Carver Mead

ENGenious met with Caltech alumnus Carver Mead (BS '56, MS '57, PhD '60) to learn more about his passions and how his Caltech education shaped him. For the past 50 years, Carver Mead has focused his research and teaching on the physics and technology of electron devices. He is a prolific inventor and is extremely creative. He also loves to teach, encouraging his students to create clean designs and contribute more than their share.

ENGenious: You seem to reinvent yourself every few years. How do you do it?

Mead: Well, you have to! That's the only way to keep going, at least for me. In my case, it's about a 13-year cycle. I get to where I feel like I'm not doing anything new anymore. I'm grinding away at the same stuff. I start getting depressed and end up mucking around for a year or two. Usually I plod from one thing to another until something grabs me. When I get into a new endeavor, I get lots of new ideas and a lot of them are wrong, of course. I explore a lot of avenues, many of which other people have done. But some, they haven't, and I don't know the difference in the beginning so I muck around and I try to get my own idea about how things are. It turns out it's extremely rare that I get all the same ideas as everybody else. I don't start by reading what everybody did—I go to seminars. I find that the fields have gotten so fragmented today that you can get a little bit here and a little bit there. I go to the astronomy seminars, the physics seminars, the biology seminars, the geology seminars, and the planetary science ones because different people have different takes on things. They think about things in different ways. Also every once in a while, somebody will say something that clicks. Caltech seminars are very unique because the speakers are instructed to make them accessible to a broader audience. For that reason, they will often say very revealing things because they're not just among specialists. So you hear people say things that you won't find in any of the papers because papers are written for a very narrow audience of people that think exactly alike. You don't ever see the out-of-the-box stuff there. That's why our seminars at Caltech are particularly good. You get insights that you just wouldn't get from a standard technical paper.

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ENGenious: What types of things grab you?

Mead: Oh, there have been lots of them. In the beginning, it was the tunneling stuff. When I was a graduate student, I got fascinated by Leo Osaki, the guy who did the tunnel diode in the '50s. I just fell in love with that whole thing and, even though I was doing my thesis on something else, when I finished I just had to work on it. When I got on the faculty in the late '50s, I had this little lab and started doing experiments. In the beginning, it was just what everybody else was doing. Gradually I figured out some different ways of looking at it, and I ended up doing a bunch of stuff that people hadn't done. That was just a wonderful period—it was my first real independent research, and it was really neat. So there have been a bunch of things like that.

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ENGenious: What are you working on right now?

Mead: Right now I'm working on reconceptualization of electrodynamics and gravitation. A lot of that's been done, but the way people are doing it is very murky and complicated. I believe there's a simpler way of doing it, and I'm gradually getting results. They seem to be holding together and that's very exciting.

ENGenious: What keeps you up at night?

Carver Mead with group of students

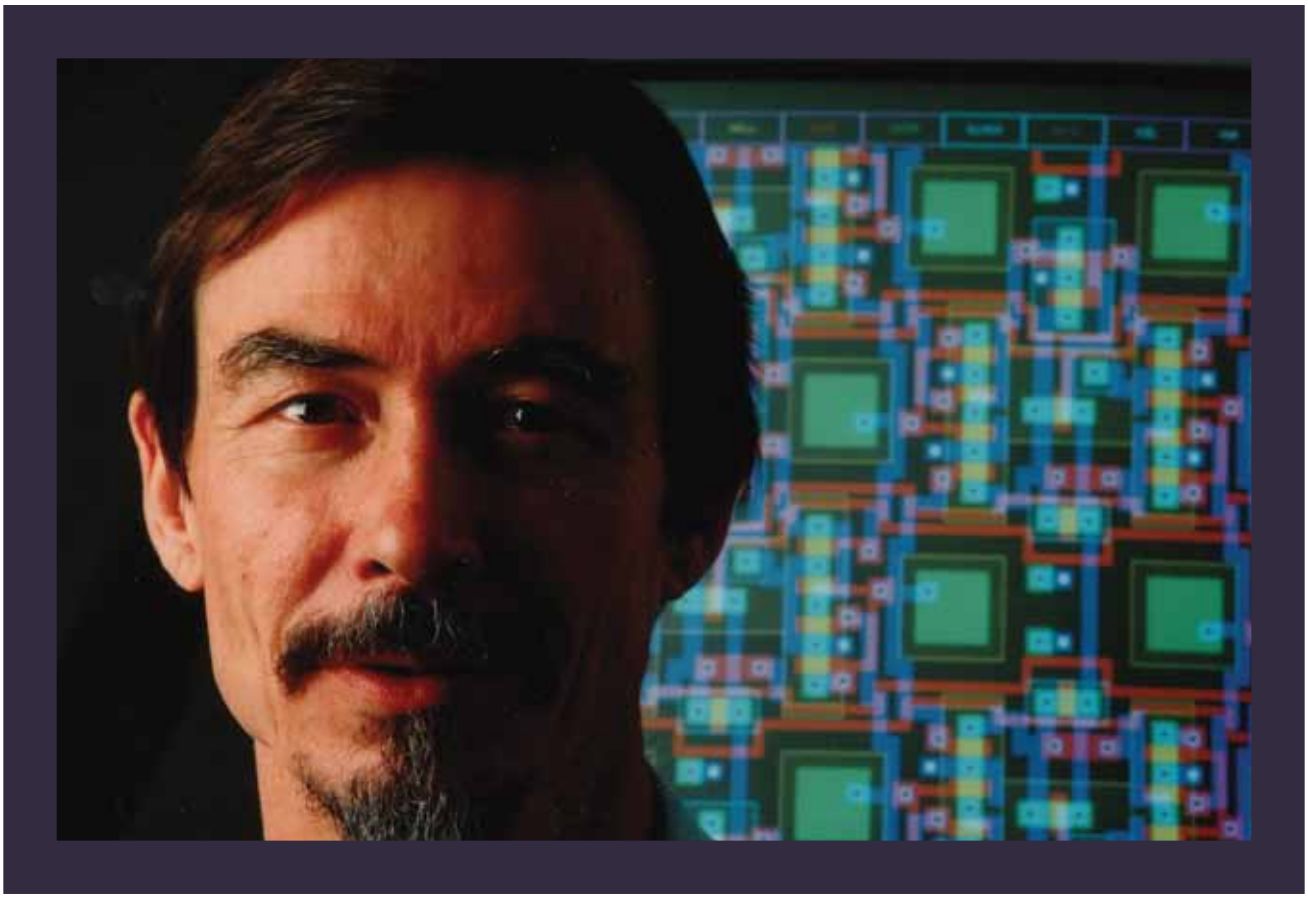
Mead: Well, what usually happens is that I'll be working on something and I get really tired. I'll have dinner, relax, and go to sleep. Then in the middle of the night, usually between one and three in the morning, I'll have this period when I'm awake and very creative. I'm told there's something that happens in your brain at those hours. I don't purport to know anything about that, but that's when I get the new ways of thinking. Then I get up in the morning and start working on the problem.

ENGenious: Who inspires you?

Mead: I tend to hang out in my mind with the people who have done really clear thinking in the area that I'm trying to push ahead. With my present work, the person I hang out with a fair bit is Einstein because he started on this path and then he went off on another path. I read his work before he went off on the path that everybody else uses now, and I can see what he was thinking. So those tend to be the people who inspire me.

ENGenious: You have a passion for teaching. What were some of your first teaching experiences?

Mead: It was the mid-fifties and Caltech had just hired Dave Middlebrook from Stanford. Dave had this wonderful British way about him, and he taught the graduate course in transistor electronics, which of course I loved, so I took it in my first year of grad school. In my second-year, Dave decided he'd take a leave of absence to write his new book, so, as a second year grad student, I got to teach the course. Talk about being thrown into the deep end of the pool! I had been a teaching assistant as an undergrad, and I was pretty good at it, but teaching an entire course was quite an interesting experience. I started the first week trying to teach it the way Middlebrook did. A lot of the students were from Europe and had had an additional year of education beyond what we had in our bachelor's degree, so they were already better at a lot of the things than I was. The first weekend I went for a walk in the mountains and thought, "I'm never going to make it." I walked and walked and thought, "I can't pretend to be a little miniature Dave Middlebrook. If I'm going to succeed at teaching this course, I have to teach it the way



Carver Mead in front of a computer chip from the '80s

I understand it, not the way he understands it." So the next Monday, I went in and I taught things the way I understood them, and the students gradually stopped harassing me and started listening. A few weeks later, we had a good relationship, and they felt they were learning something. By the end of the course, they were actually saying good things as they picked up their exams. That was an important learning experience for me. I'm never going to succeed trying to be somebody else, I just have to do it my own way. When you think about it, we've come light years from then. The transistors in those days were used in hearing aids and that's about it. It was a really, really long way from there to here.

ENGenious: This year we are celebrating the centennial of Electrical Engineering at Caltech. Where do you think we are headed?

Mead: Everybody asks me that—if we knew that, it wouldn't be the future! There are some things about the future you can predict because the question is well formed. Like Gordon Moore's question to me of "How small can transistors get?" I was working on electron tunneling, which is something that happens when things get very small, and Gordon asked me, "Does tunneling affect how small you can make a transistor?" I said, "It certainly will," and he said, "Well, how small is that?" Then I thought, "Oops, now I've got to put my money where my mouth is," so I went away and worked on it with a student. There had been enough other work done in the field that we knew the physics. We could work out approximately where you'd start to have problems, and it turned out to be a much smaller transistor than anybody thought. We were able to predict something that has actually held up for 30 years. That's because the question was well formed: This is a transistor. How small can I make it? Therefore, if I can make it that small, I can put a zillion of them on a piece of silicon this size, etc., etc. It was an important observation that led to the industry going on this path of making things smaller. Everybody points to that as a prediction of the future—but it really was an observation about physical limits. But from it you could infer that, if people got their act together, it wouldn't be physics that limited them.

ENGenious: What limits us?

Mead: Politics does for sure—but that isn't something I know anything about. The exciting ones are where we are limited because we haven't thought the thought yet. Just take a homespun example with the telephone. It used to be that when you called a phone, you called a place. Now, when you call a phone, you call a person. People don't even think about it now. But, in fact, it's a completely different thought and a very recent one. It's much more effective because, typically, most of us don't want to call a place—we want to call a person. This is an example of where the availability of the technology makes you think differently about the world and your life. Another example is the Web. It has completely transformed the world economically, intellectually, and in terms of international relations. It will, as time goes on, have a far larger effect than any political moves anybody makes. I know many of the people that did the early experiments on the Web. The integrated circuit work enabled some of it also. But none of us predicted the impact it would have on the entire fabric of human culture. It's been marvelous! It is, by far, the biggest contribution to international peace and prosperity that has ever been, and it's really our only hope for peace among nations and for a constructive world. It causes you to have a whole different global viewpoint.

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ENGenious: Will technology continue to transform the world?

Mead: Yes. Will it transform it in a positive way? Absolutely. It's the one force we have that is more powerful than human greed and control mania. Will it continue to evolve and will the next 100 years be even more positive than the last? Yes. How exactly? Part of it will be an obvious evolution of what we have now. But the most exciting part will come out of left field, and we will say, Wow!

ENGenious: What role is Caltech playing in this transformation?

Mead: Caltech exposes students to the way of thinking and designing that is essential for this transformation. Dick Feynman said, "The real glory of science is that we can find a way of thinking such that the law is evident." So instead of grinding away through piles of garbage, it's clear because you found the right way of thinking about it. With engineering, we call it a clean design. The Apple iPhone is an example of a clean design. It works the way you want it to. Tektronics used to make oscilloscopes where it was as if the instruction manual was on the front panel. If people design good instruments, it is obvious how to use them. That's the equivalent in engineering of the thing Feynman said about science. Caltech has enough of this, which the students get exposed to. The good ones will realize that that's the way they want to work, and they will go off and do remarkable things. One of our former students, Dave Gillespie (BS '86, MS '88), did the human interface work on the touch pads that are used in a lot of mobile devices. He's the best human interface person I ever knew, even when he was a student here. He made enormous contributions to the work we were doing, and he's still at it. He's the guru of Synaptics and just continues to come up with these wonderful things.

We at Caltech have contributed more than our share to the world. As we're looking to the future, which should be our aspiration, we want to give more than our share of those natural, beautiful, clear, clean, glorious contributions. E N G

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