

Table of Contents

Prologue	1
<hr/>	
Part I Foundations	5
<hr/>	
1. Introduction	7
1.1 Biological Systems Are Complex Systems	7
1.2 Goals of Synergetics	9
1.3 The Brain as a Complex System	10
1.4 Traditional Versus Synergetic Interpretations of Brain Functions	10
2. Exploring the Brain	13
2.1 The Black Box Approach	13
2.2 Opening the Black Box	14
2.3 Structure and Function at the Macroscopic Level	14
2.4 Noninvasive Methods	16
2.4.1 X-Ray Tomography	17
2.4.2 Electro-encephalograms (EEG)	17
2.4.3 Magneto-encephalograms (MEG)	18
2.4.4 Positron Emission Tomography (PET)	21
2.4.5 Magnetic Resonance Imaging (MRI)	23
2.5 Structure and Function at the Microscopic Level	27
2.6 Learning and Memory	30
3. Modeling the Brain. A First Attempt: The Brain as a Dynamical System	31
3.1 What Are Dynamical Systems?	31
3.2 The Brain as a Dynamical System	33
4. Basic Concepts of Synergetics I: Order Parameters and the Slaving Principle	35
4.1 Factors Determining Temporal Evolution	35
4.2 Strategy of Solution	39

4.2.1	Instability, Order Parameters, Slaving Principle	39
4.2.2	The Laser Paradigm or Boats on a Lake	44
4.2.3	The Slaving Principle	45
4.2.4	The Central Role of Order Parameters	47
4.3	Self-Organization and the Second Law of Thermodynamics ..	48
5.	Dynamics of Order Parameters	51
5.1	One Order Parameter	51
5.2	Two Order Parameters	55
5.3	Three and More Order Parameters	61
5.4	Order Parameters and Normal Forms *	61
<hr/>		
Part II	Behavior	65
<hr/>		
6.	Movement Coordination – Movement Patterns	67
6.1	The Coordination Problem	68
6.2	Phase Transitions in Finger Movement: Experiments and a Simple Model	68
6.3	An Alternative Model?	74
6.4	Fluctuations in Finger Movement: Theory *	75
6.5	Critical Fluctuations in Finger Movements: Experiments ...	82
6.5.1	The Experimental Set-Up	82
6.5.2	Experimental Results	84
6.6	Some Important Conclusions	87
7.	More on Finger Movements	91
7.1	Movement of a Single Index Finger	91
7.2	Coupled Movement of Index Fingers	96
7.3	Phase Transitions in Human Hand Movements During Multifrequency Tapping Tasks	99
7.3.1	Experiment: Transitions in Multifrequency Tapping ...	99
7.4	A Model for Multifrequency Behavior *	103
7.5	The Basic Locking Equations and Their Solutions *	106
7.6	Summary of the Main Theoretical Results	113
7.7	Summary and Outlook	115
8.	Learning	117
8.1	How Learning Changes Order Parameter Landscapes	117
8.2	How Learning Changes the Number of Order Parameters ...	121
8.3	How Learning Gives Rise to New Order Parameters	122

* Marks chapters or sections that are mathematically somewhat more involved

9. Animal Gaits and Their Transitions	123
9.1 Introductory Remarks	123
9.2 Symmetries and Groups	123
9.3 An Empirical Study of Quadruped Gaits	128
9.4 Phase Dynamics and Symmetries	133
9.5 Equations of Phase Dynamics	138
9.6 Stationary Solutions	141
9.7 Gait Dynamics of Lower Symmetry	144
9.8 Summary and Outlook	146
10. Basic Concepts of Synergetics II: Formation of Spatio-temporal Patterns	149
11. Analysis of Spatio-temporal Patterns *	157
11.1 Karhunen–Loève Expansion, Singular Value Decomposition, Principal Component Analysis – Three Names for the Same Method	157
11.2 A Geometric Approach Based on Order Parameters. The Haken–Friedrich–Uhl Method	164
11.2.1 One Real Order Parameter	164
11.2.2 Oscillations Connected with One Complex Order Parameter	171
12. Movements on a Pedalo	173
12.1 The Task	173
12.2 Description of the Movement Pattern	174
12.3 Quantification of the Pedalo Movement	175
12.4 Analysis of the Movement Using the Karhunen–Loève Expansion	176
12.5 A Detailed Analysis of the Movements of Arms and Legs	179
12.6 Haken–Friedrich–Uhl Order Parameter Analysis	180
12.7 Concluding Remarks on Part II	191
<hr/>	
Part III EEG and MEG	193
<hr/>	
13. Chaos, Chaos, Chaos	195
14. Analysis of Electroencephalograms	203
14.1 Goals of the Analysis	203
14.2 Identification of Order Parameters and Spatial Modes	204
14.3 Results	209
15. Analysis of MEG Patterns	219
15.1 Experimental Results	219

15.2 Temporal and Spatial Analysis	220
15.2.1 Temporal Analysis.....	220
15.2.2 Spatio-temporal Analysis	222
15.3 Modeling the Dynamics	226
15.4 Modeling the Dynamics: Towards a Field Theory of Brain Activity	232
15.5 EEG and MEG Analysis Revisited.....	234
<hr/>	
Part IV Cognition	237
<hr/>	
16. Visual Perception.....	239
16.1 A Model of Pattern Recognition	239
16.2 The Role of Attention Parameters. Ambiguous Figures	247
16.3 Influence of a Bias	251
16.4 The Role of Fluctuations of Attention Parameters	254
16.5 Learning Patterns	257
16.6 A Model for Stereo Vision	260
17. Decision Making as Pattern Recognition.....	275
18. The Brain as a Computer or Can Computers Think?	279
18.1 An Excursion: <i>What is Thinking?</i>	279
18.2 Computers	280
18.3 Artificial Intelligence	283
18.4 Neurocomputers and Connectionism	284
18.5 Can Computers Think?	287
19. Networks of Brains	289
19.1 A General Model of IRN in Terms of Synergetics	290
19.2 Collective Cognitive Processes.....	294
19.3 Iterations.....	295
19.4 Concluding Remarks	297
20. Synergetics of the Brain: Where Do We Stand? Where Do We Go from Here?	299
20.1 Looking Back	299
20.2 Mind and Matter – An Eternal Question	301
20.3 Some Open Problems	303

Appendices	307
<hr/>	
A. Analysis of Time Series	309
A.1 Time Series Analysis	309
A.2 Definition of Dimensions	313
A.3 Dimension of Attractors	316
A.4 Some Conclusions	318
B. Determination of Adjoint Vectors	318
C. The Potentials Occurring in Sect. 16.5	319
References and Further Reading	321
Subject Index	341
About the Author	349