

Wolfgang R. Hess, Anita Marchfelder

Regulatory RNAs in Prokaryotes

SpringerWienNewYork

Contents

RNAs in Prokaryotes	v
References	vii
1 Small RNAs with a Role in the Oxidative Stress Response of Bacteria	1
1 Introduction	1
2 OxyS and the Oxidative Stress Response in Enterobacteria	3
3 The Link Between Iron Levels and Oxidative Stress, and the Role of RyhB	5
3.1 How Iron Can Cause Oxidative Stress	5
3.2 Mechanisms of RyhB Regulation	6
3.3 RyhB Homologues in Other Bacteria	8
4 Photooxidative Stress-Induced sRNAs in Photosynthetic Alpha-Proteobacteria	9
5 Other sRNAs Involved in Oxidative Stress Responses	10
6 Concluding Remarks	11
References	12
2 Hfq-associated Regulatory Small RNAs	15
1 Introduction	15
1.1 <i>Trans</i> -acting sRNAs and the Role for Hfq	16
2 Regulatory Mechanisms Employed by Hfq-associated sRNAs	17
2.1 Translational Control Near the SD Sequence and AUG Start Codon	17
2.2 Primary Role for sRNAs in Translational Silencing	17
2.3 Non-canonical Repression of Translation Initiation	20
2.4 Control of Protein Synthesis Through Regulation of mRNA Decay	21
2.5 Multiple Target Control by sRNAs	22
2.6 Small RNAs with Multiple Conserved Targeting Regions ..	33
2.7 Unusually Complex Mechanisms	35
2.8 5' Regions as a Conserved Mechanism for Targeting Multiple mRNAs	36
2.9 Maturation of Small RNAs	38
2.10 Potential Evolution of New sRNAs from 3' UTRs	39
3 Perspective	39
3.1 Overlap of sRNAs and Targets in Regulons	39

3.2	Titration of Hfq: Regulation or Side-effect?	40
3.3	Titration of Hfq: Implications for Horizontal Gene Transfer	41
3.4	Design of Synthetic sRNAs	42
4	Outlook	42
	References	43
3	A Current Overview of Regulatory RNAs in Staphylococcus Aureus ..	51
1	Introduction	51
2	Cis-acting Regulatory Elements in mRNAs	52
2.1	RNA Thermosensors	53
2.2	Riboswitches	53
2.3	Erythromycin-induced Translation Attenuation	56
2.4	tRNA-mediated Riboswitches	56
2.5	Protein-mediated Transcription Termination/Anti-termination	58
3	Small Non-coding RNAs Targeting mRNAs	58
3.1	Generalities	58
3.2	Pathogenicity Island-encoded sRNAs	60
3.3	sRNA Stress Response and Metabolism	61
3.4	sRNA and Small Colony Variant	62
3.5	<i>S. aureus</i> Transcriptome	63
4	RNAIII, a mRNA and a Regulatory RNA	63
4.1	Quorum Sensing and Virulence in <i>S. aureus</i>	63
4.2	RNAIII Encodes a Small Toxin	64
4.3	RNAIII as the Regulator	65
4.4	RNAIII and its Regulatory Network	67
5	CRISPR in Defense Mechanism	67
6	Perspectives	69
	References	70
4	<i>Pseudomonas Aeruginosa</i> Small Regulatory RNAs	77
1	Introduction	77
2	Bacterial Regulatory RNAs and their Mode of Action	79
3	<i>P. aeruginosa</i> Housekeeping RNAs	81
4	Protein Sequestering RNAs	82
4.1	RsmY/Z	82
4.2	CrcZ	85
5	Verified and Candidate <i>P. Aeruginosa</i> Base-pairing sRNAs	85
5.1	Prf1/2	85
5.2	RgsA	88
5.3	PhrS and PhrD	88
6	CRISPR	89
7	Uncharacterized <i>P. Aeruginosa</i> sRNAs	89
8	Conclusion	90
	References	90

5	Natural Antisense Transcripts in Bacteria	95
1	Defining Features of an Antisense Transcript	95
2	Antisense RNAs were Discovered in Bacteria	97
2.1	Known Facts About Antisense RNAs from Bacteriophages, Plasmids and Transposons	97
3	Antisense Transcripts Come in High Numbers and Occur Throughout the Bacterial Kingdom	98
4	Bacterial Antisense RNAs are Functionally Important	100
4.1	How Bacterial Antisense RNAs Exert their Function	101
5	Outlook	104
	References	104
6	6S RNA: A Regulator of Transcription	109
1	6S RNA – The Early Years	109
2	6S RNA Interactions with RNA Polymerase	110
2.1	6S RNA-RNA Polymerase: <i>In Vivo</i> Analysis	110
2.2	6S RNA-RNA Polymerase: <i>In Vitro</i> Analysis	110
2.3	6S RNA: A Mimic of Promoter DNA Near the Active Site	112
2.4	6S RNA: A Template for RNA Synthesis	113
2.5	The 6S RNA Upstream Region and σ^{70} Region 4.2 Does <i>Not</i> Mimic Promoter DNA Interactions	114
3	6S RNA and Regulation of Transcription	116
3.1	Regulation of Transcription: <i>In Vivo</i> Analysis	116
3.2	Regulation of Transcription: <i>In Vitro</i> Approaches	117
3.3	6S RNA and Regulation of Transcription: Mechanism	118
3.4	6S RNA and σ^s -Dependent Transcription	119
4	Physiological Role of 6S RNA	120
4.1	6S RNA and Stationary Phase Cell Survival	120
4.2	6S RNA and Stress: Altered Survival at High pH	120
4.3	6S RNA Integration Into Global Pathways	121
5	Biogenesis of 6S RNA	122
6	6S RNAs in Diverse Bacterial Species	123
6.1	Identification	123
6.2	6S RNA Function in Other Species	124
7	Concluding Comments	125
	References	126
7	Archaea Employ Small RNAs as Regulators	131
1	Introduction	131
2	The Discovery of a New Type of Non-Coding RNA in Archaea: snoRNAs	133
3	Expanding the Family of Small Non-Coding RNAs in Archaea	134
4	Small RNAs in Halophilic Archaea	134
4.1	Prediction of sRNA Genes	136
4.2	Experimental Identification of Small RNAs	137
4.3	Expression of Small RNA Genes	137

4.4	Functional Analysis	138
4.5	The <i>Haloferax</i> Lsm Protein	138
5	Small RNAs in Methanogenic Archaea	139
5.1	Un-translated Regions of mRNAs	140
5.2	Small RNAs in <i>M. mazei</i>	140
6	Conclusion	142
	References	143
8	Structure, Function and RNA Binding Mechanisms of the Prokaryotic Sm-like Protein Hfq	147
1	Introduction	147
2	Prevalence of the Sm Fold	148
3	Biochemical and Genetic Analysis of Hfq	148
3.1	The RNA-binding Modes of Hfq	150
3.2	Hfq-mediated sRNA-mRNA Annealing	150
4	Hfq in RNA decay	151
5	The Role of the C-terminus of Hfq Proteins	153
6	Role of Hfq in Low GC Gram-positive Bacteria	154
6.1	Hfq in Cyanobacteria	155
6.2	Archaeal Hfq Protein	156
7	Concluding Remarks	157
	References	158
9	CRISPR/Cas and CRISPR/Cmr Immune Systems of Archaea	163
1	Introduction	163
2	Archaeal Viruses and Plasmids and Chromosomal Evolution	165
3	Diversity of Archaeal CRISPR/Cas and CRISPR/Cmr Immune Systems	167
4	Development and Stability of CRISPR Loci	170
5	Mobility of CRISPR/Cas and Cmr Modules	172
6	Targets of the CRISPR/Cas and CRISPR/Cmr Systems	172
7	Formation of crRNAs and Targeting of Foreign Elements	174
8	Anti CRISPR/Cas and CRISPR/Cmr Systems	175
9	Evolutionary Considerations	177
10	Conclusions	178
	References	179
10	Control of Bacterial Heat Shock and Virulence Genes by RNA Thermometers	183
1	RNA as Sensory Element	183
2	RNA Measures Temperature Directly	185
3	Control of Heat Shock Genes	185
4	Control of Virulence Genes	189
5	RNA-based Thermosensors That Do Not Act by Melting	189
6	Are There More RNA Thermometers?	190
	References	191

11 RNA Sensors of Intracellular Metabolites	195
1 Introduction. Gene Regulation in Bacteria: From Transcription Initiation to mRNA Degradation	195
2 Sensing of Metabolites by Cis-Acting Regulatory mRNAs	200
2.1 Riboswitch RNAs	200
2.2 Purine Riboswitch Gene Regulation Mechanisms	201
2.3 Therapeutic Applications Using Purine Riboswitches	203
3 Indirect Sensing of Metabolites by Cis-Acting Regulatory RNAs ..	205
3.1 Sensing of Amino Acids via tRNA Charging Ratios	205
3.2 Sensing of Amino Acids via tRNA Charging Ratios: Ribosome-Mediated Attenuation	208
3.3 Sensing of Amino Acids via tRNA Charging Ratios: Direct Sensing of Uncharged tRNAs	209
3.4 Sensing of Amino Acids via tRNA Charging Ratios: mRNA-Binding tRNA Synthetases	211
3.5 Sensing of Metabolites by RNA-Binding Proteins: Amino Acids	212
3.6 Sensing of Metabolites by RNA-Binding Proteins: Carbohydrates and Nucleotides	213
4 Concluding Remarks	214
References	215
12 Bioinformatics of Bacterial sRNAs and Their Targets	221
1 Computational Detection of Bacterial sRNAs	221
1.1 Definition of RNA Families	221
1.2 Detection of Homologous Structural RNAs	222
1.3 ncRNA Gene Finders	226
2 Computational Target Prediction	227
2.1 Search for Complementary Regions	227
2.2 Duplex Evaluation	228
2.3 Concatenation Approaches	230
2.4 Accessibility-based Approaches	231
2.5 Full Joint Structure Prediction	233
References	235
13 Computational Tools for Predicting sRNA Targets	241
1 Introduction	241
1.1 Training and Test Datasets	242
1.2 RNA Secondary Structure Profile	242
1.3 Machine-learning Methods	243
1.4 Construction of Prediction Models for sRNA Targets	244
2 Program and Usage	245
2.1 Predicting sRNA Targets Using sRNATarget Webserver ..	245
2.2 Predicting sRNA Targets Using Windows System	246
2.3 Predicting sRNA Targets Under Linux as the Operating System	250

3	Other Program Tools for Predicting sRNA Targets	250
3.1	IntaRNA	250
3.2	TargetRNA	251
4	An Example, Target Prediction for sRNA Yfr1	251
5	Future Thinking	252
	References	253
Index	255