BIOS AND THE CREATION OF COMPLEXITY

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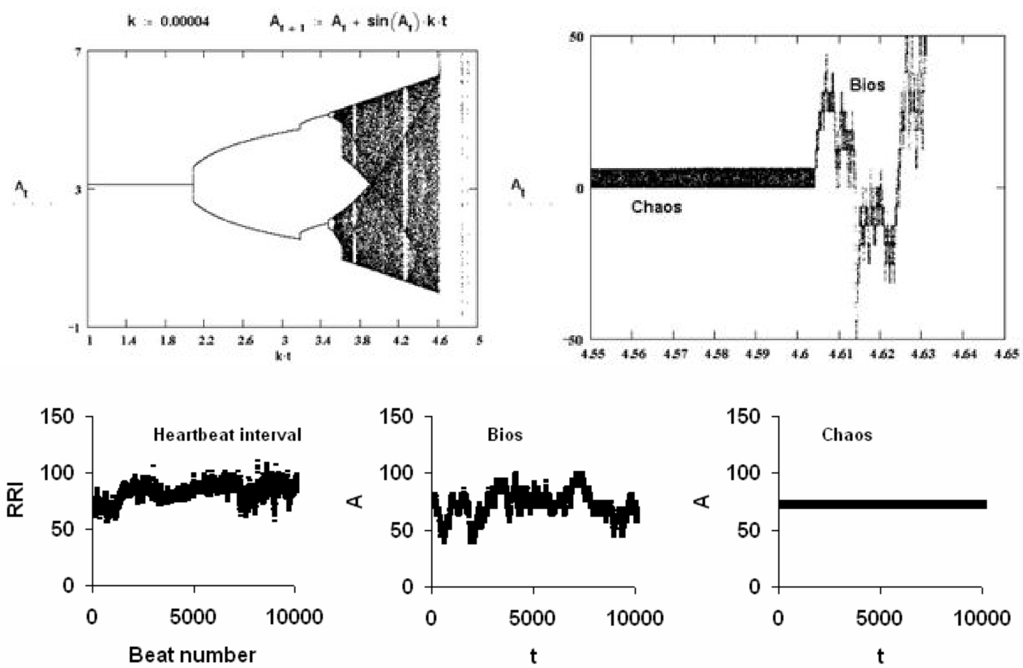
BIOS, A LINK BETWEEN CHAOS AND COMPLEXITY

BIOS is a causal and creative process that follows chaos in sequences of patterns of increasing complexity. Bios was first identified as the pattern of heartbeat intervals, and it has since then been found in a wide variety of processes ranging in size from Schrodinger's wave function to the temporal distribution of galaxies, and ranging in complexity from physics to economics to music. This tutorial provides concise descriptions of (1) bios, (2) time series analyses software to identify bios in empirical data, (3) biotic patterns in nature, (4) biotic recursions, (5) biotic feedback, (6) Bios Theory of Evolution, and (7) biotic strategies for human action in scientific, clinical, economic and sociopolitical settings.



Time series of heartbeat intervals (RRI), and of biotic and chaotic series generated with mathematical recursions of bipolar feedback.

Heartbeats are the prototype of bios.
Turbulence is the prototype of chaos.

1. BIOS

BIOS is an expansive process with chaotic features generated by feedback and characterized by features of creativity.

Process: Biotic patterns are sequences of actions or states.

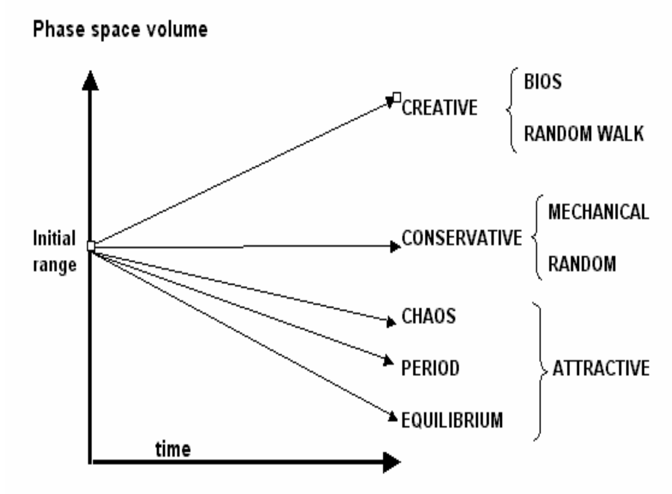
Expansive: Biotic patterns continually expand in their diversity and often in their range. This is significant, as natural processes expand, in contrast to convergence to equilibrium, periodic, or chaotic attractors. Expanding processes range from the universe to viruses, and include human populations, empires, ideas and cultures.

Chaotic: Biotic series are aperiodic and generated causally; mathematically generated bios is extremely sensitive to initial conditions.

Feedback: Biotic series are generated by cyclic processes such as bipolar feedback.

Creativity: Biotic series show greater variation than their random copies. Biotic generators are simple processes that produce complex patterns. They are creative in the same sense as language, which is made of a limited alphabet and vocabulary yet it generates an infinite number of sentences and dialogues.

Biotic patterns often are fractal, and are linked to the production of bifurcations, chaos, and other complex forms.



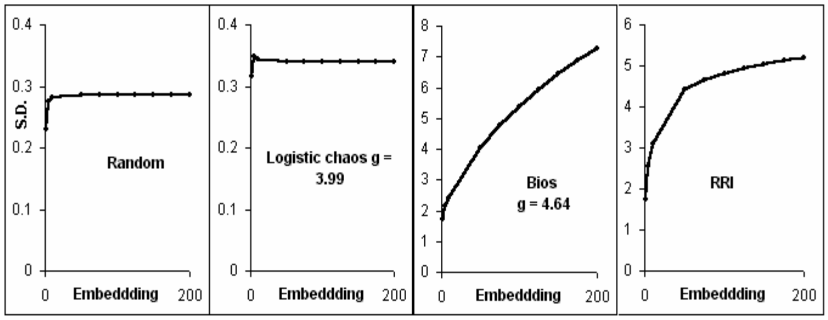
2. BIOS DATA ANALYSIS

Bios data analysis comprises a number of tests that allow the identification of periodic, chaotic, creative and causal features in the data. To demonstrate bios requires to show (1) evidence of **creativity**: increase variance with time (diversification), contiguity, transformation of pattern from one time-limited form (complex) to another, less recurrence than random (novelty), and non random complexity; and (2) evidence of **causality**: partial autocorrelation, consecutive recurrences, pattern in the time series of differences between consecutive terms. See Appendix for description of methods and a free program. The Bios Data Analyzer (BDA) is a set of programs that performs these tests. (H. Sabelli, et al. *Nonlinear Dynamics, Psychology and the Life Sciences 9: 505-538, 2005*.) The BDA is available as a CD ROM in *Bios. A Study of Creation* by H. Sabelli, with contributions by L. Kauffman, L. Carlson-Sabelli, A. Sugerman, M. Patel, J. Messer, and L. Kovacevic, World Scientific 2005. Bios Analyzer (BA) is a free data analysis software that includes these and other methods.

The generation of creative properties (diversification, novelty, complexes, non-random complexity) by causal processes defines bios. Many processes commonly regarded as chaotic or stochastic can be demonstrated to be biotic. Bios differs from stochastic processes by demonstrable features of non-random causation. Comparing the chaotic and biotic series generated by mathematical recursions reveals other important differences. Bios shows (1) contiguity (an important topological property), (2) expansion (instead of convergence to an attractor), (3) irreversibility, (4) $1/f^B$ power spectrum (as contrasted to the random-like power spectrum of chaotic series), (5) global sensitivity to initial conditions, and (6) lesser entropy.

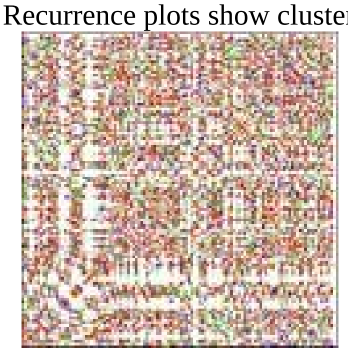
Biotic processes may also account for some forms of diffusion. However bios is not simply chaotic diffusion. What characterizes bios are features of creativity such as diversification and novelty, that can be observed in the absence of diffusion.

Features of creativity

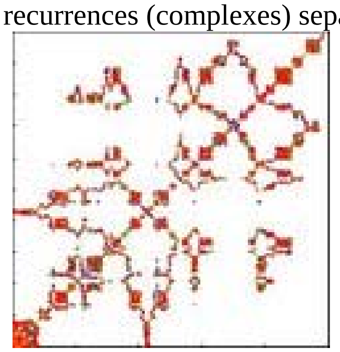


Local Diversification: increase S.D. with embedding.
Embedding: number of consecutive terms in each vector.

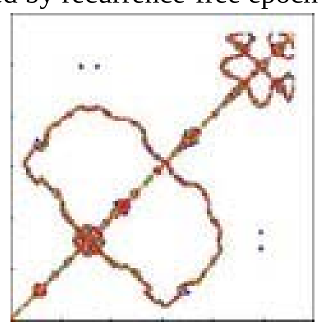
Transformation of pattern from one time-limited form to another
Recurrence plots show clusters of recurrences (complexes) separated by recurrence-free epochs



Chaos



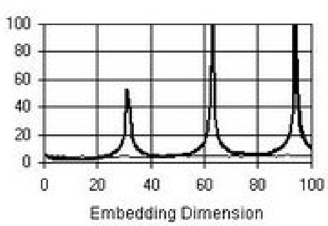
Bios



British coastline

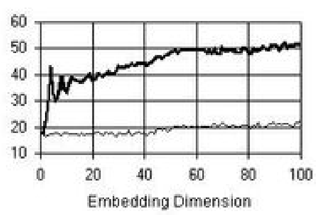
Embedding plots of recurrence isometry of mathematical series (**thick line**) and surrogate copies randomized by shuffling (thin line) measured with vectors up to 100 embeddings.

Order



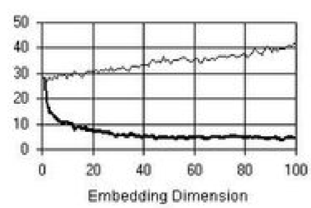
Sine wave are periodically more recurrent than their shuffled copy.

Chaos



Chaotic series are more recurrent than their shuffled copy.

Bios



Biotic series are less recurrent than their shuffled copy **(novelty).**

3. BIOTIC PATTERNS IN NATURE

Biotic patterns are ubiquitous:

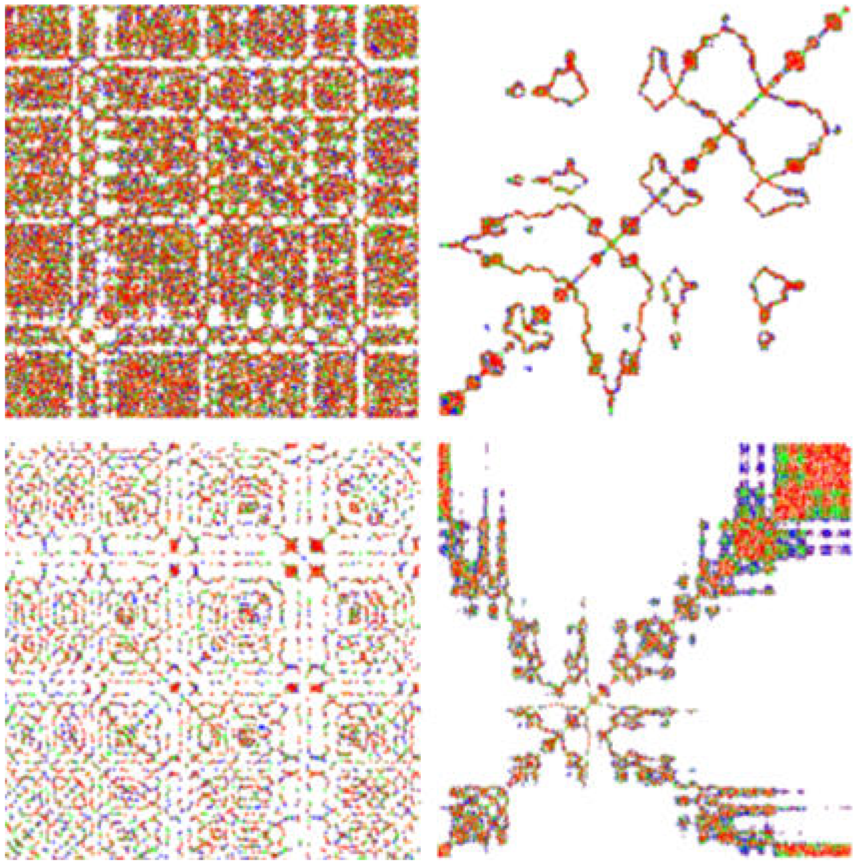
- **Quantum physics: Schrödinger's wave function**
- **Temporal distribution of galaxies**
- **Temporal distribution of quasars**
- **Air and ocean temperature, Nile river levels**
- **Geographical structures (shape of rivers and shores)**
- **Sequences of bases in DNA**
- **Biological: population size (5 of 6 species studied)**
- **Physiological: heartbeat intervals, respiration**
- **Economic: prices, stocks, currencies**
- **Some literary texts an musical compositions**

The widespread observation of biotic patterns indicates that bios must be added to steady state, periodicity, chaos and stochastic noise as one of the generic patterns observed in natural and human processes.

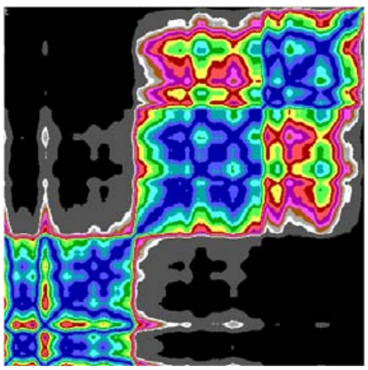
Causation	**Pattern**	
	Uniform	**Complexes**
Aleatory (chance)	RANDOM	BROWNIAN
Deterministic (cause)	CHAOS	BIOS

Being ubiquitous, bios has been observed innumerable times, but regarded as stochastic, or chaotic.

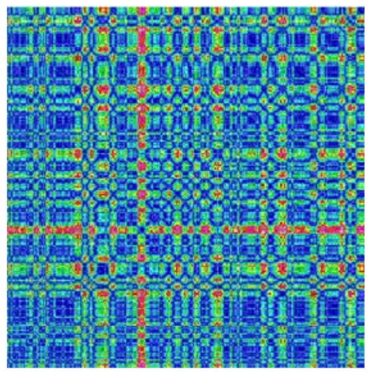
The observation of bios in such diverse processes suggests that bipolar feedback may be significant in cosmological, biological, and socioeconomic evolution.



Embedding plots show complexes in bios (upper right), Schrödinger equation (lower left) and galactic distribution (lower right) but not in chaos (upper left). From the cover of *Complexity* Volume 11, Issue 4, 2006 (H. Sabelli, L. Kovacevic Quantum bios and biotic complexity in the distribution of galaxies)



Treasury Bills (less recurrences, separate complexes)

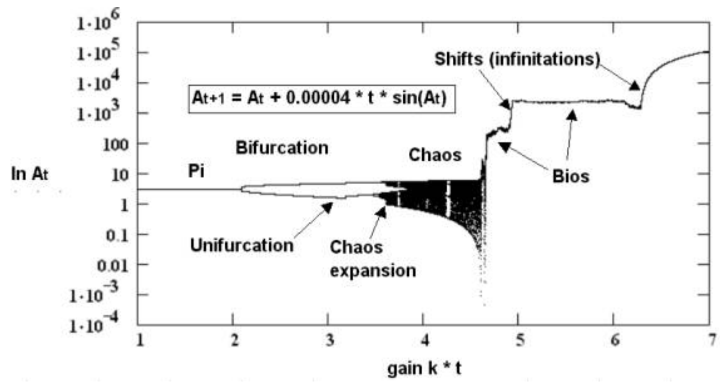


Shuffled copy (more recurrences, uniform plot)

Mathematical recursions are useful models to understand bios and to see its obvious differences with other chaotic processes. Mathematical bios was first defined as a distinct phase in the time series generated with the recursion

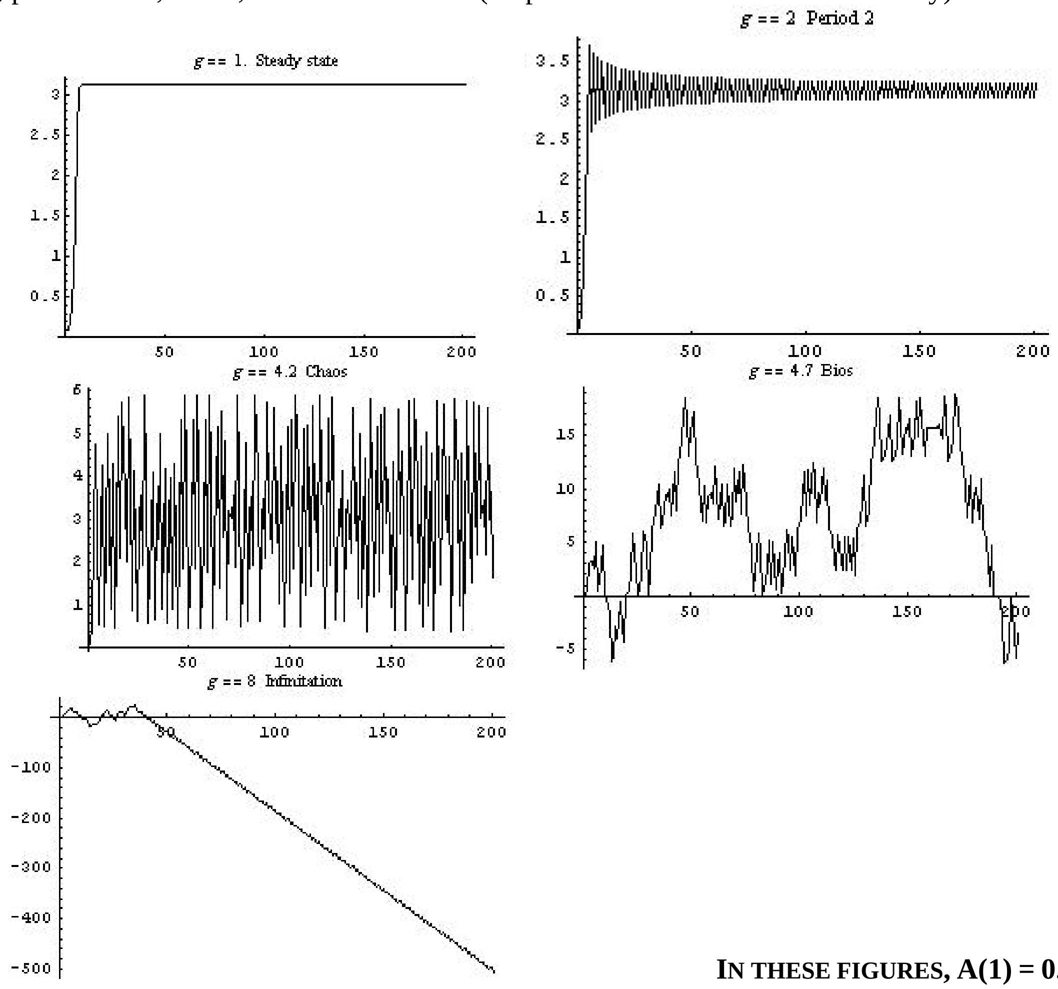
$$A(t+1) = A(t) + g * sin(A(t)) \, .$$

When $g = k*t$, where k is a small constant, this recursions generates steady state, periodicities, chaos, bios or infinitation as time increases.



Time series generated by the process recursion; logarithmic scale in the y axis.

When *g* is kept constant, then, depending on its value, this recursion generates either a steady state, periodicities, chaos, bios or infinitation (output increases in size toward infinity).



IN THESE FIGURES, A(1) = 0.1

Bios develops after chaos: creative features appear beyond chaos, not between order and chaos as so often asserted.

Mathematical experiments with biotic recursions demonstrate that the production of the creative features of bios requires:

- action, which must be of sufficient energy ($g > 4.6033\ldots$); a recursion, as contrasted to static equation, is an action.

- bipolar and diverse opposition (the trigonometric function); unipolar feedback (such as the logistic equation) produces only chaos.

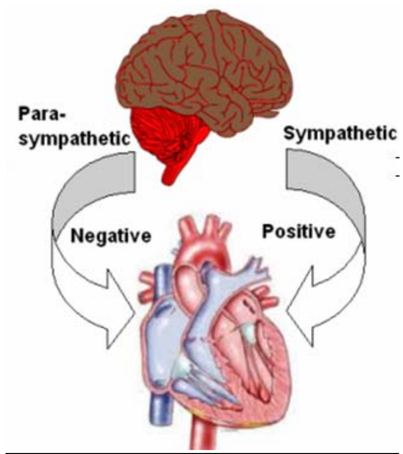
- conservation of the previous action; without a conserved term $A(t)$, recursion becomes $A(t+1) = g * \sin(A(t))$, and it cannot produce bios. In that case, pattern diversification ends with chaos.

If asymmetry is introduced to the feedback, this recursion becomes $A(t+1) = A(t) + g*(\sin(A(t))+q)$. When $q = 1$, bipolar feedback becomes unipolar, and this recursion cannot produce bios. Further experiments with q lead to the conjecture that **bios requires relatively symmetric opposition in the feedback --** q must be close to 0 for bios to exist.

Less intense, less diverse, or less symmetric feedback generates simpler steady states, periodic, chaotic, or linearly increasing patterns. The fact that complexity of outcome in mathematical models increases with intensity, diversity, and symmetry of the feedback suggests guidelines for promoting creativity in social and personal development.

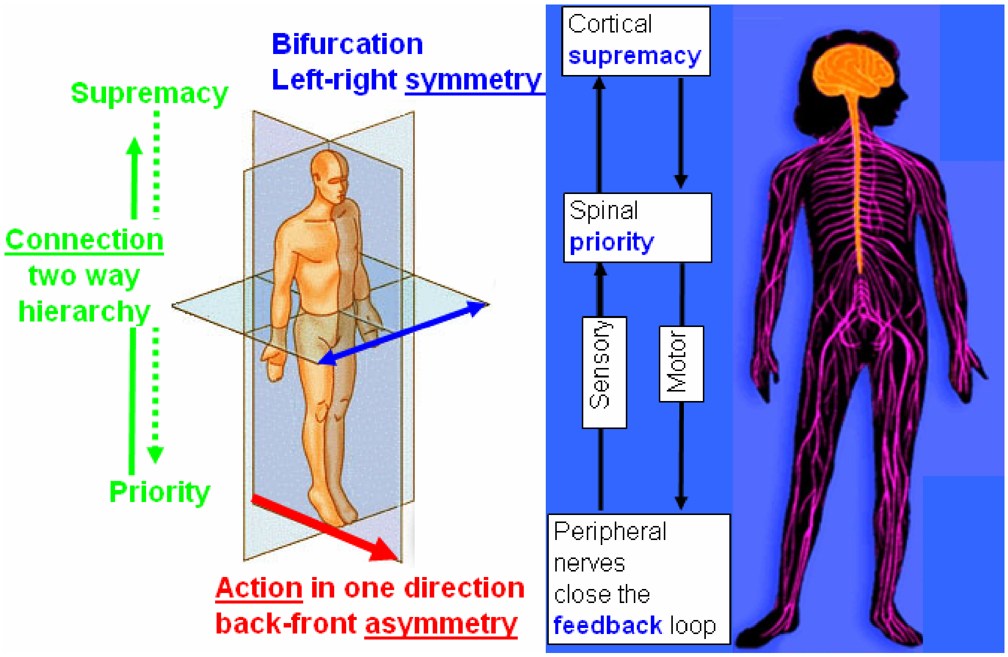
5. BIOTIC FEEDBACK

Biotic patterns are generated by recursions of bipolar (positive and negative) feedback, but not by unipolar feedback (such as the logistic equation). In nature, biotic patterns are also generated by systems in which the feedback is hierarchical, a simpler level providing energy to the higher one, and the more complex (informationally dense) level providing bipolar feedback to the simpler ones. The regulation of heartbeat intervals involves both bipolarity and hierarchy.

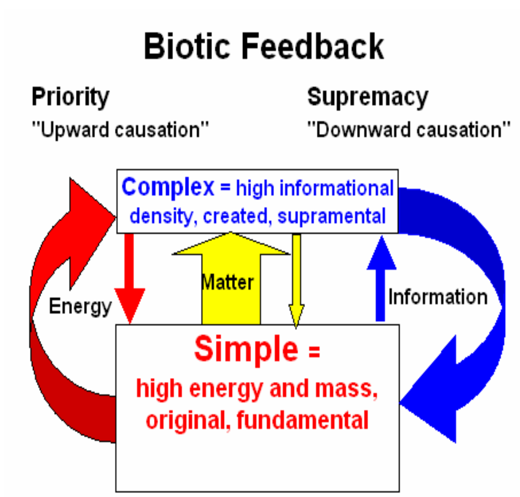


Heartbeat intervals are determined by modulation of the bipolar (accelerating and decelerating) action of the brain – the heart provides energy to the brain (**priority**) and the brain regulates cardiac activity (**supremacy** of the complex).

The notion of priority and supremacy is modeled after the hierarchical organization of the central nervous system, in which the spinal chord has evolutionary and functional priority while the cerebral cortex has functional supremacy. Simple energetic processes are global and have priority in time, necessity and exigency; e.g. respiration emerges relatively early in evolution, and respiratory distress is medical emergency. Complex processes are generated later and locally, where they feedback and transiently control the simple processes that generate, constitute, and surround them; e.g. brain appears late in evolution, but it controls the body. This bipolar and hierarchical feedback (priority / supremacy), that we call **biotic feedback**, generates biotic patterns.



Processes at each level of organization are in part endogenous and in part co-determined by processes at simpler or more complex levels. For instance, the physical and biological environment has priority in economic processes, while the social, economic and legal systems have supremacy in determining the environment.



Priority and supremacy as complementary opposite components of biotic feedback.

6. BIOTIC PROCESSES IN PHYSICAL AND BIOLOGICAL EVOLUTION

7. BIOTIC PRACTICE

These sections are under construction…

In the meantime, see slides of the current presentations at SCTPLS Baltimore meeting. PowerPoint files are available at http://creativebios.com

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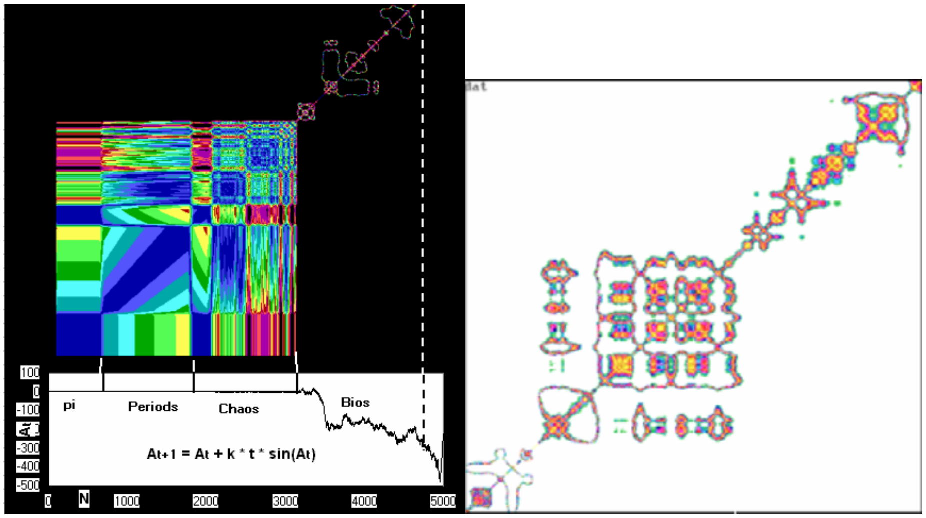

Sequence of patterns generated by the a recursion of bipolar feedback.
Complexes appear in the biotic phase. The right graph shows a complex in greater detail.

Recurrence (*isometry*) **plot** can be mathematically expressed as
$\mathbf{R}(i,j) = \Theta(\varepsilon - |(||\vec{x}(i)|| - ||\vec{x}(j)||)|), \quad \vec{x}(i) \in \mathbb{R}^m, \quad i,j = 1,\dots,N,$ where N is the number of considered states $\vec{x}(i)$, ε is a threshold distance, $||\cdot||$ a norm (Euclidean norm), $\Theta(\cdot)$ the Heaviside step function, and $\vec{x}(i) = (u(i), u(i+1), \dots, u(i+m-1)),$
where *u(i)* is the time series, *m* the embedding dimension.
While in **similarity recurrence** $\vec{x}(i) \approx \vec{x}(j)$, in **isometry recurrence** $||\vec{x}(i)|| \approx ||\vec{x}(j)||$, which means that for the similarity recurrence both the direction and length of vectors are being calculated, while for isometry recurrence only length of vectors is being calculated.

Novelty can be detected in the embedded series ($m > 1$). The time series *u* where total number of isometric points is smaller than the total number of isometric points in the series *u* after shuffling, has a feature called novelty. Novelty can be visualized in recurrence plots and quantified in embedding plots.

Different series show different patterns when presented in recurrence plots. Random and chaotic series produce uniform plots. Periodic series produce periodic plots. Biotic series produce plots with distinct complexes that are lost after shuffling the data.

Total number of calculated isometries as percent of the number of total possible isometries is a useful quantification that is used in embedding plots.

Bios Analyzer is a free program for data analysis that includes these and other methods.

SOURCES

An introductory, almost literary description of Bios Theory can be found in The Union of Opposites: from Taoism to Process Theory, by H. Sabelli. *Systems Research* 15: 429-441, 1998.

Encyclopedias: General descriptions of Bios can be found in encyclopedias:

Encyclopedia of Life Support Systems (*EOLSS*), Eolss Publishers, Oxford, UK, (http://www.eolss.net), under Bipolar Feedback.

François C. (1997). *International Encyclopedia of Systems and Cybernetics*. München: Saur, under Process theory and many other articles.

General descriptions of Bios can be found in http://creativebios.com and:

Bios. A Study of Creation, by H. Sabelli, with contributions by Louis Kauffman, Linnea Carlson-Sabelli, Arthur Sugerman, Minu Patel, Joseph V. Messer, and Lazar Kovacevic, and with *Bios Data Analyzer*. CD-ROM, by Sugerman et al. World Scientific, 2005.

Briefer descriptions are presented in these articles:

Sabelli, H. 1999. Process theory: mathematical formulation, experimental method, and clinical and social application. *Toward New Paradigm of System Science.* P. Y. Rhee editor. Seoul: Seoul National University Press, pp 159- 201.

Sabelli, H. 2001. The Co-Creation Hypothesis. In *Understanding Complexity*. Ed. by G. Ragsdell and J. Wilby. Kluwer Academics/Plenum Publishers. London.

Sabelli H and L. Carlson-Sabelli. 2005. Bios, a Process Approach to Living System Theory. In honor to James and Jessie Miller. *Systems Research and Behavioral Science* 23: 323-336.

Psychology, Psychiatry and Medicine:

Sabelli, H. and Carlson-Sabelli L. 1989. Biological Priority and Psychological Supremacy, a New Integrative Paradigm Derived from Process Theory. *American Journal of Psychiatry* 146 1541-1551.

Sabelli HC and Carlson-Sabelli L. Process Theory as a Framework for Comprehensive Psychodynamic Formulations. *Genetic, Social, and General Psychology Monographs.* 1991:117:5-27.

Sabelli HC, Carlson-Sabelli L, Patel M, Zbilut J, Messer J, and Walthall K. Psychocardiological portraits: A clinical application of process theory. In *Chaos theory in Psychology* (1995), F. D. Abraham and A. R. Gilgen (Eds). Greenwood Publishing Group, Inc., Westport, CT. pp 107-125.

Sabelli, H., Carlson-Sabelli, L., Patel, M and Sugerman, A. 1997. Dynamics and psychodynamics. Process Foundations of Psychology. *J. Mind and Behavior* 18: 305-334.

Methods of data analysis:

Sabelli, H. 2000. Complement plots: analyzing opposites reveals Mandala-like patterns in human heartbeats. *International Journal of General Systems* 29 (5): 799-830.

Sabelli, H. (2001). Novelty, a Measure of Creative Organization in Natural and Mathematical Time Series. *Nonlinear Dynamics, Psychology, and Life Sciences.* 5: 89-113.

Patel, M. and H. Sabelli. Autocorrelation And Frequency Analysis Differentiate Cardiac And Economic Bios From 1/F Noise. *Kybernetes.* 32: 692-702, 2003

H. Sabelli, A. Sugerman, L. Kovacevic, L. Kauffman, L. Carlson-Sabelli, M. Patel, and J. Konecki. Bios Data Analyzer. *Nonlinear Dynamics, Psychology and the Life Sciences 9: 505-538, 2005*.

Mathematics:

Kauffman, L. and Sabelli, H. 1998. The Process equation. *Cybernetics and Systems 2*9 (4): 345-362

Kauffman, L. and H. Sabelli. 2003. Mathematical Bios. *Kybernetes* 31 1418-1428.

Natural Science:

Sabelli, H and L. Kovacevic. Quantum Bios and Biotic Complexity in the Distribution of Galaxies. *Complexity* 11: 14-25, 2006.

Sociology:

Carlson-Sabelli L, Sabelli HC, and Hale A. Sociometry and Sociodynamics. In *Psychodrama since Moreno: Innovations in theory and practice.* Karp, Watson and Holmes, Editors (1994).

Sabelli, H. and L. Carlson-Sabelli. Sociodynamics: the application of process methods to the social sciences. *Chaos Theory and Society* (A. Albert, editor). I.O.S. Press, Amsterdam, Holland, and Les Presses de l'Université du Québec, Sainte-Foy, Canada (1995).

Sabelli, H. *If Not Us, Then Who. Scientific Bases for Social Action* (draft, **http://creativebios.com**)