

Joshua Lederberg

Tying minds together to advance science and social intelligence

Nobel Prize-winning geneticist Joshua Lederberg developed the expert system, *Dendral*, with Edward Feigenbaum while at Stanford University in the early '60s. *Dendral*, the first applied use of artificial intelligence, interprets data produced by mass spectrometers to determine molecular structures of unknown compounds.

For the past eight years, Lederberg has been president of Rockefeller University, a New York City-based biomedical research institution founded in 1901 as the Rockefeller Institute for Medical Research.

Lederberg spoke recently with Computerworld Senior Editor Janet Fiderio about the impact computers continue to make on education and society.

What role do computers now play in education? Have they changed the way we educate students?

LEDERBERG: From the research side and from the uses of computers in science, there is, of course, a very strong tradition in the indispensability of computers in data analysis; the direct connection with laboratory experimentation is well known.

But what has been perhaps a greater interest to me — and this is the thread that goes through the work I did with Ed Feigenbaum at Stanford — is the use of the computer in the communications network as the technical support for improving the social system of scientific advance. It's a way in which minds can be brought together more effectively and make an effective use of the expertise that's present elsewhere.

An expert system should be thought as much a social device as a technical instrument. It is a way the expertise that is resident in the minds of individuals can be more effectively stored, manipulated, corrected, updated and brought to bear on a range of problems, and that's really the point where I would place the greatest emphasis. It's a way of developing social intelligence.

So expert systems as social devices spur creativity?

LEDERBERG: They will allow you to be at the state of the art. If you have authentically acquired the expertise that is available on the subject, you know you're not reinventing what they're doing; you have authentic, well-crafted statements.

An expert system is not that different from a library, but it's a way of mechanizing that library so it can be operationally effective and much more efficiently managed. It also is an enormous discipline.

One of the most exciting aspects of expert systems is the discipline it puts on the experts who are providing the background. One of the things that slows the work in this field is

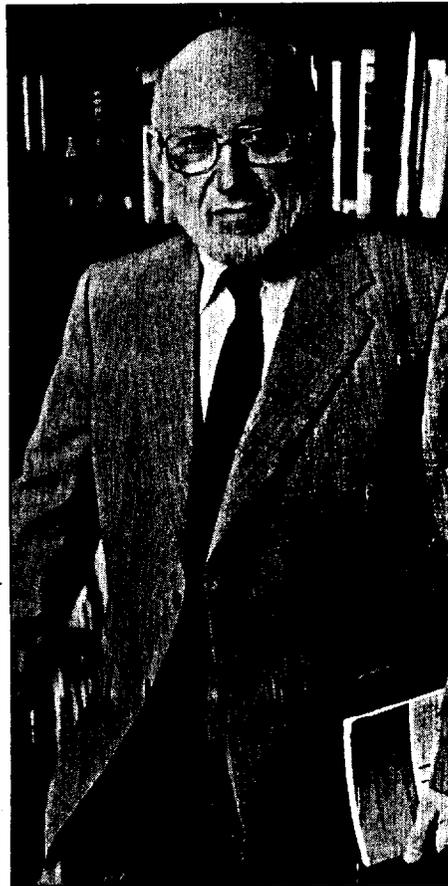
when you're putting together your production rules and so on, you discover there were inconsistencies in what you put in. It's better found at that logical level than when the bridge collapses.

You might call that criticism rather than creativity, but I think we have to keep in mind that with any scientific advance or cultural one, that these two have to be kept hand-in-hand. We need a lot of imagination, and it has to be checked by criticism. Criticism is the authenticity to self consistency. It checks that you said what you meant because the program is going to implement what you said. I think it speeds up the process of putting creative ideas to bear.

Where will we see the greatest potential for expert systems in society — medicine, research?

LEDERBERG: Anywhere there is a library, and anywhere there isn't a library and there should be, such as when the expertise is informal and not that well codified. Expert systems are a way of writing expertise down and getting at the experts before they disappear. *Chemical Week* magazine recently published a piece on expert systems in factory management. In one firm, the chemical engineers were retiring and they didn't know how they would bring up the skills of the new people to that level. They did a very wise thing — before those people left, they tried to dump their memories into an expert system and wrote down many operating rules that had never been written down before.

I wouldn't single out one area for expert system use. And the last thing in the world I would do would be to replace positions by a machine — no more than I would replace them by a few books on the shelf. I do think, however, that for providing support in the decision-making process, wherever consequential decisions rely on knowledge and expertise, we can greatly enhance that with machine systems.



Will we forget the basics of education due to expert systems? Will we become too dependent on them?

LEDERBERG: I suppose the first person who came along with a book would ask the same question: Are we going to be too reliant on this stuff written down and forget to remember stuff that we get through the oral tradition?

Of course, there is a danger, but I would say there is no other way to manage the enormous expansion of knowledge, no other way to counter the trap that we have laid for ourselves — the trap that goes under the label of specialization — without this kind of help.

Look where we are now. Knowledge in general is much too complicated. We have poor communications with colleagues in other fields. That's not a very satisfactory situation; we have systemic errors that come out of inadequate communication. You can find it every day in the practice of medicine.

What problems remain for you to investigate?

LEDERBERG: There are still some very hard problems that we never quite tackled, but I think our efforts would have been premature for some of the reasons given here. There are severe hardware limitations even now, which hurt effectively getting into things like learning systems, which is the next horizon.

We've had a little start at that, a thing called *Meddendral*, but the hardware just isn't up to it yet.

What are *Meddendral* and learning systems?

It's a way expertise can be learned by a system by looking at raw data from the outside world. Learning by experience is what I'm trying to say.

The first stage of expert systems is to learn from experts. You ask yourself how the experts learn, and a great deal of that is intellectual, learning from other experts.

But some of it, new knowledge, is gotten by experience. This part includes laboratory experiment or other sorts of data, the induction of hypothesis that can fit those data and the



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establishing of rules, the governing laws, the generalizations, the hypotheses and theories of science.

I would like to be able to move to that next step and find systems that learn the way we learn.

So, basically, the structure of learning systems needs to be addressed as a mathematical problem and as a hardware problem.

And second, the social system, the use of expert systems... there is a way of thinking about them that needs to be understood very carefully.

Knowing what you do about the shortcomings of expert systems and other computerized systems in use throughout society, does it ever concern you that computers control nuclear power facilities and nuclear bombs?

LEDERBERG: No more nervous than any complex social system. If you don't have a computer in there, you'll have some other dimwit pushing the buttons.

It's the complexity in the system, not the machine, that's driving it, that leads us to these frustrations. I think we need to have a realistic approach to the capabilities of what these nodes are.

One needs to understand the limitations thoroughly, but one also has to ask what the alternative is. There is no panacea.

If it's not one evil, it's another?

LEDERBERG: Yes. And I think, best of all, there's some balance where there's the possibility of human invention... I think a cross-check with a larger set of expertise. It's involved in human judgment and communication with other individuals and so on.

In a world with five billion, and one billion in a very advanced stage of technological and economic organization, I think that's where the problem is.

What about the question of retaining personal privacy?

LEDERBERG: I don't think we can live in a complex society and have the efficiency of transactions without sacrificing privacy. The underlying problem is that you want to have credit, you want to be able to go to far away places and have them recognize you instantly as someone who is credit-worthy. Of course, you're going to have to sacrifice something to make that possible.

We do need to maintain the integrity of the credit checking system and understand that there can be mistakes in it. We want to lean over backwards to make sure of that.

I am talking about balancing efficiency with justice, and one of the things computer systems can do is bring the cost of manipulating a great deal of data on people down to a level where there may be a temptation to not complicate the system again by adding those costs that are necessary to protect individual rights, such as the right of appeal when there is something in the credit system that doesn't belong there. But I think we're going to have to

face up to the fact that a world with five billion people doesn't have much latitude for privacy, and we'll have to be asking ourselves is it really so important that we would be willing to give up other values?

Of course, there is no answer to that question. For the most part, I think the questions about privacy are inordinate. I don't see the actuality of abuse as much as people's fears of it.

And it's a political decision, not a technological one, what abuse might be made.

You have information that's in the hands of a political authority, and it can be used to blackmail people, suppress dissidents and so forth, of course that's quite an abuse.

But I think there is the issue in that political issue — what the rights of individuals are, not about what their privacy is in the first

place, but what abuse is made on information.

I would advocate to most people that they just learn to live with the fact that private affairs are going to

be more transparent, and they always have been if you get right down to it.

There's a change of dimension with a broad range of people having access, but that also means you have a better opportunity to divide your correctives. I would come back and add that if you try to tally up all the abuses of privacy there have been in this snoopy society, I don't think they add up to a hill of beans. But people are worried about it.

Why do you think there are people out there who are still afraid of computers?

LEDERBERG: I think their real anger and anxiety is about the complexity of the social system. The computer is emblematic of it, it's a major instrument of social administration, and that is a constraint on freedom to have to share your living space with five billion others. But there it is.

The understanding of the role of computer-based communications systems is a way in which people can work together more effectively. We should be keeping our eyes on the objectives in computer advancement.

COMMENT

Forecasting 100 years in the future is a relatively low-risk proposition, since those who read my predictions in 1986 are unlikely to be around to critique them in 2086.

Few can disagree that the ultimate social impact of computers will be tremendous. Many exciting advances in computer technology are already within grasp or seem just around the corner — advances that challenge the imagination and that are bound to drive fundamental changes in human endeavor.

Consider the possibilities presented by future advances in artificial intelligence, "thinking" robots, portable personal terminals, huge data bases, even human-implantable computer chips. Individually or in combination, these and other technological marvels suggest a thousand fascinating scenarios.

For example, will society in 2086 see these marvels?

■ Robots handling routine personal chores and performing

dangerous or unhealthy manual labor tasks.

■ Credit-card-size terminals that allow people to conduct most of their personal business transactions any time, any place.

■ Human memory assisted by an implanted memory chip.

■ Computers so advanced they will develop their own understanding and logic and utilize sensors to interact with their environment just as humans do.

I think these and many other applications of computer technology may very well exist before the next century ends. As a result, individuals will certainly have more leisure time. The question is, how will they use it? Again, the possible scenarios are limited only by the imagination.

New art forms will develop as people find unique ways of stimulating the senses. Entertainment will be revolutionized as viewers or spectators become part of the event itself.

Learning will become a permanent

part of everyday life. With vast amounts of knowledge at their disposal, people must find new ways to learn and think.

Computers will allow modeling and experimenting to take place in ways that can avoid both physical disasters and social confrontations.

Computers in the workplace will contribute to the increase in leisure time. They also will change the very nature of jobs, and individuals will face a restructuring of their daily routines and the work environment.

I believe we can anticipate an exhilarating and fascinating future, thanks, at least in part, to the many wonderful possibilities offered by computers. By preparing now to make appropriate choices, we can help exploit the potential of technology to stimulate and enhance the lives of future generations.

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