computers) to another (say, implications of powerful computers for how and what we teach). How are these topics related? As a group, generate as many topic webs as possible and, for each, as many connections as possible. At the end of this session, you'll have in hand not only the fruits of Assignment #1, multiple authors discussing common topics, but you'll also have a potential connection *among* topics—basically, the necessary raw material for writing your syntheses.

Note that one synthesis—a single paper—couldn't possibly refer to every topic, or every connection among topics, that you have found. Your skill in preparing and writing a synthesis depends on your ability to *identify* closely related topics and to make and develop a claim that links and is supported by these topics.

Six readings on artificial intelligence follow: a prediction made more than thirty years ago by a noted physicist, followed by selections on the current state of the (digital) art and what we can expect moving forward. Four of these selections debate the achievement of the IBM supercomputer Watson on the television game show *Jeopardy!* After these readings, you'll find a series of linked assignments that prompt you to write some combination of summary, critique, analysis, explanatory synthesis, and argument synthesis.

TOWARD AN INTELLIGENCE BEYOND MAN'S

Robert Jastrow

Physicist Robert Jastrow (1925–2008) was the first director of the National Aeronautic and Space Administration's Goddard Institute for Space Studies, a director of the Mount Wilson Institute and Hale Solar Laboratory, and a writer who made atmospheric and cosmological science accessible to lay audiences in popular books such as *Red Giants and White Dwarfs* (1979) and *Until the Sun Dies* (1977). Born in New York City, Jastrow was educated at Columbia University and did postdoctoral work on astronomy and space exploration at Leiden University, the Princeton Institute of Advanced Study, and the University of California at Berkeley. Jastrow won numerous awards for excellence in his field, including the NASA Exceptional Scientific Achievement Medal.

The following essay, which first appeared in *Time* magazine on February 20, 1978, offers a fascinating prediction of a scientist at the height of his powers, writing early in the digital age, on the prospects for artificial intelligence in the twenty-first century and beyond. As you read his essay thirty-plus years after publication, judge for yourself: How accurate was Jastrow in his predictions? How close have we come to achieving his dreams for artificial intelligence?

As Dr. Johnson said in a different era about ladies preaching, the surprising thing about computers is not that they think less well than a man, but that they

think at all. The early electronic computer did not have much going for it except a prodigious memory and some good math skills, but today the best models can be wired up to learn by experience, follow an argument, ask pertinent questions and write pleasing poetry and music. They can also carry on somewhat distracted conversations so convincingly that their human partners do not know they are talking to a machine.

These are amiable qualities for the computer; it imitates life like an electronic monkey. As computers get more complex, the imitation gets better. Finally, the line between the original and the copy becomes blurred. In another 15 years or so[1]—two more generations of computer evolution, in the jargon of the technologists—we will see the computer as an emergent form of life.

The proposition seems ridiculous because, for one thing, computers lack the drives and emotions of living creatures. But when drives are useful, they can be programmed into the computer's brain, just as nature programmed them into our ancestors' brains as a part of the equipment for survival. For example, computers, like people, work better and learn faster when they are motivated. Arthur Samuel made this discovery when he taught two IBM computers how to play checkers. They polished their game by playing each other, but they learned slowly. Finally, Dr. Samuel programmed in the will to win by forcing the computers to try harder—and to think out more moves in advance—when they were losing. Then the computers learned very quickly. One of them beat Samuel and went on to defeat a champion player who had not lost a game to a human opponent in eight years.

Computers match people in some roles, and when fast decisions are needed in a crisis, they often outclass them. The human brain has a wiring defect that prevents it from absorbing several streams of information simultaneously and acting on them quickly. Throw too many things at the brain at one time and it freezes up; it evolved more than 100,000 years ago, when the tempo of life was slower.

5 We are still in control, but the capabilities of computers are increasing at a fantastic rate, while raw human intelligence is changing slowly, if at all. Computer power is growing exponentially; it has increased tenfold every eight years since 1946. Four generations of computer evolution—vacuum tubes, transistors, simple integrated circuits and today's miracle chips—followed one another in rapid succession, and the fifth generation, built out of such esoteric devices as bubble memories and Josephson junctions, will be on the market in the 1980s. In the 1990s, when the sixth generation appears, the compactness and reasoning power of an intelligence built out of silicon will begin to match that of the human brain.

By that time, ultra-intelligent machines will be working in partnership with our best minds on all the serious problems of the day, in an unbeatable combination of brute reasoning power and human intuition. What happens after that? Dartmouth President John Kemeny, a pioneer in computer usage, sees the

[1]Writing in 1978, Jastrow is making a prediction for 1993.

ultimate relation between man and computer as a symbiotic union of two living species, each completely dependent on the other for survival. The computer—a new form of life dedicated to pure thought—will be taken care of by its human partners, who will minister to its bodily needs with electricity and spare parts. Man will also provide for computer reproduction, as he does today. In return, the computer will minister to our social and economic needs. Child of man's brain rather than his loins, it will become his salvation in a world of crushing complexity.

The partnership will not last very long. Computer intelligence is growing by leaps and bounds, with no natural limit in sight. But human evolution is a nearly finished chapter in the history of life. The human brain has not changed, at least in gross size, in the past 100,000 years, and while the organization of the brain may have improved in that period, the amount of information and wiring that can be crammed into a cranium of fixed size is limited.

That does not mean the evolution of intelligence has ended on the earth. Judging by the record of the past, we can expect that a new species will arise out of man, surpassing his achievements as he has surpassed those of his predecessor, *Homo erectus*. Only a carbon-chemistry chauvinist would assume that the new species must be man's flesh-and-blood descendants, with brains housed in fragile shells of bone. The new kind of intelligent life is more likely to be made of silicon.

The history of life suggests that the evolution of the new species will take about a million years. Since the majority of the planets in the universe are not merely millions but *billions* of years older than the earth, the life they carry—assuming life to be common in the cosmos—must long since have passed through the stage we are about to enter.

10 A billion years is a long time in evolution; 1 billion years ago, the highest form of life on the earth was a worm. The intelligent life in these other, older solar systems must be as different from us as we are from creatures wriggling in the ooze. Those superintendent beings surely will not be housed in the more or less human shapes portrayed in *Star Wars* and *Close Encounters of the Third Kind*. In a cosmos that has endured for billions of years against man's mere million, the human form is not likely to be the standard form for intelligent life.

In any event, our curiosity may soon be satisfied. At this moment a shell of TV signals carrying old *I Love Lucy* programs and *Tonight* shows is expanding through the cosmos at the speed of light.[2] That bubble of broadcasts has already swept past about 50 stars like the sun. Our neighbors know we are

[2]Over-the-air television is broadcast as electric signals, received by earth-based TV sets. These same signals propagate beyond the earth and travel through space at the speed of light. Jastrow refers here to two particularly loved television shows whose broadcasts are being propagated into space: The situation comedy *I Love Lucy* (1951–1957 and in continual reruns thereafter) starred Lucille Ball as Lucy Ricardo, zany and endearing wife to Ricky Ricardo (played by Desi Arnez). The late-night comedy/talk show *Tonight* first aired in 1954, with comedian Steve Allen as host (and with successive hosts Jack Paar, Johnny Carson [for thirty years], Jay Leno, Conan O'Brien, and Jay Leno [again]), and has run continually since.

here, and their replies should be on the way. In another 15 or 20 years we will receive their message and meet our future. Let us be neither surprised nor disappointed if its form is that of Artoo Detoo, the bright, personable canister packed with silicon chips.

THE AI REVOLUTION IS ON

Steven Levy

Steven Levy, a senior writer for *Wired*, has reported on digital technology for a quarter century. His articles have appeared in the *New York Times*, *Rolling Stone*, and *Macworld*, as well as *Wired*, where this selection appeared on December 27, 2010. Levy is the author of several books, including *In the Plex: How Google Thinks, Works and Shapes Our Lives* (2011), *Hackers* (2010), *Insanely Great: The Life and Times of the Macintosh, the Computer That Changed Everything* (1994), *and Artificial Life: The Quest for a New Creation* (1992). Here, he distinguishes between two visions of artificial intelligence: the kind of AI currently in place (using clever algorithms to access massive databases) and the predictions of futurists who foresee the emergence of thinking machines that will mark our "next step in the evolutionary process."

Diapers.com warehouses are a bit of a jumble. Boxes of pacifiers sit above crates of onesies, which rest next to cartons of baby food. In a seeming abdication of logic, similar items are placed across the room from one another. A person trying to figure out how the products were shelved could well conclude that no form of intelligence—except maybe a random number generator—had a hand in determining what went where.

But the warehouses aren't meant to be understood by humans; they were built for bots. Every day, hundreds of robots course nimbly through the aisles, instantly identifying items and delivering them to flesh-and-blood packers on the periphery. Instead of organizing the warehouse as a human might—by placing like products next to one another—