

Contents

1	Biomimetics: Its Technological and Societal Potential	1
	Herbert Stachelberger, Petra Gruber, and Ille C. Gebeshuber	
 Part I Material Structure		
2	Bionic (Nano) Membranes	9
	Jovan Matovic and Zoran Jakšić	
2.1	Artificial Nanomembranes	10
2.2	Biological Nanomembranes	12
2.3	Functionalization of Artificial Nanomembranes Toward Bionic Structures at ISAS: TU Wien	13
2.3.1	Nanomembrane-Based Bionic Structures for Energy Harvesting	13
2.3.2	Nanomembranes as Bionic Detectors of Electromagnetic Radiation	19
2.4	Conclusion	22
3	Biomimetics in Tribology	25
	I.C. Gebeshuber, B.Y. Majlis, and H. Stachelberger	
3.1	Introduction: Historical Background and Current Developments	26
3.2	Biology for Engineers	28
3.3	Method: The Biomimicry Innovation Method	30
3.4	Results: Biomimetics in Tribology – Best Practices and Possible Applications	32
3.4.1	Application of the Biomimicry Innovation Method Concerning Mechanical Wear	33
3.4.2	Application of the Biomimicry Innovation Method Concerning Shear	35

3.4.3	Application of the Biomimicry Innovation Method Concerning Tension	35
3.4.4	Application of the Biomimicry Innovation Method Concerning Buckling, Fatigue, Fracture (Rupture) and Deformation	35
3.4.5	Application of the Biomimicry Innovation Method Concerning Attachment	37
3.5	Summary and Outlook	40
4	Reptilian Skin as a Biomimetic Analogue for the Design of Deterministic Tribosurfaces	51
	H.A. Abdel-Aal and M. El Mansori	
4.1	Introduction	52
4.2	Background	56
4.2.1	The Python Species	56
4.2.2	Structure of Snake Skin	58
4.2.3	Skin Shedding	59
4.3	Observation of Shed Skin	60
4.3.1	Initial Observations	60
4.3.2	Optical Microscopy Observations	62
4.3.3	Scan Electron Microscopy Observations	63
4.4	Metrology of the Surface	69
4.4.1	Topographical Metrology	69
4.4.2	Bearing Curve Analysis	70
4.5	Correlation to Honed Surfaces	73
4.6	Conclusions and Future Outlook	77
5	Multiscale Homogenization Theory: An Analysis Tool for Revealing Mechanical Design Principles in Bone and Bone Replacement Materials	81
	Christian Hellmich, Andreas Fritsch, and Luc Dormieux	
5.1	Introduction	84
5.2	Fundamentals of Continuum Micromechanics	85
5.2.1	Representative Volume Element	85
5.2.2	Upscaling of Elasto-Brittle and Elastoplastic Material Properties	86
5.3	Bone's Hierarchical Organization	88
5.4	Elastic and Strength Properties of the Elementary Components of Bone: Hydroxyapatite, Collagen, Water	88
5.5	Multiscale Micromechanical Representation of Bone	91
5.6	Experimental Validation of Multiscale Micromechanics Theory for Bone	93
5.7	How Bone Works: Mechanical Design Characteristics of Bone Revealed Through Multiscale Micromechanics	96
5.8	Some Conclusions from a Biological Viewpoint	98

6	Bioinspired Cellular Structures: Additive Manufacturing and Mechanical Properties	105
	J. Stampfl, H.E. Pettermann, and R. Liska	
6.1	Introduction	105
6.2	Fabrication of Bioinspired Cellular Solids Using Lithography-Based Additive Manufacturing	107
6.2.1	Laser-Based Stereolithography	108
6.2.2	Dynamic Mask-Based Stereolithography	108
6.2.3	Inkjet-Based Systems	110
6.2.4	Two-Photon Polymerization	111
6.3	Photopolymers for Additive Manufacturing Technologies	112
6.3.1	Principles of Photopolymerization	112
6.3.2	Radical and Cationic Systems in Lithography-Based AMT	114
6.3.3	Biomimetic, Biocompatible, and Biodegradable Formulations	115
6.4	Mechanical Properties: Modeling and Simulation	118
6.4.1	Linear Elastic Behavior	118
6.4.2	Nonlinear Response	119
6.4.3	Sample Size and Effective Behavior	119
6.5	Conclusion	121

Part II Form and Construction

7	Biomimetics in Architecture [Architekturbionik]	127
	Petra Gruber	
7.1	Introduction	127
7.2	History: Different Approaches	128
7.2.1	Analogy and Convergence	129
7.2.2	Strategic Search for the Overlaps Between Architecture and Nature	130
7.3	Strategies: What is Transferred and How is it Done?	131
7.3.1	What is Transferred?	131
7.3.2	Methods	131
7.4	Application Fields: Successful Examples	134
7.4.1	Emergence and Differentiation: Morphogenesis	134
7.4.2	Interactivity	135
7.4.3	Dynamic Shape	135
7.4.4	Intelligence	136
7.4.5	Energy Efficiency	136
7.4.6	Material/Structure/Surface	137
7.4.7	Integration	137
7.5	Case Studies	138
7.5.1	Biomimetics Design Exercise	138

7.5.2	Biomimetics Design Programmes, Workshops and Studies	140
7.6	Future Fields, Aims and Conclusion	144
7.6.1	Aims	144
7.6.2	Considerations About Future Developments	145
8	Biomorphism in Architecture: Speculations on Growth and Form	149
	Dörte Kuhlmann	
8.1	Introduction	149
8.2	The Essence of Nature	150
8.3	Nature as a Source for Form	152
8.4	Natural Processes	153
8.5	Organic Versus “Mechanical” Form	156
8.6	Bionics and Cyborgs	159
8.7	Ecology	162
8.8	From Fractals to Catastrophies	165
8.9	Form Follows Function	167
8.10	The Concept of Organic Unity	171
8.11	Conclusion	174
9	Fractal Geometry of Architecture	179
	Wolfgang E. Lorenz	
9.1	Fractal Concepts in Nature and Architecture	179
9.1.1	From the Language of Fractals to Classification	179
9.2	Fractals: A Definition from a Mathematical and an Architectural Point of View	182
9.2.1	Roughness and Length Measurement	182
9.2.2	Scale Range and Distance	184
9.2.3	Self-Similarity: An Important Attribute of Fractals	184
9.2.4	Architectural Examples	186
9.2.5	Developed Through Iteration	187
9.2.6	Differences Between Architectural and Mathematical Fractals	189
9.2.7	Fractals as a Design Aid	189
9.2.8	Fractals Are Common to Nature	190
9.2.9	The Factor Chance	191
9.3	From Simulation to Measurement	192
9.3.1	Curdling	192
9.3.2	Fractal Dimension	194
9.3.3	Perception and Distance	196
9.4	Fractal Dimension and Architecture	196
9.4.1	Fractal Dimension and Approaching a Building	197
9.4.2	Results of Measurement	198
9.5	Conclusions and Outlook	199

Part III Information and Dynamics

10 Biomimetics in Intelligent Sensor and Actuator

Automation Systems	203
Dietmar Bruckner, Dietmar Dietrich, Gerhard Zucker, and Brit Müller	
10.1 Research Field	204
10.2 Automation	204
10.3 Intelligence and Communication	206
10.4 Open Problems: Challenges in Research	207
10.5 Intelligence of Bionic Systems	209
10.5.1 Hierarchical Model Conception	209
10.5.2 Statistical Methods	210
10.5.3 Definition of Intelligence	211
10.5.4 Choice of the Right Model	212
10.5.5 Top-Down Methodology	212
10.5.6 A Unitary Model	213
10.5.7 Differentiation Between Function, Behavior, and Projection	213
10.5.8 Indispensible Interdisciplinarity	214
10.6 The Psychoanalytical Model	214
10.7 Conclusion	217

11 Technical Rebuilding of Movement Function Using

Functional Electrical Stimulation	219
Margit Gföhler	
11.1 Introduction	219
11.2 Principle	220
11.3 Actuation	220
11.3.1 Stimulation Signal	222
11.3.2 Electrodes	223
11.4 Stimulators	224
11.5 Control	225
11.5.1 Modeling/Simulation	225
11.5.2 Control Systems	227
11.6 Sensors	229
11.6.1 Artificial Sensors	229
11.6.2 Natural Sensors in the Peripheral Nervous System	229
11.6.3 Volitional Biological Signals	230
11.7 Applications for the Lower Limb	231
11.7.1 Cycling	231
11.7.2 Rowing	239
11.7.3 Gait	241
11.8 Applications for the Upper Limb	242
11.9 Outlook	243
References	244

12 Improving Hearing Performance Using Natural Auditory Coding Strategies	249
Frank Rattay	
12.1 The Hair Cell Transforms Mechanical into Neural Signals	249
12.2 The Human Ear	251
12.3 Place Theory Versus Temporal Theory	253
12.4 Noise-Enhanced Auditory Information	253
12.5 Auditory Neural Network Sensitivity Can be Tested with Artificial Neural Networks	257
12.6 Cochlear Implants Versus Natural Hearing	258
12.7 Discussion	259
12.8 Conclusion	260
References	260
Index	263

Biomimetics -- Materials, Structures and Processes

Examples, Ideas and Case Studies

gruber, p.; Bruckner, D.; Hellmich, C.; Schmiedmayer,

H.-B.; Stachelberger, H.; Gebeshuber, I.C. (Eds.)

2011, XVI, 268 p., Hardcover

ISBN: 978-3-642-11933-0