

Contents

1	Introduction	1
1.1	Complexity of Information Processing in Biological Systems	1
1.2	Towards the Operational Formalism in Biological Systems.	3
1.3	Contextuality of Quantum Physics and Biology	4
1.4	Adaptive Dynamical Systems	6
1.5	Breaking the Formula of Total Probability and Non-Kolmogorov Probability Theory.	7
1.6	Quantum Bio-informatics.	9
	References.	10
2	Fundamentals of Classical Probability and Quantum Probability Theory	13
2.1	Short Introduction to Classical Probability Theory.	13
2.1.1	Probability Space	13
2.1.2	Conditional Probability	17
2.1.3	Formula of Total Probability	19
2.2	Short Introduction of Quantum Probability Theory	19
2.2.1	States and Observables	20
2.2.2	Superposition	22
2.2.3	Dirac Notation	25
2.2.4	Qubit	26
2.2.5	Wave Function.	26
2.3	Schrödinger Dynamics and Its Role in Quantum Bio-informatics.	27
2.4	Theory of Open Quantum Systems in Biology	29
2.5	Compound Systems.	31
2.5.1	Entanglement	33
2.5.2	Tensor Products and Contextuality of Observables for a Single System.	34
2.5.3	A Few Words About Quantum Information	35

2.6	From Open Quantum System Dynamics to State-Observable Adaptive Dynamics.	36
	References.	38
3	Fundamentals of Molecular Biology.	41
3.1	Research Fields in Life Science and Information Biology. . . .	41
3.2	Molecular Biology and Genome	43
3.2.1	Protein Folding Problem	46
3.3	Various Information Transductions in Biology	47
3.3.1	Molecular Biology of Diauxie of <i>E. coli</i> (Glucose Effect)	48
3.3.2	Systems Biological Approach to the Diauxie (Computer Simulation)	51
3.3.3	Epigenetic Mutation and Evolution	52
	References.	53
4	Adaptive Dynamics and General Approach to Non-Kolmogorov Probability Theory.	57
4.1	Violation of Formula of Total Probability and Non-Kolmogorov Probability Theory.	58
4.1.1	Interference of Probabilistic Patterns in the Two Slit Experiment	58
4.1.2	Conditional Probability and Joint Probability in Quantum Systems	65
4.1.3	Proposal of Non-Kolmogorov Probability Theory	68
4.2	Lifting and Channel	68
4.3	Adaptive Dynamics.	71
4.3.1	Motivation and Examples	71
4.3.2	Conceptual Meaning	71
4.4	State and Observable Adaptive Dynamics	72
	References.	73
5	Application of Adaptive Dynamics to Biology.	75
5.1	Violation of the Formula of Total Probability in Molecular Biology	76
5.1.1	Reaction of Tongue to Sweetness	76
5.1.2	Glucose Effect on <i>E. coli</i> Growth	77
5.1.3	Mesenchymal Cells Context.	79
5.1.4	<i>PrP^{Sc}</i> Prion Proteins Context	80
5.2	Interpretation of the Above Violations by Adaptive Dynamics	80
5.2.1	State Change as Reaction of Tongue to Sweetness . . .	81
5.2.2	Activity of Lactose Operon in <i>E. coli</i>	83

5.3	Precultivation Effect for <i>E. coli</i> Growth	85
	References.	89
6	Application to Decision Making Theory and Cognitive Science . . .	91
6.1	Cognitive Psychology and Game Theory	91
6.2	Decision Making Process in Game	92
6.2.1	Prisoner's Dilemma.	92
6.2.2	Mental State and Its Dynamics	95
6.2.3	Numerical Analysis of Dynamics	102
6.3	Bayesian Updating Biased by Psychological Factors	107
6.4	Optical Illusions for an Ambiguous Figure.	110
6.4.1	What Are Optical Illusions?: A Mystery of Visual Perception	110
6.4.2	Optical Illusion for Ambiguous Figure.	111
6.4.3	Violation of Formula of Total Probability	113
6.4.4	A Model of Depth Inversion: Majority Among <i>N</i> -agent	115
6.5	Contextual Leggett-Garg Inequality for Statistical Data on Recognition of Ambiguous Figures.	117
6.5.1	Leggett-Garg Inequality.	119
6.5.2	Contextual Leggett-Garg Inequality.	121
6.5.3	Violation of Inequality in Optical Illusions.	122
	References.	124
7	Operational Approach to Modern Theory of Evolution	127
7.1	Lamarckism	127
7.2	Darwinism	128
7.2.1	Survival of the Fittest	128
7.2.2	Evolutionary Synthesis/neo-Darwinism	129
7.3	Neo-Lamarckism: CRISPR-Cas System of Adaptive Antivirus Immunity.	131
7.4	Evolutionary Jumps; Punctuated Equilibrium and Gradualism	133
7.5	Epigenetic Lamarckism	135
	References.	136
8	Epigenetic Evolution and Theory of Open Quantum Systems: Unifying Lamarckism and Darwinism	137
8.1	Information Interpretation.	139
8.1.1	Schrödinger Cat Meets "Schrödinger <i>E. coli</i> Bacteria"	139

8.2	Dynamics of Cell Epigenetic State in the Process of Interaction with an Environment	140
8.2.1	Epigenetic Evolution from Quantum Master Equation	141
8.2.2	On Applicability of Quantum Master Equation to Description of Dynamics of Epigenome	142
8.2.3	Evolutionary Jumps as Quantum-Like Jumps	143
8.2.4	On a Quantum-Like Model of Evolution: Dynamics Through Combination of Jumps and Continuous Drifts	144
8.3	Dynamics of a Single Epimutation of the Chromatin-Marking Type	145
8.3.1	Entropy Decreasing Evolution	146
8.4	“Entanglement” of Epimutations in Genome	148
8.4.1	Interpretation of Entanglement in Genome	149
8.4.2	Environment Driven Quantum(-Like) “Computations” in Genome	150
8.4.3	Comparison with Waddington’s Canalization Model	151
8.5	Adaptive Dynamics in Space of Epigenetic Markers	151
	References	152
9	Foundational Problems of Quantum Mechanics	155
9.1	Bell’s Inequality	155
9.2	Debate on Hidden Variables and Its Biological Dimension	156
9.3	Nonobjectivity Versus Potentiality	159
	References	160
10	Decision and Intention Operators as Generalized Quantum Observables	163
10.1	Generalized Quantum Observables	164
10.1.1	POVMs	164
10.1.2	Interference of Probabilities for Generalized Observables	165
10.2	Formula of Total Probability with the Interference Term for Generalized Quantum Observables and Mixed States	166
10.3	Decision Making with Generalized Decision and Intention Operators	168
10.3.1	Classical Scheme	168
10.3.2	Quantum-Like Scheme	168
	Reference	169
	Index	171

Quantum Adaptivity in Biology: From Genetics to
Cognition

Asano, M.; Khrennikov, A.; Ohya, M.; Tanaka, Y.; Yamato,
I.

2015, XX, 173 p. 27 illus., Hardcover

ISBN: 978-94-017-9818-1