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NOTES ON McCULLOCH-PITTS' *A LOGICAL CALCULUS OF THE IDEAS IMMANENT IN NERVOUS ACTIVITY**

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Warren McCulloch much enjoyed storytelling and one of his favorites had to do with Walter Pitts' emergence in Chicago.

Walter was just 15 then when he ran away from home, turned up in Chicago and there met a fellow who called himself Bert. Now, this Bert talked with Walter for some time of philosophy and mathematics, and came to realize that this was no ordinary youngster. Bert was impressed. He told the boy that Carnap, then Professor of Philosophy at the University of Chicago, had written a book that would interest him, and urged him to go and speak to the grand old man. So, Walter got himself a copy of Carnap's book and read it. Later, Carnap was to recount the meeting thus: "This young boy came in to see me and said he had read my book and that a certain paragraph on a certain page was not clear to him. Now when I say that something is not clear to me, I mean that that thing is nonsense. So we took down my copy of the book and opened it to the page in question and carefully read the paragraph...and it was not clear to me either!"

Bert was Bertrand Russell. The symbolic notation of *The Logical Calculus* was strongly influenced by Carnap and by Whitehead and Russell. The notation is, perhaps, not the best, but nevertheless, *The Logical Calculus* is a paper of which McCulloch was really proud. The referee for the Bulletin of Mathematical Bio-Physics, Volume 5, 1943, had pointed out that not a single word in the paper was wasted.

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The Logical Calculus is a remarkable synthesis of two concepts that McCulloch determined to unite, MAN and MACHINE. Man, especially his brain, is represented by the nets of formal neurons; mathematics, by a brand of formal logic. The main result (and what could be better!) proves the equivalence of the two: All neural nets can be represented mathematically by the logical expression of a certain well-defined system of mathematics and vice versa, all logical expressions of that system represent neural nets.

The mathematics is insightful. It shows that for neural networks to be powerful, neurons must inhibit as well as excite each other. At the time, as neurophysiologists were quick to point out, there was no evidence for inhibition in the cortex. But the mathematics demanded inhibition, so inhibition was introduced. Later it was discovered, as the mathematics had demanded.

The formal neurons were quite simply defined. Professor Anatol Rapaport, at the University of Michigan, had earlier defined and studied more complex neural models which included models of facilitation and extinction. In *The Logical Calculus*, nets of the simpler formal neurons are demonstrably capable of simulating more complex neurons. This idea was extended to the brain. The "intelligence" of that system, McCulloch would point out, lies in the complexity of the circuitry rather than the neuron.

McCulloch early drew analogies with the computer until others, no longer shocked, did the same. To understand the brain, one should study how the components are connected. Connections count for more than the idiosyncrasies of the individual components (the vacuum tubes) themselves.

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