3

Gatherings

IN SEPTEMBER 1948, AN INTERDISCIPLINARY CONFERENCE WAS HELD AT THE California Institute of Technology (Caltech) in Pasadena, California, on the topics of how the nervous system controls behavior and how the brain might be compared to a computer. It was called the Hixon Symposium on Cerebral Mechanisms in Behavior. Several luminaries attended and gave papers, among them Warren McCulloch, John von Neumann, and Karl Lashley (1890–1958), a prominent psychologist. Lashley gave what some thought was the most important talk at the symposium. He faulted behaviorism for its static view of brain function and claimed that to explain human abilities for planning and language, psychologists would have to begin considering dynamic, hierarchical structures. Lashley's talk laid out the foundations for what would become cognitive science.[1]

The emergence of artificial intelligence as a full-fledged field of research coincided with (and was launched by) three important meetings – one in 1955, one in 1956, and one in 1958. In 1955, a "Session on Learning Machines" was held in conjunction with the 1955 Western Joint Computer Conference in Los Angeles. In 1956, a "Summer Research Project on Artificial Intelligence" was convened at Dartmouth College. And in 1958, a symposium on the "Mechanization of Thought Processes," was sponsored by the National Physical Laboratory in the United Kingdom.

3.1 Session on Learning Machines

Four important papers were presented in Los Angeles in 1955. In his chairman's introduction to this session, Willis Ware wrote

> These papers do not suggest that future learning machines should be built in the pattern of the general-purpose digital computing device; it is rather that the digital computing system offers a convenient and highly flexible tool to probe the behavior of the models. . . . This group of papers suggests directions of improvement for future machine builders whose intent is to utilize digital computing machinery for this particular model technique. Speed of operation must be increased manyfold; simultaneous operation in many parallel modes is strongly indicated; the size of random access storage must jump several orders of magnitude; new types of input–output equipment are needed. With such advancements and the techniques discussed in these papers, there is considerable promise that systems can be built in the relatively near future which will imitate considerable portions of the activity of the brain and nervous system.

Fortunately, we have made substantial progress on the items on Ware's list of "directions for improvement." Speed of operation has increased manyfold, parallel

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Figure 3.1. Oliver Selfridge. (Photograph courtesy of Oliver Selfridge.)

operation is utilized in many AI systems, random access storage has jumped several orders of magnitude, and many new types of input–output equipment are available. Perhaps even further improvements will be necessary.

The session's first paper, by Wesley Clark and Belmont Farley of MIT's Lincoln Laboratory, described some pattern-recognition experiments on networks of neuron-like elements.[2] Motivated by Hebb's proposal that assemblies of neurons could learn and adapt by adjusting the strengths of their interconnections, experimenters had been trying various schemes for adjusting the strengths of connections within their networks, which were usually simulated on computers. Some just wanted to see what these networks might do whereas others, such as Clark and Farley, were interested in specific applications, such as pattern recognition. To the dismay of neurophysiologists, who complained about oversimplification, these networks came to be called *neural networks*. Clark and Farley concluded that "crude but useful generalization properties are possessed even by randomly connected nets of the type described."[3]

The next pair of papers, one by Gerald P. Dinneen (1924–) and one by Oliver Selfridge (1926–2008; Fig. 3.1), both from MIT's Lincoln Laboratory, presented a different approach to pattern recognition. Dinneen's paper[4] described computational techniques for processing images. The images were presented to the computer as a rectangular array of intensity values corresponding to the various shades of gray in the image. Dinneen pioneered the use of filtering methods to remove random bits of noise, thicken lines, and find edges. He began his paper with the following:

> Over the past months in a series of after-hour and luncheon meetings, a group of us at the laboratory have speculated on problems in this area. Our feeling, pretty much unanimously, was that there is a real *need* to get practical, to pick a real live problem and go after it.

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Selfridge's paper[5] was a companion piece to that of Dinneen. Operating on "cleaned-up" images (as might be produced by Dinneen's program, for example), Selfridge described techniques for highlighting "features" in these images and then classifying them based on the features. For example, corners of an image known to be either a square or a triangle are highlighted, and then the number of corners is counted to determine whether the image is of a square or of a triangle. Selfridge said that "eventually, we hope to be able to recognize other kinds of features, such as curvature, juxtaposition of singular points (that is, their relative bearings and distances), and so forth."

The methods pioneered by Selfridge and Dinneen are fundamental to most of the later work in enabling machines to "see." Their work is all the more remarkable when one considers that it was done on a computer, the Lincoln Laboratory "Memory Test Computer," that today would be regarded as extremely primitive. [The Memory Test Computer (MTC) was the first to use the ferrite core random-access memory modules developed by Jay Forrester. It was designed and built by Ken Olsen in 1953 at the Digital Equipment Corporation (DEC). The MTC was the first computer to simulate the operation of neural networks – those of Clark and Farley.]

The next paper[6] was about programming a computer to play chess. It was written by Allen Newell, then a researcher at the Rand Corporation in Santa Monica. Thanks to a biographical sketch of Newell written by his colleague, Herb Simon of Carnegie Mellon University, we know something about Newell's motivation and how he came to be interested in this problem:[7]

> In September 1954 Allen attended a seminar at RAND in which Oliver Selfridge of Lincoln Laboratory described a running computer program that learned to recognize letters and other patterns. While listening to Selfridge characterizing his rather primitive but operative system, Allen experienced what he always referred to as his "conversion experience." It became instantly clear to him "that intelligent adaptive systems could be built that were far more complex than anything yet done." To the knowledge Allen already had about computers (including their symbolic capabilities), about heuristics, about information processing in organizations, about cybernetics, and proposals for chess programs was now added a concrete demonstration of the feasibility of computer simulation of complex processes. Right then he committed himself to understanding human learning and thinking by simulating it.

Simon goes on to summarize Newell's paper on chess:

> [It] outlined an imaginative design for a computer program to play chess in humanoid fashion, incorporating notions of goals, aspiration levels for terminating search, satisfying with "good enough" moves, multidimensional evaluation functions, the generation of subgoals to implement goals, and something like best first search. Information about the board was to be expressed symbolically in a language resembling the predicate calculus. The design was never implemented, but ideas were later borrowed from it for use in the NSS [Newell, Shaw, and Simon] chess program in 1958.[8]

Newell hinted that his aims extended beyond chess. In his paper, he wrote "The aim of this effort, then, is to program a current computer to learn to play good chess. This is the means to understanding more about the kinds of computers, mechanisms, and programs that are necessary to handle ultracomplicated problems." Newell's

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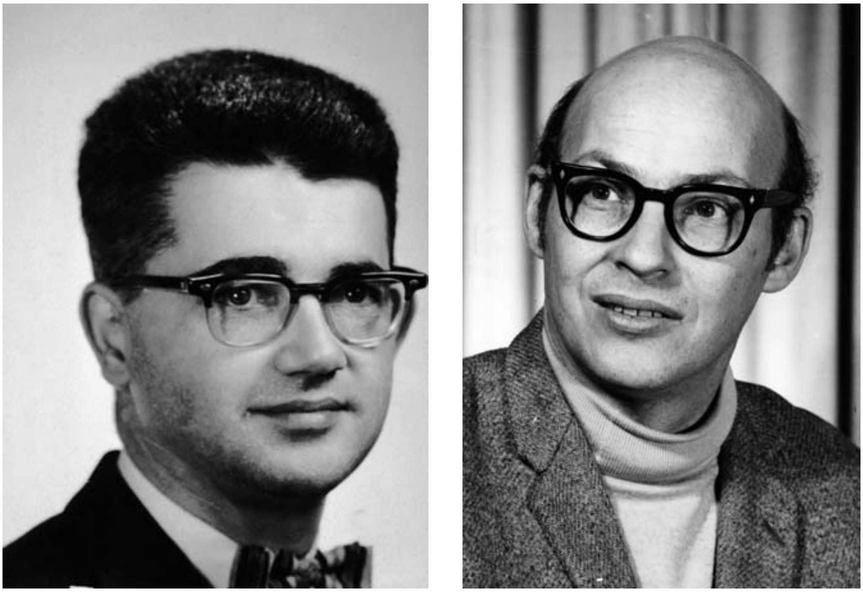

Figure 3.2. John McCarthy (left) and Marvin Minsky (right). (McCarthy photograph courtesy of John McCarthy. Minsky photograph courtesy MIT Museum.)

proposed techniques can be regarded as his first attempt to produce evidence for what he and Simon later called the Physical Symbol System Hypothesis.

Walter Pitts, a commentator for this session, concluded it by saying, "But, whereas Messrs. Farley, Clark, Selfridge, and Dinneen are imitating the nervous system, Mr. Newell prefers to imitate the hierarchy of final causes traditionally called the mind. It will come to the same thing in the end, no doubt. . . . " To "come to the same thing," these two approaches, neural modeling and symbol processing, must be recognized simply as different levels of description of what goes on in the brain. Different levels are appropriate for describing different kinds of mental phenomena. I'll have more to say about description levels later in the book.

3.2 The Dartmouth Summer Project

In 1954, John McCarthy (1927– ; Fig 3.2) joined Dartmouth College in Hanover, New Hampshire, as an Assistant Professor of Mathematics. McCarthy had been developing a continuing interest in what would come to be called artificial intelligence. It was "triggered," he says, "by attending the September 1948 Hixon Symposium on Cerebral Mechanisms in Behavior held at Caltech where I was starting graduate work in mathematics."[9] While at Dartmouth he was invited by Nathaniel Rochester (1919–2001) to spend the summer of 1955 in Rochester's Information Research Department at IBM in Poughkeepsie, New York. Rochester had been the designer of the IBM 701 computer and had also participated in research on neural networks.[10]

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At IBM that summer, McCarthy and Rochester persuaded Claude Shannon and Marvin Minsky (1927– ; Fig. 3.2), then a Harvard junior fellow in mathematics and neurology, to join them in proposing a workshop to be held at Dartmouth during the following summer. Shannon, whom I have previously mentioned, was a mathematician at Bell Telephone Laboratories and already famous for his work on switching theory and statistical information theory. McCarthy took the lead in writing the proposal and in organizing what was to be called a "Summer Research Project on Artificial Intelligence." The proposal was submitted to the Rockefeller Foundation in August 1955.

Extracts from the proposal read as follows:[11]

> We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer.
>
> . . .
>
> For the present purpose the artificial intelligence problem is taken to be that of making a machine behave in ways that would be called intelligent if a human were so behaving.

The Rockefeller Foundation did provide funding for the event, which took place during six weeks of the summer of 1956. It turned out, however, to be more of a rolling six-week workshop than a summer "study." Among the people attending the workshop that summer, in addition to McCarthy, Minsky, Rochester, and Shannon were Arthur Samuel (1901–1990), an engineer at the IBM corporation who had already written a program to play checkers, Oliver Selfridge, Ray Solomonoff of MIT, who was interested in automating induction, Allen Newell, and Herbert Simon. Newell and Simon (together with another Rand scientist, Cliff Shaw) had produced a program for proving theorems in symbolic logic. Another attending IBM scientist was Alex Bernstein, who was working on a chess-playing program.

McCarthy has given a couple of reasons for using the term "artificial intelligence." The first was to distinguish the subject matter proposed for the Dartmouth workshop from that of a prior volume of solicited papers, titled *Automata Studies*, co-edited by McCarthy and Shannon, which (to McCarthy's disappointment) largely concerned the esoteric and rather narrow mathematical subject called "automata theory." The second, according to McCarthy, was "to escape association with 'cybernetics.' Its concentration on analog feedback seemed misguided, and I wished to avoid having either to accept Norbert Wiener as a guru or having to argue with him."[12]

There was (and still is) controversy surrounding the name. According to Pamela McCorduck's excellent history of the early days of artificial intelligence, Art Samuel remarked, "The word artificial makes you think there's something kind of phony about this, or else it sounds like it's all artificial and there's nothing real about this work at all."[13] McCorduck goes on to say that "[n]either Newell or Simon liked the phrase, and called their own work complex information processing for years thereafter." But most of the people who signed on to do work in this new field (including myself) used the name "artificial intelligence," and that is what the field is called today. (Later, Newell became reconciled to the name. In commenting about the content of the field, he concluded, "So cherish the name *artificial intelligence*. It is a good name. Like all names of scientific fields, it will grow to become exactly what its field comes to mean.")[14]

The approaches and motivations of the people at the workshop differed. Rochester came to the conference with a background in networks of neuron-like elements. Newell and Simon had been pursuing (indeed had helped originate) the symbol-processing approach. Among the topics Shannon wanted to think about (according to the proposal) was the "application of information theory concepts to computing machines and brain models." (After the workshop, however, Shannon turned his attention away from artificial intelligence.)

McCarthy wrote that he was interested in constructing "an artificial language which a computer can be programmed to use on problems requiring conjecture and self-reference. It should correspond to English in the sense that short English statements about the given subject matter should have short correspondents in the language and so should short arguments or conjectural arguments. I hope to try to formulate a language having these properties . . . " Although McCarthy later said that his ideas on this topic were still too "ill formed" for presentation at the conference, it was not long before he made specific proposals for using a logical language and its inference mechanisms for representing and reasoning about knowledge.

Although Minsky's Ph.D. dissertation[15] and some of his subsequent work concentrated on neural nets, around the time of the Dartmouth workshop he was beginning to change direction. Now, he wrote, he wanted to consider a machine that "would tend to build up within itself an abstract model of the environment in which it is placed. If it were given a problem, it could first explore solutions within the internal abstract model of the environment and then attempt external experiments." At the workshop, Minsky continued work on a draft that was later to be published as a foundational paper, "Steps Toward Artificial Intelligence."[16]

One of the most important technical contributions of the 1956 meeting was work presented by Newell and Simon on their program, the "Logic Theorist (LT)," for proving theorems in symbolic logic. LT was concrete evidence that processing "symbol structures" and the use of what Newell and Simon called "heuristics" were fundamental to intelligent problem solving. I'll describe some of these ideas in more detail in a subsequent chapter.

Newell and Simon had been working on ideas for LT for some months and became convinced in late 1955 that they could be embodied in a working program. According to Edward Feigenbaum (1936–), who was taking a course from Herb Simon at Carnegie in early 1956, "It was just after Christmas vacation – January 1956 – when Herb Simon came into the classroom and said, 'Over Christmas Allen Newell and I invented a thinking machine.' "[17] What was soon to be programmed as LT was the "thinking machine" Simon was talking about. He called it such, no doubt, because he thought it used some of the same methods for solving problems that humans use. Simon later wrote[18] "On Thursday, Dec. 15 . . . I succeeded in simulating by hand the first proof . . . I have always celebrated Dec. 15, 1955, as the birthday of heuristic

Figure 3.3. Some of AI's founders at the July 2006 Dartmouth fiftieth anniversary meeting. From the left are Trenchard More, John McCarthy, Marvin Minsky, Oliver Selfridge, and Ray Solomonoff. (Photograph courtesy of photographer Joe Mehling and the Dartmouth College Artificial Intelligence Conference: The Next Fifty Years.)

problem solving by computer." According to Simon's autobiography *Models of My Life*,[19] LT began by hand simulation, using his children as the computing elements, while writing on and holding up note cards as the registers that contained the state variables of the program.[20]

Another topic discussed at Dartmouth was the problem of proving theorems in geometry. (Perhaps some readers will recall their struggles with geometry proofs in high school.) Minsky had already been thinking about a program to prove geometry theorems. McCorduck quotes him as saying the following:[21]

> [P]robably the important event in my own development – and the explanation of my perhaps surprisingly casual acceptance of the Newell–Shaw–Simon work – was that I had sketched out the heuristic search procedure for [a] geometry machine and then been able to hand-simulate it on paper in the course of an hour or so. Under my hand the new proof of the isosceles-triangle theorem came to life, a proof that was new and elegant to the participants – later, we found that proof was well-known . . .

In July 2006, another conference was held at Dartmouth celebrating the fiftieth anniversary of the original conference. (See Fig. 3.3.) Several of the founders and other prominent AI researchers attended and surveyed what had been achieved since 1956. McCarthy reminisced that the "main reason the 1956 Dartmouth workshop did not live up to my expectations is that AI is harder than we thought." In any case, the 1956 workshop is considered to be the official beginning of serious work in artificial intelligence, and Minsky, McCarthy, Newell, and Simon came to be regarded as the "fathers" of AI. A plaque was dedicated and installed at the Baker Library at Dartmouth commemorating the beginning of artificial intelligence as a scientific discipline.

3.3 Mechanization of Thought Processes

In November 1958, a symposium on the "Mechanisation of Thought Processes" was held at the National Physical Laboratory in Teddington, Middlesex, England. According to the preface of the conference proceedings, the symposium was held "to bring together scientists studying artificial thinking, character and pattern recognition, learning, mechanical language translation, biology, automatic programming, industrial planning and clerical mechanization."

Among the people who presented papers at this symposium were many whom I have already mentioned in this story. They include Minsky (by then a staff member at Lincoln Laboratory and on his way to becoming an assistant professor of Mathematics at MIT), McCarthy (by then an assistant professor of Communication Sciences at MIT), Ashby, Selfridge, and McCulloch. (John Backus, one of the developers of the computer programming language FORTRAN, and Grace Murray Hopper, a pioneer in "automatic programming," also gave papers.)

The proceedings of this conference[22] contains some papers that became quite influential in the history of artificial intelligence. Among these, I'll mention ones by Minsky, McCarthy, and Selfridge.

Minsky's paper, "Some Methods of Artificial Intelligence and Heuristic Programming," was the latest version of a piece he had been working on since just before the Dartmouth workshop. The paper described various methods that were (and could be) used in heuristic programming. It also covered methods for pattern recognition, learning, and planning. The final version, which was soon to be published as "Steps Toward Artificial Intelligence," was to become required reading for new recruits to the field (including me).

I have already mentioned McCarthy's hope to develop an artificial language for AI. He summarized his conference paper, "Programs with Common Sense," as follows:

> This paper will discuss programs to manipulate in a suitable formal language (most likely a part of the predicate calculus) common instrumental statements. The basic program will draw immediate conclusions from a list of premises. These conclusions will be either declarative or imperative sentences. When an imperative sentence is deduced, the program takes a corresponding action.

In his paper, McCarthy suggested that facts needed by an AI program, which he called the "advice taker," might be represented as expressions in a mathematical (and computer-friendly) language called "first-order logic." For example, the facts "I am at my desk" and "My desk is at home" would be represented as the expressions `at(I, desk)` and `at(desk, home)`. These, together with similarly represented information about how to achieve a change in location (by walking and driving for example), could then be used by the proposed (but not yet programmed) advice taker to figure out how to achieve some goal, such as being at the airport. The advice taker's reasoning process would produce imperative logical expressions involving walking to the car and driving to the airport.

Representing facts in a logical language has several advantages. As McCarthy later put it,[23]

> Expressing information in declarative sentences is far more modular than expressing it in segments of computer program or in tables. Sentences can be true in much wider contexts than specific programs can be useful. The supplier of a fact does not have to understand much about how the receiver functions, or how or whether the receiver will use it. The same fact can be used for many purposes, because the logical consequences of collections of facts can be available.

McCarthy later expanded on these ideas in a companion memorandum.[24] As I'll mention later, some of McCarthy's advice-taker proposals were finally implemented by a Stanford graduate student, C. Cordell Green.

I have already mentioned the 1955 pattern-recognition work of Oliver Selfridge. At the 1958 Teddington Symposium, Selfridge presented a paper on a new model for pattern recognition (and possibly for other cognitive tasks also).[25] He called it "Pandemonium," meaning the place of all the demons. His model is especially interesting because its components, which Selfridge called "demons," can either be instantiated as performing lower level nerve-cell-type functions or higher level cognitive functions (of the symbol-processing variety). Thus, Pandemonium can take the form of a neural network, a hierarchically organized set of symbol processors – all working in parallel, or some combination of these forms. If the latter, the model is a provocative proposal for joining these two disparate approaches to AI.

In the introduction to his paper, Selfridge emphasized the importance of computations performed in parallel:

> The basic motif behind our model is the notion of parallel processing. This is suggested on two grounds: first, it is often easier to handle data in a parallel manner, and, indeed, it is usually the more "natural" manner to handle it in; and, secondly, it is easier to modify an assembly of quasi-independent modules than a machine all of whose parts interact immediately and in a complex way.

Selfridge made several suggestions about how Pandemonium could learn. It's worth describing some of these because they foreshadow later work in machine learning. But first I must say a bit more about the structure of Pandemonium.

Pandemonium's structure is something like that of a business organization chart. At the bottom level are workers, whom Selfridge called the "data demons." These are computational processes that "look at" the input data, say an image of a printed letter or number. Each demon looks for something specific in the image, perhaps a horizontal bar; another might look for a vertical bar; another for an arc of a circle; and so on. Each demon "shouts" its findings to a set of demons higher in the organization. (Think of these higher level demons as middle-level managers.) The loudness of a demon's shout depends on how certain it is that it is seeing what it is looking for. Of course, Selfridge is speaking metaphorically when he uses terms such as "looking for" and "shouting." Suffice it to say that it is not too difficult to program computers to "look for" certain features in an image. (Selfridge had already shown how that could be done in his 1955 paper that I mentioned earlier.) And a "shout" is really the strength of the output of a computational process.

Each of the next level of demons specializes in listening for a particular combination of shouts from the data demons. For example, one of the demons at this level might be tuned to listen for shouts from data demon 3, data demon 11, and data demon 22. If it finds that these particular demons are shouting loudly, it responds with a shout of its own to the demons one level up in the hierarchy, and so on.

Just below the top level of the organization are what Selfridge called the "cognitive demons." As at the other levels, these listen for particular combinations of shouts from the demons at the level below, and they respond with shouts of their own to a final "decision demon" at the top – the overall boss. Depending on what it hears from its "staff," the decision demon finally announces what it thinks is the identity of the image – perhaps the letter "A" or the letter "R" or whatever.

Actual demon design depends on what task Pandemonium is supposed to be doing. But even without specifying what each demon was to do, Selfridge made very interesting proposals about how Pandemonium could learn to perform better at whatever it was supposed to be doing. One of his proposals involved equipping each demon with what amounted to a "megaphone" through which it delivered its shout. The volume level of the megaphone could be adjusted. (Selfridge's Pandemonium is just a bit more complicated than the version I am describing. His version has each demon using different channels for communicating with each of the different demons above it. The volume of the shout going up each channel is individually adjusted by the learning mechanism.) The demons were not allowed to set their own volume levels, however. All volume levels were to be set through an outside learning process attempting to improve the performance of the whole assembly. Imagine that the volume levels are initially set either at random or at whatever a designer thinks would be appropriate. The device is then tested on some sample of input data and its performance score is noted. Say, it gets a score of 81%. Then, small adjustments are made to the volume levels in all possible ways until a set of adjustments is found that improves the score the most, say to 83%. This particular set of small adjustments is then made and the process is repeated over and over (possibly on additional data) until no further improvement can be made.

(Because there might be a lot of megaphones in the organization, it might seem impractical to make adjustments in all possible ways and to test each of these ways to find its score. The process might indeed take some time, but computers are fast – even more so today. Later in the book, I'll show how one can calculate, rather than find by experiment, the best adjustments to make in neural networks organized like Pandemonium.)

If we think of the score as the height of some landscape and the adjustments as movements over the landscape, the process can be likened to climbing a hill by always taking steps in the direction of steepest ascent. Gradient ascent (or hill-climbing methods, as they are sometimes called) are well known in mathematics. Selfridge had this to say about some of the pitfalls of their use:

> This may be described as one of the problems of training, namely, to encourage the machine or organism to get enough on the foot-hills so that small changes . . . will produce noticeable

improvement in his altitude or score. One can describe learning situations where most of the difficulty of the task lies in finding any way of improving one's score, such as learning to ride a unicycle, where it takes longer to stay on for a second than it does to improve that one second to a minute; and others where it is easy to do a little well and very hard to do very well, such as learning to play chess. It's also true that often the main peak is a plateau rather than an isolated spike.

Selfridge described another method for learning in Pandemonium. This method might be likened to replacing managers in an organization who do not perform well. As Selfridge puts it,

> At the conception of our demoniac assembly we collected somewhat arbitrarily a large number of subdemons which we guessed would be useful . . . but we have no assurance at all that the particular subdemons we selected are good ones. Subdemon selection generates new subdemons for trial and eliminates inefficient ones, that is, ones that do not much help improve the score.

The demon selection process begins after the volume-adjusting learning mechanism has run for a while with no further improvements in the score. Then the "worth" of each demon is evaluated by using, as Selfridge suggests, a method based on the learned volume levels of their shouting. Demons having high volume levels have a large effect on the final score, and so they can be thought to have high worth. First, the demons with low volume levels are eliminated entirely. (That step can't hurt the score very much.) Next, some of the demons undergo random "mutations" and are put back in service. Next, some pairs of worthy demons are selected and, as Selfridge says, "conjugated" into offspring demons. The precise method Selfridge proposed for conjugation need not concern us here, but the spirit of the process is to produce offspring that share, one hopes, useful properties of the parents. The offspring are then put into service. Now the whole process of adjusting volume levels of the surviving and "evolved" demons can begin again to see whether the score of the new assembly can be further improved.

Notes

1. The proceedings of the symposium were published in L. A. Jeffries (ed.), *Cerebral Mechanisms in Behavior: The Hixon Symposium*, New York: Wiley, 1951. An excellent review of Lashley's points are contained in Chapter 2 of *The Mind's New Science: A History of the Cognitive Revolution*, by Howard E Gardner, New York: Basic Books, 1985. [49]
2. W. A. Clark and B. G. Farley, "Generalization of Pattern Recognition in a Self-Organizing System," *Proceedings of the 1955 Western Joint Computer Conference*, Institute of Radio Engineers, New York, pp. 86–91, 1955. Clark and Farley's experiments continued some work they had reported on earlier in B. G. Farley and W. A. Clark, "Simulation of Self-Organizing Systems by Digital Computer, *IRE Transactions on Information Theory*, Vol. 4, pp. 76–84, 1954. (In 1962, Clark built the first personal computer, the LINC.) [50]
3. Alan Wilkes and Nicholas Wade credit Scottish psychologist Alexander Bain (1818–1903) with the invention of the first neural network, which Bain described in his 1873 book *Mind and Body: The Theories of Their Relation.*" (See Alan L. Wilkes and Nicholas J.

Wade, “Bain on Neural Networks,” *Brain and Cognition*, Vol. 33, pp. 295–305, 1997.) [50]

4. Gerald P. Dinneen, “Programming Pattern Recognition,” *Proceedings of the 1955 Western Joint Computer Conference*, Institute of Radio Engineers, New York, pp. 94–100, 1955. [50]
5. Oliver Selfridge, “Pattern Recognition and Modern Computers,” *Proceedings of the 1955 Western Joint Computer Conference*, Institute of Radio Engineers, New York, pp. 91–93, 1955. [51]
6. Allen Newell, Newell, Allen!and chess|(“The Chess Machine: An Example of Dealing with a Complex Task by Adaptation,” *Proceedings of the 1955 Western Joint Computer Conference*, Institute of Radio Engineers, New York, pp. 101–108, 1955. (Also issued as RAND Technical Report P-620.) [51]
7. National Academy of Sciences, *Biographical Memoirs*, Vol. 71, 1997. Available online at http://www.nap.edu/catalog.php?record_id=5737. [51]
8. Allen Newell, J. C. Shaw, and Herbert A. Simon, “Chess-Playing Programs and the Problem of Complexity,” *IBM Journal of Research and Development*, Vol. 2, pp. 320–335, 1958. The paper is available online at http://domino.watson.ibm.com/tchjr/journalindex.nsf/0/237cfeded3be103585256bfa00683d4d?OpenDocument. [51]
9. From John McCarthy’s informal comments at the 2006 Dartmouth celebration. [52]
10. Nathan Rochester *et al.*, “Tests on a Cell Assembly Theory of the Action of the Brain Using a Large Digital Computer,” *IRE Transaction of Information Theory*, Vol. IT-2, pp. 80–93, 1956. [52]
11. From http://www-formal.stanford.edu/jmc/history/dartmouth/dartmouth.html. Portions of the proposal have been reprinted in John McCarthy, Marvin L. Minsky, Nathaniel Rochester, and Claude E. Shannon, “A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence,” *AI Magazine*, Vol. 27, No. 4, p. 12, Winter 2006. [53]
12. From http://www-formal.stanford.edu/jmc/reviews/bloomfield/bloomfield.html. [53]
13. Pamela McCorduck, *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence*, p. 97, San Francisco: W. H. Freeman and Co., 1979. [53]
14. See Allen Newell, “The First AAAI President’s Message,” *AI Magazine*, Vol. 26, No. 4, pp. 24–29, Winter 2005. [54]
15. M. L. Minsky, *Theory of Neural-Analog Reinforcement Systems and Its Application to the Brain-Model Problem*, Ph.D. thesis, Princeton University, 1954. [54]
16. Marvin L. Minsky, “Steps Toward Artificial Intelligence,” *Proceedings of the IRE*, Vol. 49, No. 1, pp. 8–30, January 1961. Also appears in Edward A. Feigenbaum, and Julian Feldman (eds.), *Computers and Thought*, New York: McGraw Hill, 1963. (Available online at http://web.media.mit.edu/~minsky/papers/steps.html.) [54]
17. Pamela McCorduck, *op. cit.*, p. 116. [54]
18. Herbert A. Simon, *Models of My Life*, Cambridge, MA: MIT Press, 1996. The quote is from http://www.post-gazette.com/pg/06002/631149.stm. [54]
19. *Ibid*. [55]
20. http://www.post-gazette.com/downloads/20060102simon_notes.pdf contains sketches of Simon’s simulation of an LT proof. [55]
21. Pamela McCorduck, *op. cit.*, p. 106. [55]
22. D. V. Blake and A. M. Uttley (eds.), *Proceedings of the Symposium on Mechanisation of Thought Processes*, Vols. 1 and 2, London: Her Majesty’s Stationary Office, 1959. [56]
23. John McCarthy, “Artificial Intelligence, Logic and Formalizing Common Sense,” in *Philosophical Logic and Artificial Intelligence*, Richmond Thomason (ed.), Dordrecht: Kluwer Academic, 1989. [57]

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