

CONTENTS

List of Contributors	xv
Preface	xxi

Section 1 Biochemistry of Insect-Plant Interactions

1 Plants Recognize Herbivorous Insects by Complex Signalling Networks	1
<i>Gustavo Bonaventure</i>	
1.1 Introduction	1
1.1.1 The feeding behaviour of insects is an important determinant of the plant's defence response	1
1.1.2 Insect-associated elicitors are specific elicitors of plant responses to insect feeding or egg deposition	2
1.2 Resistance (<i>R</i>) genes in the perception of piercing-sucking insects	6
1.3 Modification of elicitors by plant enzymes	8
1.4 Changes in V_m , Ca^{2+} influx and reactive oxygen intermediate generation are early cellular events induced in plants by insect feeding	9
1.5 Shared signal transduction components in microbe and insect elicitor perception	12
1.6 Regulation of phytohormone accumulation and signalling during insect feeding	14
1.6.1 Jasmonic acid	17
1.6.2 Ethylene	20
1.6.3 Salicylic acid	21
1.7 Interconnection of the phytohormone system in plants	22
1.8 Conclusions and perspectives	23
Acknowledgements	24
References	24
2 Herbivore Oral Secretions are the First Line of Protection Against Plant-Induced Defences	37
<i>Gary W. Felton, Seung Ho Chung, Maria Gloria Estrada Hernandez, Joe Louis, Michelle Peiffer and Donglan Tian</i>	
2.1 Introduction	38

2.2	Origin of herbivore secretions and initiation of contact with the host plant	40
2.2.1	Piercing-sucking herbivores	41
2.2.2	Chewing herbivores	42
2.3	How do herbivores deliver effectors to the host plant?	45
2.4	Examples of HAMPs and effectors	46
2.4.1	Piercing-sucking herbivores	46
2.4.2	Chewing herbivores	49
2.5	Effectors and host targets	54
2.6	Effectors and the host plant diet	56
2.7	Metagenomes: The interkingdom crossroads of the host plant, herbivore, and microbiome	56
	Acknowledgements	62
	References	62
3	Insect Detoxification and Sequestration Strategies	77
	<i>David G. Heckel</i>	
3.1	Introduction	77
3.2	Diverse roles of insect cytochromes P450	78
3.2.1	Furanocoumarin detoxification by <i>Papilio</i> spp. and others	79
3.2.2	Monoterpene detoxification and pheromone biosynthesis in pine bark beetles	84
3.2.3	Gossypol and CYP6AE14 in <i>Helicoverpa armigera</i>	85
3.2.4	Cactophilic <i>Drosophila</i> and alkaloid detoxification	85
3.3	Cyanogenic glucosides	86
3.4	Glucosinolates	89
3.5	O-glucosides and leaf beetles	93
3.6	Pyrrolizidine alkaloids	97
3.7	Glycosylation of host plant compounds	99
3.8	Non-protein amino acids	101
3.9	Iridoid glucosides	102
3.10	Cardenolides	103
3.11	Conclusions	106
	Acknowledgements	107
	References	107
4	Plant Semiochemicals – Perception and Behavioural Responses by Insects	115
	<i>Andreas Reinecke and Monika Hilker</i>	
4.1	Introduction	115
4.2	A semiochemical's route to the neuron	118
4.2.1	Surfing the surface – A matter of chemo-physical interaction	120

4.2.2	Odorant binding proteins, chemosensory proteins	122
4.2.3	Eliciting signals – Odorant receptors and sensory neuron responses to odorants	123
4.2.4	The clean-up company – Odorant-degrading enzymes	128
4.2.5	Odour perception – Summary	128
4.3	Behavioural responses of insects to plant volatiles	129
4.3.1	Biotic habitat factors influencing plant odour dispersal and insect orientation	130
4.3.2	Biotic factors affecting plant odour emission	131
4.3.3	'Wise' responses to plant odours? The impact of odour experience on insect behaviour	132
4.3.4	Sick insects and their responses to plant odour	134
4.3.5	Age-dependency of insect responses to plant odour	134
4.3.6	Adjusting the responses to plant odour according to the needs	135
4.4	Conclusions	136
	References	137

Section 2 Genetics and Genomics of Insect-Plant Interactions

5	Plant Transcriptomic Responses to Herbivory	155
	<i>Hanna M. Heidel-Fischer, Richard O. Musser and Heiko Vogel</i>	
5.1	Introduction	155
5.2	Mechanical wounding, feeding mode and HAMPs	157
5.3	Wounding rates and salivary gland applications	158
5.4	Responses to insects from different feeding guilds	165
5.4.1	Chewing herbivores	167
5.4.2	Piercing-sucking herbivores	168
5.4.3	The pitfalls of the generalist-specialist paradigm	171
5.5	A meta-analysis of microarray studies on transcriptomic responses to herbivory	172
5.6	Simultaneous attack or multiple feeding	176
5.7	Transcriptomics responses to herbivory – An outlook	179
5.7.1	Open questions	179
5.7.2	New tools and approaches	181
	Acknowledgements	182
	References	182
6	Transcriptome Responses in Herbivorous Insects Towards Host Plant and Toxin Feeding	197
	<i>Heiko Vogel, Richard O. Musser and Maria de la Paz Celorio-Mancera</i>	
6.1	Introduction	198
6.2	Challenges for insect herbivores and inducible responses	200

6.2.1	Phytohormones	202
6.2.2	Plant defensive chemicals – Toxins and deterrents	205
6.2.3	Proteinaceous effectors	210
6.2.4	Plant nutrients	212
6.2.5	Whole plant, tissue and organ feeding	214
6.2.6	Common expression signatures and specific differences	215
6.3	Genomic responses to plant and toxin feeding – An outlook	218
6.3.1	Open questions	218
6.3.2	New tools and approaches	221
	Acknowledgements	223
	References	223
7	Quantitative Genetics and Genomics of Plant Resistance to Insects	235
	<i>Daniel J. Kliebenstein</i>	
7.1	Introduction	235
7.2	Metabolites	238
7.2.1	Glucosinolates	238
7.2.2	Maysin	245
7.2.3	Tomato trichome chemistry	245
7.2.4	Saponins	246
7.3	Physical defences	246
7.4	Signal transduction variation	248
7.5	Physiology	249
7.6	Why have genetic variation in defence?	249
7.7	Summary	250
	References	252

Section 3 Ecology and Evolution of Insect-Plant Interactions

8	Costs of Resistance in Plants: From Theory to Evidence	263
	<i>Don Cipollini, Dale Walters and Claudia Voelckel</i>	
8.1	The cost-benefit paradigm	263
8.1.1	Hypotheses of plant defence	265
8.1.2	Why do plants have induced defences?	272
8.2	Measuring fitness costs and benefits of plant defence traits	276
8.2.1	Generating trait variation	276
8.2.2	The empirical evidence for costs of resistance	284
8.3	Ecologically relevant settings	289
8.3.1	Competition	290
8.3.2	Nutrient availability	293
8.3.3	Multiple enemies	294
8.3.4	Enemies vs. mutualists	295
8.4	Conclusions	297
	References	297

9	Plant-mediated Interactions Among Insects within a Community Ecological Perspective	309
	<i>Erik H. Poelman and Marcel Dicke</i>	
9.1	Introduction to plant-mediated species interactions	309
9.1.1	Plant-based insect community structure	309
9.1.2	Plant-mediated species interactions	311
9.2	Plant-mediated species interactions among herbivores	313
9.2.1	Specificity of plant responses to herbivores	313
9.2.2	Asymmetric plant-mediated effects on herbivore performance	314
9.2.3	Plant-mediated effects on herbivore oviposition	315
9.3	Three trophic level interactions	316
9.3.1	Attraction of natural enemies	316
9.3.2	Herbivore diversity affects plant-mediated interactions with natural enemies	318
9.4	Aboveground-belowground interactions	319
9.5	Herbivore-pollinator interactions	320
9.6	Plant-mediated species interactions in a community	322
9.6.1	Plant-mediated interactions involving multiple herbivores	322
9.6.2	Carnivores affecting plant-mediated interactions in communities	325
9.6.3	Plant-mediated interactions beyond individual plants	326
9.7	Synthesis in the context of plant fitness and future directions	327
	References	329
10	The Altitudinal Niche-Breadth Hypothesis in Insect-Plant Interactions	339
	<i>Sergio Rasmann, Nadir Alvarez and Loïc Pellissier</i>	
10.1	Introduction – Variation of niche-breadth along ecological gradients	340
10.2	Herbivorous insects, from specialists to generalists	343
10.3	Evidence for an altitudinal gradient in niche-breadth and climatic variability	344
10.3.1	Does environmental variability increase with increasing altitude?	345
10.3.2	Does variability in host-plant population size increase with increasing altitude?	346
10.4	The altitudinal niche-breadth paradigm	348
10.4.1	Pollinators	348
10.4.2	Herbivores, plant quality and plant defences	349
10.4.3	Predator effects on herbivores	350

10.5	Outlook – Other factors influencing altitudinal niche breadth evolution studies	351
10.5.1	Phylogenetic constraints and correlated life-history traits	351
10.5.2	Phylogeography	352
10.5.3	Phytophagous insect abundance	352
10.5.4	Range size	353
10.5.5	Non-linear relationship along the altitudinal clines	353
10.6	Conclusion	354
	Acknowledgements	354
	References	354
11	Revisiting Plant-Herbivore Co-Evolution in the Molecular Biology Era	361
	<i>Georg Jander</i>	
11.1	Introduction	361
11.2	Glucosinolates in the Brassicaceae	363
11.3	Benzoxazinoids in the Poaceae	365
11.4	Evolution from primary metabolism	367
11.5	Convergent evolution of defence pathways	368
11.6	Rapid adaptation through modular biosynthetic pathways	370
11.7	Specialist herbivores have evolved to detoxify secondary metabolites	371
11.8	Costs of plant resistance	372
11.9	Molecular phylogenetic evidence for co-evolution	374
11.10	The benefits of metabolic pathway co-regulation	374
11.11	Modification of secondary metabolites as a form of defensive priming	375
11.12	Use of secondary metabolites as defensive signals	377
11.13	Conclusion and future prospects	378
	References	379
	Index	385

First 8-page colour plate section (between pages 168 and 169)

Second 8-page colour plate section (between pages 360 and 361)