

# From Collective Electrodynamics to Collective Intelligence

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## 1. INTRODUCTION

Central idea of this paper is that there are similarities between the dynamics of a population of electrons, dynamics of a population of neurons and the dynamics of financial market participants. They all resonate and form waves i.e. dynamic fields, rather than point-to-point static networks assembled via Frege's compositionality principle which can be described by formal syntax. There are no sharp boundaries between atomic, molecular and cellular scale in spatial dimension or between phylogenetic, ontogenetic and epigenetic time scales. Transitions are always continuous phase shifts occurring in systems when they reach self induced criticality, rather than discrete boundaries objectively existing in the world. Sciences and their boundaries are human constructs.

The corollary idea is that neighboring fields interact, along both spatial and temporary scales. *Mutual entrainment* is a bi-directional dependence between micro and macro levels of the same phenomenon. In live organisms it is implied once we describe them as open systems. All animals exchange thermodynamic energy with their niche. Reductionists see only one way causality, in micro-to-macro direction. As we add the top-down leg of constraints to reductionistic bottom-up leg, we see that it makes no sense to ask how molecule interaction or butterfly moving its wings can cause a tornado. This is what physicist Carver Mead meant when he stated that "*Properties of each electron depend on the state of the entire ensemble*".

Neural scientist Gyorgy Buzsaki defines mutual entrainment as "*a measure of stability of two or more oscillators that they would not have on their own. Mutual feedback is the key to entrainment of oscillators of various frequencies and stabilities. When multiple single-cell oscillators with different intrinsic frequencies are connected together, they may produce a common intermediate global frequency. This is not simply a linear sum of the frequencies, because each neuron fires phase-locked to the global rhythm....The emergent population rhythm enslaves the behavior of individual units*".

New scales and emerging, higher complexity phenomena are formed by coherent waves resonating to a common rhythm. Life sciences examples are colonies of amoebas known as slime molds, polyp colonies of Sea Pens, multicellular organisms such as Trichoplax or Volvox, neural systems, brains, animals from amphioxus to vertebrates, swarms of insects, schools of fish, language based human societies and economies with divided labor. We identify some guideposts along the evolutionary road from quantum particles to collective human culture:

1. Universe is comprised of *wave fields*, continuous in space and time. Particles and solid matter are simply coherent waves.
2. Life systems are open systems. An organism is not separable from its environment and context.
3. Life forms are *dynamic* and *non-linear*, forming coherent oscillations and fast but continuous phase shifts. Like all of nature, they are *emergent fields*, not static structures.

4. New species *evolve* by symbiogenesis, not by mutations and natural selection. Higher organisms are interacting *populations* of lower life forms. Macro and micro levels of the same phenomenon *mutually entrain* each other.
5. Brains evolve in lockstep with evolution of organisms *locomotion* capabilities.
6. Neocortex and hippocampus convert *temporal* continua into *spatial* forms, accessible to memory recall.

## 2. EMPIRICAL EVIDENCE

Our field approach is grounded in neural science from which it is was extended downward to cellular biology and physics as well as upward to language and social fields, including markets and economies. Below we assembled the empirical evidence from works of seminal scientists applying field approach at different science scales.

### 2.1 Electron Populations

On the sub-atomic scale, Carver Mead concluded that *"Properties of each electron depend on the state of the entire ensemble"* adding, *"the mechanism for initiating an atomic transition is not present in an isolated atom; it is the direct result of coupling with the rest of the universe"*.

We can understand the behavior of quantum systems using only the wave properties of the matter. Problem of two coupled quantum systems in superposition state is essentially non-linear. This non-linearity leads to appearance of rapid transition which in traditional quantum mechanics were taken to be discontinuous. If the amplitude of oscillation of two atoms is identical, two atoms act like two small dipole resonators and energy is transferred from the first to the second. This energy transfer is called a photon. While this constitutes quantum jump, the transition is continuous. It only looks discontinuous because of non-linear, self-reinforcing nature of quantum transition. Thus we can view nature as being continuous in both space and time. The universe, like brain itself, is comprised of a truly enormous numbers of resonators.

### 2.2 Protein/Cell Populations

Lynn Margulis describes how populations of interacting bacteria through a phase shift deposited their separate DNA into a common nucleus and formed a higher life form, a eukaryotic cell. John Tyler Bonner describes phase shift from cells to organisms through primitive chemical signaling between unicellular organisms. Multicellular organisms exhibit mutual entrainment too. Gerald Edelman writes: *"As cells bind into specific collectives during ontogeny, the binding itself changes the form of the cell, by signaling back to the genome (phylogeny). Interactive cycle is established where the alteration of CAM binding alters morphology, and where changes in morphology alter CAM expressions"*.

### 2.3 Neuron Populations

Walter Freeman discovered mutual entrainment in mass action of neuron populations in mammalian brain. Instead of static structures, such as cognitivist view of Hebbian assemblies, he sees *"Sensory stimulation, neuromodulators and growth causing neurons to come together and form a mesoscopic pattern of activity. This pattern simultaneously constrains the activities of the neurons that support it. Every neuron participates in every experience and behavior....the*

*cooperation carries the entire hemisphere from one global chaotic attractor to the next". Buzsaki concurs: "If neurons are brought together [via oscillations] within a critical temporal window, it is immaterial for a target observer neuron whether the presynaptic neurons are connected. "*

## 2.4 Brains/Bodies

We described earlier the mutual entrainment in the movement of a swarm of insects, a school of fish and a flock of birds. J.J. Gibson states: *"We must perceive in order to move, but we must move in order to perceive."* Kurt Lewin adds: *"The person and his environment have to be considered as one constellation of interdependent factors. Life space is a field of forces - attractors and repellers with varying strength."*

## 2.5 Language/Nations

For George H. Mead, language developed before human consciousness and in fact made development of consciousness possible after long distance social communication was established. Esther Thelen is convinced that *"Perception modulates language and language modulates perception. It makes no sense to ask whether one determines the other."*

Even the structure of society itself is not fixed by some external factors but it is a dynamic process spanning two spatial scales. Berger and Luckmann in *Social Construction of Reality* write: *"By playing roles, individual participates in social world. By internalizing these roles, the same world becomes subjectively real to him. Society is a human product and at the same time man is a social product."*

## 2.6 Markets/Economies

Austrian economist Ludwig Von Mises is critical of Keynesian economists focusing just on a macro level of government and overplaying the role of central regulators. He argues instead that: *"Common man ...is like a sheep in the herd...yet the common man does choose. Society is not merely an interaction. It always involves men acting in cooperation with other men in order to let all participants attain their own ends."* George Soros adds: *Not only do market participants operate with a bias, but their bias can also influence the course of events".* Even Federal Reserve chairman, Alan Greenspan agrees: *"Stock prices are not merely a leading indicator of business activity but a major contributor in that activity."*

## 3. CONCLUSION

This paper attempts to formulate common dynamic principles accounting for the evolutionary emergence of increasingly higher spatial and temporal forms across all scales of scientific descriptions of nature, from quantum physics to macro economy. It replaces one way reductionism of cartesian dualism, Frege's compositionality principle and linear causality with two way, non-linear, mutual entrainment between neighboring scales. It further demonstrates that transitions between scales are always continuous phase shifts when systems reach self induced criticality, rather than discrete, digital boundaries objectively existing outside of observer's mind. All boundaries between sciences are created by human action. Finally, this paper replaces wave/particle dualism with a single, continuous field, spanning all spatial and temporal scales of nature. There is, as Einstein said, "only one reality" to be described.

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