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RETICULAR FORMATION AND CHOICE OF BEHAVIOR

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The important contribution of Morussi and Magoun was the re-interpretation of the function of the brain stem, mainly of pons and midbrain. Before the war many of us thought of the brain as an organ consisting of long fibre tracts, serving sensory and motor function. Stimuli travelled along the fibre paths from the periphery to the cortex. At arrival in the cortex stimuli were being transformed into conscious experience. How this was achieved, nobody could understand. Moruzzi and Magoun (1) discovered that section of the long fibre tracts did not interfere with the state of consciousness, but lesions of a system of interneurons (the reticular system) at the level of pons and midbrain did. They also found that the reticular system received an input from more than one sensory modality. Clinical neurology was in full agreement with these findings and interpretations, since it was known that lesions on the border of midbrain and the region central to it (the diencephalon) had a strong modifying effect on the state of consciousness. The problem of the relationship between the brain and consciousness appeared in a new light. Everybody rushed to find out more about the "reticular system". This happened in the early fifties. The relevance of the borderland between midbrain and diencephalon for the level of consciousness is still acknowledged. However, from the outset it was felt that the reticular formation lacked the differentiation necessary for the explanation of mental experience (see R.W. Gerard's final comments in the meeting on the Reticular Formation in 1958) (2). It has never been shown that the reticular formation was the organizer of behavior. This requires among other things the ordering of temporal sequences and the possibility of choice.

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1 Moruzzi, G. and H.W. Magoun: *Brain Stem Reticular Formation and Activation of the EEG*; EEG and Clin. Neurophysiol. 1 (1949) 455-473.

2 Gerard, R.W.: *Final Summary*. In: Reticular Formation of the Brain. Eds. H.H. Jasper et al., pp 745-754. Little Brown & Comp., Boston, Toronto, 1958.

The limitation of the RF became more apparent when the contributions to behavior of other parts of the brain were studied in more detail. I mention the hypothalamus, the amygdala, the hippocampus, the cingulate cortex.

For learning behavior the frontal lobe and the "limbic system" are indispensable. The handling of spatial relations which is fundamental to behavior, is assigned to the parieto-occipito-temporal cortex. Taking "behavior" in its full sense the entire diencephalon and the telencephalon appear to be involved. It seems unreasonable to stretch the term "reticular formation" over all these parts of the brain for the sake of argument only. It is the brain, not the reticular "core" which organizes behavior. The "reticular core" is a system of interneurons governing motor function -- somato-motor and visceral motor as well. In this sense it can be treated as the first stage toward organization.

Two questions are to be answered.

1. How can the generalized effect of lesions of the midbrain region on widespread cerebral functions be explained?
2. In how far are the considerations of McCulloch and Bill Kilmer positive contributions to the cybernetic viewpoint of cerebral function?

In answer to 1:

It should be remembered that the volume of the midbrain is small in comparison to the volume of the endbrain. From the midbrain fibre tracts diverge towards endbrain structures lying far apart. On the other hand: endbrain tracts converge toward the midbrain and beyond it. If we think of the brain as a system of circuits, interruption of the place of convergence could well have a widespread effect. This, however, does not prove that the midbrain, or, a fortiori part of the midbrain, governs cortical function. We can kill an animal by choking. This does not prove that the neck governs respiration.

In answer to 2:

The importance of McCulloch's and Bill Kilmer's work lies in the shift of emphasis towards the "black box". In early days the main contribution of cybernetics to the knowledge and understanding of clinical neurologists was the introduction of controlled loops into biology.

The concepts of positive and negative feedback, of feed-forward, of servo-mechanism could readily be applied to the description of nervous function. Here the main emphasis was put on the relation between input and output. But the black box remained black.

In recent years we have shifted our attention to the black box itself. Waddington (3) describes the process of growth. This can only be described as an organized complex of processes. This process is "self-governing" in the sense that under adverse circumstances, like increase of temperature or reduced oxygen supply, it finds its own ways towards further development. The inputs from the environment are strongly selected, therefore the most intriguing part of the process is not the relation between input and output as such, say the relation between oxygen taken up and carbon acid given off, although it gives a general impression of metabolism. The important processes are those within the organism, such as the organization of development and maintenance. At birth all living organisms are equipped with two properties: 1) inborn patterns of behavior, 2) ability to learn: i.e., to adapt behavior to the environment.

Adaptation to the environment is only possible if the animal moves and acts. His actions are part of behavior. Therefore his contacts with the surroundings are derived from behavior. This behavior, modified by the environmental constraints and supports, returns to the organism as its input. In other words: the output (behavior) determines the categories of the input. The input is the product of the output (behavior) + the modification thereof by the environment via the necessary learning process.

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3 Waddington, C.H.: *Determinism and Life* In: The Nature of Mind. Edinburgh Univ. Press, Edinburgh, 1972.

The present work on the "reticular system" foreshadows this trend of thinking. I must add that similar concepts can be found in McKay's papers since +/-1950, but he does not consider the technical implications as is done here.