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POSTSCRIPT TO
"WHAT'S IN THE BRAIN THAT INK MAY CHARACTER?"

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Warren McCulloch's search for the fundamental truths in cybernetic logic originated in one primary recognition: those feedback loops that lie wholly within a brain must ultimately be governed by feedback loops that pass through the brain and close in the brain's total environment. On this basis McCulloch's notion of higher brain processes and Kenneth Craik's notion of thought were similar. Craik said (1):

> My hypothesis then is that thought models, or parallels, reality -- that its essential feature is not "the mind", "the self", "sense-data", nor propositions but symbolism, and that this symbolism is largely of the same kind as that which is familiar to us in mechanical devices which aid thought and calculation.

Craik explained (2):

> By a model...[I] mean any physical or chemical system which has a similar relation-structure to that of the process it imitates. By "relation-structure" I do not mean some obscure non-physical entity which attends the model, but the fact that it is a physical working model which works in the same way as the process it parallels, in the aspects under consideration at any moment. Thus, the model need not resemble the real object pictorially; Kelvin's tide-predictor, which consists of a number of pulleys on levers, does not resemble a tide in appearance, but it works in the same way in certain essential respects -- it combines oscillations of various frequencies so as to produce an oscillation which closely resembles in amplitude at each moment the variation in tide level at any place.

Our Shakespearean ink must character more in the brain than just the physicist's forces, motions and energies. McCulloch often recounted Leibnitz's seventeenth paragraph of the

Monadology as beautifully clear on this. We quote from the Wiener translation (3):

> It must be confessed, moreover, that perception and that which depends on it are inexplicable by mechanical causes, that is, by figures and motions. And, supposing that there were a machine so constructed as to think, feel and have perception, we could conceive of it as enlarged and yet preserving the same proportions, so that we might enter it as into a mill. And this granted, we should only find on visiting it, pieces which push one against another, but never anything by which to explain a perception. This must be sought for, therefore, in the simple substance and not in the composite or in the machine. Furthermore, nothing but this (namely, perceptions and their changes) can be found in the simple substance. It is also in this alone that all the internal activities of simple substance can consist.

Some of the required cybernetic ideas that cannot be found in physics are: information metrons and logons (4), signal-to-noise ratios, true versus false propositions, regulation of behavior in accordance with intentions and purposes, expediency (applied, for example, to contact placing of fingers around objects), learning and memory storage by functional relations instead of by objective signal content, and thinking (an intentional activity in which the ideas intended are those of former intendings. This is von Domarus' definition contained in *Cybernetic Problem of Learning* [183], this volume).

But for the cybernetic calculus which McCulloch sought, much more was needed than the foregoing notions. In his search, McCulloch took up stoic logic in relation to legal science with F.S.C. Northrop, formerly of Yale University, a mathematical logician and philosopher of mathematical physics, contract law, and comparative cultural anthropology. They concluded that both the stoic mathematical logical and contractual legal minds of ancient Greece, and more recently Charles Saunders Peirce, realized the necessity of a calculus of intentional relations but could not formulate one. I have heard McCulloch and Northrop separately discuss the nature of this problem, but they could never satisfactorily formulate their desired calculus.

For years, McCulloch and Northrop stressed that the characteristic subject-predicate syntax of ordinary Aryan prose should

not trick one into ignoring the irreducible many-variable relational concepts found, for example, in

A thinks B likes C

or in the stoic Greco-Roman third party rule of Quintus Mucuis Scaevola (5)

> No one can benefit another to the detriment of a third party, either by an agreement, by presenting a condition, or by entering into a stipulation.

or in the forensic medical use of the term "consciousness", where

> A is conscious with B of an event E if A and B agree as independent witnesses in their report of E. (6)

In these examples the relations are all irreducibly triadic, and are levels of complexity above the single entity-property (or subject-predicate) syntax of Aryan prose, Aristotle's logic of predicables, and the propositional calculus of Principia Mathematica.

McCulloch felt that since trivalent structures can always link to form n-valent ones (see Figure 1), whereas

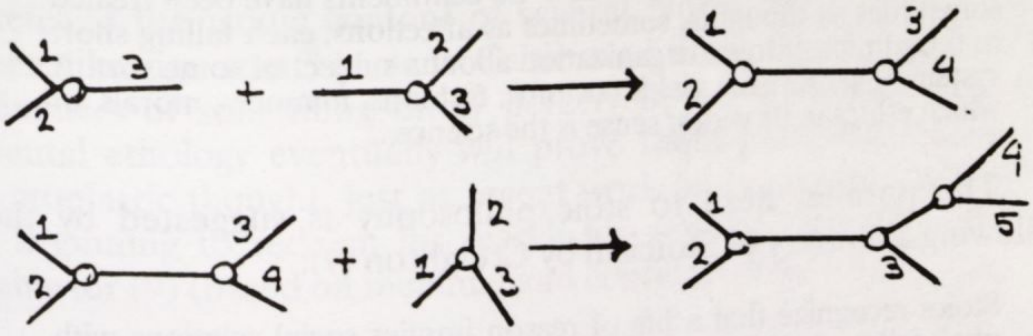

FIGURE 1

bivalent ones can only link to form bivalent chains (see Figure 2),

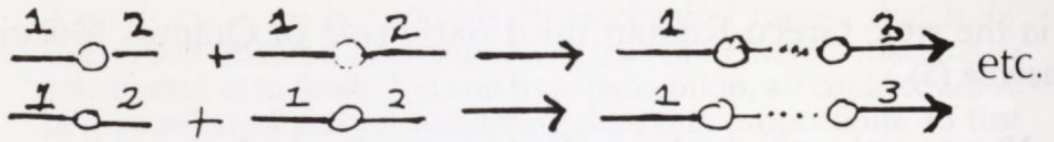

FIGURE 2

probably a triadic calculus would suffice. McCulloch's icons of thought appearing in these Figures, original with him I believe, but probably inspired by C.S. Peirce's molecular diagrams, seem to have stemmed mostly from his early interest in tetravalent carbon atoms as the basis of all life.

The above ideas of McCulloch's on triadic relations, sentiments and Stoic logic all coalesce in the following quote from *This Superfluity of Naughtiness*:

> ...Thoughts are essentially like sentiments and might be phrased "If so and so..., then I would think..." So sentiments have been treated sometimes as thoughts, sometimes as affections, each falling short of their union into an organization about a subject of some sort. A system of sentiments yields customs, fashions, manners, morals, of which ethics in its widest sense is the science...

The parallel here to stoic philosophy is suggested by the following summary of Stoicism by Creighton (7):

> Stoics recognize that a life of reason implies social relations with one's fellow men, and they given an important place in their system to the social duties and virtues, especially to the importance of justice, mercy and friendship. As reason is the essential basis of society, being the common element that unites a man with his fellows, they attach slight importance to citizenship in a particular country, and emphasize the cosmopolitan idea of social unity with all rational beings of every society and of every country. In this and in other doctrines, Stoicism, especially in its later form, goes beyond the conceptions usually prevailing in Greek ethics, and

> approaches the Christian idea of the universal brotherhood of man.

McCulloch's approach to language was not only philosophical but biologically based. His biological perspective is suggested by this passage from *Ragna Rokr* (8) (roughly translated "Last Judgment"):

> ...What I could not find in [subhuman] primates was any cortical area to which came axons for all of the associational cortices. In man it is the angular gyrus that serves this role. Without it the anatomical substrate for carrying over from a shape seen to that same shape felt is wanting. There is no place for an engram of the same thing heard, felt, seen, and so forth, and no carry-over of learning from one modality to another in primates below man -- and none in the human infant until the connections to this area develop. I do not mean that a baby cannot learn to respond in the same way to a breast seen and a breast felt. He can; but he learns them separately, each by its affective component releasing adversion and sucking. He cannot have the general object, breast, because he has no cortical connections to engender the notion. When these develop, he can have that notion, and there is nothing to stop him from learning its name of Mama.

The iconic nature of thought particularly intrigued the poetic side of McCulloch. He once said to me, "When you retell or reread a story to your children you have to use exactly the same words as you used once before or they object, right?" He next sketched the iconic content of several Norse sagas for me, and then likewise some ancient Celtic traditions. These were faint glimmers of something dimly perceived, but I believe developmental ethology eventually will prove them prescient tokens of protoplastic thought, just as recent work on language acquisition is beginning to redeem his search for general laws of linguistic behavior (9) (based on meaning and context, let us note).

At the biophysical level, McCulloch was interested in an operational mechanics for noisy neurons, partly, no doubt, because he wanted to know how statistical his relational calculus would have to be, and partly for ontological reasons. Indeed, he often mentioned in this connection Einstein's belief that statistical laws which compel God to throw dice to determine each decision are highly unlikely.

That many-entity relational verities abound to vitiate reductionist monism is the central tenet of cybernetics, and that their embodiment in physical mechanisms was McCulloch's ultimate interest is virtually certain.

REFERENCES

1. The Nature of Explanation, by K. J. W. Craik, Cambridge University Press, 1952, p. 57. In connection with my other notes in this volume, see Craik's reference: Northrop, F. S. C., 1931, Science and First Principles, Cambridge.
2. ibid., p. 51.
3. Leibnitz Selections, (ed., Philip P. Wiener), Charles Scribner's Sons, New York, 1951, paperback.
4. Information, Mechanism and Meaning, D. M. MacKay, M.I.T. Press, 1969, paperback.
5. See pp. 144 in *The Relational Personalities of Western Legal Science* (pp. 135-150) in F. S. C. Northrop's Ch. 5 of Contemporary American Philosophy: Second Series Ed. by John E. Smith, Allen & Unwin, 1970, London, and Humanities Press, N. Y.
6. Warren's "other" idea about consciousness is that we tend to be conscious only of those things that have gone against our intentions [cf. *This Superfluity of Naughtiness* and *Of I and It*, op. cit.]. Ragnar Granit, in a paper on movement [Brain, 95, pp. 649-660, 1972] maintains similarly that sensations from muscles, tendons and joints are perceived only when they are unexpected, also he says, "It is likely that normally only properly willed movements are perceived" as total movements *per se*.
7. Encyclopedia Americana.
8. op. cit., cf. Wenner-Gren Foundation, N.Y. City, Burg Wartenstein Conference, Summer 1968 (not published).
9. cf., e.g., Psycholinguistics, by Dan Slobin; Scott, Foresman and Co., Glennview, Ill., 1971, paperback.