EPISTEMOLOGY, CYBERNETICS AND UNCERTAINTY: PHILOSOPHICAL OBSERVATIONS ON THE WORK OF WARREN McCULLOCH AND JOHN DEWEY

by

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ABSTRACT

This thesis considers the application of information theory concepts to the problems of epistemology. It attempts to demonstrate that such formalistic concepts by nature must neglect the fundamentally behavioral aspects of thinking.

Part I attempts to describe a predicament which is widely felt today, that of man's inability to control a world of his own making.

It is then proposed that a comprehensive theory of human behavior is what is required to deal with the predicament.

Part II compares the theory of "Experimental Epistemology" of Warren S. McCulloch with the theory of "Inquiry" of John Dewey. Basically McCulloch's equation of sense data with information and his acceptance of negative feedback as explanatory of purposeful behavior is attacked.

Further his assumption of Cartesian Dualism and attempts to resolve it through reductionism are considered in detail.

Dewey's theory of "Inquiry" is proposed as a suitable alternative to explain how we gain warrantable assertibility as the foundation for our judgments of practice. His rejection

of any general theory of reality and insistence upon the social cultural and behavioral aspects of thinking are noted.

Part III considers the educational implications of both theories, by analyzing the kinds of choice they deal with and the consequent kinds of control they proffer. Educational ends are proposed which recognize the human organism as a dynamic process, and requirements for means to such ends are stipulated.

PART III

> To ask whether these computers think is ambiguous. In the naive, realistic sense of the term it is people who think, and not either brains or machines. If, however, we permit ourselves the ellipsis of referring to the operations of the human brain as "thinking" then, of course, our computer's think, their primary language being that of numbers.
>
> Warren S. McCulloch,
> Embodiments of Mind, 1965.

The consequences of allowing ourselves the ellipsis of referring to the operations of the human brain as "thinking" will be the primary concern of this paper. The application of the relatively new concepts of cybernetics and information theory to the operations of the brain is held by some to be a fruitful approach to understanding the complex and highly controversial subject of thinking -- the concern here then is to demonstrate that differential approaches to the subject have important consequences for our every day affairs[1]. The relationship between thinking and the older philosophical subject matter of epistemology, which is concerned with truth, knowledge and meaning, is strong and indicates that our concern must be a central issue, even today.

Hopefully our discussion of thinking will make clear its relationship with epistemology; and also make clear the effects that our way of thinking about thinking has on a particularly important issue that confronts us today.

To provide for an overall view, this paper will be composed of three sections.

The first section outlines the nature of particular contemporary problem. It holds nothing new but reflects a generality of opinion frightening in its scope and importance.

Simply put, the predicament is one of man's apparent inability to control a world of his own making. The dilemma is most clearly seen in the numerous statements of the man on the street who asks, "Now that man is smart enough to blow himself up, is he stupid enough to do it?".

The second section compares two approaches to thinking. Warren S. McCulloch, a neurophysiologist whose fundamental contribution to science is the demonstration that the properties of actual neurons can be seen as analogous to the properties of switching relays in digital computers, has proposed that we construct machines to simulate brain operations[2]. He proposes to call the building of such machines "Experimental Epistemology" and applies the theoretical concepts of cybernetics to this process.

John Dewey, a philosopher, psychologist and educator, approaches thinking from a behavioral point of view and proposes that thinking can be viewed as a relatively recent behavioral evolution which is manifested most clearly in the operations of present day science. He terms his theory "Inquiry".

Section III will contain implications for educational practice that stem from the comparison of the two approaches to thinking. Such implications will be concerned with establishing the proper subject matter for formal education as well as establishing means for its study. The central issue of the relation of educational practice to the control of human behavior will be discussed with a view to providing the basis for a reassessment of some of the current pedagogical practices. Briefly the intent is to designate educational aims and propose means for their attainment.

P A R T I

As earlier stated, man's apparent inability to control a world of his own making appears to be his single greatest problem. Paradoxically, it seems that as man gains more and more control over his physical environment, he appears to have less and less control over his own activity. The problem manifests itself in a fantastically varied number of situations:

> People believe that the great background conditions of modern life are beyond our power to influence. The proliferation of technology is autonomous and cannot be checked. The galloping urbanization is going to gallop on. Our over-centralized administration, both of things and men is impossibly cumbersome and costly, but we cannot cut it down to size. These are inevitable tendencies of history. More dramatic inevitabilities are the explosions, the scientific explosion, and the populations explosion. And there are more literal explosions, the dynamite accumulating stockpiles of nuclear bombs in nations great and small. The psychology, in brief, is that history is out of control. It is no longer something that me make but something that happens to us. Politics is not prudent steering in difficult terrain, but it is - and this is the subject of the current political science - how to get power and keep power, even though the sphere of effective power is extremely limited and it makes little difference who is in power. The psychology of historical powerlessness is evident in the reporting and the reading of newspapers: there is little analysis of how events are building up, but we read - with excitement, spite, or fatalism, depending on our characters - the headlines of crises for which we are unprepared. Statesmen cope with emergencies, and the climate of emergency is chronic[3].

> The sciences of man (the studies of the dynamics of individual personalities and groups) are infants. Their ultimate potentialities are tremendous, but it would be fatuous to expect these potentialities to be realized in brief months or years. And it is difficult to hope to prevent the calamity of a third world war. The picture of this war is not pleasant to contemplate. It will be a conflict of a new order of destructive magnitude far beyond what we knew in the last war. Most of the stories about the lethal character of atomic and bacteriological weapons which can wipe out cities in a

> very short span are not myths but sober recountings of real facts. The physical and biological sciences of destruction have now advanced to such a stage that they are largely out of our control.[4]

> When, in the course of its evolution, a species of animals develops a weapon which may destroy a fellow member at one blow, then, in order to survive, it must develop, along with the weapon, a social inhibition to prevent a usage which could endanger the existence of the species. .... Wordsworth is right: there is only one being in possession of weapons which do not grow on his body and of whose working plan, therefore, the instincts of his species know nothing and in the usage of which he has no correspondingly adequate inhibition. That being is man.[5]

> To be human is to be in danger. By virtue of his possession of a unique nervous system, a nervous system which is much more plastic and educable than that of any other living animal, man is capable of confusing and endangering himself considerably more frequently. So-called civilized man of the Western world has befuddled and endangered himself to such a degree that he stands today on the very brink of destruction - self-destruction.[6]

It seems fair to say then that man has always been a puzzle to himself, indeed, now that he controls such fantastic amounts of energy it is imperative that he control himself. The questions of how this is to be accomplished, or more accurately, of where one must begin to look for the means to control human behavior is the central concern of all that follows.[7]

Any attempt to discover the means to control human behavior which at the same time ignores the nature of that behavior is doomed to failure from the beginning. A priori assumptions about human behavior are not firm ground from which to launch the present investigation. Fortunately a priori assumptions are not necessary, since the subject of human behavior has had many investigators and, although the selection from their

investigations may be arbitrary to some degree, it cannot be said that there is no experiential base.

The most important result of the pondering about human behavior that we inherit at the outset (quite apart from the voluminous data of archeology, cultural anthropology as well as theology and literature) is the refinement of the questions to be asked. In other words we have stopped asking questions about human nature as if it were an entity to be described by adjectives such as good, bad, rational, social or divine, and have begun to direct our attention to behavior. This refinement has as its object descriptive accounts of how various men behave under various conditions, with the ultimate goal of arriving at more and more general descriptions.

Having acknowledged the above refinement, and having also disavowed the necessity for any <u>a priori</u> assumptions, we have next the obligation of making explicit the assumptions about human behavior which form the basis for our further discussion.

First: Human behavior has its origins in nature. This is not intended to deny the existence of any extra natural realm, but merely to indicate that in so far as human behavior is explainable and understandable to humans, that explanation and understanding is to be found through the observation of the world around us rather than through the postulation of an hypothetical "other" world which somehow dictates what happens in the one we observe. Such an assumption has the function of ruling out God, ideal worlds, historicism and the like <u>as explanatory principles</u>. It does not deny their existence but limits their function.

Second: Man's behavior is unique among all behavior that has been observed on this planet, as is evidenced by man's extraordinary ability to manipulate his environment. Explanations of the origins of this unique ability vary and will form the subject of subsequent discussion, but it is held that there is sufficient agreement about the complexity of man's manipulatory behavior to justify our assumption. It could also be argued that man's behavior is unique in that it involves the use of language, but such an assumption presupposes that language behavior of other systems would be known to us and there seems to be no good ground for supposing this at the outset.

Third: It is the capacity for thinking that forms the basis for man's unique ability to manipulate his environment. That there is no general agreement about the nature of thought can be seen from the most casual perusal of any of myriad discussions of it, but that it underlies man's behavioral uniqueness is commonly assumed.

This brings us back to the nature of the contemporary predicament as outlined above. As we have seen the problem is not knowing how to better manipulate man's physical environment, or at least it is not mainly that, but presents itself as the problem of knowing how to control man's own behavior. The way out of the contemporary predicament depends upon knowing the influences which can be brought to bear on man himself. In short the problem of finding escape routes from our present predicament lies in the development of a comprehensive theory of human behavior.

P A R T II

The fundamental difference between the approaches to thinking proposed by Warren S. McCulloch and John Dewey lies in the questions they ask. McCulloch poses the question, "How is man constructed so that he may think?". While Dewey asks, "What kind of behavior should we designate as thoughtful?" What we must ask ourselves is are these two approaches complementary -- are they merely different facets of the same subject which use different tools because of their different areas of application? The simple answer is yes and no. Yes, if we acknowledge McCulloch's approach as an attempt to explain what goes on in the "black box" and Dewey's approach as an examination of how an organism with a "black box" behaves in a unique manner. No, if we assume that McCulloch's assumptions about the "black box" explain the behavior which Dewey is endeavoring to define. This is so because McCulloch's work presupposes a definition of thinking that differs markedly from Dewey's definition.

The differences in the concepts of what thinking is, can best be compared when measured against the standard of traditional epistemology.[8]

Our purpose is not to force either McCulloch or Dewey into some definite relationship with the more traditional theories of epistemology but to gain as clear an understanding as possible of each man's position with respect to the terms "truth", "knowledge" and "meaning".

McCulloch's basic assumption is that by applying information theory concepts to the construction of machines, we can provide

useful models by which to understand thinking. Underlying this basic approach are other assumptions which must be examined in order to assess the validity of "Experimental Epistemology" as a method of explanation for thinking.

McCulloch's statements about truth, knowledge and meaning are as follows:

> In the world of events a true proposition is an event which materially implies another event - that is, in the simplest case, one which happens only if that other event happened. In the world of physics, a true proposition implies what it asserts.[9]

In another essay entitled "Mysterium Inquitatis of Sinful Man" we read:

> 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.[10]

and in "The Past of a Delusion" McCulloch writes:

> In the world of physics, if we are to have any knowledge of that world, there must be nervous impulses in our heads which happen only if the world outside excites our eyes, ears, nose or skin. In the case of these true signals, there is a necessary connection between events; the one in the head, the other (its cause) in the world; and this connection is a very limited kind of physical causation that goes hand in hand with meaning .... Apart from signals that are true, meaning and cause have nothing in common.[11]

and finally:

> Thus the signal received is an atomic proposition. It is the least event that can be true or false. If it is unnaturally evoked it is false, like the light you see when you press on your eyeball. How you find it is false is another question.[12]

The references to truth, knowledge and meaning are not quite so oblique in the work of John Dewey, but they are much more difficult to isolate from his highly complex theory.

Regarding truth we find:

> Sometimes the use of the word "truth" is confined to designating a logical property of propositions; but if we extend its significance to designate character of existential reference, this is the meaning of truth: processes of change so directed that they achieve an intended consummation.[13]

Elsewhere:

> The best definition of truth from the logical standpoint which is known to me is that of Pierce: The opinion which is fated to be ultimately agreed to by all who investigate is what we mean by the truth, and the object represented by this opinion is the "real." [14]

And in reference to knowledge:

> The habitual avoidance in theories of knowledge of any reference to the fact that knowledge is a case of belief, operates as a device for ignoring the monstrous consequences of regarding the latter as existentially subjective, personal and private.[15]

Dewey states further in commenting on the sources of knowledge:

> But if knowledge is related to inquiry as its warrantably assertible product, and if inquiry is progressive and temporal, then the material inquired into reveals distinctive properties which need to be designated by distinctive names.[16]

Meaning for Dewey is relational, anticipatory and shared or social:

> Primarily meaning is intent and intent is not personal in a private and exclusive sense. A proposes the consummatory possession of the flower through the medium or means of B's action; B proposes to cooperate - or act adversely - in the fulfillment of A's proposal. Secondarily, meaning is the acquisition of significance by things in their status in making possible and fulfilling shared cooperation.[17]

Comparing their statements we see that both Dewey and McCulloch distinguish between propositional and existential truth, while McCulloch unlike Dewey maintains that true propositions can be embodied in events. Knowledge for Dewey is a special case of belief arrived at through a specific mode of

behavior, while for McCulloch it must be defined finitely and unambiguously to be obtainable by machines. For McCulloch meaning is related to true signals and depends upon a limited causality. On the other hand, Dewey views the creation of meaning through cooperative anticipatory behavior and notes that as a result of such origin meaning attaches itself to both behavior and things, and to "things" because of and through behavior.

These differences can be attributed to sharply differing assumptions which underly each man's theory. In examining these assumptions the task is twofold: first to demonstrate that each man makes the assumptions imputed to him and secondly to examine the assumptions in the light of available evidence.

McCulloch's basic assumptions can be stated as follows:

I. The activity of thinking is primarily a perceptual one.

II. The "all or none" characteristic of neuron firing can be looked at as the basis for the application of truth functional logic to brain processes.

III. The brain is the uniquely constructed part of the human which enables him to think and the explanation for man's ability to think should be sought in the physiology of the brain.

IV. The understanding of brain processes will lead to an enhanced control of human behavior.

I. The activity of thinking is primarily a perceptual one.

Perception has long been the branch of psychology which deals with the question of how stimuli to our sense organs affect our activity. An ancient theory of perception was proposed by investigators who felt that our perception consisted of a fairly automatic reaction to the impingement of sense data which arrived at our sense organs in an analogous manner to the arrival of a swarm of bees, each identifiably unique and discriminable.[18] As long as each bee was discriminable, then

the redundant return of the swarm to the sense organs could possibly produce patterns. Now if we remember that the swarm of bees represents sense data, and assume sense data is what is emitted by our surroundings then it follows theoretically that the patterns of bees that returned to our sense organs would represent some isomorph of their emittors. In other words the swarm of bees that was emitted by a chair would always arrive at our sense organs in a descriminable pattern that came to represent the chair.

Those who contested this bee swarm theory of perception pointed out that the patterns of sense data emitted by some object would vary with the positional relation of our sense organs to that emittor unless one assumed a fairly knowledgeable swarm of bees that would always rearrange themselves so as to present the same pattern to the same set of sense organs. These people went on successfully to prove that the person doing the sensing had to do some rearranging of sense data on his own and the factor of learning entered the field of perception.[19] But the central problem of deciding how sense organs learn to rearrange sense data so as to maintain an isomorphic relationship with its emittor still remained.[20] This is the problem of perception that McCulloch deals with in his essays "What the Frog's Eye tells the Frog's Brain"[21] as well as "How we know Universals"[22] and "Finality and Form"[23]. It is based on the assumption that the stimuli to our sense organs must present or be made to present invariant patterns that have an isomorphic relationship with those parts of the environment from which they come in order for us to have knowledge of our environment. That this, of course, is

the assumption of Aristotle and his heirs, McCulloch proudly admits:

> Using the word "universal" in the sense of Aristotle, of the Isogogue of Porphyry, of the commentary on it by Boethius, and so on in the sense of Peter Abelard, of Duns Scotus and of William of Occam, which became formalized in the universal quantifier $(x)\,\emptyset x$, Pitts and McCulloch showed how brains could embody these universals. Our article may have been wrong in any particular attribution of function to local anatomy or local physiology; but it cannot be wrong in its all important proof that for a man to know such universals as shape regardless of size or chord regardless of key it would be sufficient for his brain to compute enough averages. Each average is an Nth of the sum, for all N transforms belonging to the group (say, dilations or translations), of the value attributed by some functional to each transform as a figure of excitation in the time and space of an appropriate matrix of relays. Thus the mechanism derives an invariant under that transformation and so shape can be seen regardless of size and chord heard regardless of key . . . So much for perceived universals.[24]

The fundamental point here is that the universal that McCulloch refers to is an invariant relationship occurring among sense data.[25] His answer to the question of how man is constructed so as to be able to perceive such universals depends upon coding and memory but more fundamentally upon the existence of atomic propositions which will be dealt with subsequently.

Coding is nothing more than a way of explaining why the perceptual wholes of the Gestalt psychologists do not appear as wholes in the brain. It is the assumption that a square can be represented by something other than four equal lines in the same plane, at right angles to each other and forming the boundary of an area. It may be represented by four dots having the same relationship as the intersection of the lines of the square, or it may be represented by the word square, or more

relevantly it may be represented by a characteristic pattern of nerve impulses having some spatial or temporal relationship or a combination of the two.[26] Simply, the physiological characteristics of neurons in the brain are such that they may act in such a way as to represent invariant relationships among the various stimuli to which they are subjected.[27]

McCulloch's experimentation with the frog's optic tract is relevant here. Not only does it bear on the concept of coding but also the earlier discussion of perception, with the implied distinction between sensation, that mode of experiencing our environment through the automatic reaction to sense data - the "bee swarm" theory, and the later idea of perception which acknowledged the necessity for learning on the part of the sensing organism.

> Fundamentally it shows that the eye speaks to the brain in a language already highly organized and interpreted, instead of transmitting some more or less accurate copy of the distribution of light on receptors.[28]
>
> The operation thus have much more the flavor of perception than of sensation if that distinction has any meaning now. That is to say that the language in which they are best described is the language of complex abstraction from the visual image.[29]

Apparently McCulloch holds that the physiological characteristics of nerves which give them the capacity for coding have blurred the distinction between sensation and perception. In other words, at least with regard to the frog's optic tract, the nervous material is organized in such a way as to automatically rearrange sense data so that its relationship with its emittor is a highly abstract one, though McCulloch seems to ignore the question of the role of learning in the process.[30] At any rate McCulloch's confusion as to the meaning

of the distinction between sensation and perception seems to depend on the observation that sense reception occurs in a highly abstract matter.

But despite the capacity of neuronal mechanisms for engaging in complex coding operations involving spatio-temporal translation there is still the necessity for explanation of how particular patterns are retained long enough to be compared with previously received ones. In short, there remains the problem of memory.

McCulloch along with many other neurophysiologists admits that the physiological basis of memory is still largely in the theoretical stages,[31] but puts forward the evidence of Dr. Lorente de No[32] who has demonstrated reverberatory nervous activity in the brain. Prior to this discovery nervous activity was thought to be a one way process of a lineal nature. With the discovery of reverberatory circuits McCulloch postulates a mechanism which can account for the temporal invariance of sense data:

> Thus in finite loops, as long as they continue to reverberate, our brains "trap" any universal that can be defined in a finite and unambiguous manner.[33]

also:

> The procedures are a systematic development of the conception of reverberating neuronal chains, which themselves in preserving the chain of events while forgetting the time of their happening, are abstract universals of a kind . . . . By systematic use of the principle of exchangeability of time and space, we have enlarged the realm enormously.[34]

What can be said in view of the above then is that when McCulloch speaks of "knowing" he is talking about knowing universals which are invariant relationships among sense data, and this activity is one of perception.[35] He also speaks of

knowing numbers. Here again the capacity for man to "know" numbers arises from the physiological characteristics of the neurons in the brain. McCulloch points out that in conjunction with Pitts he has been able to demonstrate the logical equivalence of brain function with Turing machines and in so doing has provided a physiological explanation for man's ability to compute numbers.[36]

This is a fundamental point for McCulloch's theory because it pertains directly to the uniqueness of man's ability to think. We are told that man's unique ability to recognize universals such as squares or triangles or pitch results from having enough neurons so constructed that they are able to compute enough averages. Here then the uniqueness of man's ability to perceive squares is a result of having a big enough brain (contex) to do so. The porpoises offer some corroborative evidence.[37] But McCulloch's demonstration that neurons can compute numbers leads him to a further conclusion that it is the capacity to compute number that underlies the ability to think. This is so, he holds, through Boolean Algebra, which allows logical manipulation of all objects that are capable of being included in a class. If a neuron or set of neurons can compute a number, it can also operate within the terms of Boolean Algebra and this operation is the kind of "thinking" McCulloch's theory refers to. The problems surrounding the inclusion of one object rather than another into any class are outside his theory. McCulloch does not speak of "knowing how" or "knowing when" or more fundamentally "knowing truth" which is the usual domain of epistemology. Such a fundamental omission leads to the question

of why McCulloch's theory is termed epistemology at all? He may be offering the theory as a huge cynicism, which is doubtful, or he may feel that in explaining how universals and numbers are known he is dealing with matters of truth and knowledge. The essay "Why the Mind is in the Head"[38] clears up the ambiguity.

Quite simply, when McCulloch is talking about "perceived universals", he is assuming them to have the status of immediate knowledge.[39] That is, they are not derived through any inferential function, unless we equate the automatic averaging of "n transforms" to inference. If these invariants or universals can be legitimately taken as givens, then it is the business of mathematics and physics to detect relations between them and invent new invariants ". . . which conserve whatever truth may lie in the propositions they transform".[40] Obviously man's ability to compute number must underly such transformations. But the ultimate test of McCulloch's meaning lies in the term proposition, and we have already seen that he describes neuron firings as atomic propositions.[41] His discussion of true propositions leads to an examination of his second assumption.

II. The "all or none" characteristic of neuron firing can be looked at as the basis for the application of truth functional logic to brain processes.

McCulloch equates a neuron firing, an atomic proposition, and "a least event that can be true or false". In other words, the assertion (the old one) is that propositions are events that

can be true or false, and consequently we can speak of neuron firings that are true or false. But it is apparent that the latter assumption leads to confusion unless we have some criteria for determining the difference between a true neuron firing and a false one. McCulloch is peculiarly ambivalent when he discusses true neuron firings. We see at one point he says that a false signal or firing is one that is unnaturally evoked, while in the same breath he denies us a way of determining natural or unnatural evocation.[42] But his whole theory, every shred of inference he depends upon the equation of a neuron firing with a true proposition.[43] Such an equation must be examined thoroughly.

First we must observe the distinction McCulloch makes between the world of physics and the world of events. We can assume this distinction is used to avoid confusion between existential, spatio-temporal events, which are all particular, unique and non-repeatable; and the science of physics which seeks constant relations between specific kinds of events and identifies these relations symbolically. In other words, physics deals with symbols that are propositions about the relations of events. Therefore, in order for the event of a neuron firing to be a proposition its mere existence must assert some relationship between it and another event.[44] If that is so, what is the relationship, and further, how do we find it out?

McCulloch deals with those questions by looking at the answers. He reasons that if we can "know" universals and compute numbers we must assume that neurons are hooked up in such a way as to preclude any false propositions. When the propositions are false "knowing" is impossible. In other words when McCulloch

states that a true proposition in the form of a neuron firing "materially implies" the prior firing of some other neuron or neurons in specific relation to it, he is talking about "a necessary connection between events".[45] This is equivalent to saying that if we are to have true propositions in the form of neuron firings, we must accept the ideas of physical determinism which has largely been rejected in the field of physics.[46] This is so only if we conceive of the firing of a neuron as a proposition, that is, as an assertion of its relations with other events. If we choose to make a distinction between events and propositions - which McCulloch does not - we can remove ourselves from the quandary of physical determinism. We can say that the firing of a neuron as an event either exists or doesn't exist and ignore its relation with other events. Or we can make propositions ABOUT the event of a neuron firing that assert specific relations between it and other events, realizing that it is we who are making the proposition; its truth or falsity depends upon what we say the specific relationship is and how we find that out. But we cannot say that the event of a neuron firing is a true proposition without accepting "material implication",[47] "necessary connection",[48] "limited causality"[49] or any other synonym for physical determinism.

For example, let us assume a simple case where the firing of "A" asserts only the antecedent firing of "B". In McCulloch's terms the firing of "A" is a true proposition if it "materially implies" the antecedent firing of "B". If "A" ever fires spontaneously or as the result of the firing of "D" it is a false proposition. The question then arises as to how another neuron "C" in the circuit with "A" and "B" would determine the truth or

falsity of "A"'s proposition. There is a good deal of neuro-physiological evidence to support the idea that "A" could fire spontaneously[50] and if such is the case, McCulloch is fatally remiss in not providing us with a method of distinguishing a true proposition from a false one. It would seem that he is committed to the position of asserting physical determinism or admitting that his theory is totally unable to explain how we "know" anything, universals and numbers included.[51]

Quite apart from McCulloch's difficulty with determinism there is a more obvious question left unanswered: how does any meaning other than the postulated relations between neuron firings enter the system? This is simply to ask how neuron firings in themselves say anything about anything other than other neuron firings.[52] Surely the most minute examination of a functioning brain would not reveal any kind of activity other than the various patternings of electro-chemical impulses.

Consequently in summation of our examination of McCulloch's second assumption we see that its validity depends upon the further assumption that truth lies within the event of a neuron firing and such an assumption depends on physical determinism. Also, the entrance of any other meaning than specific relations between neuronal firings is entirely ignored.[53]

III. The brain is the uniquely constructed part of the human which enables him to think and the explanation for man's ability to think should be sought in the physiology of the brain.

That McCulloch holds such an assumption as is stated above, can be seen from the following quotation:

> Because there and only there are hosts of possible connections to be formed as time and circumstance demand. Each new

> connection serves to set the stage for others yet to come and better fitted to adapt us to the world, for through the cortex pass the greatest inverse feedbacks whose function is the purposive life of the human intellect.[54]

This assumption opens two areas for discussion: first, that man's activity of knowing is a unique behavior, and since his brain is also unique it is his brain that accounts for his unique behavior. This requires an examination of the evidence available concerning the uniqueness of man's brain, and the uniqueness of man's behavior. Furthermore, since the brain is not the only unique structural characteristic of man, we must examine other structural uniqueness.

The second area opened by McCulloch's assumption is that of Cartesian Dualism. The antiquity of that problem does not diminish its relevance, and it therefore deserves our attention.

Admittedly these areas cover a great amount of subject matter that can not be dealt with fully here, but if we keep in mind that we are assessing what supporting evidence is available to evaluate McCulloch's assumptions, a brief treatment of the following questions should suffice:

1. Are there other organisms or systems whose brains are at all comparable with the brains of men?
2. Other than the brain, are there structural characteristics of men that are unique?
3. What is the measure of man's unique behavior?
4. What is Cartesian Dualism and what are the implications it holds for the investigation of human behavior?

1. In dealing with the first question we must be aware that in comparing brains of various animals the criteria of comparison have not been worked out extensively but usually include: brain weight to body weight ratio, differentiation of the layering of

the cortex, number of folds and sulci, the presence of intrinsic and extrinsic nuclei of the thalamus.[55] Using these criteria of comparison we find animals that have well developed brains which are larger than the human brain - (elephants, whales).[56] However, there is only one family whose brain weight-body weight ratio is comparable to that of man, and that is the Odontoceti, the toothed whales and more specifically the porpoises.[56]

Some investigators indicate that the cortex of the porpoise is relatively thin and poorly differentiated, while others hold that the porpoise cortex is of equal order of complexity to that of man.[57] Suffice it to say that there is general agreement that the brain of the porpoise compares favorably with that of man; an argument based mainly on the gross criterion of brain weight - body weight ratio. Indeed, there are several neuro-anatomists who hold that it is at least equal to and possibly superior to the human brain (according to still other criteria) but such a position is at present very much in dispute.[58] However, the significance of this information (in the non-mathematical sense) is questionable even to those who are well aware of the favorable anatomical comparison - in large part because of their reticence to equate complexity of behavior with complexity of brain structure.[59]

2. Though the whole taxonomic system for all living things depends to a large extent on differences in structure, we must now ask what structural differences, in addition to the brain, can be looked at as possible means for the explanation of man's unique behavior. For the present we can ignore the influence of genetic and functional factors in the taxonomic system, although

admitting that since Darwin such factors have been fundamental to it.

The most obvious difference of this sort is man's hand with an opposable thumb. No other animal has such a structure so we may be well justified in assigning the uniqueness of man's behavior to his thumbs. Let us assume a hypothetical situation and see where the assignation of man's unique behavior to his hands will lead. We take up an observation post and observe two men who are the sole inhabitants of two widely separated small islands that have never been previously occupied; let us also assume that we have undertaken the task of comparing the behavior of all living organisms on earth in terms of complexity and flexibility; further assume that both men are healthy and have similar brain structures but one has had both hands amputated.

It seems obvious enough that by purely behavioral observations we would place the two men in very different positions on any scale of behavioral complexity. Probably the same results would exist if the two men differed only in brain structure, though we are still unsure as to how large the structural difference would have to be before we would observe a difference in the complexity of behavior. Similar differences in complexity of behavior would result, though probably less noticeable, if one man were blind, or deaf. The point is obvious: if we are trying to explain the behavior of any organism, we must try to explain it as a result of a whole organism. A man's behavior is not reducible to the sum of the individual capacities of his separate organs nor is its unique complexity reducible to <u>any</u> unique organ whether it be hands or brains.[60] The point

may be trite, but there can be no denying that any attempt to explain human behavior that ignores the totality of the human organism, is doomed to failure.[61]

But in addition to this rather obvious point there is a further more fundamental consideration. Our example was deliberately chosen so that the behavior of the two men could be examined in isolation from human culture. But if we were to consider the behaviors of the men in their cultural context, we might well place them very close to each other on our scale of behavioral complexity. As long as the no-handed man had servants or mechanical aids, he could use them to regulate his behavior so that it differed very little from other of his handed companions. Similarly the man with the defective brain[62] could be taught by other companions to use tools and engage in highly complex behavior, in the same way that clever men can build very clever machines to engage in quite complex behavior.[63] Again the point is obvious, but has been ignored by most psychologists[64] since the beginning of that discipline;[65] not only is it necessary to consider the organism as a functioning whole to explain its behavior, but the organism's behavior must be viewed as part of a context which involves the totality of its transactions within its biological and cultural matrix and seen from a durational point of view.[66]

Now in fairness to McCulloch we must acknowledge that one of the common modes of scientific operation is the process of isolating factors of a complex situation so that some can be held constant while others are varied so that the effect of their variance can be observed. Consequently the concentration on brain structure as one factor of human behavior is eminently

justifiable, but to assume that a complete and exhaustive understanding of what the brain is and how it works is equivalent to a complete explanation of human behavior is obviously falacious. Of course McCulloch does not assume that an understanding of the brain can explain the totality of human behavior but he certainly does assume that it will explain the activity of knowing.[67] Additionally but for a minor matter of definition that will be dealt with later[68] he does claim:

> Pitts and McCulloch (1943) proved the theoretical equivalence of all Turing machines, whether they be made of neurons or any other hardware. From this it follows as Van Neumann said, that we can built a machine that will do with information anything that brains do with information -- solve problems, suffer emotions, hallucinate on sensory deprivation, what you will provided we can state what we think it does in a finite and unambiguous manner.[69]

Further:

> Yet, that we can design ethical robots, who may even invent games that are more fun than ours, is enough to prove that man's moral nature needs no super-natural source.[70]

And, as seen before:

> 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.[71]

3. We come now to a point that underlies the discussion of the two immediately previous questions. Until now we have been referring rather vaguely to "complexity of behavior" or "flexibility" or "adaptability", but now we must be more precise about the unique nature of man's behavior, recognizing at the outset that it is these criteria that form the basis for our concepts of intelligence. In other words we must ask of McCulloch

what it is that man does that assures him his behavior is unique. McCulloch's answer is obvious: nothing.

As long as we can design "ethical robots who may even invent games . . ." (my underlining) and are careful of our definition of "feeling, perception, consciousness, substantial knowledge...", these kinds of behavior are attainable by machines so are not uniquely human. But we must do some sorting here to examine the distinction that has previously been made between living and non-living behavior and further between human and other living behavior.

Succinctly we can say that when the cyberneticians or information theorists developed the concept of negative feedback they provided the means for designing machines which exhibited goal seeking, adaptive or purposive behavior. McCulloch sees such behavior as bridging the gap between living and non-living systems.

> Once Julian Bigelow noted that it did not matter how the information was carried, but only that the machine be informed of the outcome of its previous act, cybernetics was born and teleology had its proper mechanistic base in engineering and biology.[72]

At this point it must be noted that behavior which the cyberneticians call teleological is also termed by them purposeful or adaptive, and all these terms come under the general heading of learning. Such a concept subsumes the behavioristic concept of learning and does indeed provide a conceptual framework which bridges mechanical and biological systems. Norbert Wiener defines learning as the translation of input to output which improves with reference to a clear cut criterion of merit[73] while W. Ross Ashby proposes that ". . . A form of behavior is

adaptive if it maintains the essential variables within physiological limits".[74]

Given these definitions, it seems quite proper to say that machines as well as organisms can learn. However, we must observe that Wiener's "clear cut criterion of merit" is the source of teleological or adaptive behavior of machines. Without such a criterion there could be no identification of learning at all. The important point here is that the origin of the criterion lies outside the operation of the learning machine. In other words, to state that a machine, or an organism, exhibits adaptive or learning behavior is to make a double assertion; first that we know the criterion by which its performance is to be judged and, secondly, that the performance improves with respect to that criterion.

Also it should be noted that Ashby's "essential variables" by being built-in are completely known and can be completely arbitrary. However, an organism's "essential variables" are a result of his genotype and environment and as such are neither arbitrary nor completely known. Ashby is careful to state that his essential variables are concerned with physiological parameters about which there is much that is known.[75] But any extension of the cybernetic concept of learning to realms where there is little known about "essential variables" is liable to lead us to circular and mythical explanations.

Therefore, to say a machine is behaving adaptably or learning is quite proper so long as its functioning improves with regard to explicit criteria of performance, but to expand the analogy and state that an understanding of machines behaving

rationally is anything more than a very restricted analogy to one kind of human behavior is extremely dangerous.[76] To the extent that a mechanistic explanation of behavior has removed the vitalism from some kinds of living behavior it has proved fruitful, but to postulate the elimination of any uniqueness of human behavior on the basis of existing "experimental epistemology" can only be achieved by ignoring much of the uniqueness one is denying.[77]

But even if we accept that the creation of adaptive machines has eliminated the distinction between living and non-living behavior, we have yet to ask of McCulloch whether the distinction between human and other adaptive behavior is eliminated. The distinction here is between acting adaptively or rationally or intelligently and developing criteria which will identify adaptive, rational or intelligent behavior. It is this distinction between acting intelligently and knowing what intelligent action is, that is fundamental to understanding the differences between the approaches to thinking proposed by Dewey and McCulloch. There is no doubt that automatic behavior can be adaptive, but there is yet no good ground for assuming that adaptive behavior is adaptive <u>because</u> the adaptive system, be it an organism or a machine, knows what it is adapting to.[78]

Consequently we are lead back to a further examination of what McCulloch's conception of "thinking" is. We have seen that when he speaks of knowing, he is talking about perceiving universals (invariant relationships among sense data) and computing number. He does not talk about man's use of symbol and language or his use of tools, so we must ask if these usages are

not unique to man or if they are dependent upon man's ability to perceive universals and compute number.

What evidence is there to support the assumption that tool use is not unique to man? We do in fact find evidence of animals using tools; off the coast of Oregon otters dive for clams and when they find one, they also bring up a flat stone on which they can break the clamshell.[79] Darwin's Finches on the Galapagos use thorns to exploit the environmental niche usually filled by long-billed woodpeckers[80] and, of course, Kohler tells us about chimps using sticks to get bananas.[81] But these tools are so much more simple than a cyclotron or even a common automobile that there is slight comparison. So it seems fair to say that man is not the only tool user but definitely the user of the most complex tools.

The answer to the question of whether man's use of symbols is unique demands a careful appraisal of what symbols are. It opens up the whole area of speculation as to whether animals have languages, and how best language itself can be described. McCulloch distinguishes between signs and signals, but does not refer to symbols. For McCulloch a "signal" is a nervous impulse or an "atomic proposition" but:

> Signs are not signals. Precisely, they are not actual significant propostions. They are not excitations of a given figure, but only things that may shape excitation to their figures. . .[82]

Here it appears that the distinction is between the stimuli arriving at the particular receptors, termed signals; and the emittors of the sense data, termed signs. In other words, we don't see a chair but only numerous signals sent out by that chair which, when processed through the neural networks between

receptor and brain end up as the idea of a chair.[83] The distinction is between the object and the sense data emitted from it which recalls the discussion of perception above.

Dewey on the other hand uses the word signal to designate something that stands for something other than itself, not in the sense that McCulloch's signals, say of a sound wave, stands for the vibration of a string, but in the sense that smoke is usually a signal of fire.[84] Such a position is to be distinguished from McCulloch's atomic proposition, by the fundamental distinction that signals come to have significance through the course of behavior. Dewey's signal is dependent upon its spatio-temporal contiguity with that which it represents, in the same way that Pavlov's conditioned stimulus comes, through the process of conditioning, to stand for the unconditioned stimulus and produces roughly the equivalent reaction.[85] What Dewey calls a name is a signal freed from its spatio-temporal context. Perhaps, at this point, an elaboration will be helpful.

Birds react fairly automatically to changes in the duration of daylight in exhibiting migratory behavior. In short, slight changes in the length of days add up over a season; this, coupled with other changing environmental conditions, produce the migratory response in certain spieces of birds.[86] Man also responds to similar signals and gives evidence of this by scraping up enough money to put anti-freeze in his car radiator. But putting anti-freeze in a car radiator is potentially different in kind from the migratory response of birds. As long as man reacts fairly automatically to changes in the duration of daylight or changes in temperature the difference is very

slight, but when man can evoke the same anticipatory behavior in absence of the changes of daylight or temperature, he is doing something quite different which depends on naming. If a man who has been basking in the Tahitian sun for a month, telephones his son in Edmonton to remind him to put anti-freeze in the car, we are safe in assuming that the man in Tahiti is not reacting to signals like a bird, but is probably aware, through the use of a calendar (whether he looks at one or just keeps track of the date in his head), that it is time for a seasonal change in Edmonton. Obviously the explanation for the capacity for this kind of behavior can account for a great deal of the uniqueness of man's behavior relative to other adaptive systems. But the explanation of symbolic behavior is to be found in Dewey, not McCulloch.[87]

If, however, we examine the other possible interpretation of McCulloch's assumption about knowing; that the capacity for perceiving universals and computing number underlies the use of tools and symbols, where are we led?[88] It seems we are led to the necessity for a close examination of the mathematically defined concept of "information". We must ask whether it is permissable for McCulloch to equate the signals to the receptor organs and the subsequent neurological activity in the brain with the input of information to a computer and the subsequent data processing. He tells us that machines can do with information whatever brains can do providing that whatever it is we want done, can be defined finitely and unambiguously.[89] But is it safe to assume that the brain is dealing with "information" at all? It would seem not.

> Let us stop and think for a moment. We give the word "information" a precise meaning, though a very restricted one indeed. We link information to negentropy, and therefore to improbability. Any notion of human value is totally excluded: moral qualities, and intellectual or artistic values are totally absent. There is actually no human element introduced in this definition and our "information" should never be confused with "science" or "knowledge".[90]

It would seem that if machines can do with information whatever brains can do McCulloch must either disavow the cybernetic definition of "information" or severely restrict his claims for the functional capacity of the brain. But the problem is even more complex as we proceed; if the problem one is dealing with is to have any empirical referents, one has to admit the inevitability of a degree of error. Note that word inevitability; we cannot eliminate error in experimentation, only in logic and mathematics.[91] Hence if McCulloch assumes that the capacity to compute number underlies the capacity to use tools and symbols; he at the same time seems to disregard the necessity to use experiment to determine the limitations of any logico-mathematical theory, and fails to see that:

> The rigrous mathematical theory would mean an infinite amount of information. The physical theory, with A-B limitation, yields a finite amount of information.[92]

If we were able to obtain an infinite amount of information there would be no limit to our predictions and science would be complete.

This is not the place for conclusions, but to summarize such evidence as we have saying:

> So far there is general reluctance to assume any human behavioral complexity can be adequately explained in terms of physiology. On further examination, any explanation of behavioral complexity on the part of

> any system must include the total system and the environment in which it operates.
>
> The mechanistic basis for adaptive behavior supplied by cybernetics is severely limited in application to human behavior owing to its dependence on clear cut criteria of performance and its irrelevance to the source of human regulatory parameters.

4. Finally, we come to the question of Cartesian Dualism. Its relevance here is justified through the consideration that McCulloch is equating electrical impulses circulating in neuroral nets with ideas and purposes. Both Dr. Kohler and Dr. Kluver pointed to such an equation as an attempt to resolve the dualism in the symposium at which McCulloch presented the paper: "Why the Mind is in the Head".[93]

Briefly the Cartesian Dualism is the very old idea that mind is of a distinct nature from body, and poses the perplexing question of how physical bodies could be manipulated by a non-physical entity.[94] The postulation of the dualism leads to the search for two kinds of reality and interminable arguments as to which is more "real" than the other, and how they can interact. Some attempts to deal with the mind-body problem take the form of reducing one kind of reality to conditions that could be wholly explained in terms of the other. It would appear that McCulloch takes this tack, when he defines mind as "ideas and purposes" and body as "stuff and process"[95] and then advocates the use of "mechanism" to "rid ourselves of ghosts" and to "generate hypotheses".[96]

> These notions do not constitute mechanistic hypothese but exhort us to contruct them. Call it metaphysical if you will -- in the good sense, that they prescribe ways of thinking physically about affairs called mental and relegated to the whims of spirit manifold.[97]

Though McCulloch does not deny the existence of mental affairs, he apparently assumes that as long as they are not embodied in mechanism they are "relegated to the whims of spirit manifold". The inability to describe or assert actual or hypothetical mechanisms for imagination, or what Pierce calls abduction, as well as mechanisms to explain selection or the avoiding of one kind of stimulation by another, severely limits the application of "Experimental Epistemology" to human behavior, for McCulloch readily admits:

> We have still no way of engendering fancy, that imaginative leap beyond data into the formation of a noiseless concept, that has a reasonable chance of being right.[98]

But the mark of a good scientist is to know the limitations of his science and to identify the roads that lead beyond those limitations. McCulloch is quite clear on this subject:

> To make psychology into experimental epistemology is to attempt the embodiment of mind. Here we are confronted by what seem to be three questions, although they may ultimately be only one . . .
>
> The three exist as categorically disparate DESIDERATA. The first is at the logical level: we lack and adequate, appropriate calculus for triadic relations. The second is at the psychological level: we do not know how we generate hypotheses that are natural and simple. The third is at the physiological level: we have no circuit theory for the reticular formation that marshals our abduction.[99]

It should be apparent, however, that it is the assumption of mind-body dualism that prescribes the present limitations of McCulloch's method for the explanation of thinking.[100] The refusal to acknowledge the controlling and controllable nature of existence which is not embodied in mechanism, has postponed the understanding of human behavior via "Experimental Epistemology" until a new logic can be developed and a specific

reticular formation identified. As Bertalanffy rightly points out the cybernetic model assumed by McCulloch is still mechanistic and only once removed from simple S-R psychology by the addition of a feed back loop. Such a system is unable to explain much of the phenomena which the behavioral sciences deal with.[101]

But to point out that the limitations of McCulloch's theory result from his assumption of Cartesian Dualism does not provide an avenue of escape from the "mind-body" problem. In fact, once such a problem is assumed, there seems no way out of its implications and, indeed, its very insolubility probably accounts for its persistence. We have seen that McCulloch has attempted to resolve the dualism by proposing that all "mental affairs" can be explained in terms of the unique organization of matter a la Spinoza.[102] To many this is compelling, but in terms of McCulloch's theory this mode of solution engenders the theory's shortcomings. The best way of dealing with dualism then appears to be not to assume it at all.

It is becoming increasingly apparent that the assumption of two different kinds of reality is nothing more than a hangover from a theory of perception which has no warranted basis. Such a theory assumes a real world that was "out there" and quite separate from the observer of it. The problem comes to be how the observer "knows" the real world from which he is separate. It is only when we assign independent ontological status to the outside or inside world that we have any separation to deal with at all. We must face up to the fact that there is no "ultimate" reality.[103] This is not irrationalism nor is it mere relativism,

but the recognition that kinds or aspects in nature are not ontologically fixed but discriminable in terms of the observer's perspectives, purposes and abilities to observe.[104] This is not to imply as some existentialists would have it,[105] that we can have our way with the universe, but only to acknowledge that the diversity and variety which we see around us is discriminable and identifiable because of specific relations with our own unique characters. The combined trends of the developmental psychology of Jean Piaget; evolution, general systems theory, and the Heisenburg principle in physics, all point to the idea that the separation between observer and observed is not an initial condition, but quite the reverse. In fact it is only as an organism is able to separate himself from the world around him that he has anything like awareness or consciousness which proves so mystical and puzzling to the neurophysiologists.[106]

IV. The understanding of brain processes will lead to an enhanced control of human behavior.

Finally we arrive at the last of the assumptions imputed to McCulloch. Probably the most naive example of the logical extention of McCulloch's assumptions and the real danger of their uncritical acceptance can be seen in the following statement which occurs on one of the recent books popularizing the application of information theory to brain processes:

> The application of the life sciences may be more effective than anything else in speeding the day when, by the availability of machines that truly "think", Humanity will finally be able to enjoy the real fruits of automation.[107]

If the previous discussion has not been sufficient to expose

the naivety of such a statement, we have at least the testimony of one of the founders of cybernetics to expose it.

> No, the future offers very little hope for those who expect that our new mechanical slaves will offer us a world in which we may rest from thinking. Help us they may, but at the cost of supreme demands upon our honesty and our intelligence. The world of the future will be an ever more demanding struggle against the limitations of our intelligence, not a comfortable hammock in which we can lie down and be waited upon by our robot slaves.108

The existence of the first statement and the necessity for its explicit refutation by Wiener indicate that there is a popular assumption that machines can be made to "think". How such an assumption has become popular is an interesting question, but a close examination of McCulloch's reasoning may shed some light. If we follow the long path he has gone we may find the land of "thinking" machines. Where we go from there of course may be beyond our control. The path McCulloch would have us follow bears the following signposts:

> We are separated from the universe wherein truth lies.
>
> Knowing is that activity which discovers truth.
>
> Little bits of truth impinge upon our sense receptors in the form of signals or excitations.
>
> These true excitations are coded by the mechanisms in our head so that they form patterns in space and time called ideas which have an isomorphic relation with their emittors in the world.
>
> These ideas can be used as input to other data processing mechanisms to produce ideas of ideas and this is called mind.
>
> The mind is in the head.
>
> If we want to know more and to know how we know, we have to understand what goes on in the head.
>
> The understanding of what goes on in the head is facilitated by building machines which can do what the mind can do.
>
> As long as we are careful about our definitions we can build machines that can do anything that mind can do.
>
> Machines can think.

McCulloch takes care to point out that there are a few steps missing: such as the development of a new calculus, the ability to make natural and simple hypotheses and a circuit theory capable of embodying abduction, but the unitiated may be forgiven if he overlooks these subtle points.

If we view McCulloch's theory of "Experimental Epistemology" with the intention of finding our way out of the predicament described in section I, our obvious course of action is to improve our mathematics and refine the study of neurophysiology. Such action should facilitate our "knowing", though whether or not it would result in any change in the environment is at best problematic.

Failing the discovery of a new calculus and the development of a circuit theory for our reticular activating system, we have another alternative. Since knowledge is a matter of perception, we can always distort our perception. Granted such distortion would inevitably provide false knowledge, but since we have no way of knowing the whether such knowledge is false or not, it does not make much difference. Perhaps as Dr. Leary recommends we must distort our perception to gain true understanding.

> Inquiry is the direct or controlled transformation of an indeterminate situation into a determinately unified one. The transition is achieved by means of operations of two kinds which are in functional correspondence with each other. One kind of operation deals with ideational or conceptual subject matter. This subject matter stands for possible ways and ends of resolution. . . The other kind of operation is made up of activities involving the techniques and organs of observation. Since these operations are existential, they modify the prior existential situation, bring into high relief conditions previously obscure . . . The ground and criterion of the execution of this work of emphasis, selection, and arrangement, is to delimit the problem in such a way that existential material may be provided with which to test the ideas that present possible modes of solution. Symbols defining terms and propositions carry forward both ideational and existential subject matters in order that the situation may be unified.
>
> John Dewey,
> Democracy and Education, 1916.

John Dewey approaches the question of thinking from a viewpoint which differs markedly from that of McCulloch. The question that Dewey tries to answer can be stated as -- "How do we get firm knowledge in order to achieve our ends?" Dewey's answer to that question depends upon the following assumptions:

I. The universe is evolving, continuously and irreversibly.

II. Thought, which Dewey terms "inquiry", arises from an existential matrix.

III. The genesis of thought or inquiry is genuine doubt and it is the character of the doubt that determines the discrimination and selection of facts.

IV. All thought or inquiry institutes and results in modifications of existential situations.

I. The universe is evolving, continuously and irreversibly.

Concerning the first assumption, Dewey is succintly

explicit when he writes:

> For we live not in a settled and finished world, but in one which is going on, and where our main task is prospective, and where retrospect -- and all knowledge as distinct from thought is retrospect -- is of value in the solidity, security, and fertility it affords our dealing with the future.[109]

This is the key to the relation of truth, knowledge and thought.[110] It assumes irreversibility in the evolution of the universe, and that the implications of this irreversibility are such as to identify knowledge as a temporal thing, as distinct from an eternal thing which it would be if the universe were static or cyclincal.[111] This is a fundamental concept for understanding Dewey's "Theory of Inquiry", for it explains the difference between the nature and function of knowledge for him. In this way Dewey differs from McCulloch, who relies on a logic not wholly extricated from a structual or cyclical ontological basis.[112] A consideration of the implications for knowledge of a structural or cyclical universe in the mode of Greak science outlines the problem of knowledge as one of determining what qualities of nature are "real" or more accurately, universal, invariant, eternal or immutable.[113] This can be reduced to the problem of intuiting such qualities as did Plato, or manipulating their meanings in the Aristotelian manner, or perceiving them as invariant as does McCulloch. Such knowledge is in no sense confined to the retrospective since it is non-temporal,[114] indeed, there need be no distinction between knowledge and truth since the relation is tautological.

Contrarily, Dewey is faced with the problem of determining whether or not knowledge is still knowledge; or, put another way, of determining whether knowledge is true. The measure of the

truth of this temporal knowledge is the degree of "solidity, security, and fertility" it affords our dealing with the future, and thought or inquiry is that activity which endeavours to discover such a measure and increase it. In more mundane terms, Dewey's references to practical judgements acknowledge the practice in our everyday affairs of assessing the relevance and applicability of our retrospective knowledge in meeting the imminent future.[115]

II. Thought, which Dewey terms "inquiry", arises from an existential matrix.

Dewey's second assumption places his theory as post Darwinian, a distinction not held by many theories of knowing despite the general acceptance of the fact of evolution.[116] The assumption depends upon describing thought as an activity or special mode of behavior and the conception of "transaction".[117]

Defining thought or inquiry as a particular mode of behavior and stating that such behavior has existential origins, is more than an attempt to avoid its <u>a priori</u> injection into man at some unspecified time in pre-history. It provides a direction for further exploration into how intelligent behavior came to be and also into conditions which may facilitate its generation. It makes the recent advances in ethology which have as their objective a "phylogenetics of behavior",[118] extremely pertinent. Dewey proposes that thought or inquiry is the most recent form of adaptive behavior, which differs from the adaptive behavior of all other adaptive systems by such a degree as to constitute a qualitative difference.

The growing body of ethological and biological evidence which describes the continuous nature of differential behaviors from the simple reproduction of organic molecules, to the migratory activity of birds, to the complex utilization of language and symbols involved in thought or inquiry, provides documentation of the plausibility of such an assumption.[119] The shift is from a categorical conceptualization of organisms to a fluid continuum of behavioral complexity. There are two fundamental points here:

> If we accept adaptiveness as a criterion of intelligent behavior, man is not the only system who behaves intelligently. In fact such behavior is exhibited in some degree in all organic and cybernetic systems.[120] Looked at in this way man's behavior seems differential merely with respect to the degree of adaptability.
>
> The explanation for man's unique degree of adaptability lies in what Bateson might call his "meta-intelligence".[121] In other words man's ability to know what kinds of behavior can be called intelligent; his ability to predict the outcome of various kinds of behavior respective to various ends without the necessity to engage in those kinds of behaviors is precisely that ability which definitively identifies his behavior as human. This is the point that those cyberneticians who equate adaptive behavior with thinking miss. For Dewey, no thought can occur without the use of namings - language which is the only means by which behavior can be rehearsed.

However, we must not assume that the mere rehearsal of behavior is what Dewey means by thinking. It is the selection of one course of <u>action</u> rather than another which can only be made on the basis of observed existential differences in the results of various courses of action having similar ends-in-view. For man's behavior to exhibit the unique adaptability it does, he must remove himself from the acting of it through the use of language and select an end-in-view or a goal or purpose. In this sense the end-in-view or purpose is quite distinct from the

goals or purposes of the cybernaticians whose terms suffer from the fallacy of the observer.[122] Dewey, through his theory of "Inquiry," proposes that man initiates a process of continuous vacillation between active modification of environment and symbolic rehearsal of such modifications which has as its purpose the resolution of a doubtful situation.[123]

We can now be more specific and ask what evidence Dewey can supply to indicate that man's language behavior has natural origins. This fundamental question was dealt with by George Herbert Mead who greatly influenced Dewey while at Chicago. Mead holds that the language capacity arose as a natural consequence of social behavior of big-brained, tool-using animals. We have already seen evidence that man's most obvious structural uniquenesses are his very high ratio of brain weight to body weight and his hands with opposable thumbs. Additionally, anthropological evidence indicates that the very primitive australopithecus was a tool user.[124] What Mead proposes and Dewey and Bentley extend is that the shift from signal behavior as described above to language behavior was initially a very slight one which has had far-reaching consequences, namely that of the origin of mind as a behavioral capacity.

> The transformation of the biological individual to the minded organism of self takes place on Mead's account, through the agency of language, while language in turn presupposes the existence of a certain kind of society and certain physiological capacities in the individual organisms.[125]

The slightness of the shift seems necessary to add plausibility if we consider that we have been talking about a continuum of behavioral complexity of which language behavior is a part.

Dewey and Bentley provide a neat description of this shift by identifying the word "cue", which they mean as a verbal signal, as the most primitive form of language behavior. From the verbal signal to a naming, as described above, there is merely a gradual extrication of the name from the spatio-temporal contiguity of the cue in its context.[126]

Thus we see that there can be no clear cut historical sequence leading from one capacity to another but rather a very complex interaction of many influences such as primate society, tool use, brain size, as well as opposable thumbs, genetic behavioral traits, social gestures, rituals and language, which explain the symbolic capacity of man and which underlies his uniquely adaptable behavior. Such behavior seems to have arisen analogously to the first living behavior which resulted from the mixing of an organic soup under unique conditions of temperature and pressure.[127]

All we can say here is that Dewey has ample supporting evidence for his assumption that inquiry as uniquely human behavior can be explained in terms of natural conditions which are and have been observed by many investigators.

If we view language behavior as a social emergent on a behavioral continuum and further view language behavior as underlying the social emergent of mind, we can take a new view of Cartesian Dualism. We have seen that once the assumption of dualism is made, the investigator of behavior is forced into very awkward positions which distort the nature of many observed behavioral processes. Dewey's adoption of the term "transaction" is explicit rejection of dualism.

> We hold that observation must be set free; and that, to advance this aim, a postulatory appraisal of the main historical patterns of observation should be made, and identifying namings should be provided. Our own procedure is the TRANSACTIONAL, in which is asserted the right to see together, extensionally and durationally, much that is talked about conventionally as if it were composed of irreconcilable separates. We do not present this procedure as being more real or generally valid, than any other, but as being the one now needed in the field where we work.[128]

The important implication of the concept of "transaction" is that it represents the opposite point of view from the customarily given conditions of dualism. It is the view that organisms and environment are always in a situation characterized by wholeness. Separateness is not an initial condition, but one which emerges through the process of naming or languaging. We do not begin with a knower, ~~nor~~ something to be known, and ~~nor~~ a process of knowing which can be subsequently reified into ontologically independent "entities", but rather from a situation in which each are emergent aspects. As Piaget and Von Bertalanffy rightly point out, we cannot assume at the outset the world view of the western adult, but instead consider the developmental origins of that perspective.[129]

The rejection of dualism and the statement of the necessity for the development of a terminology which is adequate to the description of behavior as distinct from structure, brings to light this fact that Dewey's theory parallels and is corroborated by Ludwig Von Bertalanffy's "General Systems Theory".[130] Indeed, Bertalanffy argues for what he terms a "perspectivistic approach".[131] The assumptions underlying both Dewey's use of the term "transaction" and Von Bertalanffy's "perspectivistic" approach constitute a fundamental revision

in philosophical theory which is described by Von Bertalanffy as a shift from "absolutist" to "perspectivistic" philosophy.[132]

III. The genesis of thought or "inquiry" is genuine doubt and it is the character of the doubt that determines to discrimination and selection of facts.

Dewey's assumption that thought or inquiry begins in genuine doubt is really more of a postulation than an assumption. What is meant is that Dewey chooses to confine "Inquiry" to activities that have as their end the resolution of doubtful situations, as distinct from those activities sometimes referred to as thinking which are synomous with remembering, guessing, imagining, and reminiscing. It is in this sense and in this sense only that Dewey's theory of inquiry can be said to have an instrumental or indeed utilitarian base. Other purely or mainly "mental" operations are not denied existence or importance, however, Dewey's main concern is that complex behavior which has as its outcome the resolution of doubt. By distinguishing this behavior from other behaviors, he is able to avoid confusion usually generated by the "private" nature of purely mental operations, and to offer ways of dealing with the kinds of questions that were described in section I of this paper.[133]

That Dewey does in fact assert "Inquiry" begins with doubt can be seen from the following rather poetic statement:

> The ultimate evidence of genuine hazard, contingency, irregularity, and indeterminateness in nature is thus found in the occurrence of thinking.[134]

Contrast this position with that of McCulloch who bases his theory of "Experimental Epistemology" on the absence of doubt

by assuming the truth of the atomic propositions of neuron firings. The issue here is fundamental since Dewey holds that there are no sensory data that can justifiably be called "immediate knowledge."[135] While for McCulloch "knowing" is an automatic process because truth lies in the universe and our perceptual mechanism is designed to respond to it, Dewey sees "knowledge" as hard won and what truth there is has no fixed ontological basis but is dependent upon specific means-end consequences that we initiate. The difference is doubt.

The important consideration here is the source of doubt. For Dewey, as can be seen from the above statement, doubt has ontological status[136], in other words there is doubt in nature not as a result of man's separation from a fixed and certain reality, but more correctly as a quality of contingency or uncertainty which marks most transactional situations in which men find themselves. Doubt is not in our heads though we may legitimately speak of feelings of doubt which describe a state of tension between the present and possible futures. However, those men who are continually beset by doubts that most men have resolved, may be called mentally ill simply because of the purely mental nature of their doubt.[137]

But if doubt is the genesis for thought, as Dewey defines it, and doubt is a quality inherent in our world situation, we must address ourselves to the question of why man's behavior seems uniquely thoughtful or, put in another way, why man reacts to doubtful situations in a unique way.

Perhaps the best answer can be sought in terms of comparing the complexities of behaviors manifested through the study of

evolution. Complexity of behavior has increased correlatively with motility and the refinement of sensory apparatus.[138] In fact new behaviors seem to have been the genesis for new structures.[139] The gradual spatio-temporal extension of the range of experience can be seen as having been paid for through an increase in uncertainty or doubt. As behavior exhibits a taking account of more stimuli further and further removed it is called complex and is subject to increasingly greater numbers of probable outcomes. The striving to obtain one probable outcome rather than another requires taking into account more and more factors and such behavior may explain and be explained by the evolution of refined sensory apparatus, tools and the use of symbols.[140] The process is a spiral one, not linear, but there is increasing evidence to indicate that this description is accurate and fruitful.[141]

The similarities to the information model are obvious but incidental. Surely a situation involving a greater degree of uncertainty demands a more complex system to deal with it, but the cybernetic concept of uncertainty, in addition to being purely formalistic and dependent on some finite set of discrete alternatives, ignores the transactional nature of Dewey's kind of doubt. It ignores the fact that only more complex systems can experience more doubt. In other words the amount of doubt cannot be initially assumed but is directly correlated with the complexity of the system's potential interactions with its environment.[142]

Also, the circularity of the process Dewey describes seems analogous to the negative feedback cycle of information

theory, however, Dewey's circularity does not revolve around the concept of attaining an end "in and of the operation"[143] or the maintenance of fixed parameters[144] but more the character of what Bertalanffy describes as a "steady state".[145]

However, if we accept Dewey's assumption that doubt or uncertainty is the genesis of thought, we are still left with the correlative part of that assumption -- the nature of the doubt determines the selection and discrimination of the facts. The implications of this part of the assumption apply to the shift away from a concept of an "ultimate reality" as discussed above, and Dewey's refutation of the existence of "immediate knowledge". Dewey's rejection of an "ultimate reality" is explicit and definitive:

> It is often said that pragmatism, unless it is content to be a contribution to mere methodology, must develop a theory of Reality. But the chief characteristic trait of the pragmatic notion of reality is precisely that no theory of Reality in general, überhaupt, is possible or needed. It occupies the position of an emancipated empiricism or a thoroughgoing naive realism. It finds that "reality" is a denotative term, a word used to designate indifferently everything that happens. Lies, dreams, insanity, deceptions, myths, theories, just the events which they specifically are . . .
>
> The only way in which the term reality can ever become more than a blanket denotative term is through recourse to specific events in all their diversity and thatness. Speaking summerarily, I find that the retention by philosophy of the notion of a Reality feudally superior to the events of every day occurrence is the chief source of the increasing isolation of philosophy from common sense and science . . . [146]

It follows then that if "ultimate reality" is rejected there is no basis for any "immediate knowledge". There can be no category of events that has such general application to all doubtful situations which would allow us to accept its

significance without the necessity for any process of inference. For Dewey "knowledge" is synonomous with "warranted assertibility" and all "warranted assertibility" is the product of "inquiry".

If this is accepted and understood, it becomes apparent that an event which has relevant significance with regard to the resolution of one doubtful situation may be totally irrelevant or inconsequential with regard to another. For example, if our problem is to find which of a number of keys will open a particular door, the shape and size of the lock and the keys are "facts" we must determine, but if our problem is to determine which of a number of keys is to be trusted to the possession of another person, the "facts" will be far more extensive than mere shape and size and will include the contents of the rooms or containers, the characters of the persons under consideration for possession, and a host of other "facts".

It is precisely this position which differentiates the theory of "inquiry" from the deductive system of Aristotle which forms the platform on which all rationalistic theories and pure formalism stands. As long as we assume meaning inherent in the structure of the universe in the form of essences, which carry their significance and uniqueness with them on their face, then "knowing" is a perceptual matter achieved through the intuiting of Plato or reasoning of Aristotle or data processing of McCulloch. But it must be repeated here because it is fundamental to Dewey's position that a "fact" is a "fact" only insofar as it points reliably to something other than itself and that pointing is relevant to a problematic situation. Looked at

in this way we can say that "facts" are not ontologically fixed but undergo a process of becoming. They are not separate but discriminable. Consequently no particular "fact" can be specified in terms of internal traits.

However, we must not fall into that trap of thinking that we can assume whatever "facts" we like. We are not talking about solipsism and mythical thinking, and to guard against this Dewey describes the continuum of inquiry. This is nothing more than the acknowledgement that facts are to be strictly limited to the resolution of a particular inquiry or attempt to resolve a particular doubtful situation. Insofar as a significance of an event is instrumental in resolving a particular doubtful situation, it can be regarded as a "fact" in and of that inquiry, but its status as instrumental is always under suspicion in the next inquiry, if indeed its tentative significance is relevant at all. The important consideration is that the status of fact is always retrospective and consequently the instrumentality of events called "facts" is always hypothetical in each new inquiry. Of course there are some "facts" so well established through having been instrumental in many inquiries, as to be taken for granted and used without questioning their validity as instruments. But when the resolution of doubt is not obtained that status which was previously taken for granted must be re-examined. In other words for Dewey, as well as for Pierce[147] and Popper,[148] facts are discriminated as relevant to a particular problem and held in status as facts only as long as they serve as adequate instruments in the continuum of inquiry, or, more aptly, the continuum of inquiries. Such a

position makes prediction the tentative activity it is, but at the same time gives an indication of the measure of tentativeness of any prediction as well as specifying means whereby such tentativeness may be decreased. It is not a mere extrapolation of averages, nor has it the quality of certainty which characterizes formal subject matter.

IV. All thought or inquiry institutes and results in modifications of existential situations.

We move now to Dewey's fourth assumption which distinguishes his position from that of formalists who separate mental activity from the behaviors of making, doing, and examining[149] and the position of the empiricists whose deprecations of the use of formal constructs condemns them to the position of mere observers of events. That Dewey holds this assumption can be seen from the description he gives to the process of inquiry:

> In every instance, from passing query to elaborate scientific undertaking, the art of knowing criticizes a belief which has passed current as genuine coin ., with a view to its revision. It terminates when freer, richer and more secure objects of belief are instituted as goods of immediate acceptance. The operation is one of doing and making in the literal sense. Starting from one good, treated as apparent and questionable, and ending in another which is tested and substantiated, the final act of knowing is acceptance and intellectual appreciation of what is significantly conclusive.[150]

As long as we accept that doubt is not "in our head" but a quality of a transactional situation, and further accept that inquiry has its origin in doubt and has as its intention the resolution of doubt, then the assumption that "thinking" results in a modified existential situation is necessary by definition.

But the significance of the assumption lies not in the consistency of Dewey's theory but its differential recommendations as a course of action. Most of the implications of Dewey's theory lead to statements in the third section but implications specifically regarding the problem of knowing will be dealt with here.[151]

The most important implication of Dewey's method of "Inquiry" is the functional correspondence of ideational or conceptual phases with those of (overt) selection and observation. Such correspondence is not to be confused with the negative feedback loop of the cyberneticians.

The end-in-view that Dewey describes does serve as a regulator of the operations of inquiry but is not fixed. It is subject to revision based on the obstacles and irregularities which arise through the operations of selection and discrimination.

Revisions of the end-in-view dictate revisions in the operations of selection and discrimination so that specific significant events (facts), can be selected which further the inquiry as a whole. The mutual dependence of the two kinds of operations cannot easily be separated in time. In other words, it seems more fruitful to picture inquiry as a dynamic process of interrelating ideational activity with operations of selection and discrimination than to separate the activities temporally. The seperation can be effected, but as such constitutes a speciel case of inquiry which is of an unusually extended nature.

A very simple example of the functional correspondence of two kinds of activities can be seen when we are confronted with the indeterminate situation in which an automobile, which we

are driving, malfunctions. The nature of the doubt can be characterized as: "What is wrong with the car?". The first ideational activity is usually some speculation like, "Maybe it is out of gas". This hypothesis directs an observation which usually takes the form of a glance at the gas guage. The result of that operation may initiate a further inquiry that involves locating some more gas or posing another hypothesis which might account for the car's malfunction. That further hypotheses will then direct further operations of observation which may in themselves require quite sophisticated ideational activity before their significance is determinable. The idea that the situation could be resolved by the mere rehearsal of alternative hypotheses, no matter how refined their linguistic treatment, no matter how large the probability coefficient, is obviously absurd as is the idea that mere happening of the malfunction is sufficient to indicate its probable rectification.

An additional implication of Dewey's assumption is that the nature of an existential operation is that it is at least potentially <u>public</u>.[152] This condition is the cornerstone on which science as science rests. Any scientific claim that such and such is the case, is scientific only in the sense that other scientists may repeat the operation and find results in accordance with the original results. We must remember that for Dewey "knowledge" or "warranted assertibility" is a special case of belief and such beliefs have their ground in the situation that all who investigate will accept them. Consequently, the transition from private belief to that of "warranted assertibility" demands the specification of operations

such that if they are carried out, they will result in agreement or shared opinion. To the extent that beliefs are private they are not warrantable but mere whim.

The above statements are not meant to indicate that general agreement about a particular belief constitutes its validity. For Dewey all knowledge, hence all warranted assertibility is in jeopardy whenever new inquiry is begun. Insofar as it is not proven fallacious it is held true, however, no amount of success, no finite number of inquiries which affirm it is sufficient to elevate it to any ontological status. "Knowledge" is true only insofar as it does not prove obstructive to the course of inquiry.[153]

Finally, it must be noted, Dewey's assumption that inquiry results in the modification of existential situations does not specify any <u>specific</u> kind of modification. Various subject matters have unique qualities as well as various inquiries have unique aims.

The physical sciences have heretofore advanced primarily through the feasibility of quantifying concepts relevant to them and the corresponding preciseness of measurement. But there is no assumption on Dewey's part that all subject matters can be quantified, nor is there any attempt to reduce all subject matters to a common formal structure.[154] Dewey is careful to make explicit the difference between common sense and scientific inquiry[155] and the difference between the development of inquiry in the respective fields of physical and social science.[156] It would seem that Dewey would agree with McCulloch that advances in mathematic and logic are required to further

inquiry about human behavior but he would not ascribe to those advances the primacy that McCulloch does. For Dewey the advance of knowing depends upon:

1. Removing "knowledge" from any connection with ontology.
2. Continuing the development of new and refined symbolic activities in functional correspondence to advances in observational techniques and tools.
3. The encouragement of the public nature of inquiry.
4. The realization that different subject matters require different methods of inquiry and different evaluative criteria.

SUMMARY

We have completed the analysis of the respective theories about "thinking" of W.S. McCulloch and John Dewey. What remains to be done is to summarize their similarities and differences and compare the evidence which supports their assumptions. This author holds that he has demonstrated that McCulloch and Dewey do operate from the assumptions imputed to them. The assumptions were as follows:

W.S. McCulloch

I. The activity of thinking is primarily a perceptual one.

II. The "all or none" characteristic of neuron firing can be looked at as the basis for the application of truth functional logic to brain processes.

III. The brain is the uniquely constructed part of the human which enables him to think and the explanation for man's ability to think should be sought in the physiology of the brain.

IV. The understanding of brain processes will lead to enhanced control of human behavior.

John Dewey

I. The universe is evolving, continuously and irreversibly.

II. Thought, which Dewey terms "inquiry" arises from an existential matrix.

III. The genesis of thought or "inquiry" is genuine doubt, and it is the character of the doubt that determines to discrimination and selection of facts.

IV. All thought or inquiry institutes and results in modifications of existential situations.

We have already seen that though McCulloch and Dewey are talking about "thinking" the questions they ask and the assumptions which underly them constitute very different approaches to the subject.

McCulloch claims to have explained man's ability to "perceive universals" (invariant relations among sense data) and his ability to compute number, but admits failure to explain abduction and ignores the problem of the selection of facts. He explains adaptive behavior in terms of negative feedback and assumes such behavior indicates the possibility of explaining the activity of "thinking" in mechanistic terms. Such inadequacies as are admitted in his theory of "Experimental Epistemology" are to be overcome by the creation of a new calculus and refinements in neurophysiology.

However, McCulloch has failed to show that the underlying assumptions of "Experimental Epistemology" are, in fact, grounded. The assumption of the perceptual nature of knowing results from a totally unwarranted theory of perception and the adoption of a metaphysic which, though commonly assumed, is proving to be increasingly obstructive to the advancement of thinking about thinking. The assumption of the applicability of truth functional logic to brain processes commits McCulloch to a physical determinism which most modern scientists and philosophers reject, furhter he ignores the question of meaning altogether. The isolation of the brain as the primary organ of thought and the reduction of "thinking" to physiological processes has been demonstrated to be fallacious with the result that the fruitfulness of the theory of "Experimental Epistemology" for

dealing with the predicament described in section I is extremely doubtful.

On the other hand Dewey's assumption of irreversible change leads him to the conclusion that man's behavior is unique because of his unique ability to use symbolic processes to direct deliberate changes. That the assumption of irreversible change is metaphysical is granted, but the majority of our experience to date, including the whole concept of evolution, indicates that at least there is a preponderence of evidence in support. That "inquiry" or thought arises from an existential matrix is well supported by biological, ethological and anthropological evidence and provides means whereby the capacity for thought may be investigated.

By avoiding the mind-body problem and assuming that thought arises from doubt, Dewey designates a specific kind of behavior, that which he calls reflective, thoughtful or intelligent, from other human behaviors. Such a designation, by indicating what kind of behavior is appropriate to specific kinds of situations -- (those involving doubt) -- while making no claim for any other kind of primacy, appears helpful. The further assumption as to the regulative function of the kind of doubt seems to be becoming increasingly acceptable and indeed necessary as an efficacious agent in furthering knowing. Finally, the assumption that inquiry institutes and results in modifications of existential situations provides a measure of the method's fruitfulness in dealing with the predicament described in section I.

Such a situation gives thought or inquiry the role of

producing "warranted assertibility" which gains its warrant in strict correlation with its result in achieving intended change. For Dewey the model of "Inquiry" is that which has proven so successful in the advances that have been achieved within the physical sciences. Consequently, the problem of "thinking" for him is largely solved, but our difficulties as described in Section I can be attributed to the complexity of the subject matter of social inquiry as well as to the barriers to social inquiry which inevitably form its context. More clearly, Dewey assumes that social inquiry is impeded to the extent that men are unable to remove themselves from the imperative nature of their social values and are not in possession of means for defining social problems rather than dealing wholistically with problematic situations.[157] Recognizing that social inquiry demands the development of new tools of measurement and removal of social barriers, Dewey recommends the application of an already well defined mode of behavior to further the understanding of human situations.

PART III

As was stated in the introduction, part III will be concerned with establishing educational goals and the means toward their attainment.

As such, this section represents a shift of emphasis from the fairly detailed analysis of the applicability of the mechanistic and formalistic concepts of cybernetics to the behavioral activity of thinking. And from the epistemological problems that have formed the subject of part II, to a discussion of the implications that an uncritical acceptance of cybernetic theory holds for educational practice. The concern then can best be described not as an analytical examination of the fruitfulness of the cybernetic analogy to thinking, but more clearly as a discussion of what is likely to happen if educators, who are often dealing with ill defined or undefined concepts of "knowledge", "thinking", "intelligence", "learning", start viewing the educational process in cybernetic perspective.

Further, any comparison of the educational implications of "Experimental Epistemology" and "Inquiry" must make an important qualification concerning the differential intents of those theories. Whereas Dewey explicitly proposes his theory of "Inquiry" as a framework from which to build an educational philosophy,[158] McCulloch does not. In fact we have found McCulloch to be quite candid concerning the limitations of his theory of "Experimental Epistemology". Therefore, any complications arising from assuming an applicability of McCulloch's model of thinking to educational practice cannot be laid at his door, but rather at the feet of those who take it upon themselves to make the speculative leap required.

We come now to a fuller consideration of how to deal with the problem which was set forth in section I; the problem of control. Through the course of history we have been achieving an increasing amount of control over our environment until now we are faced with a situation where the mere fact of that control fills us with such awe that we are immobilized. Man has become God and in doing so he has lost the agency which heretofore ordered his behavior. Historically the agency has always lain outside human endeavor, whether in the form of Plato's ideal realm, or religion's God, or science's Reality. For Plato, the Good, the True, and the Beautiful, through the intuition of the philosopher kings, were the ordering principles of the Republic.[159] Christian theology sees the world as the creation of God, and our part in that world as defined and ordered by God's will. More recently the monolithic institution of western science continues to operate on the assumption of an "ultimate reality" whether it be ideal or material.[160] The external nature of such ordering principles has lead to a reification of the methods by which they are brought into our experience. We have institutionalized religion as the means through which one "knows" God. We have institutionalized science observing that its Latin meaning is "to know". More pertinently, however, we have institutionalized education as a means for controlling the behavior of the young in our society through the dual process of passing on the "knowledge" accumulated by society and providing them with means to new "knowledge" with which they can meet the present and the future. This process of institutionalization is the manifestation of our continual

efforts to choose how we will behave. The fact that we have such a choice available to us is the ultimate measure of our humanness.

The comparison of the theories of McCulloch and Dewey has as its major intention the comparison of two distinct ways of dealing with the fact of human choice. Both men see the issue of choice as fundamental to their concepts of control, but they deal with it in almost opposite fashions.

McCulloch's theory draws upon Wiener's equation of information with negentropy which is considered to be a major concept of cybernetics.[161] The equation rests on the assumption that uncertainty can be quantified. It is fundamental to recognize that, as such, the choice involved in the cybernetic concept of control is a purely formalistic choice between a finite number of unambiguous alternatives. The process of making such a choice is what McCulloch is referring to as "thinking". The essential idea here is that "thinking" in this sense is the process by which choice is diminished; starting from any finite number of possible alternatives the object is to eliminate all but one, or in Ashby's terms, eliminate all but a given range of alternatives.

On the other hand, Dewey views control as being increased through the creation of more choice.[162] He holds that choice is not an initial condition to be limited so that "knowing" is possible, but is a condition that it is necessary to create through the identification of means-end consequences, and to the extent that means-ends consequences become "known" control is increased. Dewey does not speak of a quantifiable uncertainty but of a substantial "doubt" which is a part of many transactional

situations.

The necessary premiss for furthering our present discussion is that there are kinds of control and kinds of choice. First there is the kind of control one achieves over a machine through "knowing" the functional interrelations of its parts, which is different from the kind of control arising from "knowing" its purpose and becoming skillful in using the machine to achieve that purpose. This distinction is that between the different kinds of control exercized by a racing car mechanic and a racing car driver. Though the difference is difficult to quantify or define unambiguously, it obviously exists. Secondly, there is a difference in the kind of choice which exists when one is dealing with small numbers of relatively immutable entities and where one is dealing with large range of dynamic events. This is like the difference between choosing the correct move in checkers and predicting the position of an electron or classifying a completely new species.[163]

If we acknowledge these differences and view the educational process as a means to control human behavior, we can address ourselves to the question of what kind of choice is most prevalent and important in our situation today as well as what kinds of control seem most desirable. Such consideration should provide a basis from which we can prescribe educational ends and means.

Viewing the cybernetic kind of control which characterizes McCulloch's "Experimental Epistemology" it seems obvious that it is analogous to the kind of control exercized by the racing car mechanic. In fact, it is basically a mechanistic kind of

control stemming from the intention to determine cause and effect. McCulloch's exhortation to construct mechanistic hypotheses to further the understanding of human "knowing" is underlain by the general intention of all mechanistic hypotheses; that of determining what cause or series of causes produces what effect. This kind of exploration depends upon the timelessness of the entities involved and additionally upon instituting a "closed system" so that change can be controlled and attributed to factors which are isolable. These requirements demand that temporal or durational considerations be neglected and additionally cannot deal with "transactional" qualities of situations.

However, the more important shortcoming of mechanistic hypotheses with regard to their pertinence to human behavior is their equation of function with purpose, or more accurately, their concentration on function, and total disregard for purpose.[164] Consequently, the assumption that McCulloch's theory has educational applications ignores the fact that educational ends are irrelevant to it.[165] If his theory were to be applied what is likely to happen is that educational ends would be assumed as fixed and final at the outset and then achieved by controlling input and output of the human machines that are assumed by the educational system. Further, the adoption of the cybernetic model seems to imply that, short of operating on the brains of students which seems criminally direct, teaching practice is relegated to the selection of information which will produce the behavior which is in accordance with previously assumed ends. The problem of what is desirable educational

practice resolves itself into the relatively simple process of finding out what kind of information (input) will produce the desired behavior (output) which seems well within the reach of present day psychology.[166]

If on the other hand we view the implications of Dewey's theory of "Inquiry" for educational practice, we see that the kind of control it is directed toward, is that which is directed toward situations in which human beings are a part. Such control is not limited to the sphere of human functioning but includes the context within which the human functions. By so doing it brings within its purview not only human functioning but the influences by which human functioning can be evaluated. This difference in scope is much more than the significant one between that of mechanistic, formalistic hypotheses and those of dynamic experimentatlism. It is most fundamentally the difference between a process of control which assumes external ends toward which it is to be exerted and one which includes the selection of ends within the process of control itself.[167] Dewey's theory demands no omniscient foreknowledge of all possible alternatives but is concerned with enhancing control through the identification of alternative means-ends relationships so that the choice of possible ends is increased.[168]

The contrast of the differential educational implications of mechanistic and dynamic hypotheses can be seen most clearly in the respective positions taken by B.F. Skinner and Carl Rogers. Skinner, perhaps the dominant influence within the present field of Behavioristic Psychology, makes the claim that almost any kind of behavior can be produced in human beings through the process

of operant conditioning.[169] In the light of this claim he proposes that the educational process should take the form of a controlled environment designed to produce specific kinds of behavior that can be agreed upon. Rogers' position actually differs very little in principle from that of Skinner's, but the specific differences are fundamental. What Rogers proposes is also an environment which is controlled, but controlled in the interest of values which are very different from those selected by Skinner. The difference is clear and explicit:

Skinner proposes the following as educational ends:

> "Let man be happy, informed, skillful, well-behaved, and productive." 170

Rogers proposes:

> "Suppose we select a set of values which focuses on the fluid elements of process, rather than static attributes. We might then value:
>
> Man as a process of becoming; as a process of achieving worth and dignity through the development of his potentialities;
>
> The individual human being as a self-actualizing process, moving on to more challenging and enriching experiences;
>
> The process by which the individual creatively adapts to an ever new and changing world;
>
> The process by which knowledge transcends itself, as for example the theory of relativity transcended Newtonian physics, itself to be transcended in some future day by a new perception". 171

A close examination should reveal not only the fundamental difference between ends as fixed and ends as ends-in-view, but also that unless Skinner's ends are defined in terms of another value system which is taken as final, they are only pseudo-ends and provide no stable ordering of human behavior. The questions that such ends leave unanswered are paramount: what is happiness, who should be informed of what, which skills are desirable, whose criteria are to be accepted as the standard

of good behavior, and: what is to be produced? What in fact is necessary for Skinner's ends to be taken as ends is that they be defined as McCulloch would have them defined finitely and unambiguously.

But do the ends proposed by Rogers fare any better? It is granted at the outset that they rest on one of the same assumptions that underpins Dewey's theory of "Inquiry"; that of an irreversibly changing universe. However, if we accept change as a fact of our experience (and it seems safe to do so if we acknowledge that there is an infinite variety of rates of change which we experience every day) then it seems that the process of definition is itself a dynamic one. That is to say that such terms as "becoming", "self-actualizing", "challenging", "enriching", "creatively adapting" and "transcending" carry no meaning which is underlain by any implicit and arbitrary value system. But they are not meaningless; their meaning is itself in a process of becoming and that process is regulated by overt shared opinion.[172]

This does not imply that ends are arbitrary, but it does assert the fundamental position that human ends are nothing more than future possible ways of behaving which have been selected out of a vast array of past behaviors by the combined forces of natural selection, cultural experience and individual past experience. Such ends are emergent qualities of every human situation and the problem of their selection is one of harmonizing projected differential consequences which can be foreseen in the pursuit of alternative ends.[173]

It is necessary to note that the choice involved in the

selection of ends whose consequences harmonize with the consequences of other selected ends, is of a different kind than the choice involved in Skinner's proposal. For Skinner the essential choice is really, who is to select ends and how are they to be defined in actual situation, while Rogers proposes that choice be made among consequences of ends. Obviously for Skinner the ultimate choice involved in human control is the selection of who is to play God, and he tries to minimize the obvious totalitarian potential of such control by rotating Gods and conditioning them well.[174] Contrarily the human control that Rogers proposes comes through a public assessment of the observed consequences of various ways of behaving. As such it is at least potentially open to the methods of science, controlled observation and measurement.

What is here proposed is that the educational ends suggested by Carl Rogers are best suited to the conditions of present day society for the following reasons:

1. The rate of social change imposed upon us as the result of being in a "Global Village" is more rapid than ever before.[175]
2. Such ends are best suited to enhancing control by increasing the amount of choice available to us, rather than diminishing it.
3. The means to such ends are presently available and are not in conflict with the present political and social customs of North American Society.

Probably the most fundamental influence of our time is that of living in close proximity with all the inhabitants of this

planet. Through the operations of modern transportation and communications the ramifications of parochial squabbles have converted the consequences of such squabbles to proportions that threaten the stability of the whole "Global Village". It would be a difficult task indeed, to find a true "Civil War". Business has become an international operation to the extent that labor disputes in formerly remote corners of the world now endanger the entire economic stability of large numbers of people. But most importantly, and in full view of everyone, the clash of cultures (heretofore separate and distinct) goes on in concert with man's increased power to control fantastic amounts of energy. Whole cultures who have had a long history of behaving in terms of the certainties of their own customs, are continually confronted with the unexplicable fact that there are other cultures who behave in terms of other customs with equal inertia. The result of course is fear stemming from the potential loss of the ultimate ordering principles. Such fear produces either panic and hopelessness or stereotypic behavior in the form of increasingly strenuous efforts to preserve the accepted ordering principles.

But stereotypic behavior is a curious phenomenon. It can be conceived of as a behavioral reflex to stressful situations, an adaptation which has been developed genetically through the course of evolution. However, the rate of social change which is an entirely new natural phenomenon, coupled with man's very recent grasp of the means of destruction, produce conditions wherein stereotopy may be dangerously maladaptive.[176]

Consequently the kind of control that is most desirable is

that which is least likely to produce stereotopy. It is that kind of control which reduces fear, as the genesis for stereotopy, as well as providing for new kinds of stereotopy which are more adoptive under present stressful situations.

Quite simply, if we take an analogy from ethological evidence of threatening behavior, we can view the results of our present stereotypic behavior as WW III. When one country or culture threatens the values or ends of another, the other assumes a threatening position as a reflex. If the threat is increased it becomes a stimulus to the acts of aggression which is released in a behavioral chunk.[177] Given the state of our technology the behavioral chunk of aggression for man includes the use of weapons which are ultimate in the sense of producing death. Lorenz takes a Malthusian position on how to prevent this by advocating the development of inhibition toward use of weapons. I would not disagree that this is a plausible mode of solution, but I propose that we deal with aggression by trying to avoid it wherever possible through instituting the habit of looking for alternatives.

The position here is that the kind of control that the educational system should exercise is that which results in positive attitudes toward change. This is not meant to imply that we are to accept all change as good, but merely that the initial reaction to change should not be one of fear, but one of reflection concerning the consequences of the particular change and a willingness to consider alternatives. It seems obvious then that the postulation of final and ultimate goods is inimical to a reflective reaction to change.

What seems indicated is the development of a habit of looking for alternatives to aggression.

This has rather profound educational implications, for what I am proposing is that educational emphasis be shifted from methods which encourage selection of the "best" or most efficient way of behaving either in situations of scientific problem solving or, as in the case of passing on traditional values, methods which are merely rationalizations of a nation's history, to methods which encourage the habit of finding as many alternatives to some end as are imaginable, and further to the consideration of as many ends as can be imagined.

What is proposed is that educational practice should be more concerned with questions than with answers; should be more concerned with viewing available choices rather than making the right one, and should be more concerned with imagination than with memorization. It is simply what Rogers proposes: that it should view the human organism as a "self-actualizing" process and provide an environment wherein that process can best take place in harmony with the other self-actualizing processes which surround it.

The final question that deserves our attention is whether or not we have the educational means to the ends that are proposed. Rogers catalogues the findings of social psychology, not as proposed means for achieving his educational ends, but as indications that such means are acquirable.

But the fundamental necessity in order to further the search for means to the dynamic educetional goals as put forward here, is a concept of man that is in accordance with his unique

characteristics.

The increasing ethological evidence all indicates that we are on firm experiential ground when we view the human organism as a self-actualizing process, that is as a process which has ends of its own which change in terms of their environment, but nevertheless exist and will find expression in some way or another.

Consequently, whatever we call the discipline which seeks explanation and control of human behavior, it must start from the premises that the human organism has a history and a future, that it has a unique biological structure and exists within a social and cultural context, and that, as an open system, it is never ultimately determinable.

FOOTNOTES

Introduction

1. M.E. Maron, "On Cybernetics, Information Processing and Thinking", Cybernetics of the Nervous System, Ed. Norbert Wiener, XVII (Amsterdam, 1965), p. 134. Maron writes: "However, as we have said, an analysis of the information flow organization of intelligent behaviour provides the logical timbers needed to bridge the gap between signal processing and behavioural indications of knowing . . ."

2. Warren S. McCulloch, Embodiments of Mind (Cambridge, Mass., 1965), p. 158.

Part I

3. Paul Goodman, "The Psychology of Being Powerless", The New York Review, (November 3, 1966), p. 1.

4. J. Miller, Current Trends in Social Psychology, Ed. Wayne Dennis (Pittsburgh, 1948), p. 220.

5. Konrad Lorenz, King Solomon's Ring (New York, 1952), pp.197-8.

6. Ashley Montague, On Being Human (New York, 1966), p. 11.

7. L. Von Bertalanffy, "Biologist looks at Human Nature", Scientific Monthly, Vol. 82, (Jan. 1956), 33-41.

Part II

8. John Dewey and Arthur Bentley, A Philosophical Correspondence (New Brunswick, N.J.), 1964.

9. McCulloch, Embodiments, p. 148.

10. McCulloch, Embodiments, p. 162.

11. McCulloch, Embodiments, p. 263.

12. McCulloch, Embodiments, p. 307.

13. John Dewey, Experience and Nature (LaSalle, Ill., 1958), p. 133.

14. John Dewey, Logic: A Theory of Inquiry (New York, 1960), p. 345.

15. Dewey, Experience and Nature, p. 129.

16. Dewey, Logic, p. 118.

17. Dewey, Experience and Nature, p. 149.

18. E.G. Boring, A History of Experimental Psychology (New York 1950). See discussion of Helmholtz's "unconscious inference" pp. 308-11. See also section entitled "Theory of Perception" pp. 311-13. See also pp. 230-1 on J.S. Mill's Associationism. For a brief complete historical discussion see pp. 671-83.

19. E.G. Boring, Experimental Psychology, pp. 611-15.

20. That both sides of the controversy assumed a dichotomy between subject and object is implicit. The problems arising out of such an assumption will be dealt with at length in the second section of this paper.

21. McCulloch, Embodiments, p. 247.

22. McCulloch, Embodiments, p. 65.

23. McCulloch, Embodiments, p. 257.

24. Warren S. McCulloch, "A Logical Calculus of Ideas Immanent in Nervous Activity", Bulletin of Mathematical Biophysics, XV (Chicago, 1953).

25. Compare McCulloch's concept of Universal with Dewey's discussion of universal and generic propositions found in Chapter 14 of Logic, pp. 265-280.

26. Information theory concepts of coding vary relative to what is being coded. All involve some type of mathematical translation of a particuler state of the cybernetic system into an analogical or benary representation of that state. The importance for our discussion here, however, is that McCulloch's insertion of a time translation into the process allows him to escape from the "isomorphism" which was a tenet of Gestalt perceptual theory but presented no neurological correlates. See Norman Abramson, Information Theory and Coding. (New York, San Francisco, Toronto, London), 1963, Chapters 3, 4, pp. 45-85. Also Norbert Wiener, Cybernetics (Cambridge Mass., 1948).

27. This is well developed in "Finality and Form" and based on the observation of the physiological properties of neurons such as: all or none firing, refractory period, threshold, latent addition, synaptic delay, the absence of temporal summation from the same neuron, irreciprocity of conduction, inhibition at a synapse, spatial summation, and irritability.

28. McCulloch, Embodiments, p. 250.

29. McCulloch, Embodiments, p. 253.

30. Here the cybernetic concepts require that a distinction be made between "learning" which occurs through "evolutionary feedback" and the more common psychological concept of learning, which is generally a modification of responses of a particular organism due to its interaction with the environment. In other words, often the cybernetic use of "learning" does not distinquish between phylogenetic adaptation and the adaptive behavior of a single organism.

31. McCulloch, Embodiments, p. 370 and also p. 85. For a further discussion see: D.E. Wooldridge, The Machinery of the Brain (New York, 1963), chapter 9.

32. McCulloch, Embodiments, p. 107.

33. McCulloch, Embodiments, p. 370.

34. McCulloch, Embodiments, p. 65.

35. Stephen Toulmin, The Uses of Argument (Cambridge 1964), p. 248. Toulmin's very perceptive remark here is "Since questions about 'the nature of human understanding' so often consist of logic marquerading as psychology, confusions within logic have only too easily led to misconceptions in the theory of knowledge also". McCulloch's own confusions in logic and specifically his unwillingness to forsake the ideal of analytical arguments while in empirical fields, which is one of the icons Toulmin demolishes, will be discussed subsequently.

36. McCulloch, Embodiments, p. 159.

37. W.N. Kellogg, Porpoises and Sonar (Chicago, 1961).

38. McCulloch, Embodiments, p. 72.

39. This idea stems from the failure to make the distinction between the evolutionary modification of perceptual "mechanisms" and the modification of those "mechanisms" which occurs through the individuals own past experience. McCulloch in fact, does equate the overaging of sensory stimulation with learning but in his sense the learning results not from any individual change in response, but through the evolutionary "mechanism".

40. McCulloch, Embodiments, p. 72.

41. McCulloch, Embodiments, p. 77 as well as p. 148 and p. 307.

42. McCulloch, Embodiments, p. 307.

43. McCulloch, Embodiments, p. 84. He writes: "But our most remote abstractions are all ultimately reducible to primitive atomic propositions and the calculus of the lowest level . . ." See also pp. 72, 77, 144, 148, 265, 283 and 307.

44. John Dewey and Arthur F. Bentley, Knowing and the Known (Boston, 1949), p. 6.

45. McCulloch, Embodiments, p. 283.

46. Leon Brillouin, Scientific Uncertainty and Information (London and New York, 1964), p. 20.
See also E.G. Boring, Experimental Psychology, pp.191-2 on Hume. See also G.H. Mead, Philosophy of the Act (Chicago, 1938), pp. 87-8 and also pp. 417-20.
Additionally see Toulmin, Argument, chap. 4, pp. 147-210.
Further see R.B. Lindsay, Foundations of Physics (New York, 1957), p. 189 and Rudolf Carnap, Philosophical Foundations of Physics, (New York, London, 1966).
Carnap states: "Today, it is true that most physicists do not accept determinism in the strict sense in which the term has been used here. Only a small minority believe that physics may some day come back to it", p. 217.

47. McCulloch, Embodiments, p. 148.

48. McCulloch, Embodiments, p. 283.

49. McCulloch, Embodiments, p. 287.

50. D.E. Wooldridge, The Machinery of the Brain (New York, 1963), chapter 9. See also K.S. Lashley, Brain Mechanisms and Intelligence: A Quantitative Study of Injuries to the Brain (New York, 1963), p. 100. See also Weiss' remarks in McCulloch, Embodiments, p. 103.

51. Merle B. Turner, Philosophy and the Science of Behaviour (New York, 1965), p. 193. Turner writes that: "Although there are troublesome initial conditions for judging an atomic event to be true or false, once these judgements are made, then there remains no conceptual freedom for ascertaining whether molecular propositions are true or false". It would seem that McCulloch has wholly neglected these "troublesome initial conditions". For further discussions on this issue see the statement by Carnap quoted in: Dewey and Bentley, Knowing and the Known, pp. 133-34, as well as L. Susan Stebbing, A Modern Elementary Logic (London, 1943), pp. 139-41. Stebbing points out two possible meanings for the logical expression "p" implies "q" which is fundamental to McCulloch's equation of a neuron firing with an atomic proposition. One meaning is that "p" could not be true and "q" false. The second meaning is "p" cannot be true and "q" false. The "could not" relationship is so by the convention of language, by definition. The "cannot" relationship is referred to as a "weaker" relationship by Bertrand Russell, and even though this meaning is unclear, it seems safe to assume that the "could not" reletionship must hold in all cases, involving the idea

of necessity, whereas the "cannot" relationship apparently holds most of the time. This "weaker" relationship is called "material implication" by Russell whereas the "could not" relationship is termed "entailment" by G.E. Moore. But McCulloch, although acknowledging his debt to Russell, seems inconsistent in his use of "materially implies". He defines a "true signal" as one which "materially implies" another event, which, if we stay with Russell's definition, excludes the idea of necessity but happens most of the time or even every time we observed it. Later, however, McCulloch refers to "a necessary connection between events" which occurs whenever there are "true signals". In short, a "true signal" for McCulloch presupposes a "necessary connection between events, as already pointed out, is physical determinism even though McCulloch refers to it as "limited causality".

Stebbing goes on to point out that: "Our discussion of material implication should have made clear that knowledge of the truth or of the falsity of "p" or "q" is alone relevant to determining whether "p" implies "q"; provided "p" is false, "q" can be any proposition; provided "q" is true, "p" can be any proposition. Hence we are entirely unconcerned with what "p", "q" may be about; thus we pay no attention to what is commonly called the meaning of the proposition". This position is; of course, consistent with Brillouin's position in Scientific Uncertainty and Information, pp. 12-13.

To provide for more clarity we shall mention three additional quotations, again: Turner, Philosophy and the Science of Behaviour, pp. 143-44, and especially p. 153 where he writes of logical empiricism: "Seeking certainty and elevating demonstrable proof to the role of exemplary knowledge, he has succumbed to the invitation to justify factual inference on the same apodictic pretense as logical inference. . . Since Hume, it has been common knowledge that experiential inference can never be the subject of demonstrable proof". And, finally, see: Dewey and Bentley, Knowing and the Known, pp. 526-27.

52. Both Drs. Kohler and Klüver point to this ~~differently~~ in the record of the symposium which is reported following McCulloch's essay: "Why the Mind is in the Head" in Embodiments. Dr. Klüver's comment seems definitive: "Ideas, logical structures, and meanings are in and of a world that is different from the world of physiological and psychological events that occur in the process of having ideas, or recognizing and enunciating propositions and meanings, even if such physiological events should represent events in reverberating circuits".

53. McCulloch, Embodiments, p. 116.

54. McCulloch, Embodiments, p. 86.

55. John Lilly, Man and Dolphin (New York, 1961), p. 144.

56. Von Bertalanffy, "A Biologist looks at Human Nature," p. 35; and Slijper E.J., Whales (London, 1962).

57. K.S. Norris, Whales, Dolphins and Porpoises (Los Angeles, 1966), p. 149. See also R.L. Conly, "Our Friends in the Sea," The National Geographic Magazine (Washington D.C., Sept. 1966), pp. 396-425.

58. Norris, Whales, Dolphins and Porpoises, p. 509.

59. It is more correct to say that a correlation between complex behavior and complex brain structure is almost universally assumed, but the degree of correlation is in such dispute that it is not generally used to predict any specific behaviour from the basis of neuroanatomical findings. The porpoises' fantastic accoustic capacity is to be expected from their prominent auditory brain sections but beyond this most investigators demand behavioral evidence. Turner, Philosophy, p. 179. Turner claims that: "Perhaps nowhere in science are the issues of reductionism and of the hierarchy of explanation more debated than they are in psychology . . . but it is a long way indeed from behaviour to the constructs of learning and personality theory to the microstructure of physiology. No one pretends to fit motivational or reinforcement theory into the family to hypotheses deducible within an extant physiology."

60. A.S. Romer, "Phylogeny and Behaviour with Special Reference to Vertebrate Evolution," Behaviour and Evolution, eds. Anne Roe and G.G. Simpson (New Haven and London, 1958), p. 73.

61. Arthur F. Bentley, Inquiry into Inquiries (Boston, 1954), pp. 335-337.

62. Provided of course it were not so defective as to prevent his motor functioning and sensory capacity, in other words, provided it were on a par with the functioning of brains of a lesser degree of complexity.

63. W. Ross Ashby, Design for a Brain (London, 1960). This is in no way intended as sarcasm as will be seen subsequently.

64. To be specific, the Behaviorists, and of necessity all Physiological psychologists.

65. George Herbert Mead, Mind, Self and Society (Chicago and London, 1934). In North America the significance of cultural context as a genetic factor in the growth of thought began with George H. Mead.

66. Ashby, Design, pp. 40-41. Ashby writes the following: "As the organism and its environment are to be treated as a single system, the dividing line between "organism" and "environment" becomes partly conceptual, and to that extent arbitrary." Additionally, this wholistic approach underlies the techniques of all ethological investigation. See Konrad Lorenz: Evolution and the Modification of Behavior.

67. McCulloch, Embodiments, p. 86.

68. McCulloch is consistently careful to demand that the definition of the functions that any of his postulated circuits can perform must be "finite and unambiguous". Also see Brillouin's very interesting discussion of this process of definition in Scientific Uncertainty and Information, pp. 12-13.

69. McCulloch, Embodiments, p. 226.

70. McCulloch, Embodiments, p. 159.

71. McCulloch, Embodiments, p. 162.

72. McCulloch, Embodiments, pp. 364-65, also pp. 257 and 266.

73. Norbert Wiener, God and Golem (Cambridge, Mass., 1964), p.14. See also: Norbert Wiener, A. Rosenblueth and Julian Bigelow, "Behaviour, Purpose and Teleology", Philosophy of Science, X (1943), pp. 18-25.

74. Ashby, Design, p. 58.

75. Benjamin Ricci, The Physiological Basis of Human Performance (Philadelphia, 1967).

76. Donald MacKay, "Mindlike Behaviour in Artefacts", The Modeling of Mind, K.M. Sayre and F.J. Crosson, Eds. (Notre Dame Ind., 1963), pp. 225-43.

77. Wiener, God and Golem, p. 63. He writes: "A goal-seeking mechanism will not necessarily seek OUR goals unless we design it for that purpose, and in that designing we must

foresee all the steps of the process for which it is designed . . ."

78. John Dewey, Human Nature and Conduct (New York, 1922), p. 77. "External reasonableness or adaptation to ends precedes reasonableness of mind. This is only to say that in morals as well as in physics things have to be there before we perceive them, and that rationality of mind is not an original endowment but is the offspring of intercourse with objectives adaptations relations . . . a view which under the influence of a conception of knowing the like by the like has been distorted into Platonic and other objective idealisms".
I read "knowing the like by the like" as the most pithy description of McCulloch's use of the logico-mathematic operations to discover logico-mathematic operations.

79. K.P. Oakley, Man the Tool Maker (London, 1954), p. 62.

80. Oakley, Man the Tool Maker, p. 62.

81. W. Kohler, The Mentality of Apes (New York, 1927), p. 99.

82. McCulloch, Embodiments, p. 265.

83. See MacKay's discussion of this in "Mindlike Behavior of Artefacts", pp. 232-6.

84. Dewey and Bentley, Knowing and the Known, pp. 149-67. "The particular type of indirection that is to be found in behaviour we shall call SIGN, and we shall so use the word "sign" that where sign is found we have behaviour, and

where behaviour occurs sign-process is involved".

85. E.G. Boring, Experimental Psychology, p. 636.

86. Carl Welty, "The Geography of Birds," Scientific American, 118, July 1957.

87. Dewey and Bentley, Knowing and the Known, chapter 6.

88. Noam Chomsky, "Language and the Mind", Psychology Today, Feb. 1968, p. 48.

89. McCulloch, Embodiments, p. 220.

90. Brillouin, Scientific Uncertainty, p. 12. Clearly, McCulloch is familiar with Attneave as well; in Applications of Information Theory to Psychology (New York and London, 1959), p. 1, Attneave writes: "The technical meaning of the word "Information" is not radically different from the everyday meaning; it is merely more precise". He then goes on to define information as: $H = \sum Pi \text{ Log } \frac{1}{pi}$.

91. Brillouin, Scientific Uncertainty, pp. 22-25.

92. Brillouin, Scientific Uncertainty, p. 24.

93. McCulloch, Embodiments, p. 116.

94. For a comprehensive review of the prevasiveness of the "mind-body problem" in the twentieth century see Herbert Feigl's discussion of dualism in volume two of Minnesota Studies in the Philosophy of Science (Minneapolis, 1956). And further discussion is to be found in Arthur Koestler, The Act of

Creation (London, 1964), pp. 145-77. Koestler attacks the assumption that the mind is "consciousness" and puts forward an extensive summary of the "unconscious" facet of mind. In addition to Koestler see Von Bertalanffy both in his recent book: Robots, Men and Minds (New York, 1967), and in his rebuttal to John Lach's review of his article "The Mind-Body Problem; A New View", Psychosomatic Medicine, XXIV (New York, 1964), pp. 29-44. Dr. Lech's review appeared as "Von Bertalanffy's New View", Dialogue, Vol.XV (Kingston, 1965), 365-70. Von Bertalanffy's rebuttal was published as "Mind and Body Re-examined", Journal of Humanistic Philosophy (Pelo Alto, Calif., Fall 1966), pp. 113-138. Finally, John Dewey and Arthur Bentley present a complete if implicit analysis of the underlying perceptual assumptions and logical distortions that have rendered the problem philosophically insoluable in Knowing and the Known.

95. McCulloch, Embodiments, p. 72.

96. McCulloch, Embodiments, p. 158.

97. McCulloch, Embodiments, p. 158.

98. McCulloch, Embodiments, p. 229.

99. McCulloch, Embodiments, p. 389.

100. Theodore H. Bulloch, "Evolution of Neurophysological Mechanism," pert II, Physical Bases of Behavior; no. 8, eds. Anne Roe and G.G. Simpson (New Haven and London, 1958), p. 166.

Bulloch writes: "But at bottom we do not have a decent inkling of the neuronal mechanism of learning, or the physiological substratum of instinctive patterns, or virtually any complex behavioral manifestation."
See also: Dewey and Bentley, Knowing and the Known, p. 51. Toulmin, Argument, p. 230, also points out that reductionism has a general weakness as a logical form of argument, "The weaknesses of the reductionist approach are most obvious in the case of astronomy and history, but they are in fact general". Further p. 231 he states: "Where a reductionist theory genuinily denies the type jump from our data and backing to our conclusion, its effect is not to solve our epistemological problems, but to shirk them."

101. Ludwig Von Bertalanffy, "The Mind-Body Problem: A New View," Psychosomatic Medicine, XXIV (New York, 1964), 29-44.

102. R.H.M. Elwes, Spinoza's Works (Covent Garden, 1891), Vol. II, 97-8.

103. Buchler, Justus, The Metaphysics of Natural Complexes (New York, 1966), see chap. 3 on "Ontological Parity."

104 George Herbert Mead, Philosophy of the Act (Chicago, 1938), p. 515.

105. Jean-Paul Sartre, Being and Nothingness, trans. Hazel E. Parnes (London, 1957).

106. This is a fundamental lesson of the developmental psychology of Jean Piaget. See the discussion of

"Ego-Centricity" in J. McV. Hunt, Intelligence and Experience (New York, 1961),p.217.

107. Wooldridge, Machinery, p. 237.

108. Wiener, God and Golem, p. 69.

109. John Dewey, Democracy and Education (New York, 1916), p.178.

110. Dewey, Experience and Nature, p. 124.

111. That an assumption of irreversibility underlies all evolutionary considerations can be seen in the discussion of general evolutionary principles in Roe and Simpson, Behavior, p. 21. See also Brillouin, Scientific Uncertainty.

112. Dewey, Logic, p. 10.

113. John Dewey, Reconstruction in Philosophy (New York, 1920).

114. McCulloch, Embodiments, p. 154.

115. Dewey, Logic, pp. 159-80.

116. This is simply, but fundamentally, the acceptance that organisms and their behavior present themselves to us now as ongoing systems rather than static kinds. This frees us from the obligation to explain all experience in terms of the present, by justifying inferences from archeological, anthropological and ethological grounds. Von Bertalanffy makes the point clear with respect to biology by stating: "Thus the theory of open systems opens a new field in physics, and this development is even more remarkable

because thermodynamics seemed to be a consummate doctrine within classical physics. In biology, the nature of the open system is at the basis of fundamental life phenomena, and this conception seems to point the direction and pave the way for biology to become an exact science." Von Bertalanffy, "Theory of Open Systems in Physics and Biology", Science, (Jan. 13, 1950) CXI, 28.

117. Dewey and Bentley, Knowing and the Known, p. 108.

118. Konrad Lorenz, "The Evolution of Behaviour," Scientific American (New York, Dec. 1967), p. 9.

119. Konrad Lorenz, Evolution and Modification of Behavior (Chicago 1965).

120. John Dewey, Logic, p. 186.

121. G. Bateson, Social Planning and the Concept of 'Deutero-Learning' in Relation to the Democratic Way of Life, Conference on Science, Philosophy and Religion, Second Symposium (New York, 1942).

122. I mean in this context that the fact that the observer of a machine which is behaving purposefully sees the purpose is no ground for saying that the machine has any intent or awareness of the purpose it seeks.

123. H.W. Burns and C.J. Brauner ed., Philosophy of Education (New York, 1962), p. 123.

124. Roe and Simpson, Evolution, p. 430.

125. Mead, Mind, Self and Society, introduction.

126. Dewey and Bentley, Knowing and the Known, pp. 156-58.

127. Isaac Asimov, An Intelligent Man's Guide to Science (New York, 1960), II chap. 1.

128. Dewey and Bentley, Knowing and the Known, p. 69.

129. Arthur Koestler, The Act of Creation, pp. 145-77.

130. Ludwig von Bertalanffy, "The Theory of Open Systems in Physics and Biology," Science, CXI (Washington D.C., Jan. 13, 1950), 23-29.

131. Ludwig von Bertalanffy, "Mind and Body Re-examined," Journal of Humanistic Philosophy (Palo Alto, Calif., Fall 1966), pp. 113-38.

132. Bertalanffy, "Mind and Body Re-examined," p. 136.

133. Dewey, Experience and Nature, p. 9.

134. Dewey, Experience and Nature, p. 60.

135. Dewey, Logic, chapter 8.

136. Dewey, Democracy and Education, p. 176.
See also: Brillouin, Scientific Uncertainty, p. 142 and pp. 34-38 and p. 99.

137. However, Dewey's conception of doubt does not make it a quality of any ultimate reality but merely a constant

occurrence in our everyday experience.

Dewey, Logic, pp. 105-6.

138. Roe and Simpson, Behavior, pp. 50, 73, 274, 277.

139. Roe and Simpson, Behavior, p. 355.

140. Roe and Simpson, Behavior, p. 154.

141. Roe and Simpson, Behavior, p. 26.

142. George Herbert Mead, The Philosophy of the Present (Chicago and London, 1932), p.

143. McCulloch, Embodiments, p. 266.

144. Ashby, Design, p. 1.

145. Bertalanffy, "The Theory of Open Systems," p. 25.

146. John Dewey, Creative Intelligence (New York, 1917), p. 55.

147. Charles S. Pierce, Essays in the Philosophy of Science (New York, 1957), pp. 228-33 and pp. 253-54.

148. Karl Popper, The Open Society and its Enemies (New York, 1963), II. pp. 374-7.

149. W. Sluckin, Minds and Machines (Montreal, 1954), pp.171-73. "In pure thinking there is nothing at all to observe", p. 173.

150. John Dewey, Experience, p. 428.

151. H.S. Thayer, The Logic of Pragmatism (New York, 1952).

152. Dewey, Experience and Nature, p. 424.

153. That this is the acceptance of Pierce's fallibilism can be seen in C.S. Pierce, Essays in the Philosophy of Science (New York, 1957), p. 233.

154. Dewey and Bentley, Knowing and the Known, p. 65.

155. Dewey and Bentley, Knowing and the Known, pp. 270-86.

156. Dewey, Logic, chapter 24.

157. Dewey, Logic, chapter 24.

Part III

158. Dewey, Democracy and Education.

159. Plato, The Republic, trans. F.M. Cornford (New York, 1957).

160. Brillouin, Scientific Uncertainty, pp. 12-13.

161. Bateson's reception of such a concept is enthusiastic to say the least: "Wiener has argued that these two concepts are synonomous; and this statement in the opinion of the writers, marks the greatest single shift in human thinking since the days of Plato and Aristotle, because it unites the natural and social sciences and finally resolves the problem of teleology and the body-mind dichotomy which occidental thought has inherited from classical authors."

J. Ruesch and G. Bateson, Communications (New York, 1951), p. 177.

162. Dewey, Democracy and Education, p. 55.

"Education is not infrequently defined as consisting in the acquisition of those habits that effect an adjustment of an individual and his environment. The definition expresses an essential phase of growth. But it is essential that adjustment be understood in its active sense of control of means for achieving ends. If we think of a habit simply as a change wrought in the organism, ignoring the fact that this change consists in ability to effect subsequent changes of the environment we shall be lead to think of "adjustment" as a conformity to environment as wax conforms to the seal which impresses it."

163. This represents more that the mathematical difference between finite sets characterized by equiprobability and those mathematical problems dealt with by statistical methods. It is the difference between manipulation of formalistic entities and operations of inclusion, exclusion regulated by observation and experimentation.

164. This is seen most clearly in Wiener, Bigelow and Rosenblueth, "Behaviour, Purpose and Teleology".

165. Wiener, God and Golem, p. 63.

166. B.F. Skinner, Science and Human Behavior (New York, 1953).

167. Dewey, Logic, pp. 495-6. See also Dewey, Experience, pp. 423-424.

168. Here Mead's theory of value is very like Dewey's. G.H. Mead, Mind, Self and Society, p. xxxiii.

169. B.F. Skinner, Walden Two (New York, 1966).

170. Skinner, Walden Two, p. 16.

171. Carl Rogers, "The Place of the Person in the New World of the Behavioral Sciences," Reading in Learning and Human Abilities, ed. R.E. Ripple (New York, 1964), p. 21.

172. John Dewey, "Ethical Subject Matter and Language," Journal of Philosophy, XLII (Dec. 20, 1945), pp. 701-712.

173. Mead, Mind, Self and Society, xxxiii.

174. Skinner, Walden Two.

175. In this case McLuhan's term "Global Village" is the apt description for the phenomenon under discussion.

176. This is really the fundament argument running through all of Lorenz's On Aggression (New York, 1966).

177. Konrad Lorenz, Evolution and the Modification of Behavior (Chicago, 1965).

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