

# Contents

<b>1</b>	<b>Introduction</b> .....	1
1.1	Towards Biology .....	2
1.2	Objectivization and Theories .....	5
1.2.1	A Critique of Common Philosophical Classifications .....	8
1.2.2	The Elementary and the Simple .....	11
1.3	A Short Synthesis of Our Approach to Biological Phenomena .....	13
1.4	A More Detailed Account of Our Main Themes: Time Geometry, Extended Criticality, Symmetry Changes and Enablement, Anti-Entropy .....	15
1.4.1	Biological Time .....	16
1.4.2	Extended Criticality .....	17
1.4.3	Symmetry Changes and Enablement .....	19
1.4.4	Anti-entropy .....	19
1.5	Map of This Book .....	21
<b>2</b>	<b>Scaling and Scale Symmetries in Biological Systems</b> .....	23
2.1	Introduction .....	23
2.1.1	Power Laws .....	24
2.2	Allometry .....	26
2.2.1	Principles .....	26
2.2.2	Metabolism .....	28
2.2.3	Rhythms and Rates .....	32
2.2.4	Cell and Organ Allometry .....	34
2.2.5	Conclusion .....	37
2.3	Morphological Fractal-Like Structures .....	38
2.3.1	Principles .....	38
2.3.2	Cellular and Intracellular Membranes .....	44
2.3.3	Branching Trees .....	45
2.3.4	Some Other Morphological Fractal Analyses .....	50
2.3.5	Conclusion .....	51

2.4	Elementary Yet Complex Biological Dynamics . . . . .	52
2.4.1	Principles . . . . .	52
2.4.2	A Non-exhaustive List of Fractal-Like Biological Dynamics . . . . .	57
2.4.3	The Case of Cardiac Rhythm . . . . .	59
2.4.4	Conclusion . . . . .	62
2.5	Anomalous Diffusion . . . . .	63
2.5.1	Principle . . . . .	63
2.5.2	Examples from Cellular Biology . . . . .	66
2.5.3	Conclusion . . . . .	67
2.6	Networks . . . . .	67
2.6.1	Structures . . . . .	67
2.6.2	Dynamics . . . . .	69
2.6.3	Conclusion . . . . .	71
2.7	Conclusion . . . . .	71
<b>3</b>	<b>A 2-Dimensional Geometry for Biological Time . . . . .</b>	<b>75</b>
3.1	Introduction . . . . .	75
3.1.1	Methodological Remarks . . . . .	77
3.2	An Abstract Schema for Biological Temporality . . . . .	78
3.2.1	Premise: Rhythms . . . . .	78
3.2.2	External and Internal Rhythms . . . . .	78
3.3	Mathematical Description . . . . .	81
3.3.1	Qualitative Drawings of Our Schemata . . . . .	81
3.3.2	Quantitative Scheme of Biological Time . . . . .	84
3.4	Analysis of the Model . . . . .	85
3.4.1	Physical Periodicity of Compactified Time . . . . .	86
3.4.2	Biological Irreversibility . . . . .	86
3.4.3	Allometry and Physical Rhythms . . . . .	87
3.4.4	Rate Variability . . . . .	88
3.5	More Discussion on the General Schema 3.1 . . . . .	92
3.5.1	The Evolutionary Axis ( $\tau$ ), Its Angles with the Horizontal $\varphi(t)$ and Its Gradients $\tan(\varphi(t))$ . . . . .	92
3.5.2	The “Helicoidal” Cylinder of Revolution $\mathcal{C}_e$ : Its Thread $p_e$ , Its Radius $R_i$ . . . . .	94
3.5.3	The Circular Helix $\mathcal{C}_i$ on the Cylinder and Its Thread $p_i$ . . . . .	94
3.5.4	On the Interpretation of the Ordinate $t'$ . . . . .	94
<b>4</b>	<b>Protention and Retention in Biological Systems . . . . .</b>	<b>99</b>
4.1	Introduction . . . . .	99
4.1.1	Methodological Remarks . . . . .	101
4.2	Characteristic Time and Correlation Lengths . . . . .	102
4.2.1	Critical States and Correlation Length . . . . .	104
4.3	Retention and Protention . . . . .	104
4.3.1	Principles . . . . .	104

4.3.2	Specifications .....	105
4.3.3	Comments .....	107
4.3.4	Global Protention .....	108
4.4	Biological Inertia .....	110
4.4.1	Analysis .....	111
4.5	References and More Justifications for Biological Inertia .....	113
4.6	Some Complementary Remarks .....	115
4.6.1	Power Laws and Exponentials .....	115
4.6.2	Causality and Analyticity .....	116
4.7	Towards Human Cognition. From Trajectory to Space: The Continuity of the Cognitive Phenomena .....	117
<b>5</b>	<b>Symmetry and Symmetry Breakings in Physics .....</b>	<b>121</b>
5.1	Introduction .....	122
5.2	Symmetry and Objectivization in Physics .....	122
5.2.1	Examples .....	122
5.2.2	General Discussion .....	125
5.3	Noether's Theorem .....	129
5.4	Typology of Symmetry Breakings .....	131
5.4.1	Goldstone Theorem .....	133
5.5	Symmetries Breakings and Randomness .....	134
<b>6</b>	<b>Critical Phase Transitions .....</b>	<b>137</b>
6.1	Symmetry Breakings and Criticality in Physics .....	137
6.2	Renormalization and Scale Symmetry in Critical Transitions .....	141
6.2.1	Landau Theory .....	141
6.2.2	Some Aspect of Renormalization .....	150
6.2.3	Critical Slowing-Down .....	155
6.2.4	Self-tuned Criticality .....	158
6.3	Conclusion .....	160
<b>7</b>	<b>From Physics to Biology by Extending Criticality and Symmetry Breakings .....</b>	<b>161</b>
7.1	Introduction and Summary .....	161
7.1.1	Hidden Variables in Biology? .....	163
7.2	Biological Systems "Poised" at Criticality .....	165
7.2.1	Principle .....	165
7.2.2	Other Forms of Criticality .....	169
7.2.3	Conclusion .....	171
7.3	Extended Criticality: The Biological Object and Symmetry Breakings .....	172
7.4	Additional Characteristics of Extended Criticality .....	177
7.4.1	Remarks on Randomness and Time Irreversibility .....	179
7.5	Compactified Time and Autonomy .....	180
7.5.1	Simple Harmonic Oscillators in Physics .....	181

7.5.2	Biological Oscillators: Symmetries and Compactified Time .....	183
7.5.3	Conclusion .....	184
7.6	Conclusion .....	184
<b>8</b>	<b>Biological Phase Spaces and Enablement .....</b>	<b>187</b>
8.1	Introduction .....	187
8.2	Phase Spaces and Symmetries in Physics .....	190
8.2.1	More Lessons from Quantum and Statistical Mechanics ..	192
8.2.2	Criticality and Symmetries .....	193
8.3	Non-ergodicity and Quantum/Classical Randomness in Biology ..	195
8.4	Randomness and Phase Spaces in Biology .....	199
8.4.1	Non-optimality .....	202
8.5	A Non-conservation Principle .....	203
8.6	Causes and Enablement .....	205
8.7	Structural Stability, Autonomy and Constraints .....	209
8.8	Conclusion .....	210
<b>9</b>	<b>Biological Order as a Consequence of Randomness: Anti-entropy and Symmetry Changes .....</b>	<b>215</b>
9.1	Introduction .....	215
9.2	Preliminary Remarks on Entropy in Ontogenesis .....	217
9.3	Randomness and Complexification in Evolution .....	220
9.4	(Anti-)Entropy in Evolution .....	223
9.4.1	The Diffusion of Bio-mass over Complexity .....	223
9.5	Regeneration of Anti-entropy .....	231
9.5.1	A Tentative Analysis of the Biological Dynamics of Entropy and Anti-entropy .....	233
9.6	Interpretation of Anti-entropy as a Measure of Symmetry Changes .....	238
9.7	Theoretical Consequences of This Interpretation .....	243
<b>10</b>	<b>A Philosophical Survey on How We Moved from Physics to Biology .....</b>	<b>249</b>
10.1	Introduction .....	249
10.2	Physical Aspects .....	250
10.2.1	The Exclusively Physical .....	250
10.2.2	Physical Properties of the "Transition" towards the Living State of Matter .....	251
10.3	Biological Aspects .....	251
10.3.1	The Maintenance of Biological Organization .....	252
10.3.2	The Relationship to the Environment .....	253
10.3.3	Passage to Analyses of the Organism .....	253

- 10.4 A Definition of Life? ..... 254
  - 10.4.1 Interfaces of Incompleteness ..... 256
- 10.5 Conclusion ..... 257
  
- A Mathematical Appendix** ..... 259
  - A.1 Scale Symmetries ..... 259
  - A.2 Noether's Theorem ..... 260
    - A.2.1 Classical Mechanics Version (Lagrangian) ..... 260
    - A.2.2 Field Theoretic Point of View ..... 264
  
- References** ..... 267