vordenker
Winter-Edition 2008/09

Warren S. McCulloch [*]

Mysterium Inquitatis *of Sinful Man Aspiring into the Place of God*

D'ARCY THOMPSON used to tell of his encounter with a biologist who had described a nearly spherical diatom bounded entirely by hexagons thus:

> "But," I said, "Euler showed that hexagons alone cannot enclose a volume." To which the innominate biologist retorted, "That proves the superiority of God over mathematics."

Euler's proof happened to be correct, and the observations inaccurate. Had both been right, far from proving God's superiority to logic, they would have impugned His wit by catching Him in a contradiction. Our first concern is to avoid the impropriety of such solecisms.

Our second resembles it slightly. Newton, Jeans, and Planck have used "God" to account for things they could not explain. Biologists, ignorant of mechanisms underlying functions, have introduced "Nature," "Vital Force," "Nervous Energy," "the Unconscious," or some other pseudonym for God. Each of these supposititious explanations, to quote Sir Thomas Browne, "puts the honest Father to the refuge of a miracle."

Today no biological process is fully understood in terms of chemistry and physics. The facts are unknown to us. Few chemical properties are yet reduced to the physical relations of atomic constituents. The mathematics is too cumbersome. Physics itself wants a unified field theory and doubts determinism in atomic processes.

So much for Comte's hierarchical unity of science! At last we are learning to admit ignorance, suspend judgment, and forego the *explicatio ignoti per ignotium* – "God" – which has proved as futile as it is profane. Instead we seek mechanisms, for two purposes.

Let us consider them one at a time. As soon as we devise a machine that will do what has to be explained, we divest the superstitious of any seeming warrant to his miracle. It is enough to show that, if certain physical things were assembled in a certain way, then, by the law of physics, the assemblage would do what is required of it. So imaginary engines led Carnot to entropy and Maxwell to his electromagnetic equations, instead of to miracles. Both machines, to their inventors, were more than metaphors for mathematics. But actual engines proved Carnot's a homolog, whereas the elastic ether's being chimerical left Maxwell's a mere analog. Yet, because each showed there could be a machine that turned the trick, it would be best to see them – at least from the logical point of view – as existential devices.

By these means biologists have exorcised ghosts from the body, whence they went to the head, like bats to the belfry. To drive them thence, my mentor, Pike, spent his life

---

* Warren S. McCulloch, in: "Warren S. McCulloch: Embodiments of Mind", The MIT Press, Cambridge, Mass. 1965, pp. 157-164. (first published in: The Scientific Monthly, vol. 80, 1955, pp. 35-39)

replacing them by simple engines to ring all the changes on the chimes. He looked on the evolution of the nervous system, on its ontogeny, on learning, even on reflexes, as spontaneous variants that survive in the competition to trap available energy and thus secure energetic *Lebensraum* in the entropic degeneration of sunshine to the *Wärmetod*. Whether atomic or molecular chaos produces a sport, its thanks are due to chance, not to divine intervention in its behalf. These notions do not constitute mechanistic hypotheses but exhort us to construct them. Call them metaphysical if you will – in this good sense, that they prescribe ways of thinking physically about affairs called mental and relegated to the whims of spirit manifold. I am of Pike's persuasion.

But most people have heard of cybernetics from Norbert Wiener or his followers. Narrowly defined it is but the art of the helmsman, to hold a course by swinging the rudder so as to offset any deviation from that course. For this the helmsman must be so informed of the consequences of his previous acts that he corrects them – communication engineers call this "negative feedback" – for the output of the helmsman decreases the input to the helmsman. The intrinsic governance of nervous activity, our reflexes, and our appetites exemplify this process. In all of them, as in the steering of the ship, what must return is not energy but information. Hence, in an extended sense, cybernetics may be said to include the timeliest applications of the quantitative theory of information.

The circuit in a servomechanism may include, as we hold it does in man's head, complicated machines of calculation. Turing showed that one having a finite number of parts and states, scanning, marking, and erasing one of four symbols at a time on an infinite tape, can compute any computable number. The first part of the tape serves to prescribe which number his general machine shall compute. Pitts and I showed that brains were Turing machines, and that any Turing machine could be made out of neurons. For this we used a calculus of atomic propositions subscripted for the time when all-or-none impulses signalized them in the relays constituting the net, or the machine. In brains the relays are neurons, and the blueprint of the net is the anatomy of their connections.

Since Hilbert arithmetized logic, the calculation of any computable number is equivalent to deducing any conclusion that follows from a finite set of premises, or to detecting any figure in an input, or to having any general idea that can be induced from our sensations. Existential operations can be introduced into our calculus by inserting in the net any circuitry that will secure invariants under groups of transformations. Memories, general ideas, and even Spinozistic consciousness, the idea of ideas, can thus be generated in robots. These robots, even simple ones having but half a dozen relays, may, without inconsistency, show that circularity of preference, or of choice, called the value anomaly which – contra Plato – precludes a common measure of "the good."

Elsewhere I have shown not merely that computing machines by playing chess may learn to play better than their designers, as Ashby would have it, but that they may learn the rules of the game when these are given only ostensively. This ensures their ability to generate their own ethic – not merely to be good, like the virtuous savage, because they are so made that they cannot break the rules, nor, like the gospeled or inspired, because they were so instructed by their fellows or their creator. Unlike solitaire, chess can be enjoyed only by a society of men or machines whose desire to play exceeds their desire to win. This is easily determined by connecting their two feedback loops in such a way that the former dominates the latter. I grant that these complicated machines resemble the elephant or some other "Colossus of Nature" rather than ants, within whose "narrow

engines there is more curious mathematic; and the civility of these little citizens more neatly sets forth the wisdom of their Maker ... ." Yet, that we can design ethical robots, who may even invent games that are more fun than chess, is enough to prove that man's moral nature needs no supernatural source. Darwin observed, but Spencer failed to note, that success in the game of life, and so survival, is "often most promoted by mutual assistance."

Hence the crucial question: Can machines evolve? John von Neumann suggests that we are familiar only with simple machines that can make only simpler ones, so that we suppose this is a general law, whereas, in fact, complicated ones can make others still more complicated. Given a suitable Turing machine, coupled to a duplicator of tape and to an assembly of parts from a common store, it could make one like itself, put in a duplicate of its own tape, and cut loose its replica ready to make a new one like itself. There are now two. Their number will double with each generation. Variations compatible with this reproduction, regardless of their sources, will lead to evolution; for, though simpler mutations must fail, some more complicated will survive. Von Neumann, Wheeler, and Quastler have computed the required complexity and find that, for general Turing machines to survive, they must be about as complex as a totipotent protein molecule, which is the simplest thing we know that does reproduce itself. Totipotent protein molecules are the littlest citizens. Man has not yet found their mechanical prescription. He has made amino acids by shaking together CO_2, NH_3, and H_2O in the light, and he has made polypeptides from amino acids. When he makes proteins by sticking these together, he can better estimate the probability of their formation by chance in evolutionary epochs. If the civility of these little citizens only sets forth an evolved efficiency in forestalling the *Wärmetod*, we may forego the astronomer's cry against their Maker:

> What? From insensate nothing to evoke
> A sensate something to resent the yoke
> Of unpermitted pleasure under pain
> Of everlasting punishment if broke:
> Oh, were that justice and His holy right.

Following Wiener we estimate the complexity of a machine or an organism to be the number of yes-or-no decisions – we call them bits of information – necessary to specify its organization. This is the logarithm (base 2) of the reciprocal of the probability of that state and, hence, its negative entropy.

But Wiener has forerunners as well as followers in Cambridge. Charles Peirce first defined "information," his "third kind of quantity," as "'the sum of synthetical propositions in which the symbol is subject to predicate,' antecedent or consequent." Of Peirce's friends, Holmes, in his *Mechanism in Mind and Morals*, excuses only volition from the sway of mechanical causation; and James, in several places, attributes the vagaries of the will to chance. Perhaps a New England conscience may afford freedom to its neighbors' wills, as Donne says we give "souls unto women only to make them capable of damnation." But surely he is damned already whose frame and fortune foredoom his failure. That he is the machine at fault ensures that he and his neighbors hold him responsible. The common law construes intention from the deed, and a windmill that kills a man is deodand. Every psychiatrist who cares for the well-being of his patient comes to look on a man's sins as his misfortune of birth or breeding and is glad that his selfrighteous brethren cannot climb into God's mercy seat.

Sin, in its widest sense, is but to miss a mark; and surely most of us are too familiar with self-guiding missiles to doubt that we can endow them with computers and target-seeking servos whereby to hit or miss their prey. The components of these circuits are too gross and inefficient for us to package in a head what fills the nose of a V-2 rocket. But given miniature efficient relays comparable to neurons, we could build machines as small to process information as fast and multifariously as a brain. The hardest thing to match is man's storage of bits of incidental information, but we can put an upper bound on that. Following Craik's lead, man's acquisition of such information has been measured and never found to exceed a hundred bits per second of sustained reception. Were it 10 times more throughout his life, he could store no more than 10^{13} such bits. Heinz von Foerster arrived at a similar figure by noting that the mean half-life of a trace in human memory is half a day, and the access to it over only 10^{6} channels, with an access time of about 1 millisecond. Hence, a man will come to equilibrium with far fewer traces than there are junctional buttons on our neurons. Moreover, von Foerster showed that if, by regenerating traces, we retained some 5 percent of all our uptake, the energy required for this remembering would be only a fraction of 1 percent of that which flows through brains. This answers Bertrand Russell's only serious question about the peculiar causality of human thinking. Ashby, in his book *Design for a Brain*, proposed a mechanism of adaptation that avoids the fallacy of simple location of a trace and makes the thing we are to seek in a given brain and its multiple locations depend upon the sequence of its learnings.

To the theoretical question, "Can you design a machine to do whatever a brain can do?" the answer is this: "If you will specify in a finite and unambiguous way what you think a brain does do with information, then we can design a machine to do it." Pitts and I have proved this constructively. But can you say what you think brains do?

In 1953, in the symposium on consciousness of the Institute for the Unity of Science, Wilder Penfield used the term, as we do in forensic medicine, to mean precisely that his patient at a later date bore witness to what he also bore witness to as having happened then and there. Of course we can make machines do that. The questioner meant "Was the patient aware that it was he himself that did it?" which is self-consciousness, requiring but simple reflective circuitry. The physiologist would have settled the argument by defining *consciousness* to mean "responsiveness to present stimulation with a lag called latency" – a trait that few things lack! – but a psychoanalyst explained to me that "a patient is conscious of what he once felt only if at a later time he can verbalize it" – which is to say, "he is conscious of those things of which he says he is conscious" – and this requires only a machine that sometimes answers "yes" to this question. That is too easy; and if all we mean by consciousness is this ghost of half of mind-stuff, we may forget it all as just a pseudo-question. But I am sure that for every empirical scientist to whom existence is as primary as it is to a true Thomist what lurks behind this ghostly facade is the old Aristotelian "substance." To Helmholtz, it appeared as the "*locus observandi*"; to Einstein as "the frame of reference of the observer"; to Russell as "the egocentric particular involved in denotation." For MacKay it yields the distinction between the languages of the observer and of the actor. Granted that we have objective knowledge of others, and substantial knowledge only of ourselves, this only proves us to be like every other thing, and divine, if you will, only as a part of all that exists. It does not demonstrate the metaphysical self-sufficient mind or soul with the unique property of perception. However one defines feeling, perception, consciousness, substantial

knowledge – so the definition is finite and unambiguous – each and all are well within the tricky scope of circuitry. So much for the existential purport of machines!

Their second *raison d'être* is to generate hypotheses. A mechanism that fits all our data is one of an infinite number of possible explanations of our findings. It always has properties disclosed by deduction and subject to the test of experience. It may even lead to an invention. Contemporary opinion, in Haldane's phrase, regards "every physical invention as a blasphemy and every biological invention as a perversion." This is less a matter of heresy than of "radical indecency." Plowing, milking, alcohol, coffee, tobacco, birth control, and artificial insemination are only the by-products of biological knowledge. The chromosome shuffling of Mendelian genes, which has stood the test longer than any other equally significant biological discovery, never offended our sensibilities, although it lets chance materially dictate our constitution. Only recently have we come to the data that set limits to the applicability of Mendel's law.

Each hypothesis predicts the outcome of numberless experiments. Hence, though no hypothesis can be proved, it may ultimately be disproved. A good one is so specific that it can be disproved easily. This requires a minimum of logical, or *a priori*, probability compatible with the data. I have sometimes boasted that my pet notion of the mechanism responsible for our seeing shape regardless of size was disproved by MacKay's experiment in my own laboratory. What grieves me is that neither I nor anyone else has so far imagined another specific mechanism to account for form vision.

Perhaps in this "best of all possible worlds" neurophysiologists, like physicists, will be compelled to call their shots "on a cloth untrue, with a twisted cue and elliptical billiard balls." Russell has already noted that the explanation of mind has become more materialistic only as our matter has become less material. So we seem to be groping our way toward an indifferent monism. Everything we learn of organisms leads us to conclude not merely that they are analogous to machines but that they are machines. Man-made machines are not brains, but brains are a very ill-understood variety of computing machines. Cybernetics has helped to pull down the wall between the great world of physics and the ghetto of the mind.

Moreover, its analysis of nervous activity reveals two limits to our aspirations – our double *ignorabimus*. The impulses we receive from our receptors embody primary atomic propositions. Each impulse is an event. It happens only once. Consequently, these propositions are primary in the sense that each is true or else false, quite apart from the truth or falsity of any other. Were this not so, they would be redundant or, in the limit, as devoid of information as tautologies. But this means that the truth of each and every one cannot be tested. The empiricist, like the Thomist, must believe that God did not give him his senses in order to deceive him.

Moreover man, like his inventions, is subject to the second law of thermodynamics. Just as his body renders energy unavailable, so his brain corrupts the revelation of his senses. His output of information is but one part in a million of his input. He is a sink rather than a source of information. The creative flights of his imagination are but distortions of a fraction of his data.

Finally, as he has perforce learned from the inadequacies of his best hypotheses, ultimate universal truths are beyond his ken. To demand them is the arrogance of Adam; to come short of them is the impotence of sorry man; but to fancy them known were very ὕβρις. Obviously, he may know something about the past, although he cannot change it. The

future he may affect, but he may never know it. Were this otherwise, he could beat the second law and build machines to operate on future information. So we may conclude that we fear no analogy between machines and organisms, either for existential purport or for generating hypotheses, and that we are safe to admit that organisms, even brains, are machines.

So long as we, like good empiricists, remember that it is an act of faith to believe our senses, that we corrupt but do not generate information, and that our most respectable hypotheses are but guesses open to refutation, so long may we "rest assured that God has not given us over to thraldom under that mistery of iniquity, of sinful man aspiring into the place of God."

The text was originally edited and rendered into PDF file for the e-journal <www.vordenker.de> by *E. von Goldammer*

vordenker
ISSN 1619-9324

How to cite:
Warren St. McCulloch: Mysterium Iniquitatis *of Sinful Man* Aspiring into the Place of God, in: www.vordenker.de (Edition: Winter 2008/09), J. Paul (Ed.), URL: < http://www.vordenker.de/ggphilosophy/mcculloch_mysterium-iniquitatis.pdf > — published in: "Warren S. McCulloch: Embodiments of Mind", The MIT Press, 1965, p.157-164. (first published in: The Scientific Monthly, vol. 80, 1955, pp.35-39)