

History of Science 233: Computers and organisms

Instructor:

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Office:

Logistics:

Meeting time: Thursday 4-6pm.

Assessment:

Final Research Paper: 70%

Class participation: 30%

Overview:

Humans have long imagined that organisms and their parts (including our own brains) might be some kind of machine. In the twentieth century in particular, this idea became both a powerful metaphor and

Week by week:

Week 1 (January 28): Introduction

Haraway; Doyle; Hayles;

- Evelyn Fox Keller (1995). *Refiguring life: metaphors of twentieth century biology*.
- Stefano Franchi and Güven Güzeldere, eds. (2005). *Mechanical bodies, computational minds: artificial intelligence from automata to cyborgs*. Cambridge, MA: The MIT Press.

Roberto Cordeschi (1989). "From the chemical machine to the action system: the origins of the modern organism-machine analogy" *Storia della Psicologia e della Scienze del Comportamento* 1(2): 25-59, 2(1): 6-25.

Week 2 (February 4): Organisms before computers

- Adelheid Voskuhl. 2007. "Producing objects, producing texts: accounts of android automata in 18th century Europe" *Studies in History and Philosophy of Science* 38: 422-444.
- Evelyn Fox Keller (1994). "The body of a new machine: situating the organism between telegraphs and computers" *Perspectives on science: historical, social, philosophical* 2: 302-323.
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- David Mindell (2002). *Between human and machines: Feedback, control, and computing before cybernetics*. Baltimore: Johns Hopkins University Press.

Jon Agar (2003). *The government machine: a revolutionary history of the computer*. Cambridge, MA: MIT Press.

R.U.R.

Seth Bullock (2008). "Charles Babbage and the emergence of automated reason" in *The mechanical mind in history*, Cambridge, MA: MIT Press, pp. 19-40.

Laura Otis (2002). *Networking: Communicating with bodies and machines in nineteenth century*. Ann Arbor: University of Michigan Press.

Christopher D. Green (2005). "Was Babbage's analytical engine intended to be a mechanical model of the mind?" *History of psychology* 8: 35-45.

Larry Owens (1986). "Vannevar Bush and the differential analyzer: the text and context of an early computer" *Technology and culture* 27: 63-95.

James M. Nyce et al. (1991). "From Memex to Hypertext: Vannevar Bush and the mind's machine" Boston: Academic Press.

Week 3 (February 11): World War II, cybernetics and cyborgs

- Peter Galison (1994). "The ontology of the enemy: Norbert Wiener and the cybernetic vision" *Critical inquiry* 21(1 – Autumn): 228-266.
- Andrew Pickering (2002). "Cybernetics and the mangle: Ashby, Beer, and Pask" *Social Studies of Science* 32: 413-437.
- Donna Haraway (1991). "A cyborg manifesto: science, technology, and socialist-feminism in the late twentieth century" in *Simians, cyborgs, women: the reinvention of nature*. New York: Routledge, pp. 149-181.
- Michael S. Mahoney, "Cybernetics and Information Technology," in *Companion to the History of Modern Science*, ed. R. C. Olby et al., Chapter 34.

Arturo Rosenblueth, Norbert Wiener and Julian Bigelow (1943). "Behavior, Purpose and Teleology" *Philosophy of Science* 10: 18-24.

Norbert Wiener (1948). *Cybernetics, or Control and Communication in the Animal and the Machine*, Cambridge, MA: The MIT Press.

H. Kalmus (1950). "A Cybernetical Aspect of Genetics" *Journal of Heredity* 41: 19-22

Jacques Monod and Francois Jacob (1961). "General Conclusions: Teleonomic Mechanisms in Cellular Metabolism, Growth, and Differentiation," *Cold Spring Harbor Symposium on Quantitative Biology*, vol. 26: 389-401.

Geof Bowker (1993). "How to be Universal: Some Cybernetic Strategies, 1943-70," *Social Studies Science* 23: 107-27.

Shannon and weaver and how cybernetics and psychology are related (edwards)

Week 3a: Psychology and neural networks

Warren S. McCulloch and Walter Pitts (1943). "A logical calculus of the ideas immanent in nervous activity", *Bulletin of Mathematical Biophysics* 5: 115-33 [Reprinted in Warren S. McCulloch (1965). *Embodiments of mind*. Cambridge, MA: The MIT Press]

Stephen C. Kleene (1956). "Representation of Events in Nerve Nets and Finite Automata" in C.E. Shannon and J. McCarthy (eds.), *Automata Studies*. Princeton: Princeton University Press, pp. 3-41.

Tara H. Abraham (2002). "(Physio)logical circuits: The intellectual origins of the McCulloch-Pitts neural networks" *Journal of the History of the Behavioral Sciences* 38(1): 3-25.

Lily E. Kay (2001). "From logical neurons to poetic embodiments of mind: Warren S. McCulloch's project in neuroscience" *Science in Context* 14(4): 591-614.

Michael A. Arbib (2000). "Warren McCulloch's Search for the Logic of the Nervous System" *Perspectives in Biology and Medicine* 43(2): 193-216

Paul N. Edwards (1996). *The closed world: computers and the politics of discourse in cold war America*. Cambridge, MA: The MIT Press, Chapter 6 ("The machine in the middle: cybernetic psychology and World War II) and 10 ("Minds, machines, and subjectivity in the closed world").

Week 4 (February 18): Information metaphors in molecular biology

- Lily E. Kay (2000). *Who wrote the book of life? A history of the genetic code*. Palo Alto: Stanford University Press.
- Lily E. Kay (1997). "Cybernetics, Information, Life: The Emergence of Scriptural Representations of Heredity", *Configurations* 5: 23-91
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- Lily E. Kay (1995). "Who Wrote the Book of Life? Information and the Transformation of Molecular Biology," *Science in Context* 8: 609-34.

Claude E. Shannon (1948). "The Mathematical Theory of Communication" *Bell System Technical Journal* 27: 379-423, 623-656.

Claude E. Shannon and Warren Weaver (1949). *The Mathematical Theory of Communication*, Urbana: University of Illinois Press.

Henry Quastler, ed. (1953). *Essays on the Use of Information Theory in Biology*, Urbana: University of Illinois Press.

F. H. C. Crick (1958). "On Protein Synthesis" *Symposium of the Society for Experimental Biology* 12: 138-63.

J.B.S. Haldane (1965). "Data Needed for a Blueprint of the First Organism" in Sidney W. Fox, ed. *The Origins of Prebiological Systems*, Academic Press.

Sahotra Sarkar (1996). "Biological Information: A Skeptical Look at Some Central Dogmas of Molecular Biology" *The Philosophy and History of Molecular Biology: New Perspectives*, Kluwer, pp. 187-231.

Soraya de Chadarevian (1996). "Sequences, Conformation, Information: Biochemists and Molecular Biologists in the 1960s" *Journal of the History Biology* **29**: 361-86.

Week 5 (February 25): Early computer and/as living systems

- Alan Turing (1950). "Computing machinery and intelligence" 59: 433-460.
 - John von Neumann "First draft of report on EDVAC," Technical report. Moore School of Electrical Engineering, University of Pennsylvania.
- M.D. Godfrey and D.F. Hendry (1993). "The Computer as von Neumann Planned It" *IEEE Annals of the History of Computing* 15(1).
- John von Neumann (2000). *The computer and the brain*. New Haven, CT: Yale University Press.
 - John von Neumann (1966). *Theory of self-reproducing automata*. Urbana: University of Illinois Press.

John von Neumann (1951). "On a logical and general theory of automata" in *Cerebral Mechanisms in Behavior: The Hixon Symposium*, ed. L.A. Jeffries. New York: Wiley, pp. 1-31 [reprinted in William Aspray and Arthur Burks, eds. (1987). *Papers of John von Neumann on Computing and Computer Theory*, Cambridge, MA: The MIT Press, pp. 391-431].

Claude E. Shannon (1953). "Computers and Automata" *Proceedings Institute of Radio Engineers* 41: 1234-1241 [reprinted in *Methodos* 6: 115-30; and in (1993) *Claude Elwood Shannon: Collected Papers*, IEEE Press, pp. 703-10]

Christopher G. Langton (19??). "Self-Reproduction in Cellular Automata" in *Cellular automata*, D. Farmer et al., eds., North-Holland, pp. 145-156.

Christian Burks and Dooyne Farmer (19??). "Towards Modeling DNA Sequences as Automata" in *Cellular automata*, D. Farmer et al., eds., North-Holland, pp. 157-67.

Arthur W. Burks (1960). "Computation, Behavior and Structure in Fixed and Growing Automata" in Marshall C. Yovits and Scott Cameron, eds, *Self-Organizing Systems: Proceedings of an Interdisciplinary Conference, 5 and 6 May, 1959*, New York, pp. 282-311.

Christian Burks (1970). "Von Neumann's Self-Reproducing Automata" in C. Burks, ed, *Essays on Cellular Automata*, University of Illinois Press, Chapter 1.

Week 6 (March 4): Simulating life I

C.H. Waddington (1968). "The basic ideas of biology" in *Towards a Theoretical Biology*.

C.H. Waddington (1968). "Form and Information" in *Towards a Theoretical Biology*.

Eigen, Manfred et al. (1981). "The Origin of genetic information" *Scientific American*.

Herbert Simon (1962). "The Architecture of Complexity" in *The Sciences of the Artificial*.

Rupert Riedl (1975). *Order in Living Organisms*, Chapters 1, 2, and 8.

Stephen Wolfram (2002). *A new kind of science*. Champaign, IL: Wolfram Media.

Gardner, M. (1970). *Scientific American*. October. [Conway's 'Game of Life']

Daniel C. Dennett (1991). *Consciousness explained*. Boston: Back Bay Books.

Walter Fontana, et al. (1994) "Beyond Digital Naturalism" *Artificial Life* 1: 211-227.

Walter Fontana and Leo Buss (1994). "What would be conserved if 'the tape were played twice?'" *Proceedings of the National Academy of Sciences USA* 91(2): 757-761.

Maturana and Varela?

Week 7 (March 11): Artificial intelligence

Paul N. Edwards (1996). *The closed world: computers and the politics of discourse in cold war America*. Cambridge, MA: The MIT Press, Chapter 8 ("Constructing artificial intelligence").

Marvin Minsky (1954). *Neural nets and the brain-model problem*. PhD thesis, Princeton University.

A. Newell, J.C. Shaw, and H.A. Simon (1958). "Elements of a theory of human problem solving" *Psychological review* 65(3): 151-166.

Pamela McCorduck (1979). *Machines who think: a personal inquiry into the history and prospects of artificial intelligence*. New York: W.H. Freeman.

Minsky?

Spring break

Week 8 (March 25): From the the ARPAnet to the matrix

- Joseph C.R. Licklider (1960). "Man-computer symbiosis" *IRE transactions on human factors in electronics* 1: 4-11.
- Joseph C.R. Licklider (1965). *Libraries of the future*. Cambridge, MA: MIT Press.

- Martin Campbell-Kelly. (2006). "From the world brain to the world wide web" Lecture at Gresham College, 9 November. Transcript available at: <http://www.gresham.ac.uk/event.asp?PageId=39&EventId=486>
- Fred Turner (2006). *From counterculture to cyberculture: Stewart Brand, the Whole Earth Network, and the rise of digital utopianism*. Chicago: University of Chicago Press.
- (1999). *The Matrix*. Directors: Andy Wachowski and Larry Wachowski. Village Roadshow Pictures / Silver Pictures.
- William Gibson (1984). *Neuromancer*. New York: Ace Books.

Week 9 (April 1): Computing life

Robert S. Ledley (1965) "Digital Electronic Computers in Biomedical Science" *Science* 130(3384), 1225-1234.

Joe November (2004). "LINC: Biology's Revolutionary Little Computer" *Endeavour* 28(3): 125-131.

Peter Friedland and Laurence H. Kedes (1985). "Discovering the Secrets of DNA" *Communications of the ACM* 28(11): 1164-86. [MOLGEN]

Lindsay, Robert K., Bruce G. Buchanan, and Edward A. Feigenbaum (1993). "DENDRAL: A Case Study of the First Expert System for Scientific Hypothesis Formation." *Artificial Intelligence* 61: 209-261.

Timothy Lenoir, " Shaping Biomedicine as an Information Science"

Evelyn Fox Keller, "Models of and Models For: Theory and Practice in Contemporary Biology"

Eric S. Lander, Robert Langridge, Damian M Saccocio, (1991) "Computing in Molecular Biology: Mapping and Interpreting Biological Information" *Computer* 24(11): 6-13.

Joshua Lederberg (1987). "How DENDRAL Was Conceived and Born" *A History of Medical Informatics*, New York: ACM Press, pp. 14-44.

Temple F. Smith (1990). "The History of Genetic Sequence Databases", *Genomics* 6: 701-707.

Week 10 (April 8): Biocomputing

LINC, etc.

- Leonard Adelman (1994). "Molecular computation of solutions to combinatorial problems" *Science* 266(5187 – November 11): 1021-1024.
- Roger Penrose (1989). *The emperor's new mind*. Oxford: Oxford University Press.
- Stuart Hameroff (2006). "Consciousness, neurobiology, and quantum mechanics" in *The*

emerging physics of consciousness, J. Tuszynski, ed.

Sorin Istrail, Smadar Ben-Tabou De-Leon, and Eric H. Davidson (2007). "The regulatory genome and the computer" *Developmental biology* 310: 187-195.

Week 11 (April 15): Simulating Life II

Artificial life; Wolfram;

- Stefan Helmreich (1998). *Silicon second nature: culturing artificial life in a digital world*. Berkeley and Los Angeles: University of California Press.

Claus Emmeche, *The Garden in the Machine: The Emerging Science of Artificial Life*.

Richard Doyle. *On Beyond Living: Rhetorical Transformations of the Life Sciences*, Chapter 7, "Emergent Power: Vitality and Theology in Artificial Life."

John L. Casti, *Alternate Realities: Mathematical Models of Nature and Man*, Chapter 2.

Christopher Langton, "Artificial Life", in Margaret A. Boden, ed., *The Philosophy of Artificial Life*, Chapter 1.

Genetic algorithms:

John H. Holland (1962). "Outline for a Logical Theory of Adaptive Systems" *Journal of the ACM* 9(3): 297-314

John H. Holland (1975). *Adaptation in Natural and Artificial Systems: An Introductory Intelligence*. Ann Arbor: University of Michigan Press.

Stephanie Forrest (1993). "Genetic Algorithms: Principles of Natural Selection Applied to Computation" *Science* 261(5123): 872-878

Melanie Mitchell (1998). *An Introduction to Genetic Algorithms*. Cambridge, MA: The MIT Press.

Sim life?

Week 12 (April 22): Post-human life

- Sherry Turkle (1984). *The second self: computers and the human spirit*. New York: Simon & Schuster.
- Sherry Turkle (1995). *Life on the screen: identity in the age of the Internet*. New York: Touchstone.
- Tom Boellstorff (2008). *Coming of age in Second Life: An anthropologist explores the virtually human*. Princeton, NJ: Princeton University Press.

Drexler, *Engines of Creation*.

[science fiction: Greg Bear (Blood Music) or Hans Moravec (Robot: Mere Machine to transcendent mind);]

Modeling evolution;

Systems biology;

Neurology – brain as computer; neural nets;