# Chapter 2
# Holonomic Brain Processes

## 2.1 GENERAL SCOPE OF THE HOLONOMIC BRAIN THEORY

**Comparative introduction.** Pribram's Holonomic Brain Theory[1] emphasizes that brain processes are parallel-distributed (as many contemporary computational models like Hopfield's, synergetic and other so-called associative neural nets mimic them[2]) as much as localized (as the main-stream neuroscientific experiments show). According to the holonomic theory, brain processes are multi-level and operate top-down (like Haken's synergetic computer model) as well as bottom-up (as the reductionist majority states). In contrast to conventional cognitive neuroscience, which advocated neurons and their networks, and in contrast to PDP neural-net models which are model-networks of "units" or "nodes" or "(formal) neurons" (and

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the true biological nature is usually not specified), the holonomic theory advocates parallel-distributed processing (PDP) in *dendritic networks*.

**Polarization patterns.** Thus, the connectionist models[3] are in general compatible with the holonomic theory under two essential re-interpretations. First, the "focus" of the multi-level brain model is transferred from neural cells to their dendritic trees and the "matrices of interaction-junctions" of these trees. *The activity of a "unit" or "formal neuron" does not correspond to a (biological) neuron any more*[4], *but to the fluctuating electric polarization at a location within the dendritic crisscross-ings.* Instead of a neuron firing or staying quiescent, we have depolarization (+) or hyperpolarization (–)[5] in parts of the dendrites, including their spines, especially in membranes and the surrounding (peri-membranous) space.

**Phase-Hebbian memory-storage.** Secondly, in addition to Hebbian computation based on a matrix of amplitude-correlations, the holonomic theory suggests that *phase*-encoding is essential. Thus, a combination or an essential extension of the memory-storage process, which I will call *phase-Hebbian*, is postulated to be much more effective.[6] This postulate of the holonomic theory has origin in the holographic analogy[7], because it is essentially connected with collective *oscillatory* phenomena.

Recently, many neuroscientists report relatively autonomous changes of complex *intrinsic* temporal dynamics, mainly involving membrane currents, inside a neuron with oscillatory activity (Marder *et al.*, 1996).[8] Intrinsic changes with memory effects may occur independently of, or concurrently with, changes in the synaptic transmission-rate, thus complementing them. Different synaptic strengths can cause opposite changes in an oscillator's response to a synaptic input at an oscillator's particular phase. Thus, modulation and control of neuronal oscillations might be very subtle. Marder *et al*. (1996, p. 13481) continue:

"Some neurons display intrinsic oscillatory properties involving periodic bursts of action potentials. Modification in the number of each channel type present in the membrane can change a variety of neuronal properties, including firing frequency and threshold, rate of spike repolarization, degree of postinhibitory rebound, burst amplitude and burst period."

**Dendritic nets.** What are dendritic networks in biological detail? Each neuron has tree-like dendrites. These branches of two or more neurons cross each other many times on very many sites, called junctions. They do not cross literally, of course, but they have contacts – synapses. Dendrites have membranes on their cylindric surfaces, and the charge-transfer processes on/through the membrane are naturally accompanied by electric fields.[9] So, dense bunches of dendrites (Hellwig, 2000) and their synaptic junctions are "swamped into" their own electric field. Relative differences of the electric field, called electric polarizations, constitute a pattern all-over the densely-connected webs of dendrites and other neuronal outgrows (dendritic spines, axons).