

Chapter 8

Bios Hypothesis

Abstract: Mathematical experiments show that the generation of biotic series with features of novelty, diversity and complexity requires intense action, complete conservation, and harmonic (bipolar, bidimensional, quasi-symmetric and diverse) feedback, indicating the necessary conditions for creative (bios-like) thinking and action. Asymmetric opposites generate trended bios (parabios). A range of asymmetries generates a complex pattern (bias) of synchronous actions. It is proposed that biotic and parabiogenic generators are generic processes operating at all levels of organization and that they play a major role in evolution.

The empirical studies described in Chapters 4 to 7 identify biotic and stochastic patterns (Table 8.1), and also indicate that other natural processes often show novelty. Bios may account for some of the many patterns that show a preponderance of lower frequencies (negative β power spectrum exponent) and novelty. However, these two features often appear together in natural processes (cosmic background radiation, DNA sequences) in which we find no evidence for causation. Is this form of novelty another name for chance? In my view, its association with $1/f$ power spectrum and with complexes indicates the existence a generator and excludes randomness. This indicates the need to search for other forms of deterministic creativity. The generation of $1/f$ patterns by filtering does not address the issue.

In the analysis of empirical series, we did not find random processes. Random and chaotic series, albeit often regarded as creative, are patternless, as it is evident in recurrence plots. They do not generate the features that characterize natural creative processes. The oft-quoted

notion that any pattern whatsoever can emerge from random change is belied by actual observations. The sequence of π digits, which is the most random sequence ever found, never includes biotic features such as novelty, diversification, expansion, and complexes. What processes generate these creative features like diversity, novelty and complexity?

8.1 The Concept of Bios

Bios is a new mathematical concept grounded on empirical studies. Bios is (1) defined by newly developed analytic methods to measure diversification, novelty, and complexity; (2) exemplified by complex biological processes such as series heartbeat intervals that do not diffuse; and (3) generated mathematically and, we propose, also in nature, by the interaction of opposites as in bipolar feedback.

Bios serves as a model for creative and causal processes in which simple interactions generate a complex outcome. *Simple* origin means causation by low dimensional interactions, and implies that the process of creation is natural, rational, understandable, and in principle controllable. Stochastic processes, albeit often considered simple, are in fact complex insofar as each random event is a new phenomenon; random events are not controllable. *Complex* outcome implies increasing diversity, novelty, nonrandom complexity (higher dimensionality), greater informational content, and intricate form, including self-similar fractal structure. Complex outcome excludes predictability and reducibility to simple levels, but allows for control.

We use the term bios to name a family of simple creative processes that generate irregular, multifractal patterns with $1/f$ spectrum such as observed in a wide variety of natural processes rather than complex forms such as anatomical or artistic. These patterns have been regarded up to now as chaos or noise, but are clearly distinguishable from them. The concept of bios must be compared with those of chaos and noise. Chaos is an unpredictable, erratic, irregular, fluctuation among (multi-valued) opposites. Chaos has been described as “deterministic random”, meaning that it appears random but is generated by a simple, well-determined process. We speak of chaos when a deterministic system

governed by simple equations behave unpredictably. The hallmark of chaos is sensitivity to initial conditions, absent in true random series.

Table 8.1

	Empirical time series				Mathematical time series					
	Natural Flux (CBR)	Natural Bios (Heart)	Parabios (Economic Processes)	Chaos (Rain)	Bios	Chaos	Random	Random Walk	Expand. Random	Pink Noise
Mean Stationary	Yes	Yes	No	Yes	Yes or No	Yes	Yes	No	No	No
Asymmetry	No	Yes	Yes	Yes	Yes	No	No	Yes	No	No
Power Spectrum β	-0.14 to -1.16	-1 to -1.8	~ -2	~ 0	~ -1.7	0 **	0	~ -2	0	~ -1
Diversification	Rare	Yes	Yes	No	Yes	No	No	Yes	No	Yes
Complexes	Blurred	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes
Novelty	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes
Nonrandom Complexity	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes
Consecutive Recurrence*	No	L, H	H or L, H	L	L, H	L	No	H	H	No
Sensitivity To Input	Yes ?	Yes ?	Yes ?	Yes ?	Global	Local	No	No	No	No

* At low (L) or high (H) embedding dimension
 ** For logistic and process chaos. There are chaotic series in which power is inversely proportional to frequency.

Noise (stochastic time series) are statistical time series such as those generated by the addition of random changes. However, the same patterns can be generated deterministically. The term noise is also misleading insofar as these series display significant patterns that appear in significant natural processes. Noise also shows an unpredictable, erratic, irregular, alternation of (multi-valued) opposites. Notably, noise can produce diversity, novelty and nonrandom complexity. Stochastic processes are generated externally. Creative processes generate themselves (autodynamism) through interaction with their environment.

Bios is generated by bipolar feedback. Biotic patterns meet the definition of chaos, and displays additional features that differentiate bios from low dimensional chaos: (1) expanding phase space volume; (2) episodic patterns separated by interruptions (complexes) rather than stationarity; (3) properties associated with creativity, namely diversification, novelty and nonrandom complexity –this excludes periodicity. Bios resembles natural processes and human language in continually generating new patterns. In contrast, an attractor, including chaotic attractors, is changeless –the more it changes, the more it stays the same.

The biotic pattern is expansive and bipolar –it travels in both positive and negative directions (enantiodynamia). Expansion is observed in many physical processes, from the expansion of the universe to the expansion of human populations. Enantiodynamia is also widespread – cosmological evolution and entropic decay, evolution and extinction of biological species, growth and ageing of individual organisms, economic development and reversed development, rise and fall of nations and empires, social progress and decline. Enantiodynamia has clear implications regarding economic and social strategies.

Bios is also characterized by: (1) asymmetric rather than symmetric statistical distribution, (2) high auto-correlation (Pearson's correlation), (3) anti-persistence (Hurst exponent < 0.5), (4) patterned wavelet and recurrence plots resembling those obtained with $1/f$ noise, and (5) ring patterns in complement plots. In contrast, to random series, bios is characterized by determined novelty and determined recurrences rather than abundant recurrence and low determination.

Bios is a class of patterns. Different types of biotic patterns obtain in series of heartbeat intervals in healthy and sick individuals, in various physiological, meteorological and economic processes, and in series generated by different recursions of trigonometric functions.

The definition of bios is evolving. It is being developed based on the analysis of empirical time series and numerical series generated by difference equations. We first looked upon bios as a pattern, but we have come to regard it as a process, namely harmonic (bipolar and diverse, hence bidimensional) feedback. A lack of a more precise definition at this stage in our research should not be surprising. Although the concept of chaos has proved extremely useful, there still is no definitive characterization of chaos. Its definition still remains somewhat ambiguous; there are at least sixteen different definitions of chaos.¹ In the same manner, the concept of fractal has no rigorous definition and Mandelbrot thinks that such a definition is unnecessary and could be useless and even harmful.²

In the process equation, bios occurs after chaos, as the series expands beyond the initial basin of attraction. However, what defines a creative process such as bios is diversification, not non-stationarity. Mathematical bios such as that generated by the process equation has a non-stationary mean and a non-stationary SD. But there are a number of variants of this recursion that generate bios with a stationary mean and a non-stationary SD such as observed with cardiac data.

In the process equation, there is another fundamental difference between the biotic and chaotic phases, namely the emergence of low frequencies. Biotic series have a broad but non-uniform f^{β} power spectrum, in contrast to chaotic series that often have a white noise-like f^0 power spectrum. (This is the case for chaotic series generated by bipolar feedback and by the logistic recursion, but there are chaotic series with f^{β} power spectra.) Biotic processes may account for many of the widespread $1/f$ patterns.

¹ Kaplan, D. and Glass, L. *Understanding Nonlinear Dynamics*. Springer-Verlag, 1995. For instance, Smale's definition of chaos by the presence of a transversal homoclinic point is based on the proof that homoclinic points imply chaos, but the converse has not been formalized; further, Smale allows for "some borderline cases in which this may not be exactly right". In many cases, it is not possible to demonstrate chaos unequivocally in empirical data, differentiating it from random.

² Mandelbrot, B. B. *Multifractals and 1/f Noise*. Springer. New York. 1998.

Is bios new?³ I have asked myself the question, but after some reflection I came to the conclusion that it is trivial. As bipolar feedback is widespread in nature, biotic patterns have been encountered numerous times. Real phenomena by necessity are rediscovered many times. Bios, as chaos, has been found again and again, but it has been labeled noise. There is a great difference between bios and noise. First, bios is generated causally, while noise is a stochastic process. Second, bios implies meaningful change, whereas noise implies a meaningless one. Biotic patterns appear in many processes ranging from astronomy to economics. To continue using the term “noise” is inappropriate, and misleading. What may be noise in radio communication is the pattern of creative processes. The cosmic microwave background radiation first appeared as “noise” (Section 4.2).

Bios has also been labeled chaos and deterministic diffusion, but has not been recognized as a separate pattern. Many empirical and several mathematical time series labeled chaotic (including weather models developed by Lorenz) show biotic patterns. The integration of some chaotic series produces bios. Biotic patterns are also generated by a number of nonlinear equations described by Chirikov⁴ and others, and investigated as a model for deterministic diffusion without remarking on a new pattern distinct from chaos, or on the concept of biotic feedback.

We interpret bios as a prototype for natural creation, and we identify the recursions that generate it as a simple example of widespread processes of causal creation. I wish then to echo Ueda’s disclaiming of priority for finding a pattern observed by many. Our study concerns the concept of bios and bipolar feedback as a creative process. The co-creation of opposites is a fundamental philosophical concept. As a model

³ The same question has been asked regarding fractals and chaos. Before he discovered the fractal geometry of natural forms, mathematicians had found some “mathematical monsters,” points out Mandelbrot. Poincaré had found chaos in the 19th century and, even before, Newton realized that planetary orbits may require divine intervention to remain regular. With oriental elegance, Ueda explains that, even when at this time many researchers attribute to him the discovery of chaos, he remembers how chaotic series were repeatedly found in the research projects carried out in the laboratory where he worked, but its director, interested in regular, periodic, beautiful configurations, simply disregarded them. Ueda recognized that it was worthwhile to study these chaotic series.

⁴ Chirikov, B. V., Lieberman, M.A., Shepelyansky, D.L., and Vivaldi, F. (1985). A Theory of Modulational Diffusion. *Physica 14D*: 289-304; Geisel, T. and Nierwetberg, J. (1982). Onset of Diffusion and Universal Scaling in Chaotic Systems. *Physical Review Letters* 48: 7-10.

for natural processes, bios must be compared with chaos, noise, terminal dynamics⁵, Lévy flights⁶, and cellular automata models⁷. In their discussion of terminal dynamics, that they also call “non-Lipschitz” and “nondeterministic” dynamics, as they are unhappy with each of these terms, Zak and co-workers describe “good” instabilities that lead to evolution, progress and creativity. They regard noise as a possible deterministic system that we cannot explain.

Like fractals and chaos, bios represents the recognition of a pattern, not the finding of an object. Naming serves to define concepts. The concept of bios represents a step towards a theory of creative processes and its application to human behavior. It points out that a seemingly exceptional type of chaos actually constitutes the rule in a wide variety of natural processes, and allows one to explain a large number of phenomena considered by most to be stochastic processes generated by accidental change. What is new is the concept of biotic pattern as a sign of causal creation and the concept of biotic feedback (bipolar, bidimensional, and diverse) as an apparently widespread creative process operating at all levels of organization. Also new is the focus on creative processes as contrasted to determinism and probability, and the application of these concepts to thermodynamic, biological, social, and psychological matters.

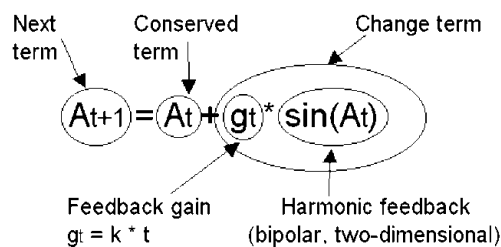
8.2 Biotic Factors: Action

To study what principles are necessary for creation, we experiment with various recursions, examining the effect of altering their components on the pattern of the time series generated. The three major factors are action, opposition and conservation (Fig. 8.1).

⁵ Zak, M., Zbilut, J.P., Meyers, R. E. (1997). *From Instability to Intelligence*. Berlin: Springer-Verlag.

⁶ West, B. J. and Deering, B. (1995). *The Lure of Modern Science*. Singapore: World Scientific.

⁷ Ilachinski, A. (2002). *Cellular Automata*. Singapore: World Scientific; Wolfram, S. (2002). *A New Kind of Science*. Winnipeg: Wolfram Media.



A: action = energy * time At: action at time t
 Process: At, At+1, At+2, ...At+n

Fig. 8.1 A biotic generator: bipolar feedback process with conservation.

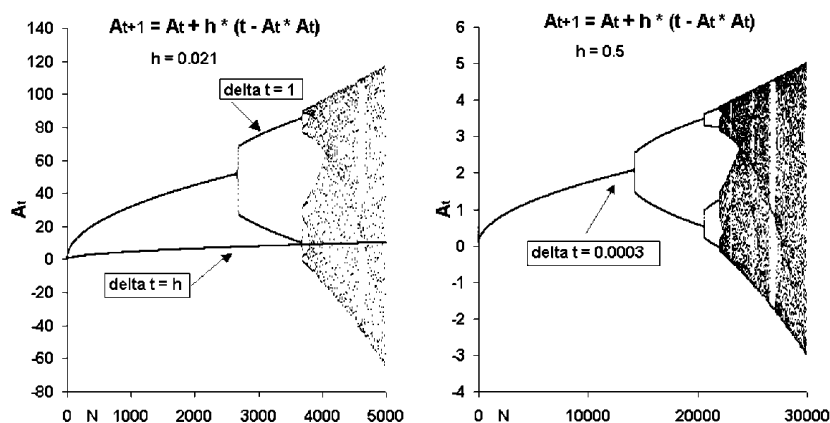


Fig. 8.2 A recursion is computed as a difference equation ($\Delta t = 1$) and as a differential equation using Euler's approximation ($\Delta t = h$). When h is small (left), the discrete recursion generates a complex logistic-like trajectory while the differential equation generates simple exponential growth. When h is larger, the logistic trajectory is observed even if the time steps are very small (right).

The need for action is obvious. Equations generate numbers; only recursions generate pattern. Without action, without iteration, there is no pattern. The intensity of action is given by the magnitude of the parameter. Its intensity determines pattern. In both biotic and logistics development, complexity increases with the intensity of the parameter, from equilibrium to periodicity to chaos to bios, and then decreases as linear infinitation or blow-up. Thus, maximum complexity occurs at

moderate values of the parameter, as expected;⁸ there is a nonlinear relation between quantity and quality (Chapter 9).

Notably, the process equation $A_{t+1} = A_t + k \cdot t \cdot \sin(A_t)$ and the diversifying equation $A_{t+1} = A_t + \sin(A_t \cdot k \cdot t)$ generate very similar patterns. This similarity is noteworthy because obviously $x \cdot \sin(y)$ is not the same as $\sin(x \cdot y)$. The two parameters have a different function: g represents the feedback gain (intensity or energy), while J represents diversity (frequency or information). A simple comparison illustrates this point: if we compute the sine wave $g \cdot \sin(A_t \cdot J)$, the amplitude is determined by g and the frequency by J . Both energy (gain) and information (diversity) contribute to power, as expected from intuition.

The quantic nature of action is often critical for the generation of bios and certain types of chaos. The logistic differential equation generates a simple curve while the difference equation generates a complex trajectory. Similarly, the process difference equation generates periodicity, chaos and bios, but the corresponding differential equation generates only convergence to a steady state regardless of the feedback gain. The Rössler attractor, which is generated by a set of differential equations, can also be generated by a set of difference equations. The comparison of differences and differential equations provides a mathematical stage upon which to scientifically examine the category of discrete versus continuous. As all other general ideas (categories), these concepts emerge as a pair of opposites. As in other cases, the opposites transform into each other. Differential equations can be approximated by discrete recursions. Consider the numerical solution of the equation $dx/dt = t - x^2$ by Euler's method. If the step size h is small, a simple curve is obtained, but if h is somewhat large, the computed values fluctuate at each step, first periodically and then chaotically, generating a logistic-like bifurcation diagram. This has been regarded as a breakdown in Euler's method.⁹ What is seen as error in the computation of a differential equation may instead be interpreted as a signal generated by a difference equation. What is an error or a signal depends on our

⁸ Galaxies and atoms are less complex than living organisms. Taking life and mind as the highest known entity, maximum complexity occurs at moderate temperature, moderate frequency and duration, and moderate size. This is in line with the Apollonian notion of moderation.

⁹ Acheson, D. (1997). *From Calculus to Chaos*. Oxford University Press.

perspective: mutation is an essential mechanism for genetic variation from a process perspective, but is an error from a static perspective. The shift from continuous to discrete mathematics is likewise a change in perspective. From the perspective of discrete processes, one may regard h as a feedback gain rather than as a time step; a logistic-like trajectory is also obtained when the time steps are small if h is sufficiently large (Fig. 8.2). Approximating differential equations with Euler's method shows us that there often is continuity between the discrete and the continuous extremes. This dialectic of the continuous and the discrete applies to the real world, e.g. quantum and classic mechanics. In almost every process, there are both discrete and continuous transformations at different levels of organization. As the level changes, there is transformation from continuous to discrete or vice versa.

The pattern and rate of change of the parameter determines the development of pattern. Notably, the gain at which new patterns emerge is lower when the rate of change of the parameter g or J is lower. Alternating the sign of the gain increases the amplitude of the biotic phase, whereas random increments decrease it.

8.3 Biotic Factors: Opposition, Symmetry and Asymmetry

Chaos is generated by nonlinear (two-dimensional) opposition; for instance, the logistic recursion is quadratic. Bios also requires two-dimensional opposition, such as trigonometric feedback. The same sequence of patterns, from asymmetric steady state to bios, can also be generated by replacing the trigonometric function by a pair of numbers such that $r^2 = A_t^2 + B_t^2$, $A_{t+1} = A_t + \Delta B_t$, and $B_{t+1} = B_t - \Delta A_t$.¹⁰ In this process, the change of one quantity acts to change the other, its opposite. This creates circularity and movement. Sine and cosine are paradigmatic of out of phase, complementary opposites. This experiment indicates how the coexistence of complementary opposites implies an infinity of oppositions.

¹⁰ Sabelli, H. and Kauffman, L. (1999). The process equation: formulating and testing the process theory of systems. *Cybernetics and Systems* 30: 261-294.