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VEHICLES: EXPERIMENTS IN SYNTHETIC PSYCHOLOGY. By VALENTINO BRAITENBERG. Cambridge, Bradford Books/MIT Press, 1984. Pp. ix, 152.

The working hypothesis that the mind is the brain may set us off on the right foot, but it doesn't take us very far. The problems that then confront the would-be empirical theorist are enormous: the human brain's billions of neurons overwhelm piecemeal analysis by the biologist, and the productive variety and evanescence of the human mind's activities baffle the psychological modeler. In this elegant little gem of a book, Valentino Braitenberg, an eminent brain researcher at the University of Tübingen, proposes a method for cutting through this daunting complexity, and exhibits with delightful wit and enviable clarity the power of a strategic insight: "the law of uphill analysis and downhill invention."

As Braitenberg observes, ". . . it is much more difficult to start from the outside and try to guess internal structure just from the observation of behavior" than it is to "create little machines that do certain tricks" and then "observe the full repertoire" of their behavior. Artificial Intelligence researchers have always exploited this "law," of course, and have often been delighted or dismayed by the actual repertoire of their creations. Braitenberg's strategy is to model whole organisms rather than bits of human micro-competence (playing chess, answering questions about restaurants), and to obtain the needed oversimplification of his models by starting with comically simple, idealized organisms—"Vehicles"—and gradually adding complications and refinements, a process that fruitfully

I am not in a position to challenge this fascinating story. I will comment on a footnote to it, Kitcher's interesting explanation (pp. 268–270) why Frege's work was largely ignored by mathematicians (at least before Russell's paradox). Kitcher sees Frege as motivated by a foundationalist *philosophical* program to seek to carry the process of "rigorization" beyond what was called for by the mathematical problems of the time. Reasonably enough, mathematicians were not moved by this philosophical program. As far as it goes, this explanation seems to me very plausible.

Nevertheless, we should remember that Frege's great technical achievement was the discovery of a quantificational logic. Kitcher's general approach tends to de-emphasize the role of logic in mathematics. This is a useful corrective to the dominance of the logician's perspective. Kitcher admits, however, that the paradoxes of set theory created a situation where Frege's logic was useful for an enterprise answering to a mathematical problem. In my view, late nineteenth century mathematics was already developing in a direction calling for an integration of mathematics and logic. Weierstrass' use of "ϵ–δ" definitions in analysis involved a greater explicitness about complex interactions of quantifiers than had prevailed previously. Peano reacted to what must have been a clear need in creating a compact notation to express such relations. Another tendency was the more careful development of the axiomatic method, in evidence in the work Kitcher discusses on characterizing the real numbers, but also in the work on geometry culminating in Hilbert's *Grundlagen der Geometrie*.[6] Frege's logic had much to contribute to clarifying Hilbert's conception of axiom systems as implicit definitions of structures; the mutual misunderstanding in the "Frege-Hilbert controversy" is sad to contemplate.[7]

Though quite successful in its own terms, the last part of the book is less challenging to the views of someone who stresses the difference between mathematics and science than the author may think. This is partly due to the questions raised above about what it does for the case for Kitcher's form of empiricism. A traditional view that I uphold, that mathematics is necessary, Kitcher does not contest (p. 32). Other issues that have been important for me, such as the intimate connection of mathematics and logic and its applicability to objects quite generally, Kitcher does not address.[8]

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[6]Moritz Pasch, a leading participant in this work, expressed appreciation of Frege's work in a letter to him in 1894; see Frege, *Wissenschaftlicher Briefwechsel*, ed. Gabriel et al. (Hamburg: Meiner, 1976), pp. 169–170.

[7]See Michael D. Resnik, *Frege and the Philosophy of Mathematics* (Ithaca and London: Cornell University Press, 1980), pp. 106–119.

[8]See *Mathematics in Philosophy*, pp. 16–18.

These 14 Vehicles cry out for computer simulation, and just as I had resolved to spend the next year or so getting them—and dozens of cousins that occurred to me—to trundle about on the screen of my micro-computer, I learned from the publisher that Braitenberg is preparing just such software simulations, which should be available for several popular micro-computers from the publisher in the near future. At last: Dungeons and Dragons for grownups, and a completely serious method of investigating biological and psychological hypotheses at the same time.

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