THE CLAUDE BERNARD DISTINGUISHED LECTURE

The Claude Bernard Distinguished Lectureship honors both its namesake and its recipient for their outstanding contributions to physiology education. The American Physiological Society established the Lectureship in 1994 when the Teaching of Physiology Section of the Society selected Dr. Arthur J. Vander as its first Lecturer. Subsequent Lecturers have been Dr. Howard S. Barrows in 1995, Dr. Stanley G. Schultz in 1996, and Dr. Donald T. Frazier in 1998. The 2000 Lecture was presented by Dr. Clyde F. Herreid on April 16 at the Experimental Biology meeting in San Diego, California.

Clyde Herreid is the consummate scientist-educator. Having earned a Ph.D. in Zoology and Entomology from Penn State University in 1971, he embarked on an academic career replete with creative teaching, research, writing, and performing. Whereas some would cite his being named “Distinguished Teaching Professor” at the State University of New York at Buffalo in 1988 as his preeminent achievement, colleagues and former students are more likely to refer to other significant highlights of his professional life.

Dr. Herreid currently holds the titles of Professor of Biological Sciences and Academic Director of the University Honors Program at SUNY-Buffalo. In his association with the honors program, he provides vision for program development and engages outstanding scholars in the teaching/learning enterprise. As facilitator for faculty development workshops, he leaves an indelible mark on his home campus having trained countless new faculty and graduate teaching assistants; numerous other institutions of higher learning have tapped his pedagogical expertise. In the last several years, Dr. Herreid has become synonymous with the use of case studies to teach science. He was recently awarded a grant from The Pew Charitable Trusts to establish a National Center for Case Study Teaching in Science.

Buffalo, New York provides Dr. Herreid with a mailing address, but “the world is his stage.” Radio and TV appearances in New Zealand, Australia, and the U.S., field studies in Alaska, Montana, Texas, Panama, and Kenya, classroom appearances as Malthus and Darwin, and consulting editor and columnist for the Journal of College Science Teaching all combine to provide a venue for the talents of this extraordinary comparative physiologist. His passion for teaching and flair for the dramatic are not lost on his audiences!

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“My interest is in the future because I am going to spend the rest of my life there.”

—Charles Kettering

I want to talk about the future. I do this for two reasons. First, like Charles Kettering and everybody else, I am going to spend the rest of my life there; and second, because I believe that we’re passing through a revolution so profound that it rivals that of the discovery of fire or writing or the printing press. It is the technological revolution led by the transformation of our world by computers. Music, art, entertainment, medicine, and science are being changed before our very eyes by technological Merlins waving silicon wands. And so is teaching.

Why do I choose to focus on the world of 2061? The answer: this is when Haley’s Comet returns to Earth. About 10 years ago, the American Association for the Advancement of Science decided to launch an educational initiative to produce a scientifically literate America by the time Haley’s Comet returned to Earth. (Hope springs eternal!) They knew this would be a tough job, because only 5% of today’s population are judged scientifically literate. I think that they put this far enough into the future not only so that there would be enough time to reach their objective, but also because they thought none of us would be around to check up on them. So, taking a page from their book, I, too, want to talk about 2061. But to get there, we have to travel through the intervening years.

Before donning our seven-league boots, let’s recognize that trying to predict the future is fraught with pitfalls. For every H. G. Wells and Leonardo da Vinci who correctly predict the invention of the atomic bomb and the submarine, there are countless Jean Dixons and astrologers who have trouble even predicting tomorrow. Isaac Asimov, the biochemist polymath who became perhaps the world’s greatest science fiction writer, told a marvelous cautionary tale about the vicissitudes of prognostication. He pointed out that at the time of the moon landing, no one was particularly surprised at the event. After all, people had been writing about it for generations. Even the Buck Rogers cartoons of the 1930’s had shown space travelers wearing space suits very similar to those worn by our astronauts. Yet, with all of our foresight, no one anticipated the most amazing thing of all about the moon landing: when it occurred, the whole world would be watching—on television!

**TODAY’S CLASSROOMS**

Claude Bernard, our society’s patron saint of experimental science, would recognize today’s classrooms. They haven’t changed much over the centuries. Students sit dutifully, taking down the words of the master as he lectures to them from yellowed notes. In fact, Plato and Socrates would be fairly comfortable too. They wouldn’t have much trouble seeing that drawing on a blackboard or on an overhead projector isn’t much different from drawing in the sand. But a PowerPoint presentation might give them pause and the Internet—by Apollo! This would be a world apart. Imagine being able to tap into the world’s knowledge and read your very own *Republic* electronically.

I think that E-mail might give them trepidation, especially if they taught 500 students in an amphitheater like I do. Of course, they would be initially enamored
with the possibility of being in touch with their students 24 h of the day, but they would soon become jaundiced having to spend as much as 20% of their time answering messages like some of my colleagues. When would there be time to think great thoughts?

I don’t think that electronic bulletin boards or distribution lists would be too novel, but listservs and chat rooms would certainly stagger them. Just think, they could run their symposia not with just a handful of colleagues reclining on cushions and imbibing on vino ordinaire, but they could commune with a cacophony of buddies and strangers. In fact, the Plato of today would have written his dialogues in an electronic chatroom with a Cyber Timaeus, Crito, and Phaedo. Surely, they would soon discover, like many professors of today, surviving listservs and chat rooms with freewheeling students is challenging to the hardest educators. It is better to set up scheduled office hours on chatrooms to limit the dialogue.

Then there are webpages. What might our classic personages say about these? Gad zooks! At least a third of my university’s courses now have webpages, and most students have the computers to access them. In my evolutionary biology class, students not only can log in and see class notices, policies, and the course syllabus, but can hear lectures they have missed, view the slides and overhead displays, take practice quizzes, see video demonstrations, and take practical exams on virtual anatomical dissections (however, I must note, with apologies to Bill Gates, that despite all this electronic jazz, I have not found a trace of improved learning).

And what of computers in the classroom? Here, latter day Claude Bernards, instead of taking hours to set up a dog to run an experiment only to have time to get one run through, can run dozens of simulations and collect data to analyze. Genetics students can play Mendel and run simulated crosses of pea plants without digging a weed or planting a seed. Ecologists and meteorologists can run computer models of the different scenarios of global warming without the glaciers melting or sea levels rising. But as amazing as all of this would be to our visiting scholars from the past, I think they would be most astounded with the potential of distance learning.

FROM CORRESPONDENCE COURSES TO VIRTUAL CLASSROOMS

Remember the days when you could take a correspondence course on practically any subject, everything from becoming a pianist to becoming a brain surgeon? Correspondence courses are still doing well, thank you very much, but in a new form as distance learning. It was a small step for schools like Pennsylvania State University to go from running television courses for 2,500 students in 1960 to setting up TV classrooms around the state. From the school’s television studio, the grand professor could pontificate and his message would speed across the airwaves to remote sites where students and their facilitators would discuss the wisdom of the latest missive.

Now that computers are here, it is another small step to have the students tune in electronically. Classmates can be anywhere. The teaching can be “synchronous,” where teacher and students are online at the same time, or “asynchronous,” where the professor’s lessons are prerecorded and may be accessed at any time, day or night, a great boon to the working student. In the last few years, there has been an enormous jump in the development of these “virtual classrooms.”

Here is just a sampling of the many institutions now engaged in distance learning. The State University of New York has 40 of its campuses linked together using virtual learning. The Virtual College of Texas has 70,000 community college students using virtual learning. Sixteen southern states with their 260 campuses are joined together into something called the Electronic Campus of the Southern Regional Education Board; they offer 3,000 courses in distance learning. Then there is the Open University operating out of the United Kingdom with 160,000 students in 40 different countries; 35% of their distance learning courses are computer-based. And this is only the beginning of a world-wide trend, the switch to computer education. How far this trend will take us away from our traditional ways can only be appreciated by looking at the future of computers.

THE FUTURE OF COMPUTERS

Gordon Moore, the inventor of the transistor and later the Chairman of Intel, noted that the number of com-
ponents that could be placed on a computer chip was doubling every 2 yr. This increase has occurred because of improvements in optical lithography used to position the transistors on silicon chips on an ever-smaller scale. The resulting exponential rise in the number of calculations per second that can be achieved by our computers has become known as “Moore’s Law of Integrated Circuits” (Fig. 1). Consequently, computers today are 100 million times more powerful per unit cost than they were 50 years ago, says MIT’s Ray Kurtzweil: “If the automobile industry had made as much progress in the past 50 years, a car today would cost one hundredth of a cent and go faster than the speed of light.”

The end is not in sight. Computer experts argue that the ever-tighter packing of transistors onto silicon wafers will continue to follow Moore’s Law for the next 15–20 yr. Well before their limit is reached, other innovations will be in place to keep the exponential rise going. Here are a few of the promising innovations waiting in the wings.

**Three-dimensional chips.** Traditional chips are flat. Some venture-backed companies are now beginning to pack circuitry into layers to produce cubes.

**Optical computing.** Recently, people have been working with streams of photons rather than electrons to produce faster computers.

**Molecular computing.** DNA computers promise to be more flexible than electronic or optical computers where massive numbers of solutions must be evaluated and assembled.

**Computers as crystals.** Data can be stored as holograms where as many as a trillion bits of information can be stored in each cubic centimeter.

**Nanotubes.** Recently discovered elongated carbon molecules, called nanotubes, can perform all the electronic functions of silicon units used in our current computers. Because of their small size (50,000 laid side by side would equal a human hair), nanotubes promise to lead to a revolution in miniaturization.

**Quantum computing.** Considered to be the Holy Grail of the computing industry, quantum computing is not a digital system like those just mentioned. Bits of information are not encoded as either off or on but may be simultaneously both zero and one at the same time and potentially much more powerful. It has been said that quantum computing is to digital computing as the hydrogen bomb is to a firecracker.

**A LOOK INTO THE FUTURE**

“If we were to go back in time 100 years and ask a farmer what he’d like if be bad anything, he probably would tell us he wanted a borse that was twice as
strong and ate half as many oats. He would not tell us be wanted a tractor."

Philip J. Quigley

“When inventing movable type. Gutenberg wasn’t thinking of the revolution that would follow it. He certainly didn’t anticipate Adam Smith’s Wealth of Nations, Charles Darwin’s Origin of Species, or Adolf Hitler’s Mein Kampf. Nonetheless, his device changed everything, and it changed everything forever.”

Gregory J. E. Rawlins

Prognostication is not for the timid, and Ray Kurzweil of MIT is anything but timid. His 1999 book, The Age of Spiritual Machines: When Computers Exceed Human Intelligence, is filled with exactly the kind of predictions one needs if we are to envision how rapidly the world will change in the next decades. Among Kurzweil’s accomplishments is the development of voice-recognition computer systems. Recipient of nine honorary degrees and the 1999 National Medal of Technology from President Clinton on March 14 of this year, Kurzweil has identified some notable benchmarks ahead that I have modified slightly.

DATELINE 2010

- A $1,000 PC (1999 dollars) will perform a trillion calculations per second.
- PCs will range in size from those small enough to be inserted in watches up to the size of thin books.
- PCs will be increasingly wireless, and vocal interaction between computers and people will be common.
- Most routine business transactions (reservations, purchases) will occur between a human and a virtual personality, such as an animated human face.
- Traditional classrooms still exist, but intelligent interactive software is now a common method of learning.

DATELINE 2020

- A $1,000 PC has the computational ability of a human brain.
- Miniaturized computers are embedded everywhere: in furniture, appliances, walls, jewelry and our bodies.
- Three-dimensional virtual reality displays embedded in eyeglasses are common.
- High-resolution virtual reality with visual, auditory, and tactile sensations enable people to do practically anything with anybody anywhere.
- Communication with computers is largely by voice or gesture.
- Papers and traditional books are rarely used and traditional libraries are anachronisms.
- Most learning occurs via intelligent simulated software-based teachers.
- People are beginning to develop personal relationships with computers as friends, teachers, and lovers.

DATELINE 2030

- A $1,000 PC has the computing capacity of 1,000 human brains.
- Neural implants are beginning to be used to enhance visual, auditory, and tactile perception, interpretation, memory, and reasoning. These are merely extensions of the cochlear and retinal implants used in the year 2000.
- All literature, music, and art will be scanned into the computer network.
- All knowledge will be theoretically available to anyone’s PC.
- There will be no jobs for receptionists, bookkeepers, general physicians, family lawyers, or school teachers as their skills can be easily automated.
- Automated agents are now learning on their own, and knowledge is being created by machines with little human intervention.
Computers will routinely pass the Turing Test, whereby people cannot tell if they are talking to a machine or a human.

Machines will claim to be conscious and people will begin to believe them. (A page out of Isaac Asimov’s robot stories will have come true.)

DATELINE 2061

$1,000 PC has the computing power of all human brains.

VIRTUAL REALITY

The word “virtual” is becoming cant for anything that is simulated. “Virtual reality” means more than that. It refers to a simulated environment in which everything seems real. It started with the military and its interest in training pilots. The Link Trainer was originally designed to simulate the cockpit of a fighter plane so that aviators could gain the necessary flight experience without the expense or danger involved in flying a real plane. As airplanes became increasingly complicated, so did the flight simulators with their computer-generated scenery and combat missions. Simulators are now used to train ship and submarine crews, tank and artillery operators, and missile battery teams. Their cousins are found in arcades and home-computer games.

Today, virtual reality is being used in research labs around the world. There are single-wall systems that appear as large cinema screens with three-dimensional images dancing out at the viewer as seen through goggles. Chemists are able to manipulate giant molecules floating in space by a wiggle of a wand and can walk into their innards like a human enzyme. Architects and civil engineers are able to stroll through their buildings and cross their bridges before they are built. Of course, this is already possible with some computers and software systems, but the ultimate is not to sit in front of a computer screen, but to move freely about in a virtual world. “Caves” are the closest answer to this total immersion. These are rooms built with computer screens on all four walls and floor and ceiling. There are fewer than a hundred worldwide in operation at the moment, but don’t be surprised to find them in the living rooms of the next generation.

The new technology can only get better. By linking a robot’s senses with our own, we will be able to project our telepresence into distant worlds. Surgeons will operate on patients in other countries or cruise through the circulatory system. Miners will dig ore under oceans, and astronauts will explore alien planets without ever leaving home. The better the simulation of sight, sound, touch, and smell, the more we will begin to believe we are actually in the other world.

More than that, we will be able to create worlds that do not exist at all. Think how far we have come in the last couple of decades. Consider motion pictures. Recall the computer animations that we have witnessed in Jurassic Park, Star Wars, Terminator 2, and The Matrix. Or consider the animated humanoids in the arcades and home computer games like Sony’s Play Station 2. Certainly, we can still tell the difference between the real people and the simulated. But, these distinctions won’t last long. Right now, real people from past movies are plugged into new scenes; we have commercials with Humphrey Bogart in scenes he never played and Fred Astaire in dances he never danced. We have a fictional celluloid Forrest Gump meeting American presidents from the past. Special effects experts warn us that movie moguls are well on their way to devising a virtual movie actor that will be indistinguishable from a real person. They warm to the prospect of paying virtual salaries instead of the real ones they do now.

WHAT WILL THIS MEAN TO TEACHING? EVERYTHING

We will be able to train students in “real-world” problems because we will be able to simulate the real situation. Novice surgeons will practice on virtual patients without killing or maiming a one. Students will dissect virtual animals without being harassed by animal-rights activists. Fledgling scientists will mix chemicals, manipulate genes, and alter ecosystems. Those of us that think that case studies are the way to teach will be able to immerse the students directly into the virtual situation and have them become the person who must solve the
problem or suffer the consequences. The sights will be there. The sounds will be there, the touch and the smell, giving new meaning to the phrase “experience is the best teacher.”

Virtual reality will not be confined to “caves” or special rooms in the future. Originally virtual reality required the use of special helmets, then goggles. Right now there are PCs that have been reduced to the size of eyeglasses. By 2020, three-dimensional display systems will be provided by contact-lens systems and implanted retinal-imaging devices. Later in the century, these systems will be connected directly to the brain by neural implants.

So if we can create simulated movie actors, why not simulated teachers that will act as customized guides to knowledge?

But who needs teachers if all knowledge has been scanned into the computer network and we have miniature PCs embedded in our bodies? All knowledge is essentially within our grasp. We will have become cyborgs—a synergy of human and machine—part of a cyberhive of beings.

We can say that it will never happen. We don’t like the vision. Things will never move this fast.

Never say never. As Gregory Rawlins in his book *Moths to the Flame* points out, recall that only 35 years separate our discovery of DNA from the first patented artificial animal. Only two generations separate the Wright brothers’ *Kitty Hawk* from rockets to the moon or water wheels from nuclear power plants or fireworks from hydrogen bombs.

“*Given the present stupendous rate of technological change, it is almost useless to extrapolate twenty years into the future, far less fifty. Provided that we don’t destroy ourselves first, the world of fifty years from now may be as different from today’s as our era is from the Stone Age. The world of a hundred years from now may as well be from another planet. And the human race may still call itself human, but it may as well be a new species.*”

We may lament that change is coming; but come it will. The world of 2061 and its computer technology will cause the demise of our universities and libraries as we know them, just as surely as the printing press displaced hundreds of scribes in the 1500s. As the scribes before them, faculty and librarians will wail and gnash their teeth and argue that it can’t come to pass. But as Gregory Rawlins has put it, commenting on a similar historical moment:

“*They were kings of the hill. They dominated every ecosystem. But for them, as for all life, there is only one rule: adapt or die. As they roamed the veldt and the marshes and the seas, living life as they had for millions of years, an asteroid was entering the atmosphere. Things were about to change greatly. And the dinosaurs had no idea.*”

Then again, we may choose to take one day at a time. Perhaps Albert Einstein had the right attitude about this prediction business all along when he commented, “*I never think of the future. It comes soon enough.*”

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