Meetings

Information and Control Processes in Living Systems

The development of distributive models of biological function and the consideration of hierarchical control mechanisms were the themes at the fifth of a series of conferences on information and control processes in living systems held in Pacific Palisades, California, 23–26 February 1969. The emphasis at this conference, as well as at other conferences in this series, was on creative discussion between members of different disciplines aimed at the development of significant new correlations or recognition of profitable future lines of inquiry in the area of information processing in the nervous system.

The conference began with a consideration by Otto H. Schmitt (University of Minnesota) of dispersive and interpenetrating domain models for information processing in the nervous system. He introduced the notion of a temporal-spatial representation as the dispersing variable in a distributed holographic model of the nervous system, a model which fits well with much of what is known about perception as well as the electrophysiology and neuroanatomy of the nervous system. K. Nicholas Leibovic (State University of New York, Buffalo) then cited the parallel development of progressively more complex sensory organs and brain structure as one moves up the phylogenetic tree. He suggested that the forces of evolution have produced a hierarchical control in complex nervous systems that permits subsystem autonomy for performance of routine functions.

The concept of hierarchical organization again appeared in the discussion by Albert G. Wilson (Douglas Advanced Research Laboratories, Huntington Beach, California) who presented a paradigm for ordering cosmic bodies in astronomy. He described three classes of hierarchical structures: (i) modular hierarchies wherein stable, semiautonomous modules aggregate into higher level modules which themselves serve as submodules for supermodular systems; (ii) control hierarchies; and (iii) polyarchies. By plotting the log mass of cosmic bodies versus their mass density (number of grams per centimeter), three natural, hierarchical levels are revealed. He suggested the possible applicability of such models of hierarchical organization found useful in astronomy to the study of control processes in living systems. Ernst O. Attinger (University of Virginia Hospital, Charlottesville) then presented evidence to support the existence of such a hierarchy of control in the mammalian oxygen transport system.

Hussein El-Sum (El-Sum Consultants, Atherton, California) introduced the discussion on holographic concepts and transform principles that suggest models for distributed biological information processing and control by presenting the conferees with a thorough exposition of the principles of holography.

Some interesting features that brain information processing and the physical phenomenon of holograms may have in common were developed. For example, one attractive feature of the hologram is its capability for massive storage of information. One can comfortably fit 10^5 bits of information in one plane and, considering all planes available in a film, can accommodate 10^9, or even 10^{12}, bits of information. Man has long been amazed at the great amount of data that the human brain can store, correlate and retrieve; thus, the hologram provides us with an excellent example of such data optimization. Another feature of the brain difficult to explain is its ability to use many different points of entry for the retrieval of a specific item of information. The hologram can reproduce an entire image by using just a piece of the original image in the reference wave; therefore, it too allows output of an entire information set using any point of entry. Still another point of analogy pertains to the ability of the brain to use both temporal and spatial referents for retrieving information. A challenge to the brain-hologram analogy was brought forward in response to data cited by one of the conferees on the strong temporal relation observed in recovery from memory loss by trauma, suggesting that memory scanning possibly has a temporal ordering. This was quickly resolved since the hologram likewise can be made using either a temporal or spatial reference.

In order for the brain to store the great amount of information that it does, it may be necessary for a single neuron to be a member of a number of different specific information sets of neurons. Given one neuron (A), it may be active in a certain memory set (X), or as a correlation circuit between memory X and Y, or even as a component of Y memory and X memory simultaneously. Likewise in the hologram any point on the film can be active in containing the information for different objects depending upon: (i) the storage of physical alterations at that point in the film induced by the reference wave, and (ii) its response to a particular reference wave in conjunction with all the points surrounding it. The essential feature here is the capability of using an individual point as an active part or carrier of many different information sets. One can change an object in an object beam and change the reference angle beam and so obtain multiple information on the same plate using the same points. A final feature of analogy between the brain and holograms is the Markovian factor or the distributivity feature inherent in the mathematics of both phenomena.

Objections were raised as to the efficacy of using the hologram as a model for the brain. One difficulty that arose was a comparison between the technical precision required in the construction and the retrieval of a hologram and the limits of technical precision that could be envisioned as operable within the constraint of brain structure as it is known. A further question arose concerning how temporal ordering could be accomplished in the brain using current knowledge of the function of neurons. An even more crucial difficulty in application of the hologram analogy is the requirement of fixed geometric positions in the hologram which has no counterpart in the fluid milieu of the brain.

Julian H. Bigelow (Institute for Advanced Study, Princeton, New Jersey) then reviewed the Longuet-Higgins model, which is an extension of holography techniques from light to sound (phonoholograms). The essential feature brought out in this discussion was that the exact geometry of the optical hologram, for instance, is not a fundamental requirement, but rather that many methods for the storage and recovery of information about both amplitude and phase (or their counterparts) might serve in analogous situations.

Willard F. Libby (University of California at Los Angeles) opened up the discussion on possible cell and molecular levels of interaction by examining the possibility of communication between molecules, for example, between the subunits of hemoglobin. The level of understanding of hemoglobin structure and the kinetics of association of the alpha and beta subunits into hemoglobin provided the opportunity for reflections on how the heme groups "communicate" with each other, such that when one heme has acquired an oxygen, the other does not have to pay the same price in free energy for acquiring an oxygen as did the first. Possibilities suggested were that electronic shift in the proteins attending the heme due to the first oxygen attachment lowered the required association energy for other hemes, or that the charged groups just outside of the heme plates relaxed symmetrically due to heme polarization induced by oxygen attachment and thus lowered the initial entry energy barrier. William R. Carroll (National Institutes of Health) pointed out that the many subunits of glutamic acid dehydrogenase disassociate when steroid hormones are present, possibly because electronic shifts cause an entropy-based reconfiguration (steric shift). This association greatly affects the activity of the enzyme. He further pointed out that there are many such examples of "communication between molecules." However, two basic questions remained unresolved—if this kind of molecular interaction should indeed be called "communication" at all, and how such interaction could be active in information storage and transfer in the nervous system.

Melvin Klein (University of California, Berkeley) provided an added dimension to a possible molecular explanation of neuronal subsystem interactions by examining the role of liquid crystals (mesophases) as possible elements in molecular communication. The interchangeable smectic and nematic crystalline phases can order spontaneously, orienting in electric and magnetic fields into specific three-dimensional configurations. These dynamic structures then can be modulated chemically or thermally, and respond to subsequent mechanical stresses or electrical fields. It was pointed out that many biological molecules (DNA, RNA, and protein alphahelices) exhibit similar properties and that perhaps the brain might contain information in such dynamic geometrical structures which are continually being shifted and recorrelated by neuronal impulses. The question arose, however, how this information might be stored and accurately retrieved from what is known about brain tissue structure.

Francis O. Schmitt (Massachusetts Institute of Technology), in discussing the cell and molecular level of brain structure, noted that there exists much intercellular space in brain tissue filled with hyaluronic acid fibers, ions, and proteins, all packed into approximately 150-angstrom tubes. He speculated that there might be some analogy between the behavior of these molecules confined in small spaces and paracrystalline structures. These intercellular spaces are continuous in the brain, and hydration of their hyaluronic acid, with the association of water molecules, could effect ion movement by filling or ordering intercellular space. Another potential role that molecules might play in information processing in the nervous system could be facilitated by the differential movement of metabolites and gene products along the numerous microtubules and neural filaments of brain axons. The presence of different materials at synaptic junctions, controlled by electrical activity of neurons or feedback to the genome might provide a molecular rationale for specific neuronal interactions, and the establishment of dynamically interacting neural nets. The differential activity of microtubules, coupled with what is known of differential RNA synthesis, vesicle deposition at axon endings, and the principles of allosteric molecular recognition (ab-ag, enzyme-substrate interactions) all provide some circumstantial basis for the possibility of alteration of a building stone or structural unit of synaptic membranes which could serve adequately as a "recognition factor" between neurons of the same set. For example, the successful regeneration of the fibers from the optic tectum and their proper reconnection to the optic nerve would require such specific recognition.

Josiah Macy, Jr. (University of Alabama), in describing the components of a large hierarchical computing complex which serves a number of research laboratories, emphasized the problem of constructing indexing techniques to find stored information in computer memory. He drew an analogy to human information processing in the central nervous system and noted that present-day computer systems are not adequate to handle the massive amounts of data that the human brain is capable of storing and retrieving.

John H. Milsum (McGill University) characterized the ocularmotor control system as an open-loop system that has been optimized by evolution. When an organism's response to some aspect of its environment requires a consistent set of neural controls for survival, then the original open-loop neural pathway becomes a closed-loop, autonomous operation. He cited what appears to be the accretion of longer, more complex control pathways in the nervous system through evolution, followed by a "streamlining" of these control modes by bypassing certain unused portions of the pathways. He then noted the interesting possibility that certain mental pathologies might be interpreted as a reopening of these discarded pathways which should be bypassed for normal, adaptive behavior.

Julian H. Bigelow (Institute for Advanced Study, Princeton, New Jersey) drew together much of what had been discussed by sketching the beginnings of a model of neuronal behavior analogous to the functional properties of holography. In his model the precise geometric constraints necessary for recovery of information with holographic optics were replaced by the concept of distributed storage of information in the nervous system, recoverable en masse by sampling with "strobing" scans using precise timing. This model provides a mechanism for erasure of information by inverse cancellation and incorporates the requirement for a conformal mapping of neuronal activity in the brain over convoluted rather than planar areas.

The conference, chaired by Otto H. Schmitt (University of Minnesota), was organized under the auspices of the Interdisciplinary Communications Program, formerly of the New York Academy of Sciences and now of the Smithsonian Institution (M. C. Sheles-nyak, director; Frank Fremont-Smith, director emeritus) and was supported by funds made available by NASA. An edited transcript of the proceedings is scheduled for publication.

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Forthcoming Events

October

14–22. Pan-Pacific **Surgical** Assoc., 11th congr., Honolulu, Hawaii. (H. DeVault, Room 236, Alexander Young Bldg., Honolulu 96813)

16–17. Association of **Earth Science Editors**, 3rd annual conf., Houston, Tex. (W. D. Rose, Kentucky Geological Survey, Univ. of Kentucky, Lexington 40506)

16–17. National Conf. on **Fluid Power**, Chicago, Ill. (W. R. Smith, NCFP, 3300 S. Federal St., Chicago 60616)

16–17. **Rapid Excavation,** 2nd symp., Sacramento, Calif. (H. L. Hartman, Dean of Engineering, Sacramento State College, Sacramento 95819)

17–19. Society for **Social Responsibility in Science**, New Haven, Conn. (H. Bloom, SSRS. 221 Rock Hill Rd., Bala-Cynwyd, Pa. 19004)

18–23. American Acad. of **Pediatrics,** Chicago, Ill. (G. E. Hughes, Secretary for Education Affairs, 1801 Hinman Ave., Evanston, Ill. 60204)

19–22. American **Mining** Congr., San Francisco, Calif. (R. W. Van Evera, Ring Bldg., Washington, D.C. 20036)

19–25. American College of **Gastroenterology**, 34th annual, Houston, Tex. (D. Weiss, Executive Director, ACG, 33 W. 60 St., New York 10023)

20–21. **Polymer-Modified Hydraulic Cements** Symp., Philadelphia, Pa. (H. B. Wagner, Dept. of Chemistry, Drexel Inst. of Technology, Philadelphia 19104)

20–22. **George H. Hudson Symp.,** 5th annual, Plattsburgh, N.Y. (G. F. Kokoszka, Dept. of Chemistry, State Univ. College, Plattsburgh 12901)

20–22. American Assoc. of **Stratigraphic Palynologists**, University Park, Pa. (A. Traverse, Dept. of Geology and Geophysics, Pennsylvania State Univ., University Park 16802)

21–24. **Optical** Soc. of America, 54th annual, Chicago, Ill. (M. E. Warga, The Society, 2100 Pennsylvania Ave., NW, Washington, D.C. 20037)

21–25. Association of **Engineering Geologists**, 12th annual, San Francisco, Calif. (P. Vardy, AEG, P.O. Box 985, San Francisco 94101)

23–25. American **Astronautical** Soc., Las Cruces, N.M. (J. Penwarden, New Mexico State Univ., Las Cruces)

24–26. **Orton** Soc., 20th annual, New York, N.Y. (V. A. Graff, The Society, 15 Claremont Ave., New York 10027)

25–29. American Soc. of **Anesthesiol-**