

Contents

Contributors	xi
Preface	xiii
1 Temperature sensing in plants	1
Steven Penfield and Dana MacGregor	
1.1 Introduction	1
1.2 Passive and active temperature responses in plants	1
1.3 Temperature sensing during transcriptional regulation	3
1.4 Sensing cold: A role for plasma membrane calcium channels in plants	8
1.5 A role for membrane fluidity as an upstream temperature sensor?	11
1.6 Temperature sensing by proteins	12
1.7 Summary	14
2 Plant acclimation and adaptation to cold environments	19
Bob Baxter	
2.1 Introduction	19
2.2 Chilling and freezing injury	20
2.3 Freezing avoidance and tolerance at the structural and physiological level	21
2.3.1 Freezing avoidance	21
2.3.2 Freezing point depression, supercooling, deep supercooling, and extracellular and extraorgan freezing	23
2.3.3 Ice nucleation and structural and thermal ice barriers	23
2.3.4 Glass transition (vitrification)	25
2.3.5 Antifreeze factors	25
2.4 Freezing tolerance	26
2.4.1 Cold acclimation (hardening)	26
2.4.2 Genes and regulatory mechanisms in cold acclimation	27
2.4.3 Dehydrins	30
2.4.4 Heat shock proteins	30
2.4.5 Enzymatic and metabolic response in cryoprotection	30
2.4.6 The role of hormones in low-temperature acclimation	31

2.5	Cold deacclimation (dehardening) and reacclimation (rehardening)	32
2.6	Spatial and temporal considerations of plant responses to low temperature	34
2.6.1	Interactions between cold and light: Winter dormancy	35
2.6.2	Interactions between cold and environmental drought	36
2.6.3	Interactions between cold and light: Photosynthesis, photoinhibition, and reactive oxygen species in cold environments	36
2.7	The survival of cold and freezing stress in a changing climate	38
2.8	Plant cold acclimation and adaptation in an agricultural context	42
2.9	Summary	42
3	Plant acclimation and adaptation to warm environments	49
	Martijn van Zanten, Ralph Bours, Thijs L. Pons, and Marcel C.G. Proveniers	
3.1	Introduction	49
3.2	Implications of high temperature for agriculture and natural ecosystems	51
3.3	Temperature perception and signaling pathways	52
3.4	Photosynthesis	53
3.5	Respiration and carbon balance	57
3.6	Growth and allocation of biomass	58
3.7	Architectural changes in response to high temperature	58
3.7.1	Heat-induced hyponastic growth in <i>Arabidopsis</i> and hormonal and light control	59
3.7.2	High-temperature-induced hypocotyl elongation in <i>Arabidopsis</i>	60
3.7.3	PIF4 as central regulator of high-temperature acclimation in <i>Arabidopsis</i>	61
3.8	Hormonal regulation of thermotolerance	62
3.9	Functional implications of plant architectural changes to high temperature	63
3.10	Interactions between drought and high temperature	64
3.11	Carbohydrate status control of plant acclimation to high temperature	65
3.12	Thermoperiodic effects on plant growth and architecture	66
3.13	High-temperature effects on the floral transition	68

4 Vernalization: Competence to flower provided by winter	79
Dong-Hwan Kim and Sibum Sung	
4.1 Introduction	79
4.2 Vernalization requirement in <i>Arabidopsis</i>	80
4.2.1 Molecular basis of <i>FRI</i> -mediated <i>FLC</i> activation	81
4.2.2 Mutations in autonomous pathway genes: Another route to confer vernalization requirement	82
4.2.3 Other chromatin-remodeling complexes required for <i>FLC</i> activation	83
4.3 The molecular mechanism of vernalization	84
4.3.1 Vernalization-mediated epigenetic repression of <i>FLC</i>	84
4.3.2 The dynamics of PRC2 and TRX at <i>FLC</i> chromatin	86
4.3.3 Mechanisms underlying PRC2 recruitment to <i>FLC</i> chromatin by vernalization	87
4.4 Resetting of <i>FLC</i> repression during meiosis	88
4.5 Vernalization in other plant species	89
4.5.1 <i>Arabis alpina</i>	89
4.5.2 Cereals (wheat and barley)	90
4.5.3 Sugar beet (<i>Beta vulgaris</i>)	90
4.6 Concluding remarks	91
5 Temperature and light signal integration	97
Harriet G. McWatters, Gabriela Toledo-Ortiz, and Karen J. Halliday	
5.1 Introduction	97
5.2 Convergence points for light and temperature sensing	101
5.3 Phytochrome-Interacting Factors as signal integrators	102
5.4 ELONGATED HYPOCOTYL 5 (HY5): A cool operator	105
5.5 Light and temperature converge at the circadian oscillator	107
5.6 Photoperiodic and thermal control of flowering	113
5.7 Light-dependent circadian gating of cold-acclimation responses	115
5.8 Temperature and light regulation of cell membrane fatty acid composition	117
5.9 Concluding thoughts: Implications for a changing future	118
6 Temperature and the circadian clock	131
Kathleen Greenham and C. Robertson McClung	
6.1 Introduction	131
6.2 Temperature compensation	136

6.3	Temperature entrainment	142
6.4	Cold tolerance	146
6.5	Splicing	150
6.6	Concluding remarks	151
7	Temperature and plant immunity	163
	Jian Hua	
7.1	Introduction	163
7.2	Plant immunity	164
7.2.1	Immunity against microbial pathogens	164
7.2.2	Immunity against necrotrophic pathogens	166
7.2.3	Immunity against herbivorous insects	166
7.2.4	Immunity against viruses	167
7.3	Temperature effects on plant disease resistance	167
7.3.1	High-temperature suppression of disease resistance	168
7.3.2	Low-temperature inhibition of plant immunity	169
7.3.3	Disease resistance induced by high and low temperatures	169
7.4	The molecular basis for temperature sensitivity in plant immunity	170
7.4.1	Heat-sensitive NB-LRR R proteins	170
7.4.2	Involvement of NB-LRR R proteins in heat-sensitive immune responses	172
7.4.3	Enhancement of immunity by ABA deficiency at high temperatures	173
7.4.4	Cold sensitivity in RNA silencing-mediated immunity	173
7.5	Evolution of the temperature sensitivity of immunity	174
7.5.1	Coevolution with pathogens	175
7.5.2	Competition between biotic and abiotic responses	176
7.6	Concluding remarks	176
8	Temperature, climate change, and global food security	181
	Robert J. Redden, Jerry L. Hatfield, P.V. Vara Prasad, Andreas W. Ebert, Shyam S. Yadav, and Garry J. O'Leary	
8.1	Introduction	181
8.2	Climate change on a global basis	181
8.3	The impact of temperature on crop water relations	183
8.4	The influence of high temperature on crop physiology and yield processes	186

8.5	The interaction of climate change factors on crop development	188
8.5.1	The interaction of rising temperature and CO ₂	188
8.5.2	The interaction of high-temperature and drought stress	189
8.6	The impact of global climate change on food quality and plant nutrient demand	190
8.7	Breeding high-temperature stress tolerance using crop wild relatives	190
8.8	Global food production and food security	191
8.8.1	Wheat production	192
8.8.2	Rice production	192
8.8.3	Potato production	192
8.8.4	Maize production	193
8.8.5	Sorghum production	193
8.8.6	Cassava production	193
8.8.7	Pulse production	193
8.8.8	Predicted impacts of climate change on global crop production	194
8.9	Crop nutritional content	194
8.10	Discussion	196
8.11	Conclusions	197
Index		203

Color plate section is located between pages 130 and 131.