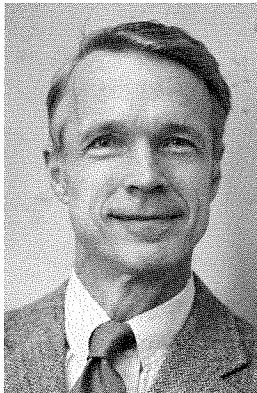# Computers and Society: Evolution and Revolution

by John Hopfield

Humans are at the top of the heap now, but there's no question that in about 20 years, that role will be filled by computers.

I will limit my contemplation of the unexpected to the information and computer revolutions, which I have no doubt will have a profound impact, not only on the future, but quite possibly on the vision that future generations will have of a sustainable world. In 1981, I bought my first desktop computer. Today, 10 years later, I have a different one that costs about the same amount of money, but has approximately 100 times as many transistors, five times the speed, four times the CPU (Central Processing Unit) capacity, and perhaps 2,000 times the effectiveness of my original model. This rate of change isn't going to stop, and it isn't restricted to desktop computers. Megacomputers have grown equally and perhaps even more rapidly, thanks to the advent of parallel-processing techniques. Many of the costly and complicated calculations we perform in engineering, science, and economics are now carried out on these large machines. Megacomputers are also going to play a part in making predictions about such things as ecological systems, a role that's in a sense both more important and more ominous than their current function in science or economics. It's ominous because, unlike biological systems, computers and their programs tend to be relatively brittle. They're engineered to do what they do fairly well, but they aren't designed for a large number of possible eventualities. Remove a few parts from a biological system, and it still tends to function. Do the same with a computer, and suddenly there's no phone service in New York City. The real hazard of this change is that mankind is going to invest responsibility in computers that

computers haven't had before. There is a real potential for danger there.

In another sense, however, this whole scenario is just a replay of a universal evolutionary trend. The evolution of animals has really been the story of the evolution of information-processing systems. The animals that function best are those that can most effectively use information about the present to predict what might happen in the future. Humans are at the top of the heap now, but there's no question that in about 20 years, that role will be filled by computers. And in this arena, I think the great challenge to humans will come, not from the megacomputers, but from smaller systems somewhat like today's desktop model. The human brain has approximately 100 million more computing elements in it than a typical desktop computer. But the computer has hardware that works about 100 million times faster. If we project the current pace of advances in computer technology into the not-too-distant future, it's quite clear that 25 years from now, we're going to have in our homes and our workplaces something of greater-than-present human intelligence. Computers are going to completely take over many mundane tasks that people now do and take great pride in. They will be the best medical diagnosticians. They'll be the lawyers who can present the most convoluted arguments. They'll be the safest and most alert cross-country truck drivers. They'll take over the jobs now held by secretaries and postal clerks. In the 19th century the Industrial Revolution displaced large numbers of people who had made their living by skills of the hand, and the result

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was massive unrest and social turmoil. In the 21st century, the computer is going to have exactly the same effect on an immense number of jobs now held by the middle class. Thus, my first real suggestion for the unexpected is a strong anticomputer movement in the workplace, spearheaded by those seeking to preserve traditional human jobs. At the same time, there are going to be only a relatively few people who have a detailed understanding of how all this computer technology works. And that means that there's going to be an enormous amount of power concentrated in those few hands.

My second candidate for the unexpected comes from quite another direction. We all know the extent to which television, movies, and interactive games have the ability to captivate people for long periods. Our current megacomputers can generate extremely complex and realistic artificial worlds of moving 3-D images and sounds that respond to a participant's motions and actions. The most sophisticated of these interactive systems go by the name of "virtual reality." Twenty-five years from now, these "hypertelevisions" are probably going to be in millions of homes. What use is going to be made of them? Taking the optimistic view, they could be a powerful force in education—perhaps the only means we have left of bringing our educational system up to the standards that will be needed in the 21st century. But it is just as easy to envision virtual reality being used as an opiate of the masses, to pacify or manipulate a large underclass of undereducated citizens. I can see it also as a fatal intruder into our political process, complet-

ing the job that television has already begun so well of replacing substance by form.

I don't mean to be a complete pessimist. I'm enormously enthusiastic about this computer revolution as a way of eliminating simple drudgework. But we must remember that, historically, technologies are never purely benign. The same technology that makes it possible to navigate airplanes safely in foul weather has also produced the television that allows children to sit for hours in a mind-numbing trance and is undermining our educational system. What is going to be the dominant use of this hypertelevision medium—education or anti-education?

The final question I wish to raise brings me back to our conference theme of a sustainable world. Perhaps we ought to start thinking about what that concept might mean to a computer. I mentioned earlier that the history of evolution has been characterized by the emergence of increasingly intelligent systems. Thirty or fifty years from now, silicon-based machines are going to be the most intelligent systems on the planet. Are they going to make decisions that emphasize preserving diversity in the biological world, or are they going to be looking out for themselves? Stay tuned to see whether life on Earth, 100 years from now, is based on carbon or on silicon. □

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