Berth, urges, however, that education also needs to be perceived as a value-added investment in oneself—unlike financing a fancy car, which "five years later will be a pile of rust."

What can be done? Many educators call for more massive infusions of funds from all sources for scholarships—and occasionally for more belt-tightening at their own institutions. The somewhat fractured federal policy needs careful scrutiny, too. Under the new federal income-tax law, most borrowers will no longer be able to deduct interest paid on their student loans. Other provisions of the bill prevent parents from channeling income to their offspring to be taxed at a lower rate. The bill also taxes some forms of financial aid and it inhibits the private sector in raising scholarship funds. *Change* magazine suggested that colleges clarify to students any loan obligation; that loans be limited to upperclassmen who have proven they have an 80 percent chance of graduating; that loans be tailored by discipline, class year, and even intended career.

Rob Ruth, the future physician and dairy farmer's son, says, "I knew my money would be well spent at F&M. The level of liberal-arts education is well worth the money." He believes that businesses are looking for the well-educated liberal arts graduate, the "well-versed individual." Rob chose F&M because it is a private college. He liked the prestige, the small classes, the close contact with faculty committed to teaching. A young man firmly focused on achieving his personal goals, he muses, "As I've gone through F&M, I've wondered, if I hadn't majored in biology, would I have put this much money into it if I had majored in drama or history?" He answers his question with a hesitant Yes.

Donna Shoemaker is editor of the Alumni Magazine Consortium.

Ed Thorsett

Willard Clay

Autumn Fire

A languorous fall in England, a dazzling display in America. The contrasts found in these woods and moods are rooted in climatology.

By Jonathan Richardson

Season of mists and mellow fruitfulness,
Close bosom-friend of the maturing sun. . .

Harvest time. Hives brimming with honey. Fleecy barred clouds and cider presses oozing sweet juices. John Keats's ode "To Autumn" overflows with ripeness, plenty, and contentment. His is a slow season—warm, fulfilled, drowsy—the laziest, most comfortable time of the year.

But isn't there more to autumn? Widely spaced memories return me to my boyhood's Connecticut hills, fiery with crimson foliage; to sassafras leaves—half green, half scarlet, still pungent to the nose—scavenged lovingly from Pennsylvania sidewalks by my young daughters; and, near a highway south of Lancaster, to a lone shagbark hickory—a blaze of saffron, still searing my senses like a spicy curry.

Was Keats blind to the vigor of autumn? Had he forgotten the clarity of October sunlight, the air's apple-sharp bite, the brilliance of blue sky glimpsed through painted foliage? Was this most sensuous of poets immune to the exuberance of the season?

Exhilaration, not Keatsian languor, is eastern America's fall theme. To the poet Bliss Carman, New Brunswick-born and New England-bred, "There is something in October sets the gypsy blood astir." In *A Vagabond Song*, it is reveille he hears, not taps:

The scarlet of the maples can shake me
like a cry
Of bugles going by
And my lonely spirit thrills
To see the frosty asters like a smoke
upon the hills.

Why do poets in England and America evoke this season so differently? In this case, comparative climatology illuminates a question from comparative literature. Keats and Carman were capturing very accurately the spirit of the autumn each knew. And these autumns are indeed different. America, unequaled worldwide for brilliant foliage, also is notable for fall's sudden onset, its clear-skied daytime warmth and nightly chill, its swift crescendo to forest splendor and rapid subsidence to dormancy. Keats's English autumn is a gentle, drawn-out, mellow season, joining summer and winter across months of gradual change. If you want "more, and still more later flowers for the bees, until they think warm days will never cease," spend the third season in Keats's part of the world. But stay in America if you seek Carman's passionate autumn, "when, from every hill of flame she calls and calls each vagabond by name."

Arctic winds, the Gulf Stream, and the botanical diversity of our eastern forests all underlie this trans-Atlantic contrast. Some of our native species turn true exhibitionists in autumn; others don more modest garb. But the sum of all is an exceptionally rich, many-hued forest tapestry.

In Europe the deciduous forests are far less diverse and no species approaches the brilliance of our gaudiest American maples, ashes, and oaks. The autumn tapestry of English forests thus is both thinner and paler than our own.

Willard Clay

From ridges to valleys, autumn in America unveils a multi-hued tapestry. Above: a golden glow of maples weaves its way through Arizona's Chiricahua Mountains. Center: A vibrant display of Vermont's finest fall finery is reflected in Keiser Pond.

But why paler? To put this down as a typical illustration of American excess and British reserve begs the question. Let's investigate climatic differences.

In many American forests the heat and dryness of late summer have already signaled the end of the growing season by early September. The chilly northern air masses that successively invade the deciduous region in early fall thus find our trees already approaching winter dormancy, withdrawing nutrients from their leaves, and losing their lustrous green as the metabolic balance shifts from chlorophyll manufacture to chlorophyll decay. More stable yellow and orange leaf pigments—the chemically similar carotenes and xanthophylls—are unmasked by the destruction of chlorophyll. As cool nights come on with a rush, still other pigments—the purple to scarlet anthocyanins, whose manufacture is stimulated by these fall conditions—suffuse the leaves of our most brilliant species. The result of this rush to glory? By early October, foliage pilgrims clog New England highways, and two weekends later most of Washington, D.C., seems to have migrated to the Skyline Drive to see autumn unfurl in the Blue Ridge Mountains of Virginia.

If it is to be unusually brilliant, this autumn must have special weather: Cool, clear, dry conditions produce the finest foliage because lowered temperatures (not so low as to bring early killing frosts), bright sunshine, and moderate drought all favor the manufacture of vivid anthocyanin pigments. But such weather is common enough in an American autumn and anthocyanin-rich species such as staghorn sumac, red and sugar maples, sweetgum, scarlet oak, and white ash seldom fail to delight. In exceptional autumns they do more than delight—they take your breath away.

Western Europe and the British Isles, meanwhile, bask through autumn under the influence of the tropic-spawned Gulf Stream. These lands normally escape Arctic winds until late in the season. Caribbean-born, the Gulf Stream is still warm after thrusting thousands of miles north and east to bathe the shores of Europe. Sea winds, warmed in turn by this mighty current, blow inland with pro-

Willard Clay

found climatic consequences. In autumn, the effect is to keep northwestern Europe moist and mild, favoring deciduous forests but not anthocyanin-rich foliage. Maps depicting the world's vegetation zones clearly demonstrate the Gulf Stream's moderating influence. Although they lie at the latitudes of northern Newfoundland and Hudson's Bay, the forests of England, Denmark, and even southern Sweden are deciduous—the northernmost anywhere in the world. Equivalent latitudes in North America do not receive the Gulf Stream winds and, climatically too fierce for deciduous forests, are home instead to spruce, fir, and muskeg. Because of the Gulf Stream, the chill of autumn comes surprisingly late to Europe's northern deciduous forests, and the trees can safely keep their leaves until the days are very short.

Thus when planted together in city parks and streets, deciduous trees from Europe and America display contrasting fall patterns adaptive to the native climate of each. In New York and Philadelphia, for example, common European species—Norway and sycamore maples, linden, European beech—remain green and leafy far into fall while the American species color and drop early. By quickly entering dormancy, the American species are protected against the early frosts and the unpredictable onset of real winter weather on this side of the Atlantic. But true to their European heritage, the Old World species resist entering dormancy until the days are very short. American city dwellers thus experience a "longer autumn" than do country folk. The latter enjoy only the brief glory of native species, while in town, the bravura performance of "natives" is followed by the paler encore of the immigrants. (Most of these, interestingly, do not produce appreciable anthocyanin even in our climate; like some of our own species, they apparently have never evolved this capability.)

Having not yet entered winter dormancy, the European immigrants are at risk as the American autumn wanes. At home in Pennsylvania, I more than once have seen Norway maples caught in Thanksgiving snowstorms with their leaves still green, fooled by the longer late-autumn days in this alien latitude. Because their leaf-loss timetable is written primarily in terms of day-length rather than temperature, our Norway maples had ignored other indications of the lateness of the season and had kept their foliage. Native species alongside them, however, following day-length timetables evolved in the American climate, were leafless and safe in dormancy long before the snows.

That deciduous trees of both continents use day-length as their autumn leaf-shedding cue is demonstrated by a phenomenon I have often observed: If situated beside bright street lamps, trees tend to keep their leaves later than usual. Sometimes just the branch nearest the light remains clothed. But for those leaves affected, the street lamp evidently mimics a longer day and fools the day-length-activated timing mechanism that triggers leaf loss. If the "perceived" day-length is too long, the hormonal changes that initiate leaf loss do not occur.

Deciduous forests are earth's quintessential litterbugs—the first throwaway society. But before it falls, a leaf in its native climate will have transferred most of its minerals and soluble organic compounds back into the stem and roots—the tree's perennial storage organs. When it falls, the senescent leaf will take with it little more than its cellulose skeleton and its fading pigments. But a severe early frost will forestall this recycling process by killing the leaf prematurely, thus leading to the loss of important nutrients.

American trees in their native latitudes meet this fate relatively seldom because of their genetically programmed early senescence, but this obviously is not true of European species introduced to America. Here, their late leaf retention is maladaptive, and the nutrient losses suffered each fall from frost-killed leaves may be considerable. To be successful in America, these ill-adapted immigrants probably need to be pampered in domesticated landscapes. Here, competitors are discouraged and fertilizers may be applied, helping to restore lost leaf nutrients.

Pamela Zilly

Red maples reward the eye best when cool, clear, dry weather has created just the right conditions. Deciduous trees take their cues from the length of the day and the strength of the light. Before falling, these leaves will transfer their nutrients back to the tree.

Though anthocyanins are the pigments responsible for our most fiery forest hues, species lacking anthocyanin capability are among my fall favorites. Aspen, tulip tree, hickory, the introduced ginkgo, and larch (one of our few deciduous conifers) turn gloriously golden due to a foliar abundance of carotene and xanthophyll. During the growing season these pigments reside with chlorophyll in the leaf chloroplasts, apparently having an accessory light-trapping function in the photosynthetic production of sugar. Another function may be that of screening the sensitive chlorophyll from harmfully bright light: Many of the carotene-rich species grow in exposed habitats or, like aspen, at high altitudes where sunlight is especially intense. In any case, leaf carotenes persist later than less stable chlorophyll, and autumn gold is the result.

Botanists know less about the function of anthocyanin pigments. Adaptive explanations are elusive for the high anthocyanin-producing capability of species like red and sugar maples. Perhaps these pigments, like carotenes, play a shielding role for chlorophyll. But since anthocyanins are produced primarily in the fall, when chlorophyll is disappearing anyway, that explanation seems insufficient. We do know that a deficiency of nitrogen induces anthocyanin production; perhaps this explains the unusually early reddening of sour gum, a species often found on poor soils. Sparse nitrogen supply may also account for the early senescence of bog vegetation: Bogs often form oases of color in still-green September landscapes.

American deciduous species do not march in lock step toward winter dormancy, even though the foliage season is comparatively short. Sour gum often begins its crimson display in August, long before its neighbors show signs of leaf senescence. Another early quitter is witch hazel, a species unusual among trees in postponing its flowering period till fall. Premature leaf loss by this species may make the flowers more visible to fall insects, promoting pollination and successful seed production. Early dormancy also characterizes white ash, whose compound leaves probably have the shortest life span of any in the forest. Appearing late in the spring, ash leaves are gone by early fall, after a few days of bronze and purple splendor. This species must be a very efficient photosynthesizer during its short growing season because it is bare for a remarkable fraction of the year.

As autumn continues, the maples and hickories have their turn, with oaks and beech concluding the foliage parade. Indeed, beech and certain oaks often retain dead leaves through winter, having never fully developed the layer of weak abscission cells that permits aging leaves to break off at their base. The American species, with their subtle, overlapping sequence of autumnal senescence, differ among themselves in latitudinal range and local habitat (such as ridgetops or valleys, dry soils or moist). Each species has thus evolved its own specific day-length timetable for senescence.

Toward the close of the American foliage season, the anthocyanin-rich species have lost their brilliance. A serenity akin to Keats's English autumn brings, at least partly, a new mood. Late last fall, weeks after the foliage pilgrims had departed, my wife and I visited the Berkshire Hills of Massachusetts. As we stepped outdoors on a crisp and sunny morning, waning glory enfolded us. Beyond the low-lying mists of the valley, a mostly leafless forest clothed the slopes in the peaceful bluish-brown hue of bare branches seen through refracted early light. Only two species still bore leaves, and one—red oak, now russet-brown and somber—blended easily with leafless neighbors on the humps of distant hills. Not so the aspen groves! Great streaks of now-pale gold slashed unforgettably through ranks of dormant colleagues. Keats's mood was not complete. Though the fires of an American autumn were banked and dying, the aspens trumpeted one last hurrah.

Willard Clay

Above: A storm stretches over New Hampshire's White Mountain National Forest, dousing for a moment the blazing landscape. Left: On the forest floor, birch branches frame the evidence that trees are the litterbugs of nature.

An ecologist equally at home in forests and tropical lakes, Jonathan Richardson enjoys searching for answers in the great outdoors. He is the Dr. E. Paul and Frances H. Reiff Professor of Biology at Franklin and Marshall College. He is the author of the textbook, Dimensions of Ecology.

Of Father Time, Mother Nature, and a Newborn Idea

Could science be sexist?

A new breed of critics says a male bias in methodology, mindset, and metaphor has hampered the search for scientific truth. This might be the next scientific revolution.

By Leslie Brunetta

Illustrations by Linda Draper

"All of the activities of the scientific method are characterized by a scientific attitude, which stresses rational impartiality."—"Science" in *The New Columbia Encyclopedia.*

And that's precisely what's wrong with science, say a new breed of feminist theorists. Rational impartiality, or scientific objectivity, they argue, is a figment of scientists' imagination because, like any other human activity, science is influenced by its practitioners' culture. The problem is, that culture harbors profound masculine biases.

Science is the last sacred cow among the intellectual disciplines. In recent years, revisionists of many kinds have brought new perspectives to the other academic fields. For instance, it's now an accepted commonplace that "history" is a subjective explanation of events rather than a collection of facts. Society decides what events are important enough to study in the first place, and then in what light they should be seen. The same goes for anthropology, sociology, and all the social sciences. But "pure" science depends upon scientific facts, natural laws, proven models, doesn't it? Where does culture fit in? And how could gender politics affect science?

Easily, say the feminists, especially when gender has something to do with the subject of scientific study. "Science has been used fairly often in the past to justify sexist projects," says Sandra Harding, professor of philosophy and director of women's studies at the University of Delaware. Harding's book, *The Science Question in Feminism,* and her articles are considered by many feminists to be central to the new critique of science. "For instance, when the women's colleges opened in the 1800s, there were scientists who had all sorts of 'evidence' and sincerely believed that intellectual work would physically debilitate women." Women were advised by the nation's top physicians that, since reproduction was the primary function of a woman's body, vital energy routed away from the uterus and ovaries toward the brain would result in a drastic unbalancing of the body's natural equilibrium, and disease was sure to follow.

The male bias can be seen in more contemporary scientific issues, too, as for instance, in theories of human evolution. The widely accepted "man-the-hunter" theory postulates that men were responsible for the invention of tools as aids in hunting. These tools in turn favored the development of bipedalism and an upright stance as well as "male bonding"—men working together without women on the community's most important business. "Such a hypothesis," says Delaware's Harding, "presents men as the sole creators of the shift from prehuman to human cultures."

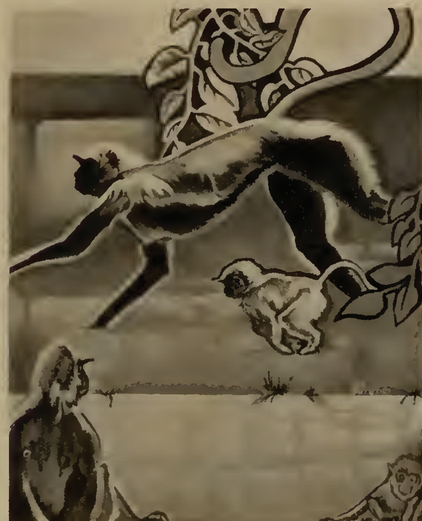
Harding also notes that the only evidence for man-the-hunter is the chipped stone tools found at hominid living sites. There's no way to tell if these tools were used by men for hunting or by women for digging up roots and preparing meat. In fact there's no evidence that women didn't hunt and men didn't work in the hut. Yet those arguing that men's "natural" place is in active, important work and women's "natural" place is in the home often trot out this theory as proof. "The whole hypothesis," Harding says, "is based on androcentric notions."

From the world of animal biology comes another tale of androcentric bias. Ever since the first observers set out to examine the mysteries of primate life, interest has focused on the "dominant male," who was seen to rule the group, choosing his mates and fighting off other males. Using modified versions of Darwin's sexual selection theory, animal behaviorists saw this male as determining his troop's genetic future: His aggressive behavior ensured that his chromosomes were passed on in greatest numbers to future generations. Females were seen to have a passive, though essential, role in passing on his chromosomes.

But females play just as important a role as the dominant male, anthropologist Sarah Hrdy found while studying langur monkeys in the 1970s. A female would often mate with more than one male, with the result that these males wouldn't attack her young, assuming it to be their own. Females also badger and attack other females and their young, causing spontaneous abortions, injuries, and sometimes even death. This behavior helps to ensure that the attacking female's own offspring face less competition and so are more likely to survive and to reproduce. But because this behavior didn't fit into the dominant male model, say the feminists, early observers either ignored it or treated it as a freak occurrence that didn't affect the ongoing life of the group.

Perhaps those are just examples of bad science, of researchers who haven't followed the rules of objectivity. If scientists would rid themselves of sexism when looking at problems involving gender roles or relationships between the sexes, there wouldn't be any problem with science, would there? And surely gender influences only a tiny minority of scientific problems?

Wrong, say the feminists, who argue that science's masculine bias reaches right to the core of the scientific method. Physics and chemistry, as well as the life sciences, are affected in research areas that would seem to have nothing at all to do with gender. Bad science isn't the culprit; science itself is.



Early observers didn't see female langurs as active players in the genetics game.

Historically, men and *not* women have been scientists. Only recently have women had any real access to scientific work above the technician level. (Princeton, for example, which ranks among the nation's top research universities, did not admit women to the graduate physics program until 1971, to graduate astronomy until 1975, and to graduate mathematics until 1976.) Most people would agree with the idea that women's limited access to the scientific world has adversely affected the lives of women. The feminists argue that it has hampered science as well. Simply allowing women in isn't going to solve the problem.

"Our culture puts men into a hierarchy and so they tend to see nature as a hierarchy," says Harding. "It happens to be a way men are conditioned to think." According to the new critics, scientists—partly because they have been raised as men and partly because men have shaped the ground rules of science—look for hierarchies in nature to explain phenomena and then look to see what at the top of the ladder is controlling the lower rungs. That may mean, as in the sexist projects described above, finding surefire "evidence" that the uterus determined the functioning of all other physiological systems; that hunting led by men shaped the beginnings of human culture; that a dominant male controls the life cycle of a monkey troop.

But, say the feminists, the masculine slant also means looking for the unifying laws of physics that will reveal the cause of all physical events; or looking for master molecules (like DNA) to explain the cause of all surrounding functions; or looking for a single virus to account for an illness. The preference for hierarchy has also led to a ranking of the sciences from hard (physics and mathematics) to soft (anthropology and psychology). It has led to assigning greater value to quantitative analysis than to qualitative work. And it has led to dismissing models that stress interdependencies of functions and events rather than controlling elements.

Take, for example, the case of Evelyn Fox Keller. A mathematical biologist, she became interested in the history and philosophy of science in the 1970s and has gone on to become a central figure in the feminist critique of science. Her book, *Reflections on Gender and Science*, is often cited by other feminists as a central text. In the late 1960s, Keller became fascinated with how and why cells in an organism develop different forms and functions even though originating from the same cell. To examine the problem, she focused on cellular slime mold, *Dictyostelium discoideum*, because it can exist in two states. When there is enough food, it remains a self-sufficient single cell; otherwise, the single cells aggregate into clumps. These clumps eventually crawl away like slugs, erect stalks, and differentiate into stalk and spore cells. The spores finally germinate into single-celled amoebas.

The mystery: How does the aggregation, which signals the cells' differentiation, start? A model already existed proposing that "pacemaker" cells spurred on aggregation: The pacemakers gave off signals, passed on by the other cells, calling them together. Keller and her research partner, Lee Segel, had two problems with this model—there was no evidence that the pacemaker cells existed, and aggregation continued even when the supposed pacemaker center was removed.

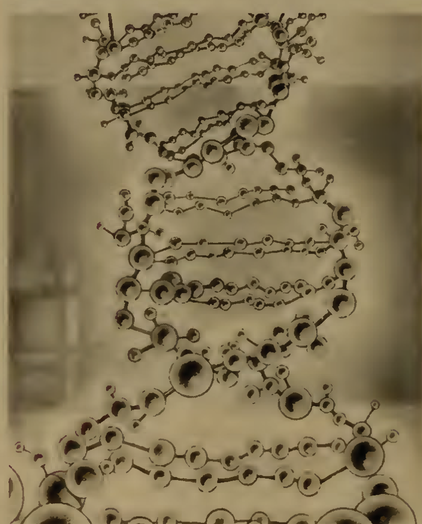
Keller and Segel already knew that each of the undifferentiated cells produces a chemical to which it and the other cells are sensitive. They proposed an alternative to the pacemaker model: before differentiation took place, the cells would either produce more of the chemical or become more sensitive to it in response to a change in their environment. This change in their behavior would upset the cells' spatial stability and cause the onset of aggregation. (Later independent experiments confirmed that these chemical changes did occur and that aggregation followed.) In other words, Keller and Segel believed that the undifferentiated cells' interaction rather than the actions of any master cell lay at the center of the mystery.

The rest of the biology community didn't seem to agree. Even though proof of the pacemaker cells failed to come forward, the pacemaker hypothesis was generally accepted and the search for the pacemakers ended. Keller grants that her model could be greatly improved, given newer, non-linear mathematical equations. But her real complaint, she says, is that the central question—why do the cells aggregate?—was virtually abandoned because the accepted explanation fit neatly into a "central-governor" framework that most scientists were predisposed to accept, even without proof. Keller says in her book: "Such explanations appear both more natural and conceptually simpler than global, interactive accounts; and . . . we need to ask why this is so."

In other words, the critics say, science isn't objective—it's partial. Scientists are predisposed to accept certain ideas as plausible because they fit into the framework of existing masculine experience, which is perceived as reality. Meanwhile, they may be ignoring or discarding more comprehensive explanations and models without even considering them. Scientists may take an objective stance within that framework, but since the framework itself may be skewed, the stance may actually be subjective (albeit unconsciously). Think of the theory of relativity: You may be sitting still in your chair reading this, but since the earth is moving within a moving galaxy, you're moving at a speed and in a direction entirely unfelt and very difficult to determine.

But if the critics are right, why would control be so central to our concept of masculinity that it would carry over into an endeavor stressing objectivity? And would science have been so very different if women had been involved from the beginning? "I question whether wanting to find control is a male-female issue," says Carol Rouzer, a 1976 chemistry major graduate of Western Maryland College who is now a senior research biochemist at Merck Frosst Canada, Inc. "Seeing answers in terms of control may be just a plain human fallibility—some people believe that that's how religion started."

The feminist critics counter that, in the most obvious way, science has been conceived as a pursuit so masculine that females have historically been considered constitutionally incapable of carrying out scientific work. From the time of the Greeks, men have been considered rational and women emotional, men objectively interested in the world around them and women subjectively. There's a resulting circular chain of events, the feminists say: Men value objectivity and so "valuable" pursuits must stress objectivity. Once these pursuits stress objectivity, women (and their attendant subjectivity) must be kept out so that objectivity can be maintained. And, the feminists believe, the concepts of objectivity and control go hand in hand: Men can more happily control what happens around them because they are encouraged by our culture to feel very little subjective, emotional relationship with the objects, people, and events around them. They then tend to interpret the world in terms of their own experience.



DNA's "master molecule" status is a product of the masculine bias, say the critics.

There's a basic psychological reason why men and women tend to see things in these differing ways, according to Keller. (Keller and the other feminist critics sharply distinguish between sex and gender: Sex is a biological determination and gender a sociological/psychological one. In other words, no man or woman has a biological imperative to approach scientific problems in one way or another.) A man's psychological development in our society stresses the importance of autonomy. A boy grows away from his mother, basing his sense of gender on "not-mother" and on the authority of his father. A girl, on the other hand, is encouraged to empathize with others, to be emotional, as she grows away from her mother and yet identifies with her as a member of the same sex and gender.

The boy's autonomy becomes further pronounced, Keller says, if he enters into scientific objectivity's circular logic. Certain people even may find scientific fields attractive for just that reason. The stress on scientific objectivity will reinforce a man's perception of the importance of his own autonomy. He will be encouraged to distance himself from his subject. As his own autonomy becomes more important, his objectivity—his feeling of emotional distance from his subject—will deepen.

"I think you can make Keller's same arguments without drawing on Freudian theory," says Katherine O'Donnell, assistant professor of sociology and a member of the women's studies committee at Hartwick College. "I do believe that women see things differently even though men and women both have the same potential. We have different historical, cultural, social, and personal experiences."

Other feminist critics say that, because most women are not raised to wield power but instead to respond more emotionally to other members of the family and community, they may be able to offer different insights into investigations of scientific problems. These insights may lead to greater understanding of the world around us. Because most of the few women who have so far entered science have had to buy into the masculine-objectivity-control model, the world hasn't had a chance to see where these insights might lead.

It's very hard to resist that model because it is at the very center of our culture's idea of science. "Many practicing scientists think this whole discussion is ridiculous," says Anne Fausto-Sterling, professor of biology at Brown University and author of *Myths of Gender: Biological Theories About Men and Women.* "They're so convinced of their ideology that the criticism is inconceivable. It's like telling a fish that there's some other atmosphere than water."

In this atmosphere, certain assumptions hold fast and influence all thoughts around them. "You can look at science as a system of discourse," says chemistry professor Stephen J. Weininger of Worcester Polytechnic Institute. He studies the influence of language on the development of science. "Science is a way of talking about the world, and so part of the training of scientists is to learn their field's language. It gives people an internal cohesion, a sense of belonging."

Like any other group, says Weininger, scientists not only add to their own language, they are also in turn greatly influenced by that language. "There's certainly a heavy metaphorical content to most scientific terminology," says Weininger. "And after a while the metaphors, which are just supposed to be an aid to understanding, become entrenched. So when other phenomena occur that don't fit into the discourse, they're often swept under the rug."

For instance, Weininger explains, one of the fundamental metaphors in chemistry is that of molecular structure. These structures are conceived as existing in three dimensions and can therefore be imaginably flipped this way and that to reveal different aspects to the mind's eye. "There are kinds of physical data that seem to connect with the 3-D concept," Weininger says. "The measurements we come up with seem to work well in these terms."

About 30 years ago, Weininger says, a chemist announced that he was going to explain these measurements without using the 3-D model. His article wasn't even accepted for publication, even though Weininger says that there were no real scientific flaws in the chemist's reasoning. Recently, another similar paper was published, but "even though non-molecular explanations of chemistry are starting to become more acceptable now, there's a lot of heavy resistance to the whole idea," Weininger says. "We've been indoctrinated to talk about phenomena in certain ways, and people simply resist other metaphorical explanations."

The feminist critics argue that, since the time of Plato, science has used metaphors to describe science as a project that can be carried out only by a masculine mind. And because the culture quite strictly defines what "masculine" means, science itself has been strictly confined within prescribed definitions.

According to Keller, Plato planted the idea in the Western consciousness that the mind's attainment of knowledge is like a man's attainment of an ideal sexual union. As Plato wrote in the *Symposium*, "When a man, starting from this sensible world and making his way upward by a right use of his feeling of love . . . begins to catch sight of that eternal beauty, he is very near his goal." By the early 1600s,

Individual slime mold cells aggregate when food runs short. But what causes this?

Francis Bacon—whom many reckon to be the "father" of modern science—wrote that science should be "a chaste and lawful marriage between Mind and Nature." The relationship, as Bacon envisioned it, was not one between near equals, but one in which a masculine mind controls and dominates a feminine Nature. Bacon promises a budding scientist that he will "lead to you Nature with all her children to bind her to your service and make her your slave."

The founding of the Royal Society in 1662 marked the realization of Bacon's imperative in the eyes of many of its members, says Keller. A secretary of the Society announced that the group would "raise a Masculine Philosophy . . . whereby the Mind of Man may be ennobled with the knowledge of Solid Truths." Joseph Glanvill, another Society member, warned that it was impossible to discover scientific truth if the mind didn't maintain this masculine standpoint: "The *Woman* in us, still prosecutes a deceit, like that begun in the *Garden*; and our *Understandings* are wedded to an *Eve*, as fatal as the *Mother* of our *miseries*."

The metaphors of contemporary science still support science's masculine bias, Harding says. For instance, Richard Feynman, in summing up his 1965 Nobel Prize speech, said his attraction to his early theories was "like falling in love with a woman." The love sustained him throughout his career, even though the theory has undergone change; the theory he had fallen in love with in his youth, he said, has "become an old lady, who has very little that's attractive left in her, and the young today will not have their hearts pound when they look at her anymore. But, we can say the best we can for any old woman, that she has become a very good mother and has given birth to some very good children."

And the bias surfaces even in the words of younger women in science. A researcher and assistant professor at a prestigious technological university recently said, when asked if she had ever encountered sexism in her studies or career, "I have to say that I've never felt as though I've run into any barriers. But I've always been very mathematically and analytically inclined. I have maybe more of what people consider a masculine mind, so I haven't had any troubles."

The problem with the pervasiveness of this bias in scientific metaphors is twofold, according to Keller, Harding, and others: It not only reveals a basic flaw in science, it perpetuates it. That flaw is that scientists psychologically distance themselves from nature and its processes because they unconsciously accept a formulation of the world as based on a male-female dichotomy: The scientist is masculine and virile while nature is feminine and passive. Scientists are then more prone to see everything in terms of dichotomy: male vs. female; scientist vs. nature; rational vs. irrational. And since things can be divided, they can also be arranged in hierarchies with higher elements controlling lower elements.

There are bound to be troubles if a scientist isn't perceived as having a masculine mind, says Keller. She cites the case of Barbara McClintock, whose genetic theories were considered heretical for more than 20 years before they were recognized as breakthroughs and McClintock was awarded a Nobel Prize. While studying corn seedlings, McClintock had noticed that some of the plants had mutations—patches of color that shouldn't have appeared where they did. She observed these patches occurring in patterns that could be deciphered as exhibiting the plant's underlying genetic history—when and how frequently in the plant's life the mutation had taken place. To McClintock, the pattern revealed that each plant had its own rate of mutation, which remained unchanged throughout its life cycle. This meant something was controlling the rate of mutation, she theorized.

McClintock eventually identified factors on the plant's chromosomes that work cooperatively to move one of the factors to another chromosomal position. This movement changed the course of the cell's development. McClintock saw this not as an abnormal process, but as the normal process of cell differentiation happening at an abnormal time. The implication, as she announced at the Cold Spring Harbor Symposium in 1951, was that interdependent, organized systems of factors in the cell's nucleus, not independent genes alone, determine the cell's future.

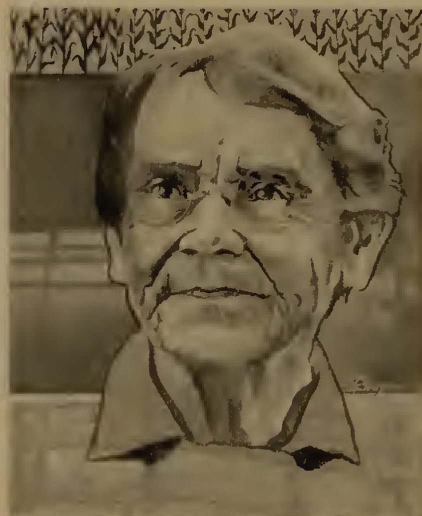
McClintock's colleagues treated her theories with disbelief. Many thought she had jumped the rails, completely abandoning the scientific track. The idea that a regulation mechanism rather than random genetic variation was involved in genetic heredity was at odds with the neo-Darwinian doctrine of the time, Keller says. In fact, it smacked of Lamarckism: McClintock had proposed that organisms evolved by actively responding to their environment rather than by passing on random variations that better equipped them to cope.

Things got worse for McClintock. The big news in 1953 was the Watson-Crick DNA model. Having discovered DNA's structure, the two men proposed that DNA was the cell's ultimate dictator: It passed on orders and information to other components in the cell, but never itself accepted any orders or information. The genetic flow of command was one-way.

Like other biologists, McClintock was excited about the new model, but had more reservations than did most of her colleagues, says Keller. McClintock thought the model tried to explain too much and erred in reducing an incredibly complex function to a small series of relatively simple steps. But despite her reservations, the rest of the scientific community enthusiastically embraced the theory. And that meant that McClintock's models became even more unacceptable.

Finally in the 1970s, when molecular biologists realized that genetic mobility did occur, McClintock's work was recognized as being fundamentally important to a complete understanding of genetics.

Keller argues that McClintock's position as a woman in a nearly all-male field and the obstacles this position presented to her encouraged in her a belief that establishment views were not necessarily correct. McClintock matches a psycho-



Barbara McClintock was branded a heretic. But her theories have gained supporters.

logical profile Keller describes of a "gender-free" scientist, one without the scientist-vs.-nature dichotomy and hierarchy. McClintock does not believe that science will ever be able to "master" nature, but instead that nature is infinitely more resourceful than our capacity to understand it. In an interview with Keller, McClintock asserted, "There's no such thing as a central dogma into which everything will fit." Instead of imposing models on nature and then discounting phenomena that don't fit, McClintock feels it's necessary to "let the experiment tell you what to do," and to recognize seemingly strange occurrences not as exceptions to the rule but as clues to the larger picture.

"This is much more threatening than getting women into science and letting them play," says Leslie Burlingame, associate professor in the history and philosophy of science department at Franklin and Marshall College. She says she isn't sure about the validity of the feminist critique. "But even if it doesn't totally revolutionize science, it will shake people up."

That's what the feminists are hoping. They believe science has been allowed to become complacent about its assumptions and methods, practically to set itself up as an infallible institution. "It's a process that modern science itself started—the idea that you want to include a maximal vision, that you don't assume preconceptions are right," says Harding. "But they won't submit to the process themselves. There's a belief that science is a fundamentally unique kind of social activity." The critics' prescription: Scientists, research thyselves. Says Fausto-Sterling, "Science is a social process that requires the same kind of analysis as any other discipline."

Some scientists who may be willing to entertain the idea that there may be basic problems with modern science still have grave reservations about the feminists' critiques. Rouzer cautions that science needs to train young scientists for a truer objectivity. But she isn't sure that gender is the problem: "It's almost as if they're saying that, if you're narrow-minded and controlling you're masculine and if you're imaginative you're feminine. I'm not sure that that's fair."

Rouzer may be right—women might be just as control-oriented as men. "It might be true that women would come up with the same framework as men have," says O'Donnell, "but they might not. The point is that a different approach hasn't been given a chance." Again, the feminists point out that, for all the complaints they have, they aren't proposing throwing out the baby with the bathwater. "We don't stop speaking English," Harding says, "just because we find out it's sexist."

How would science be different if men weren't in control? "Keller and other feminist critics are insisting on permission for difference," says Ruth Perry, director of women's studies at the Massachusetts Institute of Technology. "The alternative is not to replace science, but to exhibit and consider differences in approach." In other words, there is no "feminist science" to take the place of established science. At least for now: "No critic is obliged to come up with a blueprint for the future," says Fausto-Sterling. "These are thoughts that weren't even permissible 10 years ago. We need now to break out of the first generation of questions."

Leslie Brunetta is moving on from the Alumni Magazine Consortium to become a free-lancer in Boston.

The Goal Is in the Striving

Says EE Professor Dan H. Wolaver, WPI's Outstanding Teacher of the Year.

By Shirley Standring
Photos by Michael Carroll

"Teaching is the most mysterious of all the arts," Dan Wolaver asserts, "because the good teacher must constantly examine 'What is thought?' and 'What is the process of understanding?' It's an exciting profession because you're never through learning about it. There isn't any one best way to teach. You're constantly striving for a goal you never reach, but the goal lies in the striving, in bringing a freshness to your classroom."

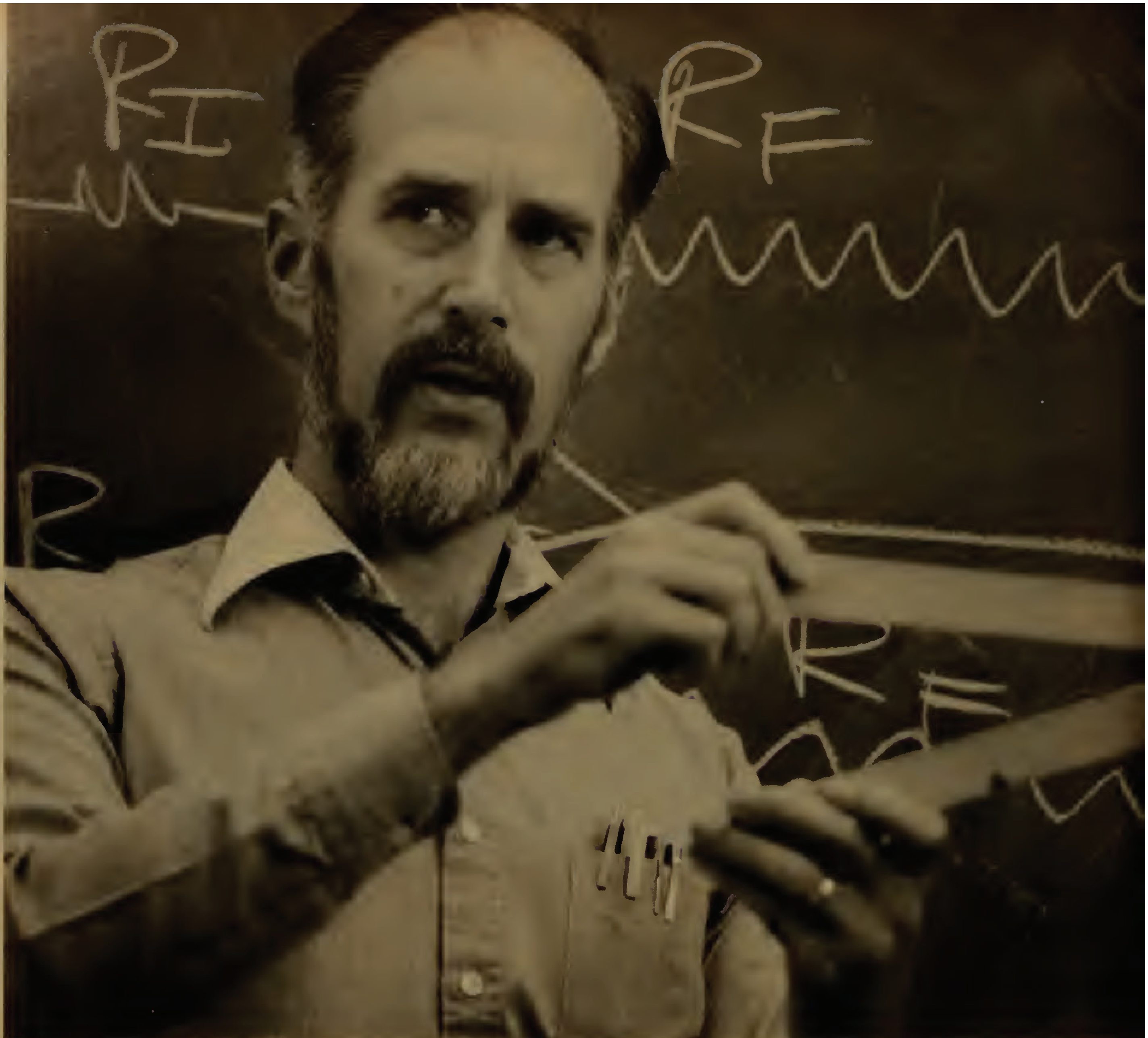
Wolaver has been honored by his students and colleagues with the 1986 WPI Board of Trustees' Award for Outstanding Teaching. "This honor," says William H. Roadstrum, professor emeritus of electrical engineering and a close colleague of Wolaver's, "places Dan on a footing with past recipients such as John M. Boyd, Ralph Heller, and C. William Shipman, to name a few, in the very top of a top class of distinguished professionals."

Adds Roadstrum, "Dan's personality is ideally suited to teaching. He's able to carry his enthusiasm over to the students, he is conscientious about his method, and he knows exactly what he's going to do when he goes into the classroom."

Created in 1960 to honor Professor Hobart H. Newell's distinguished career in education, the award has been given each year to recognize WPI's most outstanding teacher.

In the award's early years, faculty members determined among themselves who would be honored, according to Dean of Academic Advising John van Alstyne (himself the 1970 recipient), who has served on the selection committee many times. But for the last 15 years, the committee's deliberations have included student input as well. The committee is appointed by the dean of the faculty and consists of five faculty members and five students.

Says Robert Long II, associate professor of physics and selection committee



"A hunch can bring students closer to an answer, and they often learn something by going through the process."

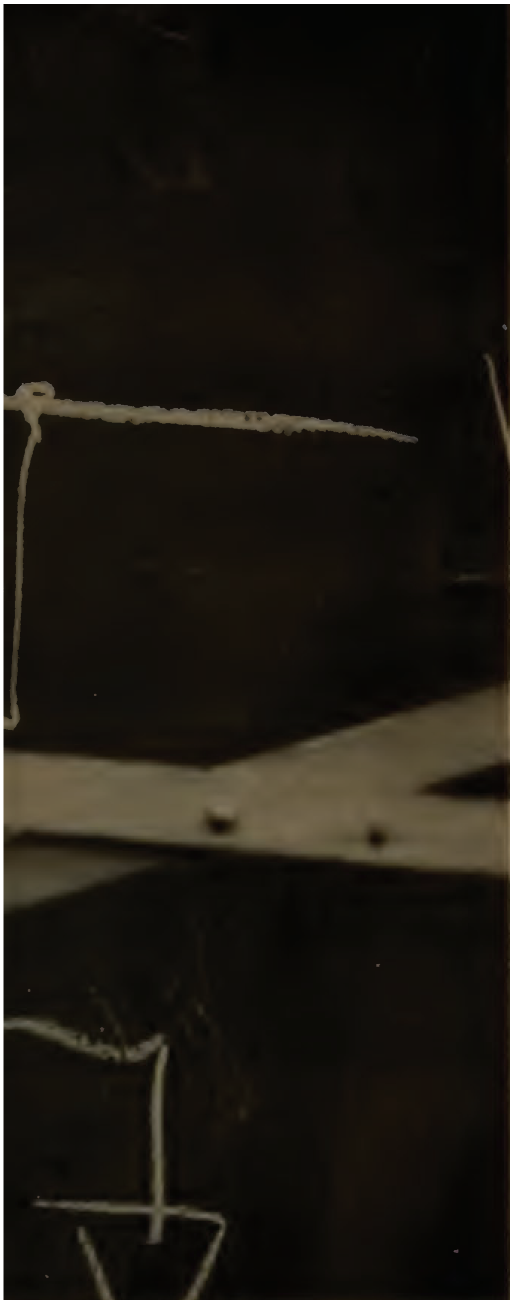
chairman for 1986, "It's a thorough and time-consuming process, and we try hard not to let our decision leak to the rest of the campus before the recipient is announced at the annual Faculty Dinner in the spring.

"I read each letter this year looking for the items students seemed to value most. In those letters recommending Dan, they all mentioned his availability outside of the classroom, his style of presentation, his concern for students, and his ability to relate to a situation in such a way that students readily learn new material."

Says Wolaver of the honor, "It says to me that what I have been trying to do is successful, that somebody appreciates it. It's the ultimate to me, to be the teacher of the year."

A transplanted midwesterner who has come to love the Eastern landscape and its beautiful color, Wolaver says he has always been interested in teaching. He was influenced by an uncle, also an engineer and teacher, who worked for General Electric before settling into an academic position. Wolaver obtained a bachelor's degree in electrical engineering from Rensselaer Polytechnic Institute in 1964 and M.S. and Ph.D. degrees from the Massachusetts Institute of Technology (MIT). He then joined the technical staff of Bell Labs. An MIT advisor, Wolaver recalls, had praised Bell's leadership in research as a good preface to academia.

Wolaver remembers his baptism into the business world as "a dip into a cold



stream. I hadn't touched a slide rule in two years, and my research had become unapplied, dealing in theoretical concepts rather than in making things work. It was a difficult awakening when I had to have a project built and working."

The project was a high-speed digital transmission system with an automatic equalizer. "I was in control of the theory, but I couldn't find the bugs that kept the system from working. I avoided the lab, and spent a lot of time at the computer, where I could simulate the processes. It was not an easy time for me. But I kept banging my head against real problems and began to lose my fear of the bugs I couldn't understand. Eventually, I worked it out, and I learned a valuable lesson as well."

Wolaver credits his experience at Bell Labs with instilling in him three important concepts that he tries to pass along to his students: the importance of creativity; understanding how practical constraints influence a project's design; and the need for clear, concise written and oral communication on a project.

Wolaver spent 10 years with Bell Labs, obtaining the practical experience he felt he needed before facing a classroom of eager young students. Several factors, he recalls, convinced him that the time was right to leave industry for academia. "My uncle spent about 10 years in industry, and the timing seemed right for him. My wife deserves a lot of the credit, too. She would clip ads for teaching positions and leave them for me to read," Wolaver laughs.

Perhaps the determining factor was his last assignment at Bell. The project involved a lot of circuit design, and Wolaver approached it with the assurance of a veteran engineer. "I had full responsibility for it," he says. "When I had completed it, and could see the whole picture and make it work, there were no more dark corners of electrical engineering. It gave me a great deal of confidence."

Wolaver's first introduction to WPI was through an article in an IEEE (Institute of Electrical and Electronic Engineers) professional journal about the WPI Plan. "The Plan's emphasis on education through projects intrigued me," he says, and he applied for a faculty position here.

William Roadstrum remembers his friend's introductory lecture to the EE Department: "I realized immediately that Dan was unusual. He gave quite a good talk, but there was something else about him. He was so open and full of ideas. My colleagues must have recognized it as well because an offer was made and Dan joined the faculty."

Wolaver remembers the emphasis his WPI interviewers placed on teaching. "Every other college dwelt on my

"Students believe teachers think in equations because that's what we write on the board. But sometimes pictures explain things best."

"Engineering is a harmonious process, and what you accomplish is more the discovery of order that's already there than the cold process of putting blocks together."

research at Bell. Whenever I brought up education, they dismissed it quickly, commenting that good teaching was expected. At WPI, my interviewers never mentioned research. They wanted to talk about education. I was also impressed with the faculty, particularly John Orr and the late Donald Eteson."

Joining the faculty in 1979, Wolaver immersed himself in his new profession. He set out to impart to his students valuable gifts like confidence along with a thorough knowledge of electrical engineering. He became a student of teaching theory and methods, and gained a reputation for the all-too-often elusive ability to relate information to his students clearly and concisely. It is a skill that Wolaver has painfully scrutinized in others and developed for himself.

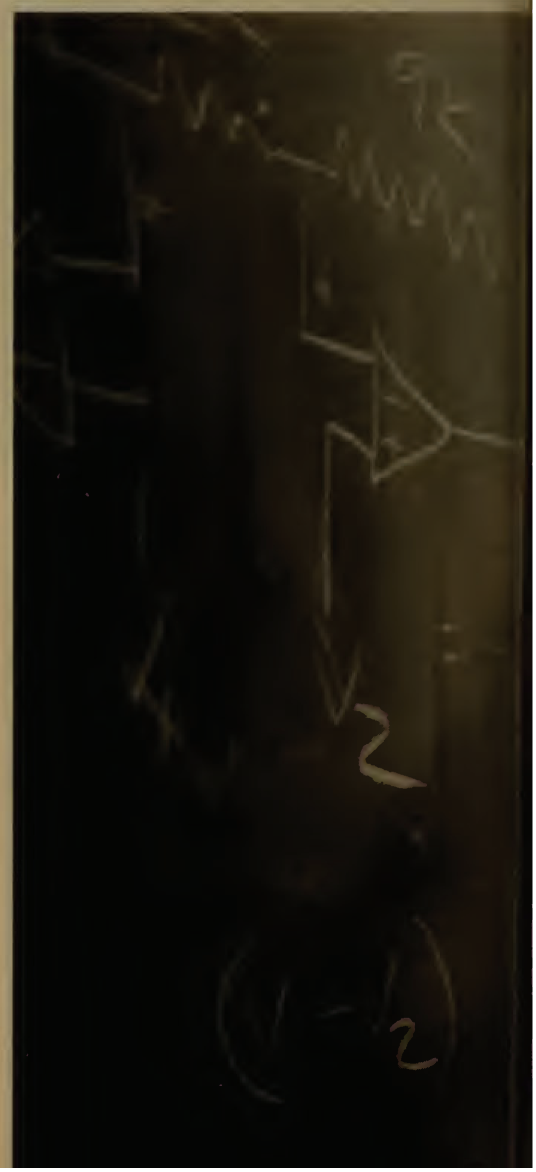
"Students have more confidence in what they are being taught if they can see how they would have arrived at the solution by working at it themselves. Students need to be taught in small steps so they don't get lost, but the steps must be logical."

Adds Wolaver, "We must let students experience the mental dilemma of 'Where do I go from here?' long enough to feel the problem, but not so long that they become discouraged." The process is what William Roadstrum speaks of as "controlled agony." "I don't want my students to suffer fear and uncertainty to the extent that I did," says Wolaver.

Standing before a class, he isn't content merely to teach the elements of a circuit breaker, for example, and the process by which it works. He wants his students to know why that circuit breaker has been so designed, and to understand how the constraints laid upon the designer influenced the design.

"Some educators believe that analysis is the most important ingredient to design, that if you analyze long enough, you can design," he says. "But it's an entirely different philosophy when you begin with the problem and work your way through to the solution. Part of this kind of learning is knowing through analysis the many different things that will—and won't—work. But you can't create a design until you know what you want the system to do. That's why the MQP [Major Qualifying Project] is so valuable. Students really learn design here."

Wolaver launches into an explanation of a typical MQP. Ideally, he explains, a student will begin with a loosely defined problem: "Let's say I, a student, want to identify an abnormal heartbeat. I must first decide how to do it. Will I monitor the pulse, the heart sounds, electrical



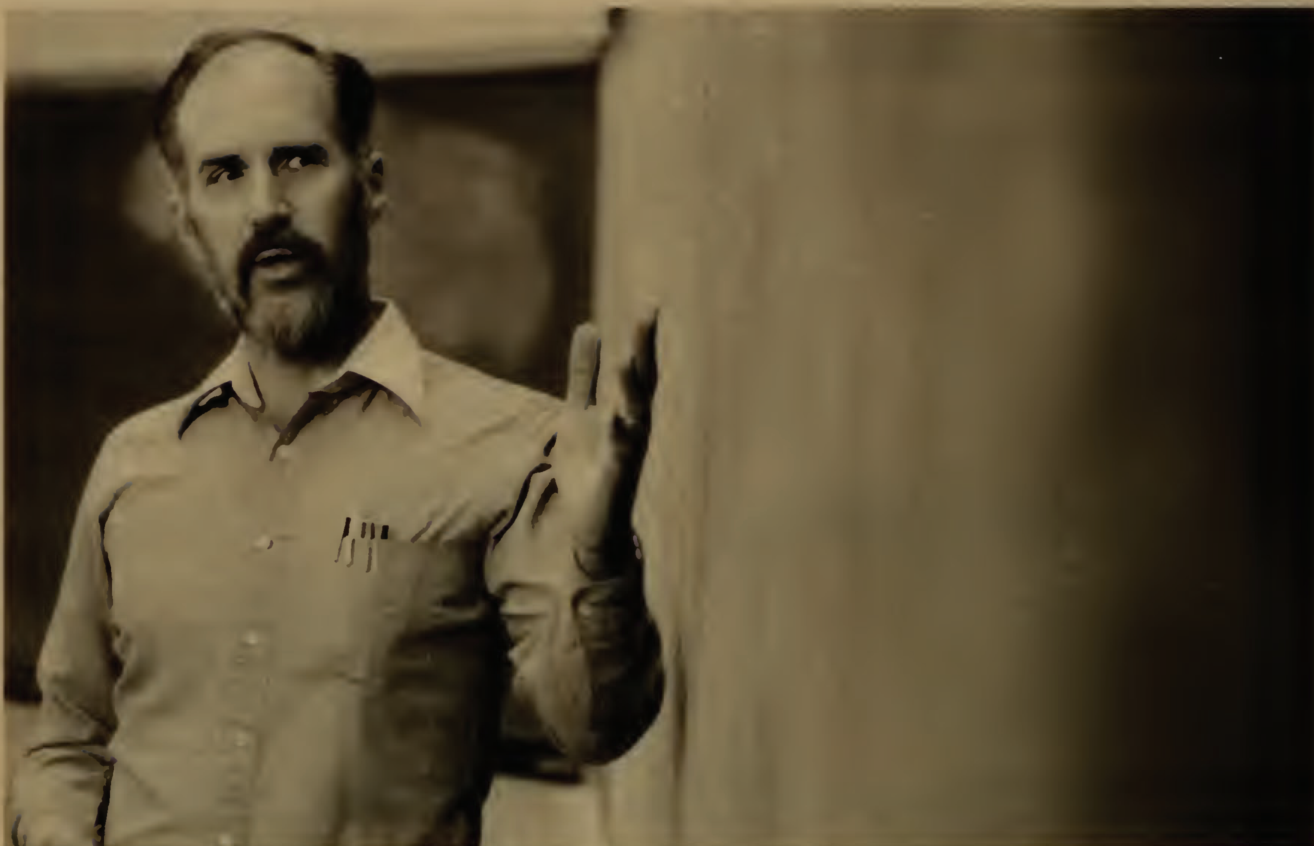
signals or some other function? Once I've decided on the process, I must determine what features will then define normal/abnormal qualities. Next, I decide on a circuit to seek out those features. This step involves the nitty-gritty of circuit operation. This is the design process emphasized at WPI, and only a fraction of it relies on the ability to analyze.

"Teaching the creative process is much harder than teaching analysis," he goes on. Wolaver believes that truly creative designers have difficulty explaining where their designs come from. At times, he says, they seem to come from nowhere.

"My thinking process includes visualization. I encourage my students to plot their equations. This helps them to get an overview of their thoughts by seeing a picture. Often, students believe teachers think in equations because that's what we write on the board. Sometimes pictures explain things more clearly.

"I also encourage students to try things," he says. "Usually students feel they need to go straight to a solution; they feel that playing around with an idea is unprofessional. I don't care if the

"Students have more confidence in what they are being taught if they can arrive at a solution by working at it themselves."



answer they arrive at is wrong. Their hunch may have brought them one step closer to the answer that works, and they may have learned something by going through the process."

Beyond all of the preparation for working as an electrical engineer, Wolaver feels he must introduce students to the enjoyment of being an engineer. "If they don't enjoy it, there's no point in playing the game. Creativity is the necessary ingredient for enjoying the adventure of engineering. There's also joy in interacting with others involved with the enterprise and in identifying a practical need of mankind and providing a working answer.

"WPI is very strong on encouraging students to maintain their sights on the use of a product or a process. They should ask themselves what the benefits to society are of transportation, stereo televisions, and missile guidance systems, for example. If, in their efforts as engineers, they feel it's more important to make transportation safer, they should do that instead of designing stereo TVs. WPI offers students opportunities to examine issues of social awareness."

Wolaver says he loves to see ideas that at first look strange and complex begin to make sense. "Engineering is not terribly different from the arts," he contends. "Whether you're designing a system or composing a piece of music, rules must be followed. The way in which things fall together is harmonious, and it seems that what you're accomplishing is more the discovery of order that's already there than the cold process of putting blocks together."

His mind seems to race to all facets of a question. Yet Wolaver answers slowly when asked about future goals. He admits that he's looking forward to publishing a new book, *Electrical Engineering for All Engineers*, which he co-authored with William Roadstrum, and, of course, to teaching better.

Also, he sees the need for more communication with his colleagues in both EE and other departments: "If I can say to my students, 'This follows from what you learned from Professor X,' I can build on that concept. But I have to know what's being taught."

He suggests several avenues of interaction with colleagues: more team teaching, joint appointments between departments, giving the faculty opportunities to work together on research projects, and hosting more retreats and workshops.

But, he says, the most effective interaction comes from having the time available for just this purpose—at convenient places on campus such as lounges and the faculty dining room in Higgins House, "We have to continue to make this kind of atmosphere available to both faculty *and* students."

A believer in WPI, the Plan, and the mission of the Institute, Wolaver is not shy in expressing his dismay over the research/education schizophrenia with which many universities grapple.

"Many students don't realize the benefits of an institution that emphasizes education over research because often they don't know anything else. But students who have gone on to other institutions have commented to me on the difference. At research-oriented institutions, they say the faculty can become almost invisible. Researchers need time to do their own work, which is appropriate, but at what expense to the majority of their students?

"The whole issue of research vs. education is a question of balance," Wolaver asserts. "Presumably, the balance can be different for each individual. The Plan did a lot of advertising for WPI, but you can't be famous due to a single initiative for very long unless you continue the experiment.

"Research doesn't have to be only in engineering, science or the humanities. It should also be in teaching. We should be writing more articles about new methods in teaching. These ideas should be given at least equal weight with articles about new technologies."

Beside his faculty appointment, Wolaver continues to consult on outside projects, something he enjoys very much because it keeps his understanding of the field current. Often, he says, some element of his consulting projects becomes source material for his teaching.

It has been said that "Those who can, do, and those who can't, teach." Wolaver prefers it this way: "Those who can, do; and those who are aware of how they do it, teach. The doers do, and the teachers explain how the doers did it.

"To be a good teacher," he believes, "you have to *enjoy* the doing or you don't have the motivation to *teach* the doing."

Shirley Standring is a freelance writer living in Spencer, MA.

"The whole issue of research vs. teaching is a question of balance. Presumably, that balance can be different for each of us."

THE ENTREPRENEURIAL SPIRIT

FIFTH IN A SERIES

INSURING SUCCESS

Frederic A. Stevens '61 first made his mark providing insurance companies with software. Now he's delivering their mail.

By Michael Shanley

Each letter is like a guided missile, whistling down the center of the room-length sorting machine at an outrageous rate of speed, then slamming into a zip-coded cubbyhole.

Fred Stevens '61 raises his voice to be heard over the constant din in the shop at Mail Processing Systems Inc. (MPS) in East Hartford, CT. "We presort 5 million pieces of first class mail a week," the MPS vice president notes proudly. "A million a day."

Stevens, who knows more about mail than your mailman, explains the workings of various folding, stamping, scanning, sealing, and wrapping machines. He seems genuinely to like these machines because he understands how each works—appreciates, for example, the elegant simplicity of an automatic letter-folding machine. He is equally at home in the sleek high-tech room where a bank of sophisticated computers and high-speed laser printers churns out letters by the thousands.

"If you have enough mail," says Stevens, explaining MPS's basic premise, "you can send it first class for 18 cents instead of 22. But it has to be properly sorted. So what we do is take a company's first class mail, sort it, and send it off."

MPS is *the* national-mail presort service bureau in the Northeast. The company deals with major mailers in Boston, Hartford, and New York, many of them insurance companies like Travelers, Aetna, Connecticut General, and John Hancock. "There are other companies like ours," Stevens says, "but we've pretty much got the national mail locked up. Nobody else in the area can presort mail to all 50 states."

The company also offers electronic printing and data-processing services—developed by Stevens when he joined the company two years ago—that can create a piece of mail from a company's magnetic tape. Consider, for example, statement processing for a credit union, a growing new MPS service. The traditional procedure is for a credit union to produce monthly or quarterly statements in-house—a time-consuming and labor-intensive process. MPS, on the other hand, can reprocess a company's data and print the statements on a state-of-the-art laser printer, producing the entire document in an instant. Headings, logos, numbers, gray panels, whatever, are laser-generated, at one time, in one pass, on both sides of the paper. Clients save on paper as well as postage costs. The operation then moves to MPS's mail shop, where the statements are folded, inserted in window envelopes, and presorted.

"We offer one-stop shopping," says Stevens, who in June won WPI's Robert Goddard '08 Award for outstanding professional achievement. "You send us the tape, and we take care of everything else, including mailing. And we do it in less turnaround time than you could do it in-house."

Some of MPS's clients, however, use only the mail shop

Frederic A. Stevens '61, computer pioneer for the insurance and bulk mailing industries, sits outside Sanford Riley Hall, his residence during his WPI days. Stevens won this year's Robert Goddard '08 Award for professional achievement.

"If you're persistent enough to get through a drought, then one day something will click—and business will flourish."

service. "They send us their mail with 18 cents postage and we sort it in one of two ways. Either we'll use the presort machine, which 'reads' only certain type fonts, or we do it by hand." Despite all the high-tech hardware at MPS, fully half the sorting is done the old-fashioned way—by hand. Many of the 400 employees who work on one of the company's three shifts simply sift through mountains of mail, arranging it in zip code order.

MPS is much more than just a printing and mailing house, however. And the crucial difference is the combination of data processing and electronic printing.

As Stevens says, "There's a big advantage for us in massaging the data and getting it to print in a unique manner. One of our credit union customers, for example, can't just get up and walk away. We print some pretty complex material for them, and if they want to stay with that capability, they've got to stay with us because nobody else can do it.

"If they were to take what we're doing to some other printing company that has a Xerox printer and say 'Here, we want you to produce this format statement like Mail Processing Systems does,' they wouldn't be able to do it because without the data processing end, you can't do what we're doing. We've put a lot of investment into building computer programs and we've got a proprietary product."

Total sales for MPS are currently at about $6 million, up from about $3.5 million when Stevens came on board two years ago.

In 1970, back when the word entrepreneur was hardly ever used off Wall Street, Stevens and a colleague, Robert Maltempo, left the comfortable fold of Aetna Life and Casualty to form Vantage Computer Systems. They had $12,000, borrowed from a friend of Maltempo's.

Vantage would go on to enjoy unprecedented success in the writing of software programs for insurance companies, but not before going through some hard times. Stevens, a physics major at WPI, chuckles when asked if there was ever a time when he was unsure Vantage would be a success. "I had no conception it would ever work," he admits.

"The environment was much different then," explains Stevens, who currently lives in South Glastonbury with his wife, Guerri, a programmer and systems analyst who occasionally does work for MPS. "The whole idea of software firms hadn't been established. Most corporations had their own data processing divisions and developed their own software. They wouldn't buy any from outside."

Struggling against tradition, Stevens, Maltempo, and a handful of employees kept at it for several years, working for individual companies on a time plus materials basis, or, as Stevens puts it, "for whatever it took.

"Those were some lean years," Stevens recalls with a smile. "There were times when you almost felt like giving up."

Basically, Stevens was the technical expert and Maltempo the salesman. But in the early years, they each did a little of everything. "For a while there," Stevens says, "I was chief systems designer, programming manager, operations manager—anyone on the technical side of the business reported to me. And in many situations, you're not only the chief manager but the chief doer as well."

In 1977–78, things started to come together. "We finally developed an actual product," Stevens explains, a prepackaged computer program, aimed at insurance companies, that would handle the complex bookkeeping involved in variable annuities. A hot new product at the time, variable annuities allow customers to vary the premiums paid on retirement savings and give them shares of investment funds separate from an insurer's general fund.

Vantage's computer software was so good that it made all the insurance companies' in-house programs virtually obsolete. Soon all the biggies were at little Vantage's door.

Stevens and Maltempo then added computer programs for other non-traditional insurance products—flexible premium retirement annuities and universal life policies. Such products require enormously complex accounting procedures. As an insurance executive puts it, "It gets hairy. You're carrying lots of buckets. If you change interest rates, you can have three or four buckets for each year carried forward forever."

Stevens once calculated that the 25,000-line variable annuity program took the equivalent of four man-years of effort to produce. By the same token, it took 50 man-years to perfect a 5,000,000-line universal life program. The insurance companies paid accordingly.

A second major development in Vantage's growth came with the advent of the individual retirement account, or IRA. IRAs were first developed around 1976, Stevens recalls. "At the same time we were trying to sell our variable annuity system to John Hancock in Boston. They told us about this new product they were trying to get on the street right away. It was a fixed annuity for the IRA market.

"We changed course and modified our variable annuity system to be primarily a fixed interest annuity system and installed it for John Hancock. Then we sold a number of other programs to different companies. That got us well on the way to becoming a major vendor in the annuity market.

"Eventually we made a crucial change to the annuity system and we became *the* vendor. If you wanted a system to process annuities for the insurance business, you called Vantage. It was that simple."

While discussing these Vantage boom years, Stevens takes the time to point out a crucial aspect of the entrepreneurial spirit. "People say to me, 'You were pretty lucky to be there when the IRA product came around.' And I say, 'Well, you can look at it as luck or you can look at it as persistence.' If you're persistent enough and you can live through these things, then probably one day you're going to find something that clicks and you'll be in business.

"The IRA opportunity was there for a lot of people, but there weren't many who were in a position to take advantage of it."

Stevens also notes the importance of a broad-based knowledge of a given field. In the same way that he's learned more about mail processing than seems necessary for his position, he once studied every aspect of the insurance business.

"My background was primarily in the technical end," he says of the Vantage days, "but if you're going to be successful in software you've got to understand the business you're dealing with. So I got to know a lot about life insurance. For example, I had to learn enough actuarial mathematics to talk to actuaries in their own language. With insurance products, you're dealing with very complex situations. You have to be able to understand what these people are telling you, and often what they're telling you isn't explainable in any other way except the mathematics. So you study it and you learn it."

Ironically, it was Vantage's success that ultimately caused Stevens to leave. "It got too big for me," he says of the company that now employs about 150 people, most of them professionals. "I prefer smaller companies, watching them grow. MPS has more employees overall, but only a handful are in the professional end."

"To be successful in developing software means you've got to know a *lot* about the industry you're dealing with."

Stevens did, however, retain a major interest in Vantage until last spring, when he sold his remaining stock and resigned as a director.

"I like the challenge of building an operation," Stevens says of his decision to join MPS. He had taken some time off and served as a consultant after leaving Vantage in December of 1983. "I like learning new things. I think of myself as a technologist in that I can understand technology and put it to work. And I've got a broad enough background so that I can understand a lot of different fields. Here at MPS I'm getting interested in desktop printing and electronic publishing—the whole process of getting words on paper. We've only just begun to go in that direction."

Stevens traces the direction of his own career back to WPI. "There was a very small computer in the math department," he says. "I was using it for some of my work in physics, and got very interested in programing. So when I graduated, I got a job as a programer with Aetna."

That job lasted all of about four months, as Stevens was drafted. But after spending two years as a health physicist for radiation safety at the Army Chemical Center in Maryland, he returned to Aetna as a programer and systems analyst.

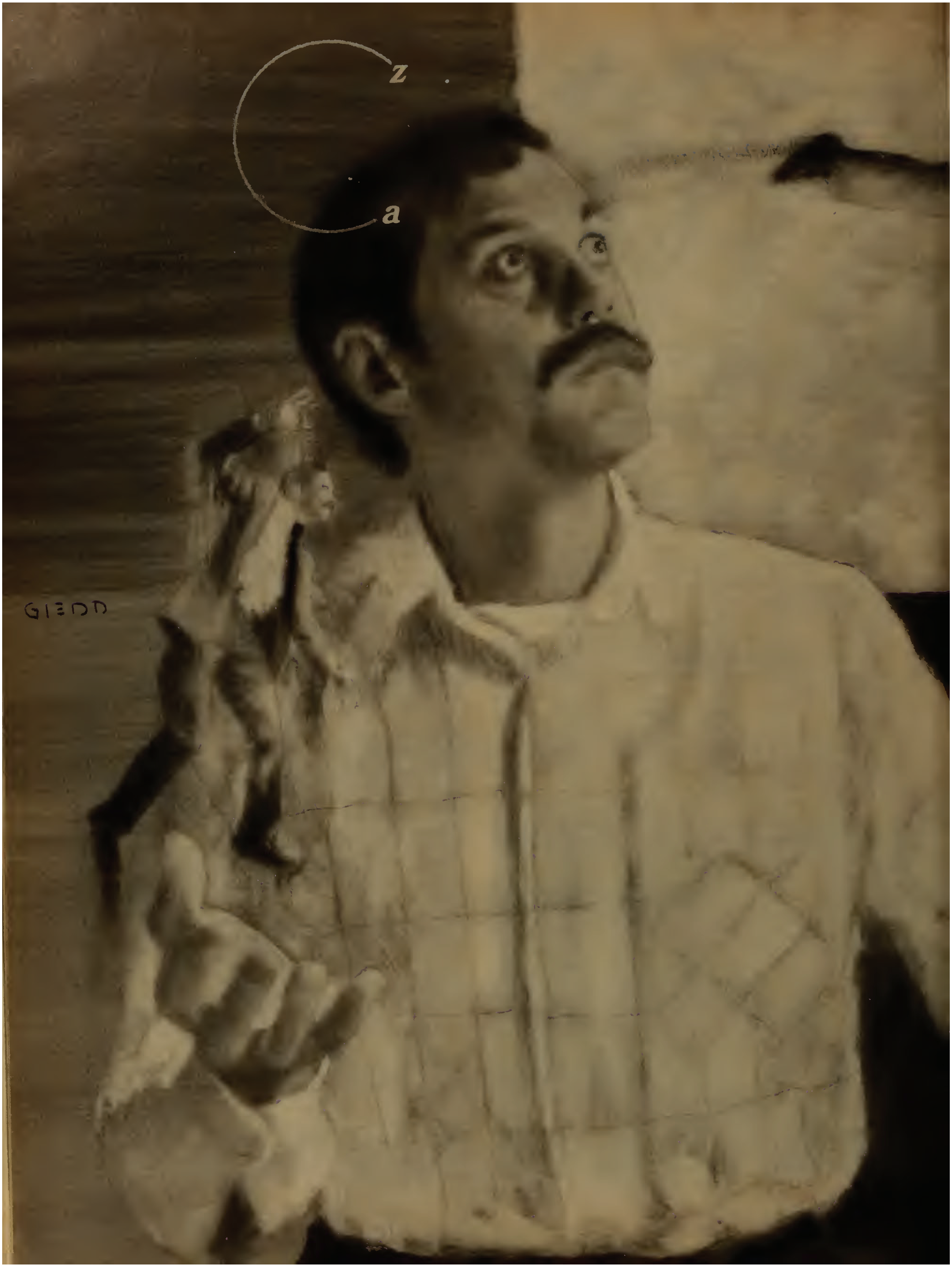
Those were the pioneering days of computer science, Stevens recalls. "The first computer I worked on at Aetna was an IBM 1401 with 8K memory. Today's personal computers would run rings around the mainframes of the '60s.

"Back in those days, we learned as we went along. It was all on-the-job training. Actually, in my first few months at Aetna, they handed me some manuals and asked me if I wanted to go to school. I said, 'No, I'll wing it.'"

That attitude has served him well. "I've never had a really good plan for where I'm going to be at any given point in time," says the East Hartford native. "I've just never really given it that much thought."

Given Fred Stevens' track record, why should he start now?

Michael Shanley is a free-lance writer living in Holden, MA.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GIEDD

To Market, To Market

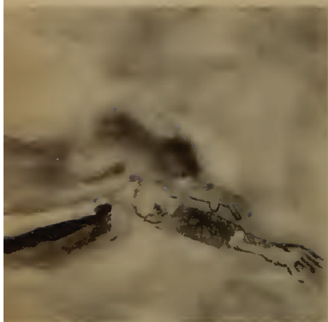
WPI has bred many an invention. But for every successfully conceived, patented, manufactured and marketed idea, many more go down the drain.

By Paul Susca

Illustration by Richard Giedd

"Invention breeds invention," Emerson wrote. But formal education can only be a first step on the road to successful invention. Finding or creating an environment conducive to invention, knowing what to look for and how to recognize a good thing even when you're not looking for it, getting the right help with patenting, manufacturing, and marketing, and having the energy to keep on trying in the face of disappointment are all part of an inventor's curriculum.

In his nearly 30 years at WPI, Thom Hammond, professor emeritus of mechanical engineering, has helped dozens of students get their feet wet as inventors. Hammond has routinely used exercises in invention to teach his students about the engineering design process. Steadily coming up with a wide assortment of ideas for inventions, Hammond passes them on to his students, who then pursue the design, fabrication, and sometimes the ultimate patenting of the gadgets. The inventions have included a front-wheel drive electric tricycle, a device to control the pressure of cranial fluid in



"Corporations have become so large and conservative that there's much less invention going on than there ought to be."

patients after brain surgery, and a wheel chair controller designed for one-armed patients.

Hammond often has greater faith than his students in their ability to develop useful apparatus. He especially likes to tell about the ones that got away, the inventions he urged his students to patent but that later showed up on the market patented by someone else. In one case, 12 or 15 years ago, when Hammond was teaching senior design, he pointed out the need for an after-market device that could be fitted to cars, allowing them to move sideways into tight parallel parking spaces. He suggested how his students could go about designing and building the device, and they did.

"But three years after they graduated they sent me a clipping from a British newspaper describing how an almost identical device was being marketed," Hammond relates. "I was delighted. I said they should have patented it when I first told them to!"

If invention breeds invention, then simple inventions also breed more complex inventions. Henry S.C. "Pete" Cummings Jr. '50 has spent years improving on the lowly ratchet as president of Lowell Corporation in Worcester. Founded when Cummings's great grandfather, Professor John Sinclair (once head of WPI's Mathematics Department), bought a ratchet patent and set out to become a "master of ratchetry," Lowell Corp. has pinned its survival on ratchet innovations.

Cummings himself has been awarded five patents in his 32 years with the company. His innovations include a layout that increased the number of teeth in a ratchet without decreasing their strength, a quick-release device for changing ratchet gears, and a handle-less ratchet, or ratchet clutch.

Cummings says that the simplicity of the ratchet, which he considers to be the sixth basic machine after Archimedes' five, is what makes further innovation so challenging. "If there was all that development potential in [basic machines like] the wheel or the screw or the lever," he contends, "then by gosh there's got to be that kind of development potential in ratchets."

Breeding grounds for inventors and inventions must offer more than development potential, more than an idea that serves as a focus for further invention. Gordon B. Lankton, a WPI trustee and president of NYPRO, Inc., in Clinton, MA, believes in creating the kind of environment in which inventors can flourish. You have to expose future inventors to those who are already inventive, says Lankton, who has been managing inventors for 20 years at NYPRO. "It's a supporting role, a coaching role. You bounce up and down as their moods change," Lankton says about the job. "It's a recognition that you can't impose hours of the day." Inventors tend to be loners, he says; they're also hard to manage, and they don't easily fit into the structured environment typical of most corporations.

Once inventive types emerge, the next challenge is to keep them happy, Lankton says. Inventors in an organization don't generally respond to the usual monetary rewards that corporations bestow; they often crave recognition. Lankton tells about one of his company's inventors who thrives on recognition in the form of ever-escalating titles.

But inventors can't be expected to make effective managers and presidents, Lankton says. "There comes a point when you have to take a project away from the inventive types and hand it over to the business types if you expect to get things done."

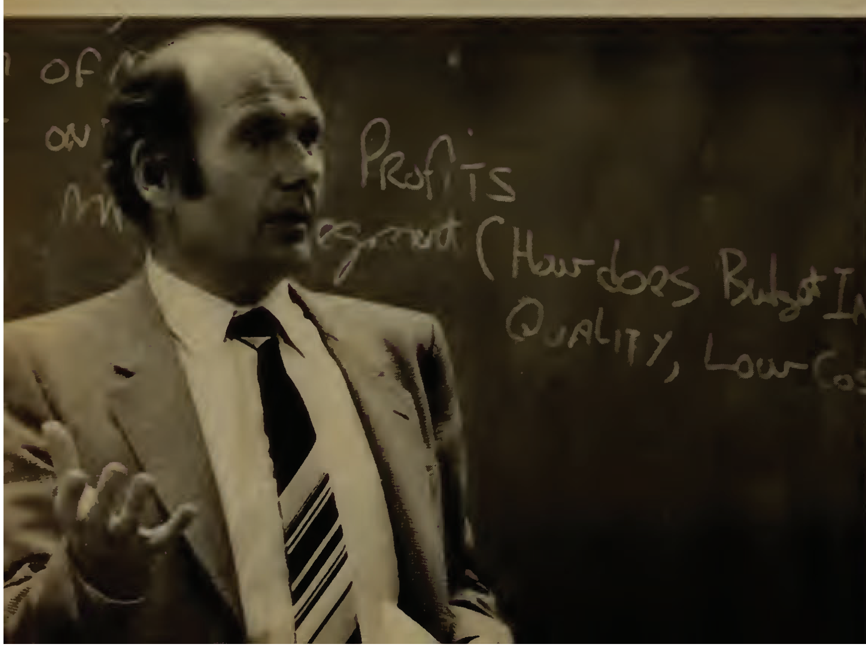
Managing invention in large organizations has occupied a good deal of David E. Monks's time, too. Monks, Class of '64, once director of the photographic science group of Eastman Kodak and now president of Kodak subsidiary Eikonix in Bedford, MA, was part of the team that developed Kodak's disc camera. The concept of disc film was developed as far back as the 1920s, Monks says, but his team applied additional knowledge about camera design to develop a camera that he says is all-around more capable than those employing roll film.

The disc camera illustrates the difference between discovery and invention. Invention, Monks says, is the process of bringing together known principles in a new form, whereas discovery involves finding knowledge that is completely new. One engineer who worked for Monks was an example of the classic inventor—most effective at putting together existing building blocks in new ways. It was he who invented the mechanical brain that controls processing in the disc camera, based on a differential gear train.

Since thinking about old things in new ways seems to be the essence of invention, conventional wisdom can have a dampening effect, in his experience. You have to put inventors in an environment where they can spread their wings, he says, but American companies are failing to do that with their often overly bureaucratic organizations.

Another reason why we aren't producing inventors the way we used to, Monks says, is that we

Hans J. Thamhain



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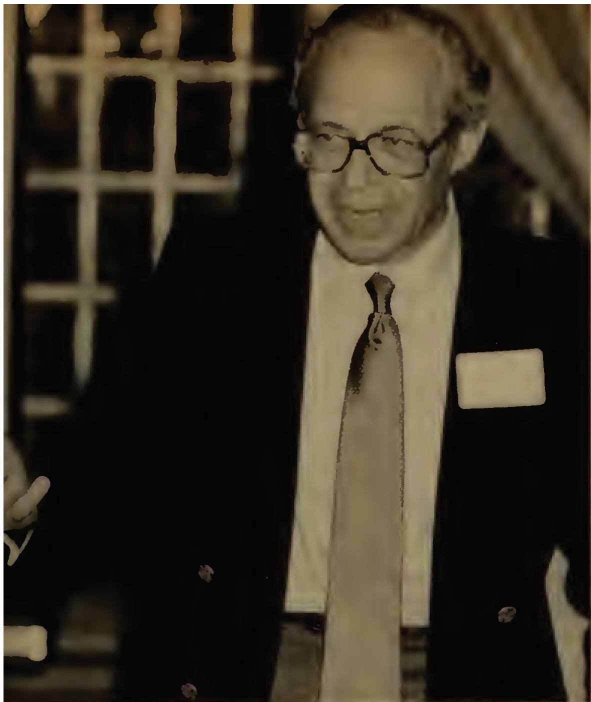

Michael Carroll

Arthur Gerstenfeld

tend to think in terms of applying new technologies rather than taking a step back to consider the fundamental scientific and engineering principles supporting those technologies. His experience indicates that inventors tend to think in terms of applying those underlying principles to new needs.

Management Professor Arthur Gerstenfeld, the author of two books on invention, also has some thoughts on what has happened to America's inventive genius. "The independent inventors sitting in their basements doing invention are quickly disappearing," he says. Despite the sometimes stifling atmosphere of large companies, these organizations seem to be the source of many of today's inventions. One reason, according to Gerstenfeld, is the expensive equipment needed to push ahead with the new technologies. Another reason is the nature of our organizations. Says Gerstenfeld: "One of the big problems facing the nation is that our organizations have become so large and so conservative about risk taking that there's not as much invention taking place as there should be." Corporations should not be so well organized that inventiveness gets trampled upon, he says. Some of the better inventions developed in large companies have to be bootlegged—people work on them in their spare time, with extra or "borrowed" materials, no budget, no program.

But bootlegging is just part of what we call "Yankee ingenuity." Gerstenfeld, who makes frequent trips abroad, says, "In Japan they always talk about Americans as the great inventors and the Japanese as the great copiers. That's partly because we're taught from day one to be very independent thinkers, even to be rule breakers."

Gerstenfeld, who holds a baccalaureate degree in mechanical engineering, did his doctoral dissertation on innovation in large companies and now teaches a course on innovation. He also has several inventions to his credit, holding four patents with two more pending. Gerstenfeld thinks of himself as the atypical inventor: he has pursued inventions on his own, rather than relying on the backing of a corporation. But one thing he has in common with other inventors is the source of his motivation. He talks about a spark, a desire to document his ideas and to leave a legacy: "I've known many inventors," he says, "and very seldom do they invent and say 'Boy, I'm going to be a millionaire.' It's more the opportunity to see your own ideas come to fruition." He likens it to other forms of artistry—music, writing, and the visual arts.

Gerstenfeld is now working on an invention that employs artificial intelligence to control air traffic around airports, drawing on his experience as a radar technician in the Navy. "If you watch people in a radar room at an airport, air traffic control is done the same way now as it's been done for the last 20 or 30 years," he says.

Making that kind of observation, recognizing a need for improvement, is the essence of the kind of inventing that Gerstenfeld has done. He refers to his inventing as demand-pull: responding to a perceived need. Technology-push inventions, in contrast, are prompted by the emergence of new technology and the drive to find applications for it.

"Invariably, demand-pull inventions have enjoyed greater success than the technology-pushes," Gerstenfeld says, explaining the results of his study on innovation in Germany. Research carried out by Gerstenfeld's students a few years ago, focusing on small inventors, came up with the same conclusion. "But on the other hand," he adds, "sometimes the technology-pushes are the really great inventions. My stuff is much smaller but has a greater chance of being used."

"Product development normally requires an iterative loop, racing between research, marketing, and the customer."

Serendipitous inventions, those conceived by accident in the search for something else, generally fall into the area of technology-push, according to Gerstenfeld. Robert A. Rowse '49 knows all about serendipity. As a research sci-

Thom Hammond

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"Inventors need agents who have the imagination, honesty, and ability to know which ideas are worth pursuing."

entist at Norton Company, Rowse always regarded research results with an open mind because that's what it takes to recognize the value in what appears to be an accident or a failed experiment. Once, for example, looking for abrasives boasting high strength and durability, one of Rowse's subordinates grew discouraged when he found only weak, brittle substances. But Rowse, as director of a broader research effort, recognized their value, and now those same abrasives are used in sandpaper and grinding wheels.

But successful invention takes more than perspective. It takes a great deal of persistence. Inventors often rejoice when they make that long sought-after find, Rowse says, but it's a long way from invention to marketing, and you have to be committed to your ideas. "You find that at times you have to bootleg in order to keep it going," he says, "That can be very frustrating and—careerwise—may be rather precarious at times."

Rowse speaks from experience. When Norton's domestic marketing people balked at putting newly developed grinding wheels into field trials, Rowse went out on a limb by sending the wheels off to Sweden for testing. More than once, he says, he came close to being let go because of his stubborn attachment to ideas. But that's what it takes to get your inventions through the mill: "It's an inner drive that makes me crazy. I always react when somebody says something can't be done."

The toughest part of invention, he says, can be dealing with resistance within your own organization, when people don't pick up the ball and run with it the way you think they should. "In a small company it's usually a problem of finances to keep it moving," Rowse says. "In a big company it's the interfaces of one department and another department and another as the idea progresses from conception to commercialization."

Yet things have usually seemed to work out for him in the end. When Rowse retired as vice president of Norton's High Performance Ceramics Division after 35 years with the company and nearly 60 patents to his credit, a colleague trotted out this line: "The unfortunate thing about being ahead of your time is that, when people finally realize that you were right, they will say it was obvious all along."

Robert L. Norton

Rowse's successor at Norton, Dick Allegro (Institute of Industrial Management '67), holder of 11 patents himself, has had nearly 30 years to observe invention at Norton. He says that inventors are commonly perceived as Ph.D.s in cobwebbed laboratories toiling for years and finally coming up with something. But invention as he knows it, ultimately leading to commercialization, is a repetitive process that calls for close cooperation between inventive types and marketing people. "Products rarely work the first time or the second time," he says. "There is a loop that needs to be cycled many times, racing between research, marketing, the customer—you have to have undying faith that your technology or your product is going to win."

Several of Allegro's patents deal with ceramic armor. Illustrating his point about the iterative nature of turning inventions into products, he tells of Norton Company's rapid development of ceramic armor vests for helicopter crews during the Vietnam era. The state of the art in 1964 was flat tiles, he says, which developed into curved tiles, 14 to a vest by May of 1965. By September Norton engineers had it reduced to five pieces; by February 1966 it was down to three pieces with raised edges for joint protection, and by November of that year the one-piece ceramic armor vest was ready.

One of the keys to the successful development of the vest, Allegro says, was the ability to assemble a team and commit considerable resources to the task. But inventors outside large companies don't have those luxuries; they often have to go to bat alone.

"Lone inventors need help but sometimes try to carry the ball too far themselves," says patent lawyer Paul Kokulis '45, senior partner in the Washington, DC, firm of Cushman, Darby & Cushman. Some think they can commercialize their inventions without any assistance, he adds. Other inventors know they need help but don't know where to find it. Often that's because such help is hard to find.

Kokulis sees a need for agents who can help inventors license or commercialize their ideas, but as yet there are few places where inventors can find "the imagination and the honesty and the ability to assess a spectrum of ideas and recognize which ones are worth pursuing." He thinks patent firms and engineering schools like WPI might be able to develop such practices in the future.

Management Associate Professor Hans J. Thamhain, who specializes in studying product development, probes the middle ground between the lone inventor without resources and the sometimes oppressive environment of a bureaucracy. "For an individual without any support system, there's a tremendous amount of individual drive and accountability and commitment, but without resources it's *very* difficult," he says.

"At the other end of the spectrum are inventors with all of the resources but in addition all kinds of procedures and sign-offs and checkpoints. Because of this, they lose the entrepreneurial spirit; they lose that special magic and commitment. Somewhere in between, maybe closer to a small company, is the optimum as far as entrepreneurial output is concerned."

That means more than creative output; entrepreneurs have to know when to make business decisions, too. Gerald Finkle '57, president of Wachusett Molding Corporation of West Boylston, MA, has seen many lone inventors make fatal business mistakes in commercializing their ideas. Finkle, whose company makes custom-designed molded plastic parts and helps its customers—individual and corporate—in the design of those parts, says the greatest disincentive afflicting individual inventors tends to be lack of capital. "Nowadays most individuals just don't have the financial punch that's required to bring products to the marketplace," Finkle says. "The process is too involved." Advertising, packaging, distribution, and building inventory all cost money.

Each of the individual inventors his company has worked with has failed, Finkle says, because they lacked capital, marketing skills, or the willingness to hand over their inventions to large companies on a royalty basis. That's why Wachusett Molding no longer deals with individual inventors, he adds.

Finkle tells the story of an individual who invented a new method of fabricating dental prostheses such as caps. Based on plastics technologies, the manufacturing method was fast, relatively inexpensive, and very precise—where precision counts. But the inventor was undercapitalized and tried to save money on tooling costs. As a result his demonstration products, made on the cheap, lacked the precision that was so important, and the product failed.

The heartaches of inventing can be too much for those with more design expertise than business acumen or time. Mechanical Engineering Associate Professor Robert L. Norton swore off design consulting 10 years ago because the rewards didn't make up for the headaches. Once a junior member of a research team that developed a biomedical product some years ago, Norton watched as incompetent managers brought in by venture capitalists drove the venture bankrupt within four years.

"Inventors won't be successful unless they are good at business," Norton says. "What it all boils down to is the marketing of the product." And being an inventor for a large corporation may even be worse, he contends. "You see most of your designs in the trash can not because they're bad designs but because somebody changed his mind about what he wanted," he says. The alternative, going it alone, calls for 18-hour days for three or four years, Norton says. Because of the demands of WPI's project-based system, he says, it becomes nearly impossible for faculty to usher their ideas into the market.

Pamela Weathers

But bringing a new idea to market isn't totally impossible, not for Biology and Biotechnology Assistant Professor Pamela Weathers. Weathers expects to bring a new plant tissue cultivator to market within the next 18 months—after more than five years of effort. Maybe her edge was working part-time at WPI at the beginning, or the guidance she received from Helen Vassallo, associate professor of management, but Weathers still has war stories to tell.

Arising from outside research work carried out before 1982 by Professor Kenneth Giles, then head of the Biology and Biotechnology Department, the idea for a new plant tissue cultivator immediately appeared to offer the promise of saving substantial amounts of labor, time, and materials over existing methods of tissue culture.

Giles, who now directs R&D efforts at Twyford Plant Labs in Baltonsborough, England, as vice president of Twyford International, teamed up with Weathers, then a post-doctoral researcher at WPI. Some of their first efforts toward commercializing the cultivator involved investing in business consultants "who didn't really know what they were doing," Weathers says. "They had put together restaurants but they hadn't put together high-tech firms."

Weathers' next step was to contact firms specializing in patent law. But at that time, she says, biotech was so new that the law firms didn't have anyone who understood the innovativeness of the cultivator. "They kept thinking it conflicted with existing patents," Weathers says. After spending nearly $2,000 of their own money at a well-known Boston law firm, Weathers, who had been running the whole effort since Giles left for Twyford, was running out of places to turn for help.

Then Giles suggested she contact Gary S. Winer '81, a biotechnology graduate who had gone on to earn a law degree. "Gary spent five minutes listening to me explain the technology, and he said, 'I'm absolutely confident you have at least one—

"Nowdays, most individuals don't have the financial punch required to bring new products to market."

Kenneth McDonnell

Helen Vassallo

maybe more—patents,' " Weathers recalls. "He said, 'You have found something really fantastic' because he understood what we were talking about."

Shortly after that conversation with Winer, Weathers and Giles had a patent filed. Now they are developing new applications for their tissue culture method and device, with a new research program that started this fall. Weathers says they hope to have a product on the market—with virtually no competition—by the end of 1987.

Weathers and Giles have high hopes for their cultivator. Plant tissue culture is normally a tedious, labor-intensive process, and their cultivator promises to cut the labor and materials costs by as much as 75 percent, Weathers says.

"In the end, there are very few products that are so unique that there are no substitutes."

Prospects look good now, but Weathers says she might not have come this far if she had known the headaches beforehand. "We probably would have said 'Forget this,' published a paper, and let it go at that!" she says. Sticking it out through the tough times took perseverence, some spare cash, and a support network consisting of Giles as well as Vassallo, who provided Weathers with invaluable business advice. There were difficult financial times and days when her patience wore thin, and she could have used help in making business contacts in the beginning. But the whole experience has given Weathers a good education in the "hard knocks" school of business.

What's the most important lesson Weathers learned? "Be fiscally conservative." Finding a competent attorney who understands the technology is also important. Weathers hastens to add that there are resources at WPI that inventors can turn to for help, such as the Management Department and Reference Librarian Joanne Williams, who helped Weathers with her patent search.

Vassallo, who also holds an appointment in the Biology and Biotechnology Department, had experience both in biological research and in management to draw upon in offering advice to Weathers. Directing research on local anaesthetics at Astra Pharmaceutical in Worcester and Framingham until 1982, Vassallo was part of a team that won a patent in the use of extremely powerful nerve toxins as spinal anaesthetics.

Saxitoxin, the deadly poison found in red tide, and tetrodotoxin, a sister material found in Japanese puffer fish (which kills a number of gourmet diners every year), were the subjects of Vassallo's work. The patent arose out of a brainstorming session in which she marveled at the toxins' remarkable ability to pass through membranes, leading to the idea of using them as spinal anaesthetics. But that experience was atypical, she admits, since such a short time elapsed from the "light bulb going on" to doing the key experiments to getting the patent. These toxins, which are 300,000 times as powerful as currently used anaesthetics, are still somewhat unpredictable and hence are not yet used in humans, Vassallo reports.

Getting the patent was as easy a task for Vassallo's team at Astra as it was fraught with disappointment for Weathers and Giles. But there's more to the game than just getting a patent. Paul M. Craig Jr. '45, a Washington, DC-based patent lawyer, stresses that possession of a patent is worth less—commercially—than many people think. "There are very few products that are so unique that there is no substitute available," he says. A patent can help the inventor in selling an idea, but it is seldom salable by itself. Know-how associated with the patent and its application are the real keys to successfully selling an invention.

For many, inventing is only the beginning of the entrepreneurial dream of building a company around one's own inventions. Alfred A. Molinari Jr. '63, president of Data Translation, Inc., of Marlboro, MA, brought his considerable marketing knowledge to bear in getting his computer peripherals company off the ground 12 years ago. Already familiar with the market for data acquisition equipment, Molinari started off with a data acquisition module that measured sensor inputs for process control computers and for medical and scientific applications.

His first unexpected challenge was the months-long delay in getting publicity from trade magazines. Molinari also found that he had to order certain integrated circuit chips months ahead of time. Those initial disappointments taught him the importance of factoring timing into his market planning.

Successfully going public with his company a year and a half ago was a big hurdle for Molinari, the result of 10 years of planning and hard work. But now he is used to taking a long-term approach to marketing inventions. Molinari's maxim of entrepreneurship: "Today is just a report card on what you did two years ago."

Editor's note: For more accounts of inventors and entrepreneurship, see "The Entrepreneurial Spirit," an ongoing series that began in the August 1985 issue of the *WPI Journal*.

Paul Susca is a free-lancer living in Rindge, NH.

LETTERS

Editor: In the fall of 1979, I received an unsolicited brochure in the mail from WPI. My parents and I read the brochure and were interested in the Plan. I applied to WPI and was accepted to start in the fall of 1980.

In the four-year period that I attended WPI, I watched the Plan slowly become dismantled. First there was the infamous ABET [Accreditation Board of Engineering and Technology] visit which triggered the Plan changes. As a result of that visit distribution requirements were added. Then around the time of my graduation the AD/AC/NR grading system was replaced by a A/B/C/NR system. I was dismayed by this as I felt the AD/AC/NR system led to less competition and more cooperation among the students.

In the August issue of the *WPI Journal* I was shocked to learn of the dropping of the Competency Examination! The Comp had a very special purpose. It proved that you had learned something in your classes and had not just squeaked by. I feared my Comp as it approached, but in reality it was not as bad as I had thought it would be. After completing it, I felt I had truly accomplished something!

By altering the Plan, WPI, in my opinion, has lost its advantage over other well-known engineering schools, both in the Boston area and nationally. Students have less reason to consider WPI in today's competitive college market. I would not have attended WPI under today's modified version of the Plan! I also do not feel I can unhesitatingly recommend WPI to future students!

Leslie Arlene Schur '84
North Reading, MA

1986–87 WINTER SPORTS CALENDAR

WRESTLING

DECEMBER		
3	at Boston College	7:00 p.m.
5–6	at Coast Guard Tourney	10:00 a.m.
10	at Plymouth State	7:00 p.m.
13	Harvard/UNH/NYU	7:00 p.m.
JANUARY		
14	Amherst	7:00 p.m.
17	RIC	1:00 p.m.
20	WNEC	7:00 p.m.
24	at U. Lowell	1:00 p.m.
25	N.E. Invitational (at MIT)	10:00 a.m.
28	MIT	7:00 p.m.
31	at Bowdoin	1:00 p.m.
FEBRUARY		
3	at Coast Guard	7:00 p.m.
4	Williams	5:00 p.m.
7	at Brown/Princeton/ Boston U.	1:00 p.m.
14	Wesleyan/Trinity	1:00 p.m.
26–28	NECCWA (Amherst)	TBA
5–7	NCAA III Nationals (U. Buffalo)	TBA

MEN'S WINTER TRACK

DECEMBER		
3	at Tufts	6:00 p.m.
6	at MIT/Brandeis	1:00 p.m.
FEBRUARY		
4	at Holy Cross/ Worcester State	7:00 p.m.

MEN'S BASKETBALL

NOVEMBER		
21, 22	Worcester 4-T at Clark	6:00 & 8:00 p.m.
DECEMBER		
2	Babson	8:00 p.m.
6	at Bowdoin	4:00 p.m.
9	Amherst	8:00 p.m.
11	Wesleyan	8:00 p.m.
13	at NYU	4:00 p.m.
JANUARY		
9, 10	at Union Tournament	TBA
15	Worcester State	8:00 p.m.
17	at Bates	4:00 p.m.
22	at Brandeis	7:30 p.m.
24	Kings Point-U.S.M.M.A.	8:00 p.m.
27	Trinity	8:00 p.m.
30	at CGA	8:00 p.m.
FEBRUARY		
4	at Williams	8:00 p.m.
7	Tufts	8:00 p.m.
12	MIT	8:00 p.m.
14	at Salve Regina	7:30 p.m.
17	at Nichols	7:00 p.m.
19	SMU	8:00 p.m.
21	Anna Maria	8:00 p.m.
25	Suffolk	8:00 p.m.
28	Clark	8:00 p.m.

MEN'S SWIMMING

NOVEMBER		
21	Holy Cross	7:00 p.m.
24	Babson	6:00 p.m.
DECEMBER		
3	at Boston College	7:00 p.m.
6	at RPI Invitational	Noon
9	at Clark	6:00 p.m.
JANUARY		
17	at Connecticut College	2:00 p.m.
24	CGA	2:00 p.m.
28	at U-Mass Boston	6:00 p.m.
31	SMU	2:00 p.m.
FEBRUARY		
5	at Trinity	7:00 p.m.
7	Colby	2:00 p.m.
11	Bridgewater State	6:00 p.m.
14	at Keane State	1:00 p.m.
18	Brandeis	7:00 p.m.

WOMEN'S BASKETBALL

NOVEMBER		
21–22	City Championship	6:00 & 8:00 p.m.
DECEMBER		
1	Fitchburg	7:00 p.m.
5–6	Chuck Resler Invitational NYU/ Worcester State/ Rochester	6:00 & 8:00 p.m./ 1:00 & 3:00 p.m.
9	at Bridgewater	7:00 p.m.
11	at Framingham	7:00 p.m.
JANUARY		
17	at Bates	2:00 p.m.
20	CGA	7:00 p.m.
27	at Wheaton	7:00 p.m.
29	at Nichols	6:00 p.m.
31–1	New England Invitational Colby/ USM/U. Mass	TBA
FEBRUARY		
4	Brandeis	7:00 p.m.
7	at RIC	7:30 p.m.
10	Amherst	7:00 p.m.
12	MIT	6:00 p.m.
14	Western New England	2:00 p.m.
17	Emmanuel	7:00 p.m.
19	SMU	6:00 p.m.
21	at Anna Maria	2:00 p.m.
24	at Trinity	7:00 p.m.
26	at Bowdoin	7:00 p.m.
28	at Clark	6:00 p.m.

WOMEN'S SWIMMING

NOVEMBER		
23	Regis Invitational	Noon
24	Babson	6:00 p.m.
DECEMBER		
10	Clark	7:00 p.m.
JANUARY		
17	at Connecticut College	2:00 p.m.
23	at Southern Connecticut State	7:00 p.m.
28	at U. Mass Boston	6:00 p.m.
31	SMU	2:00 p.m.
FEBRUARY		
3	at Regis	7:00 p.m.
11	Bridgewater State	6:00 p.m.
14	at Keane State	1:00 p.m.