Contents

1. Necessity for a Science of Complex Systems .................. 1
   1.1 Introduction ........................................... 1
   1.2 Chaos ................................................. 4
   1.3 Chaos and Complexity .................................. 8
   1.4 How Has Chaos Changed Our Way of Thinking? ........... 11
       1.4.1 Dialectic Method to Overcome the Antithesis
               Between Determinism and Nondeterminism
               or Between Programs and Errors ..................... 11
       1.4.2 Dialectic Method to Overcome the Antithesis
               Between Order and Randomness ..................... 12
       1.4.3 Beyond the Antithesis Between Reductionism
               and Holism ...................................... 12
   1.5 Dynamic Many-to-Many Relations and Bio-networks ...... 13
   1.5.1 The Necessity of Dynamic Many-to-Many Relations .. 13
   1.5.2 Metabolic Systems, Differentiation, and Development . 15
   1.5.3 Ecosystems .......................................... 16
   1.5.4 Immune Systems .................................... 17
   1.5.5 The Brain ......................................... 18
   1.5.6 Rugged Landscapes and Their Problems ............. 18
   1.5.7 Conclusion ......................................... 20
   1.6 The Construction of an Artificial (Virtual) World ...... 21
   1.7 A Trigger to Emergence .................................. 24
   1.8 Beyond Top-Down Versus Bottom-Up ....................... 26
   1.9 Methodology of Study of Complex Systems ............... 28
       1.9.1 Constructive Way of Understanding .................. 29
       1.9.2 Plural Views ....................................... 30
       1.9.3 Mathematical Anatomy ............................. 31
       1.9.4 The Problem of Internal Observers ................. 31

2. Observation Problems
   from an Information-Theoretical Viewpoint .................. 33
   2.1 Observation Problems of Chaos .......................... 33
   2.2 Undecidability and Entire Description ................... 37
2.3 A Demon in Chaos ..................................... 38
2.4 Chaos in the BZ Reaction ............................... 39
2.5 Noise-Induced Order .................................... 43
2.6 Could Structural Stability Lead to an Adequate Notion
   of a Model? ............................................ 47
2.7 Information Theory of Chaos ............................ 50

3. CMLs: Constructive Approach
to Spatiotemporal Chaos ............................... 57
   3.1 From a Descriptive to a Constructive Approach
      of Nature .............................................. 57
   3.2 Coupled Map Lattice Approach to Spatiotemporal Chaos...
      3.2.1 Spatiotemporal Chaos ............................ 59
      3.2.2 Introduction to Coupled Map Lattices .............. 61
      3.2.3 Comparison with Other Approaches ................ 64
   3.3 Phenomenology of Spatiotemporal Chaos
      in the Diffusively Coupled Logistic Lattice .............. 65
      3.3.1 Introduction ..................................... 65
      3.3.2 Frozen Random Patterns and Spatial Bifurcations ... 66
      3.3.3 Pattern Selection with Suppression of Chaos ....... 69
      3.3.4 Brownian Motion of Chaotic Defects
         and Defect Turbulence ............................... 70
      3.3.5 Spatiotemporal Intermittency (STI) ................. 71
      3.3.6 Stability of Fully Developed Spatiotemporal Chaos
         (FDSTC) Sustained by the Supertransients ............. 75
      3.3.7 Traveling Waves .................................. 77
      3.3.8 Supertransients ................................. 81
   3.4 CML Phenomenology as a Problem of Complex Systems ...
   3.5 Phenomenology in Open-Flow Lattices ................. 84
      3.5.1 Introduction ..................................... 84
      3.5.2 Spatial Bifurcation to Down-Flow .................. 85
      3.5.3 Convective Instability and Spatial Amplification
         of Fluctuations ..................................... 86
      3.5.4 Phase Diagram ................................... 89
      3.5.5 Spatial Chaos .................................... 91
      3.5.6 Selective Amplification of Input .................... 93
   3.6 Universality ........................................... 94
   3.7 Theory for Spatiotemporal Chaos ....................... 97
   3.8 Applications of Coupled Map Lattices ................. 100
      3.8.1 Pattern Formation (Spinodal Decomposition) ........ 100
      3.8.2 Crystal Growth and Boiling ....................... 101
      3.8.3 Convection ...................................... 101
      3.8.4 Spiral and Traveling Waves in Excitable Media .... 103
      3.8.5 Cloud Dynamics and Geophysics .................... 104
5.2.5 Selective Amplification of Input Signals
by the Unidirectionally Coupled Map Lattice ........ 170
5.3 Information Dynamics of a CML with One-Way Coupling ... 171
5.4 Design of Coupled Maps and Plastic Dynamics .......... 175
5.5 Construction of Dynamic Many-to-Many Logic
and Information Processing ............................. 178
5.6 Implications to Biological Networks .................... 179
   5.6.1 Prototype of Hierarchical Structures ............ 180
   5.6.2 Prototype of Diversity and Differentiation ......... 180
   5.6.3 Formation and Collapse of Relationships ........... 184
   5.6.4 Clustering in Hypercubic Coupled Maps;
       Self-organizing Genetic Algorithms .................. 184
   5.6.5 Homeochaos ..................................... 186
   5.6.6 Summing Up ..................................... 189

6. Chaotic Information Processing in the Brain .......... 191
   6.1 Hermeneutics of the Brain .......................... 191
   6.2 A Brief Comment on Hermeneutics
       (the Inside and the Outside) ......................... 194
   6.3 A Method for Understanding the Brain and Mind –
       Internal Description .................................. 195
   6.4 Evidence of Chaos in Nervous Systems ............... 196
   6.5 The Origin of Neurochaos ............................ 198
   6.6 The Implications of Stochastic Renewal of Maps ....... 203
       6.6.1 Chaotic Game ................................... 203
       6.6.2 Skew-Product Transformations ................. 204
   6.7 A Model for Dynamic Memory .......................... 205
   6.8 A Model for Dynamically Linking Memories .......... 206
   6.9 Significance of Neurochaos ........................... 212
   6.10 Temporal Coding .................................... 214
   6.11 Capillary Chaos as a Complex Dynamics ............. 219
       6.11.1 Significance of Capillary Pulsion
           in the Brain Functions ............................ 219
       6.11.2 Embedding Theorems ............................ 220
       6.11.3 Experimental Systems ......................... 221
       6.11.4 Reconstruction of the Dynamics ............... 222
       6.11.5 Calculations of Lyapunov Exponents ............ 224
       6.11.6 The Condition Dependence ...................... 226
       6.11.7 Cardiac Chaos .................................. 230
       6.11.8 Information Structure .......................... 231
       6.11.9 Implications of Capillary Chaos ............... 235
7. Conversations with Authors .................................. 237
   7.1 Concluding Discussions ................................. 237
   7.2 Questions and Answers ................................ 239
      7.2.1 The Significance of Models ........................ 239
            in Complex Systems Research ....................... 239
      7.2.2 Chaotic Itinerancy ................................ 243
      7.2.3 New Information Theory and Internal Observation ... 246

References .................................................... 251

Index .......................................................... 267
Complex Systems: Chaos and Beyond
A Constructive Approach with Applications in Life Sciences
Kaneko, K.; Tsuda, I.
2001, XIII, 274 p., Hardcover
ISBN: 978-3-540-67202-9