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INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
00 TRIESTE (ITALY) - P.O.B. 586 - MIRAMARE - STRADA COSTIERA 11 - TELEPHONE: 2240-1
CABLE: CENTRATOM - TELEX 460392 - I

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COLLEGE ON NEUROPHYSICS:
"DEVELOPMENT AND ORGANIZATION OF THE BRAIN"
7 November - 2 December 1988

"Brain Waves: Origins, Evolution and Significance"

and

"Information Processing in the Nervous System"

Theodore H. BULLOCK
University of California, San Diego
School of Medicine
Department of Neurosciences
La Jolla, CA
USA

Please note: These are preliminary notes intended for internal distribution only.

Lecture Notes November 30, 1988

BRAIN WAVES: ORIGINS, EVOLUTION AND SIGNIFICANCE

Theodore Holmes Bullock
University of California, San Diego, La Jolla, CA 92093

I. Introduction

A. Ongoing compound field potentials of organized neural assemblies are unpredictable from extensive knowledge of cellular physiology; hence a descriptor of the state of neural activity needful of study in its own right, apart from clinical utility.

B. Current view is that micro-EEG is an information-rich sign, with microstructure both in time and space; a chaotic dynamical system with correlation dimensions between 4 and >8.

C. We will consider it as a biological phenomenon and look at the natural history.

II. Origins

A. Spike contribution is very small; but after-potentials may be an important component.

B. Synaptic potentials are believed to be the largest contribution; but little solid basis.

C. Other sources are probably important from time to time or place to place: e.g. pacemaker, plateau, glial, vascular, ependymal potentials and hyperpolarization of long duration with membrane conductance decrease.

D. Since most generators are small parts of neurons, orientation is mostly random - thank goodness; possible slight statistical tendencies locally (e.g. cortical dendrites).

E. Since most generators are contributing events (p.s.p., after-potential, etc.) rather than regular rhythmic oscillations, the power spectrum is broad and EEG is not basically made up of rhythms or oscillations (with special exceptions such as alpha and theta waves).

III. Evolution

A. EEG as a high amplitude-low frequency activity (chiefly <40 Hz) is essentially a phenomenon of higher centers in higher vertebrates; but it is not dependent on lamination or cortex or brain size.

B. Ongoing compound field potentials in cord, medulla, cerebellum, and invertebrate higher centers is like that of the single cell: even broader spectrum which falls little until >300 Hz; mean amplitude at any frequency is low.

C. This may mean that vertebrates, especially mammals, evolved synchrony of low frequencies (measurable by volume of tissue at or above some coherence level, such as 0.5); but the synchronized percent of the population may normally be low, until seizures or large evoked potentials occur.

IV. Causal significance

A. Many EEG correlates with brain development and state are known; they are useful as signs of state or of events, such as cognitive events; but evidence that brain waves influence neurons is circumstantial.

B. Some speculate that the occasional high amplitude waves tend to modulate the generators that are properly oriented, in their subthreshold state or firing rate or phase.

C. Probably the "DC" potentials (<0.5 Hz), which are large but usually ignored, are more important as modulators than the spectrum >0.5 Hz.

Lecture notes December 1, 1988

INFORMATION PROCESSING IN THE NERVOUS SYSTEM

Theodore Holmes Bullock
University of California, San Diego, La Jolla, CA 92093

I. Introduction

-This topic is a first order one for the CNS whose functions are to **decode** and **evaluate** input, **reencode** and **integrate** different inputs with present state and past history, **select** repertoire and goals, and **formulate** output.
-Although most attention today is on the componentry (hardware: channels, transmitters, hodology), major discoveries lie ahead in the system aspects (software: dynamics of interactions).
-Here we will survey briefly some of the major aspects from single cell integration to many-celled assemblies and their operations, such as recognizing - deferring to other lectures learning and motor command formulation.

II. Neuronal transducing, encoding and integration; single unit level.

-Output signals of cells include spikes (not always!), graded potentials of several kinds, many chemical transmitters and modulators.
-Both can be all-or-none or graded.
-Some act very locally, e.g. at synapses in the EM sense, some act more widely, over at least several micrometers.

-Codes are of two groups: spike and graded; each has several different types.
-Spike codes include: latest interval, mean interval over shorter or longer time; weighted mean with forgetting time constant; variance of intervals; pattern of intervals; number of spikes in a burst; phase relative to a reference. Textbook spikes per sec is only one of the possibilities.
-Nothing is digital, since there are not time slices agreed upon between sender and receiver; great variety of analogue, including pulse-coded analogue representations.

-Integrative variables are numerous - what determines output.
-A much longer list includes these:
1. Amount of impedance shift per mV of depolarization.
2. Nonlinearity of summation of heterosynaptic potentials.
3. Facilitation or its opposite, time course, succession, loci.
4. Effect of postsynaptic activity back upon presynaptic.
5. Non-classical synaptic rfesponses, e.g. postsynaptic hyperpolarizations of long duration, with decreased conductance.
6. Electrical transmission modulated by chemical and the reciprocal.
7. Spike threshold, as depolarization from resting potential.
8. Recovery cycle.
9. After-potentials, in sign, magnitude, and duration.
10. Accomodation, both in magnitude and rate.
11. Time constants; space constants.

12. Iterativeness under maintained depolarization.
13. Spontaneous pacemaker activity, in rate and regularity.
14. Invasion of pacemaker locus by input spikes, or not.
15. Others, incl. burstiness; rebound; erasability; hysteresis; autoinhibition.

-Labelled lines are a primary principal of animal nervous systems.
-Corollary of the principal of large scale parallel processing.

III. Integration and representation of information at the level of assemblies

-Can the operation of assemblies be understood in terms of circuits?
-Only as a first, very important, approximation.
-Other factors include the spatial form and distribution of axonal arbors and dendritic ramifications, the wide variety of chemical signals, the graded effectiveness of both chemical and electrical signals, even if weak, at distances of several micrometers to tens of micrometers. We need a new imagery to go beyond circuit thinking.

-Can the recognition of features and combinations of features be understood in terms of spatiotemporal patterns of activity in large sets of cells (model 1)?
-Only as a first, inadequate approximation.
-Adequacy of this large population model 1 is untestable.
-We must take account of the known instances of high level cells with complex requirements, approaching normal, ethologically significant stimuli.
-These are sometimes said to suggest a "grandmother cell" (model 2), usually used as an absurd strawman model.
-Very nearly proven is model 3: a small set of cells, approximately alike, not requiring to be activated in a particular spatiotemporal pattern, with complex requirements, e.g. a familiar face - model 2 with redundancy. These cells receive from model 1 and model 3 sets and may output to higher level model 1 and model 3 sets.