

## Contents

**Preface** *XI*

**List of Contributors** *XIII*

### **Part I From Model Systems to Crop Improvement 1**

#### **1 General Stress Response of a Model Bacterium 3**

*Abram Aertsen, Philipp De Spiegeleer, Laurence Van Melderren, and  
Chris W. Michiels*

- 1.1 Introduction 3
- 1.2 General Stress Response 3
  - 1.2.1 The  $\sigma^S$  Regulatory Network 4
  - 1.2.2 *E. coli* Osmotic Shock Resistance 5
  - 1.2.3 *E. coli* Acid Resistance: An Example of a Differentially  
Controlled  $\sigma^S$  Module 6
- 1.3 Regulation of  $\sigma^S$  7
  - 1.3.1 Transcriptional Regulation of  $\sigma^S$  7
  - 1.3.2 Translational Regulation of  $\sigma^S$  8
  - 1.3.3 Post-Translational Regulation of  $\sigma^S$  9
  - 1.3.4 Competition for RNAP and Promoters 10
- 1.4 Conclusions 11

#### **2 Moss as a Model System for Plant Stress Responses 17**

*Andrew C. Cuming*

- 2.1 Introduction 17
- 2.2 Model Systems 19
- 2.3 *Physcomitrella* as a Model System 22
- 2.4 Water Stress and Abscisic Acid 24
- 2.5 *T. ruralis*: A Model for Poikilohydry 28
- 2.6 Cold Stress and Abscisic Acid 29
- 2.7 Future Perspectives 30

<b>3</b>	<b>Emerging Trends in Functional Genomics for Stress Tolerance in Crop Plants</b>	<b>37</b>
	<i>Swatishmita Ray, Prasant K. Dansana, Avantika Bhaskar, Jitender Giri, Sanjay Kapoor, Jitendra P. Khurana, and Akhilesh K. Tyagi</i>	
3.1	Introduction	37
3.2	Abiotic Stresses Encountered by Plants	38
3.3	Genome-Wide Investigations to Understand Components Involved in Abiotic Stress Responses	39
3.3.1	Transcriptome Analysis	39
3.3.2	Role of MicroRNAs in Stress	41
3.3.3	Analysis of Abiotic Stress-Responsive Genes using Proteomic Approaches	42
3.4	Quantitative Trait Loci for Abiotic Stress Tolerance	44
3.5	Networking the Stress Response Gene Function	44
3.5.1	Sensing Systems	44
3.5.2	Calcium and Calcium-Sensing Proteins	45
3.5.3	MAPK Proteins: At the Crossroads of Signaling Pathways	47
3.5.4	Other Pathways	48
3.5.5	Transcription Factors at the Junction	49
3.6	Functional Characterization of Stress Response Genes by the Transgenic Approach	51
3.7	Conclusions	52
<b>Part II</b>	<b>Stress Responses and Newly Involved Plant Hormones</b>	<b>65</b>
<b>4</b>	<b>Stress Physiology of Higher Plants: Cross-Talk between Abiotic and Biotic Stress Signaling</b>	<b>67</b>
	<i>Miki Fujita, Yasunari Fujita, Fuminori Takahashi, Kazuko Yamaguchi-Shinozaki, and Kazuo Shinozaki</i>	
4.1	Introduction	67
4.2	Cuticles and Stomata	68
4.3	Hormone Signaling Governs Biotic and Abiotic Stress Responses	71
4.4	Roles of ROS at Points of Convergence between Biotic and Abiotic Stress Response Pathways	73
4.5	Transcription Factors Involved in the Cross-talk between Abiotic and Biotic Stress Signaling	74
4.6	Mitogen-Activated Protein Kinase Cascade	76
4.7	Effects of Humidity and Temperature on Biotic Stress Responses	78
4.8	Conclusions	79

<b>5</b>	<b>Jasmonates in Stress, Growth, and Development</b>	<b>91</b>
	<i>Claus Wasternack</i>	
5.1	Introduction	91
5.2	JA Biosynthesis	92
5.3	JA Metabolism	95
5.4	Bound OPDA – Arabidopsides	97
5.5	Mutants of JA Biosynthesis and Signaling	98
5.6	COI1–JAZ–JA-Ile-Mediated JA Signaling	101
5.7	Transcription Factors Involved in JA Signaling	104
5.8	Jasmonates and Oxylipins in Development	106
5.9	Conclusions	108
<b>6</b>	<b>Brassinosteroids Confer Stress Tolerance</b>	<b>119</b>
	<i>Uday K. Divi and Priti Krishna</i>	
6.1	Introduction	119
6.2	BR Signaling	120
6.3	BR Increases Stress Tolerance	121
6.3.1	Temperature Stress	121
6.3.2	Salt Stress	123
6.3.3	Drought Stress	123
6.3.4	Pathogen Attack	124
6.3.5	Other Stresses	126
6.4	Anticancer and Antiviral Effects	126
6.5	Genetic Evidence for a Role of BR in Plant Stress Responses	126
6.6	BR-Independent Role of BAK1 in Innate Immunity and Cell Death	127
6.7	Systematic Study to Dissect the Role of BR in Abiotic Stress Tolerance	130
6.8	Future Directions	131
<b>7</b>	<b>Cold, Salinity, and Drought Stress</b>	<b>137</b>
	<i>Narendra Tuteja</i>	
7.1	Introduction	137
7.2	Abiotic Stress Response and Stress-Induced Genes	139
7.3	Cold Stress	141
7.3.1	Effect of Low-Temperature Stress on Plant Physiology	141
7.3.2	Cold Acclimation	142
7.3.3	Function of Cold-Regulated Genes in Freezing Tolerance	142
7.3.4	Calcium Signaling in Cold Stress Response	144
7.4	Salinity Stress	144
7.4.1	Negative Impact of Salinity Stress	146

- 7.4.2 Calcium Signaling and SOS Pathways in Relation to Salinity Stress 147
- 7.4.3 ABA and Transcription Factors in Salinity Stress Tolerance 148
- 7.4.4 Water Stress due to Salinity 149
- 7.4.5 Proline and GB in Salinity Stress 149
- 7.4.6 ROS in Salinity Stress 150
- 7.5 Drought Stress 151
  - 7.5.1 Effect of Drought on Stomata and Photosynthesis 152
  - 7.5.2 Sugars and other Osmolytes in Response to Drought Stress 153
  - 7.5.3 Phospholipid Signaling in Drought Stress 154
- 7.6 Conclusions and Future Prospects 154
  
- 8 Heavy Metal Stress in Plants 161**  
*Ann Cuypers, Karen Smeets, and Jaco Vangronsveld*
  - 8.1 Introduction 161
  - 8.2 Uptake and Distribution of Metals in Plants 162
  - 8.3 Metal Stress Affects the Plant's Physiology 163
  - 8.4 Unraveling the Cellular Responses of Metal Stress 165
    - 8.4.1 Metal-Induced Oxidative Stress 166
    - 8.5 Signaling Under Metal Stress 167
  - 8.6 Conclusions 170
  
- 9 Systematic Analysis of Superoxide-Dependent Signaling in Plant Cells: Usefulness and Specificity of Methyl Viologen Application 179**  
*Simone Jacob and Karl-Josef Dietz*
  - 9.1 Reactive Oxygen Species and Antioxidant Defense 179
    - 9.1.1 Reactive Oxygen Species – Generation and Biological Relevance 179
    - 9.1.2 Detoxification of ROS – Antioxidative Network in Plants 181
  - 9.2 Methyl Viologen: From Redox Indicator and Herbicide to Application as Effector in Oxidative Stress Investigation 183
    - 9.2.1 General Considerations to Methyl Viologen as Herbicide and Toxin 183
    - 9.2.2 Mechanism of Methyl Viologen Toxicity in Plants and Animals 185
    - 9.2.3 Lipid Peroxidation as a Consequence of Oxidative Stress upon Methyl Viologen Application 186
    - 9.2.4 Requirement of the Antioxidative Network upon Methyl Viologen Application 186
  - 9.3 Gaining Insights into Superoxide Anion-Mediated Signaling in Plants – Goals and Limitations of Methyl Viologen Application 187

- 9.3.1 Superoxide Anion and Hydrogen Peroxide Signaling: A Problem of Differentiation? 187
- 9.3.2 Transgenic Plants as a Powerful Tool towards Understanding the Participation of Superoxide Anion in Signal Transduction Processes 187
- 9.3.3 Towards Understanding of Superoxide Anion Signaling in Plants 190
- 9.4 Conclusions 191

### **Part III From Transcriptomics and Proteomics to Signaling Networks 197**

#### **10 Insights into the *Arabidopsis* Abiotic Stress Response from the AtGenExpress Expression Profile Dataset 199**

*Dierk Wanke, Kenneth W. Berendzen, Joachim Kilian, and Klaus Harter*

- 10.1 Introduction 199
- 10.2 The AtGenExpress Abiotic Stress Experiment 200
- 10.3 General Findings 201
- 10.4 The Nine Stresses 204
  - 10.4.1 UV-B Light Stress 204
  - 10.4.2 Osmotic Stress 206
  - 10.4.3 Salt Stress 208
  - 10.4.4 Cold Stress 209
  - 10.4.5 Drought Stress 210
  - 10.4.6 Heat Stress 211
  - 10.4.7 Wounding Stress 211
  - 10.4.8 Genotoxic Stress 212
  - 10.4.9 Oxidative Stress 213
- 10.5 Signal Integration 213
- 10.6 Novel Approaches and Future Developments 221
- 10.7 Conclusions 221

#### **11 Integrative Approaches to Elucidate and Analyze Protein Interaction and Signaling Networks 227**

*Sergio de la Fuente van Bentem, Alberto de la Fuente, and Heribert Hirt*

- 11.1 Introduction 227
- 11.2 Protein Networks 228
  - 11.2.1 Introduction to Protein Networks 228
  - 11.2.2 CNA 229
- 11.3 PINs 230
  - 11.3.1 Toward Global *Arabidopsis* PINs 231
  - 11.3.2 An *Arabidopsis* PIN of Calmodulin- and Calmodulin-Like-Binding Proteins 240
- 11.4 PSNs 240
  - 11.4.1 Introduction to PSNs 240
  - 11.4.2 From Perturbations and Responses to PSNs 241

x | *Contents*

11.4.3	High-Throughput Approaches to Create Perturbations and to Measure Responses	242
11.4.4	A NetworKIN Approach to Construct Plant Phosphorylation Networks	243
11.5	Future Outlook on Plant Networks	245
	<b>Index</b>	249