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Gordon Moore and the Legacy of Fairchild

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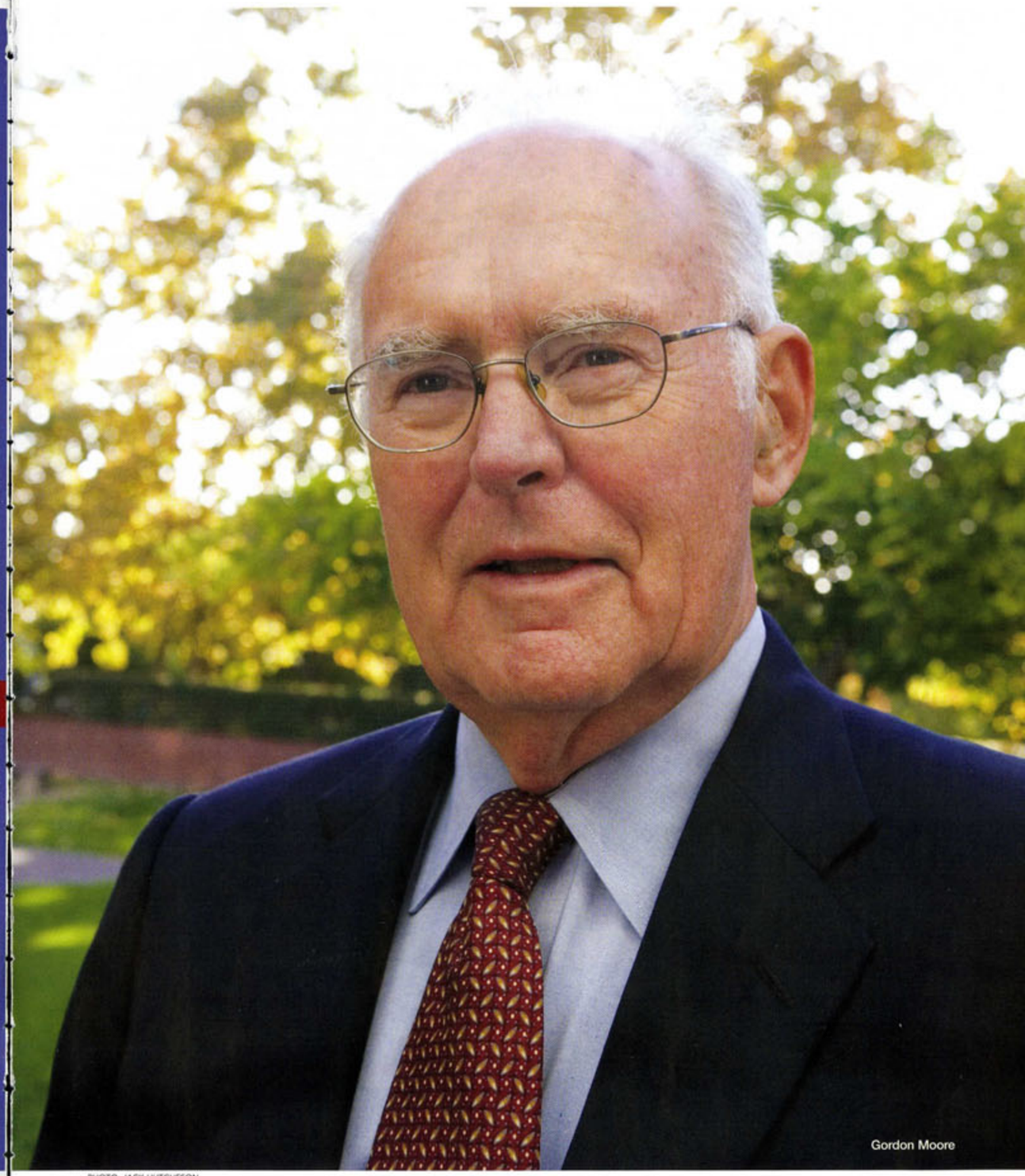

Gordon Moore

PHOTO: JACK HUTCHESON

In 1939, Sheriff Walter Moore was the only law enforcement west of the mountains on the coast of San Mateo County. Promoted that year, he moved with his wife, Mira, and three young sons from the small village of Pescadero to the county seat in Redwood City. "The area was a bunch of small rural communities connected by a railroad and a couple of highways that went down the peninsula," his son Gordon recalls. "There were fruit trees all over." Sheriff Moore was sometimes called to settle fights in the farm labor camps. He drove down El Camino, where cows grazed along green fields, never dreaming that his 10-year-old son would be among the small handful of men who would turn that rural valley into a sprawling electronic hub, transforming the modern world.

Gordon Moore would become a founder of Fairchild Semiconductor, the seed of Silicon Valley, and go on to launch Intel, the company that would develop the microprocessor, an invention as world-changing as writing or electricity. Mira Moore died in 1972, never to know that her son had sown the seed of a future as different from her world as Redwood City from a Roman village.

The valley of Gordon Moore's youth was an alluvial plain 25 miles long and 10 miles wide, an agricultural horn of plenty whose cherry, apricot, peach, and prune-plum orchards were the most prosperous in the nation. When the winds came through the mountains off the Pacific Ocean, a blizzard of pink and white fruit blossoms would stop traffic in the small town streets. For several thousand years the Valley had been the home of the Ohlone Indians. With the coming of the Spanish, displacing the Ohlone and founding the first mission in 1777, thousands of cattle roamed the Valley. Then came the Irish, Italians, and other immigrants in the late 19th century, and fruit trees displaced the cattle. But a third great transformation was already stirring early in the 20th century.

The same year that Walter Moore's family moved to the Valley, two young Stanford graduates named Hewlett and Packard were working in a Palo Alto garage, building the audio-oscillator that would put them in business. Two brothers, Russell and Sigurd Varian, working without pay in an unoccupied lab at Stanford, had just developed the klystron tube that would give Allied radar the edge in World War II. And in the chemistry lab he built in his garage, Sheriff Moore's 10-year-old son fashioned firecrackers from homemade nitroglycerin converted to dynamite.

Resolved from the age of 10 to become a chemist, Gordon Moore entered San Jose State College in 1946, transferred to Berkeley for his Bachelor's degree in chemistry, and at 24, earned his Ph.D. in chemical engineering from Caltech. In 1956, after two and a half years with the Applied Physics Laboratory at Johns Hopkins, he got a call one evening from William Shockley, coinventor of the transistor, who had left Bell Labs to form his own company in Mountain View. Shockley had gotten Moore's name from a list of people who had turned down job offers from Lawrence Livermore Laboratory in Berkeley. Working in what was not much more than a Quonset hut behind an old storefront on San Antonio Road next to what is now the Sears shopping center, Moore joined the group of talented scientists and engineers that Shockley had assembled with the intention of making a silicon transistor.

"I hardly knew what silicon was," Moore reminisces. "Shockley not only got me into semiconductors, he unwittingly gave me the push to go off and found Fairchild." When Shockley abandoned the silicon transistor in pursuit of an impractical four-layer diode, Moore became one of the now famous "traitorous eight" who tired of Shockley's paranoid personality and left to found Fairchild Semiconductor, the group that invented the planar transistor and the integrated circuit, launching the digital age. "Shockley made an entrepreneur out of me," he says, "an accidental one. It all happened by chance."

When the eight defectors approached some investment bankers, hoping to find a company that would hire them as a group, they were advised to set up their own company instead. "That didn't sound bad," says Moore, "we had all bought houses by then—they were affordable in California at that time—and we wouldn't have to move. And starting a new company was easier than looking for a job." In their quest for corporate backing, 35 companies turned them down without even talking to them. Finally, Fairchild Camera and Instrument invested $1.5 million. "Each of the eight of us invested $500 in this start-up," Moore recalls. "That may not sound like much now, but it was a month's salary in 1957."

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Fairchild developed the first commercial silicon transistor, pioneering the use of photolithography and a new form of mass production that allowed multiple transistors on a single wafer. They then developed the "planar" process that protected the circuits from contamination and produced an ultra-reliable transistor. It was the planar process that enabled them to develop the first reliable, mass-produced integrated circuit. And the rest, as they say, is history (see "The *Real* Revolution," Gentry, February 2008).

"We had no idea of the magnitude of the opportunity we were dealing with," says Moore. "We were still a bunch of guys in a laboratory, somewhat amazed that people actually wanted to buy our products. We had little notion of the impact of our discovery. Here we had developed and engineered the first integrated circuits, the first family of logic circuits—very simple devices with simple gates and flip flops—and put them into production. I remember calling the senior people in the laboratory together and saying, 'OK, we've done integrated circuits. What'll we do next?' And we started looking for all the peculiar physical effects we could find to see what *new* devices we could invent. We had *no* idea at all that we had turned the first stone on something that was going to be an $80 billion business. It was a very young industry. We were all learning together."

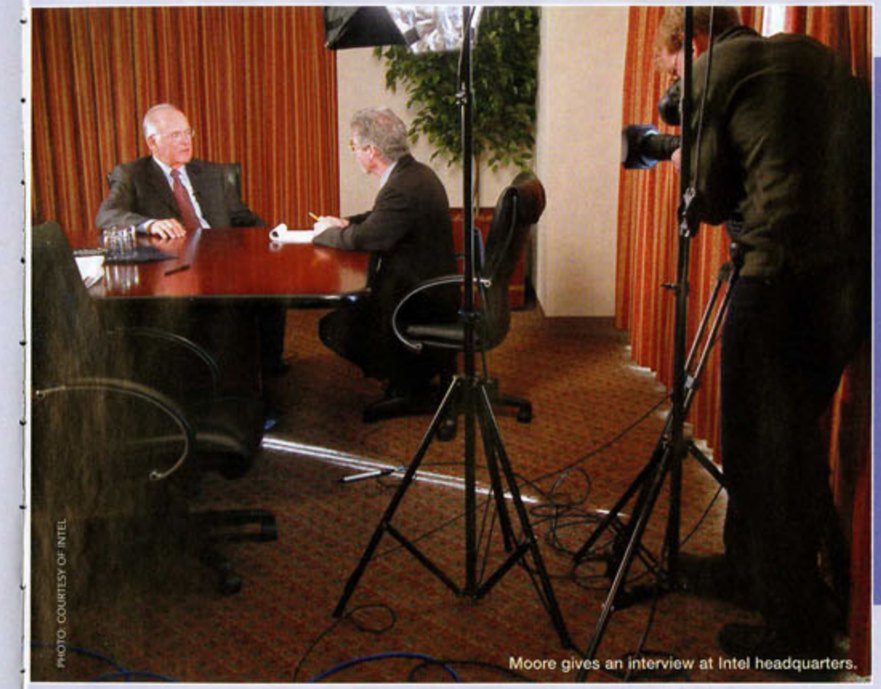
PHOTO COURTESY OF INTEL

Moore gives an interview at Intel headquarters.

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They weren't the only ones unaware of the potential. Integrated circuits didn't catch on for five years. Customers were concerned that they couldn't test the sealed-in transistors, and "they felt that they didn't really need integrated circuits," says Moore. "So Bob Noyce sold the circuits for less than they could buy the individual parts. This was a shock because we couldn't make them for that. But Bob extrapolated that we'd be able to make them cheaper if we could get a volume base going. And that kind of tipped the scales. There was a big push for miniaturization with the military and the space program, and the major breakthrough came when the Minuteman 2 program decided to go extensively with integrated circuits."

To sell the idea that integrated circuits were the way of the future, Moore published an article in *Electronics Magazine* in April 1965. He saw that the number of transistors in an integrated circuit was doubling every year and predicted that this would continue for the next 10 years. "Amazingly enough, we stayed almost exactly on that curve for ten years," he says. The article also predicted computer terminals, "personal portable communication systems," and computerized automobiles. He modified his projection in 1975, suggesting that the number of transistors on a chip would double every two years. "I was a little too pessimistic," he says, "it now doubles somewhere between 18 months and two years." The projection, now known as "Moore's Law," has become the primary meter of modern technology.

"For a long time I was embarrassed to have it called Moore's law," he says, "but I've gotten used to it. Anything that changes exponentially and remotely relates to the industry is called Moore's Law these days and I'm happy to take credit for all of it." More than chronicling the history of the industry, he adds, it's become a driving function "because the companies in the business recognize that unless they progress at least that fast, they're going to fall behind. So we really are using it to decide how fast we have to develop new technology and how rapidly we have to introduce new products." Though the fact that materials are made of atoms will eventually become a limitation, he feels that the sheer complexity at that point will "still allow a phenomenal range for people to be creative."

For awhile, it appeared that Moore's Law also applied to the

PHOTO: JACK HUTCHESON

George D. Wells, Gordon Moore, and Bill O'Mara smile for the Gentry camera at the 50th Anniversary celebration for Fairchild at the Computer History Museum in Mountain View in October 2007.

explosion of startups in the Valley. That was a time, he says, when "it seemed like every new idea that came along spawned one to five new companies. At Fairchild, we were mining an extremely rich vein of technology, but the mining company was too small to handle what was going on. So literally dozens of companies came out of the Fairchild experience. Not only did the technology come out of it, but Fairchild also served as a successful and encouraging example of entrepreneurship—the if-that-jerk-can-do-it-so-can-I syndrome. Fairchild set this whole idea in motion that a few young engineers with some good ideas could take some money and go off and set up a new company. That was really the difference between Silicon Valley and other places. The Boston area had a lot of high-technology companies, but they tended to operate in the classical vertically integrated mode and they never had this tremendous fractionation that existed out here. In Silicon Valley, people weren't risking anything when they tried to start a new company; if they failed they could still get jobs for 20 percent more because they were experienced. There was really no stigma at all to failing and that's been an important part of this area."

Even the general manager Fairchild had hired went down the street to form Rheem Semiconductor. In the reshuffling, Moore became director of R&D. "I liked doing science and engineering," he says, "but somebody had to take the management job, and it fell on me. I had no training in business. After my sophomore year of college I didn't take any courses outside of chemistry, math, and physics." When he had applied for a job at Dow Chemical, the tests concluded that he was fine technically but would never manage anything. "Managers are people-focused," he says. "They set directions and review projects. I was never very systematic at doing those things. For one thing, I'm a natural-born procrastinator. But even without the usual management skills, I did okay. In our industry, having technical understanding and vision is probably a lot more important than being able to run a project well." Arthur Rock, now known as the dean of venture capitalists, once told *Fortune* magazine that "Gordon, more than anyone else, set his eyes on a goal and got everybody to go there."

In 1968, Moore and Bob Noyce founded Intel, focusing on memory chips. They went public in 1971 on the same day and at the same price per share as Playboy Enterprises. A few years later, an analyst looking at the reports announced: "The market has spoken. It's memories over mammaries ten to one!" "By luck, we had hit on a technology that had just the right degree of difficulty for a successful start-up," says Moore. "By concentrating on a technology called silicon-gate MOS (metal oxide semiconductor), we were able to solve some of its difficult problems. The established companies that were tending their main business and doing new process development on the side didn't have time to focus on solving the problems and took several years to get going on it. Our initial estimate was that we had five years to grow big enough to prevent the existing companies from putting us out of business. In fact, we had seven years before the big companies got into our technology. That was how Intel began."

In the explosive pace of the Valley, missed opportunities were inevitable. "Long before Apple," Moore reminisces, "one of our engineers came to me with the suggestion that Intel ought

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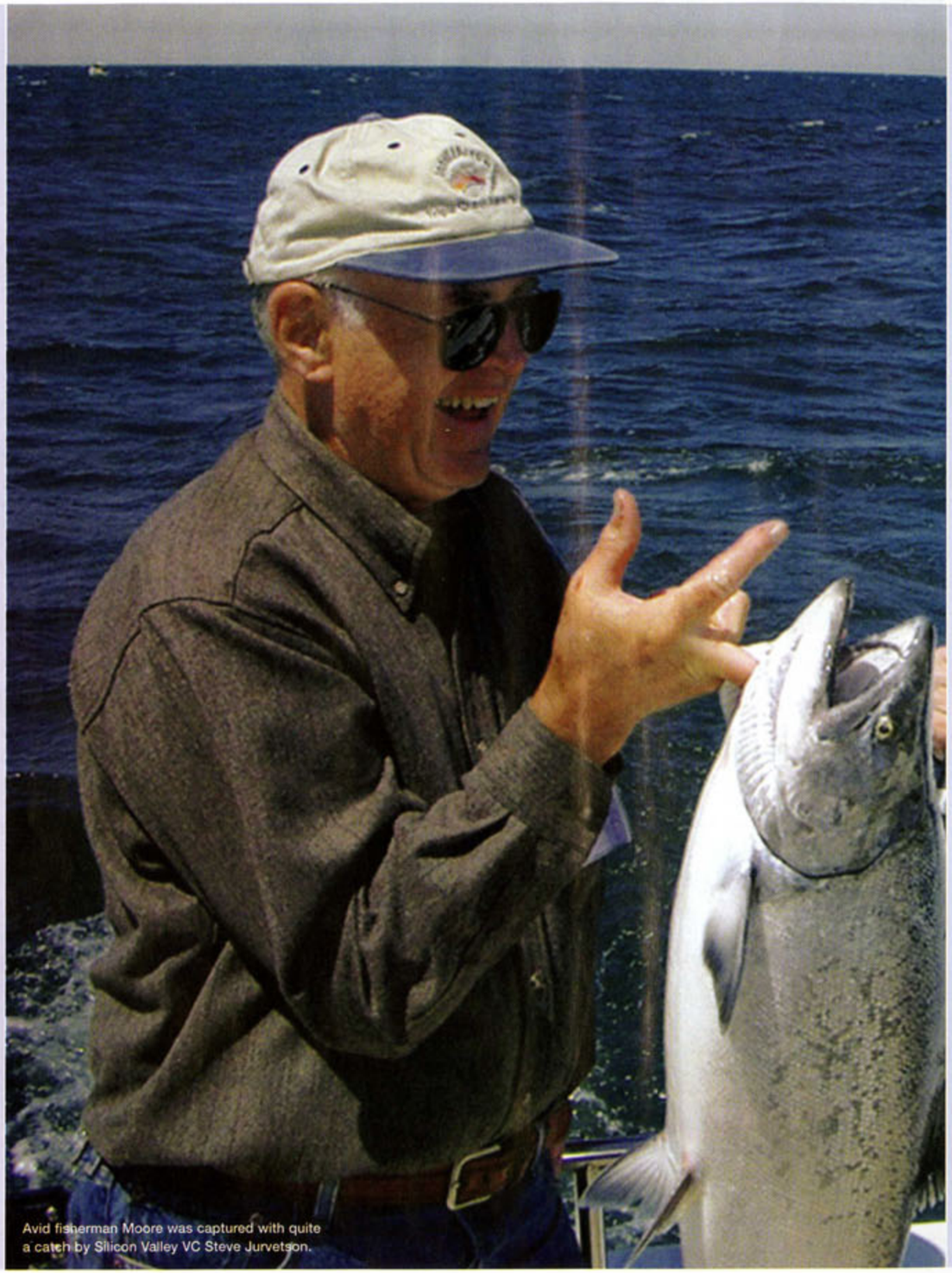
to build a computer for the home. And I said, 'What the heck would anyone want a computer for in his home?' The only example he could come up with was something for the housewife to put her recipes on. I could imagine Betty at the stove cooking, poking at her computer to read the recipe. It seemed ridiculous! Perhaps we didn't miss that opportunity after all, because Intel does make a profit out of the PC business—not by being in it, but by serving it. And that may be the best way. I don't really regret having missed it, but I would rather have missed it for a different reason than just thinking it was impractical."

In 1971, Intel introduced the world's first commercial microprocessor, the third world-changing innovation to come out of Silicon Valley. The first was the transistor, co-invented by Shockley and perfected at Fairchild. The transistor gave us the basic switch and made possible the integrated circuit, conceived at Fairchild by Bob Noyce. "It was the integrated circuit that drove down the cost," notes Moore, "and to me, the decrease in cost is the principal driving force for what's happened subsequently." From the integrated circuit came the microprocessor, developed by Ted Hoff at Intel, which made possible the home computer, the Internet, and the whole digital revolution on which nearly all technologies now rest. Microprocessors are now essential to every control application in the world, from consumer electronics and home appliances to automobiles and factory equipment. In the evolution of our species, these three innovations are equivalent to the invention of the wheel or metal casting, and Gordon Moore was there for all three.

Now Chairman Emeritus of Intel, Moore donated $5 billion in 2000 to create the Gordon E. and Betty I. Moore Foundation, one of the nation's largest philanthropic institutions, focusing on environmental conservation, scientific research, and Bay Area projects. When the Foundation awards a grant, he says, the parties "negotiate measurable things that have to happen or be looked at in order to see how effective the grant was. This represents a new discipline for potential grantees."

Moore earmarked some $300 million for preserving biodiversity. He is a major supporter of Conservation International, a science-based organization that centers on saving Earth's so-called "hot spots" of biodiversity. These hot spots make up only 1.4 percent of Earth's land surface, but they are thought to contain some sixty percent of its terrestrial plant and animal species. "If enough of these hot spots aren't preserved," he says, "we may be the last generation to have wild places on Earth. These regions are being wiped out, opened up, and developed. We are seeing the impact of a single species gone amuck in the world." He cites a theory that world population will peak during this century and drift down, decreasing the pressure on resources and these hyper-rich ecosystems. "If you believe this," he says, "we have a chance at saving something that might last a very long time."



Avid fisherman Moore was captured with quite a catch by Silicon Valley VC Steve Jurvetson.

When funding for the Search for Extraterrestrial Intelligence (SETI) was discontinued by such far-seeing senators as William Proxmire, who gave it his "Golden Fleece" award, Moore got involved in rescuing it, thinking it would work its way back into NASA funding. The cost of SETI is equivalent to about a nickel per taxpayer per year. "It's a legitimate part of NASA," says Moore. "And if we discover intelligent life, it could change the course of human history." Moore and his wife also donated $200 million to Caltech and the University of California in 2007 for the construction of the world's largest optical telescope; its mirror will be thirty meters across.

Moore's many other gifts include the Betty and Gordon Moore Library at the Centre for Mathematical Sciences at the University of Cambridge and the Gordon and Betty Moore Laboratory of Engineering at Caltech, a 90,000-square-foot research and teaching facility. The Laboratory's many areas of research include Caltech's program in computation and neural systems, tackling complex problems at the interface of neurobiology, electrical engineering, computer science, and physics. He donated $600 million to Caltech, the largest gift ever to an institution of higher education. His comment: "The education I received there has served me well."

"I've been fortunate to be in the right place at the right time and make a lot of money in this business over the years," he says. "My biggest challenge now is figuring out how to use that to have the most impact. I think it's harder to give it away than it is to make it initially if you want to do it carefully and be sure what you're doing makes sense." Moore was awarded the National Medal of Technology in 1990; and in 2002 he received the Medal of Freedom, the nation's highest civilian honor, from George W. Bush.

"I talk to a group of students at the Stanford Business School about once a year," he says. "It amazes me—everybody in the class wants to start their own company. I don't think any of them have an idea of what they want that company to do, they just want a company. I couldn't operate from that direction. I have to operate from the idea first and then set up something to pursue it. We saw an opportunity in setting up Fairchild to complete Shockley's vision, which he had abandoned, to make a silicon transistor. At Intel, we saw an opportunity to make very complex circuits and change the leverage in the business—which we did, starting with memory, and then by moving into the microprocessor. If we hadn't seen those opportunities, I would have been very reluctant to just go out and set up a company." Nor is it as simple as many think. "When you're a startup company," he says, "you have to bet the company on a lot of the programs you do. When you get bigger you only want to bet half the company if you can do that. You don't want to do something that will put you out of business completely if it doesn't work. On the other hand, you gotta keep reaching. If everything you do works, you're probably not trying hard enough."

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The problem now is that production costs, in line with Moore's Law, continue to rise exponentially. "When Intel was started in 1968," he reflects, "a piece of equipment cost about $12,000. Now when we build a plant, each of those pieces of equipment costs in the three to five million range. For today's cost of one piece of equipment we started Intel. When you combine that with the increase in process complexity, a modern factory costs billions of dollars. I'm concerned that the economics are more likely to limit progress than any fundamental physical problems."

But he remains optimistic. "I sure wish I could be around in 40 years to see what happens," he says, noting the exponential progress in genomics and the promise that it will lead to personalized medicine down the road. "Imagine what the next hundred years will do." As to Moore's Law, he says he'd rather be able to change the future than predict it. "What you can do tomorrow depends on what you have done today."

There is something mythically American about the story of this soft-spoken, unassuming man, who gave 600 million dollars to his alma matter. He grew up in small town where the family kept a milk cow behind the store across the street. Reminiscent of young Thomas Edison, he blew his ears out with homemade explosives and sent rockets onto his neighbor's roof. Only one relative, a cousin, had gone to college (Moore's father had quit school in the seventh grade to help support the family when his father died). Gordon entered Caltech, thinking he would become an academic chemist, and his wife went to work to put him through. But by a chain of opportunities and chance events he found himself in Palo Alto in 1957, putting up $500 to start a little company on Charleston Road. His return on that investment has been something like ten million percent, while the return on the founding of Fairchild for the future of humanity is immeasurable—perhaps infinite. Journalist Michael Malone described Moore as "brilliant, tough, and deeply moral, a man of both self-effacement and deep humility," who combines "earthiness and high-mindedness, hands-on pragmatism, and a belief that he can change the world." Apparently it was more than a belief. ■

Quotations are from Gordon Moore, "The Accidental Entrepreneur"; Computerworld Honors Program International Archives, "Gordon Moore Oral History"; Rob Walker, "Interview with Gordon Moore"; Hillary Bhaskaran, "Calibrating Gordon Moore"; and Michael Malone, *Betting It All: The Entrepreneurs of Technology*.