

65

7728-3923

Introduction to Ecological Biochemistry

FOURTH EDITION

J.B. Harborne
University of Reading, UK



ACADEMIC PRESS

Harcourt Brace & Co., Publishers

London • San Diego • New York

Boston • Sydney • Tokyo • Toronto

Contents

| | |
|--|------|
| Foreword by Dr Miriam Rothschild, CBE, FRS | xi |
| Preface | xiii |

1. The Plant and Its Biochemical Adaptation to the Environment

| | |
|--|----|
| I. Introduction | 1 |
| II. The biochemical bases of adaptation to climate | 5 |
| A. General | 5 |
| B. Photosynthesis in tropical plants | 5 |
| C. Adaptation to freezing | 11 |
| D. Adaptation to high temperatures | 12 |
| E. Adaptation to flooding | 13 |
| F. Adaptation to drought | 15 |
| III. Biochemical adaptation to the soil | 17 |
| A. Selenium toxicity | 17 |
| B. Heavy metal toxicity | 19 |
| C. Adaptation to salinity | 22 |
| IV. Detoxification mechanisms | 26 |
| A. General | 26 |
| B. Detoxification of phenols | 27 |
| C. Detoxification of systemic fungicides | 27 |
| D. Detoxification of herbicides | 29 |
| V. Conclusion | 30 |
| Bibliography | 32 |

2. Biochemistry of Plant Pollination

| | |
|--|----|
| I. Introduction | 36 |
| II. Role of flower colour | 38 |
| A. Colour preferences of pollinators | 38 |
| B. Chemical basis of flower colour | 40 |
| C. Evolution of flower colour | 46 |
| D. Honey guides | 51 |
| III. Role of flower scent | 53 |
| A. Types of scent | 53 |
| B. Insect pheromones and flower scents | 57 |
| IV. Role of nectar and pollen | 60 |
| A. Sugars of nectar | 60 |
| B. Amino acids of nectar | 62 |

| | |
|--|----|
| C. Lipids in nectar | 64 |
| D. Nectar toxins | 65 |
| E. Extrafloral nectaries | 65 |
| F. Nutritive value of pollen | 66 |
| V. Summary | 67 |
| Bibliography | 68 |

3. Plant Toxins and Their Effects on Animals

| | |
|--|-----|
| I. Introduction | 71 |
| II. Different classes of plant toxins | 73 |
| A. Nitrogen-based toxins | 73 |
| B. Non-nitrogenous toxins | 79 |
| C. Fate in animals | 82 |
| III. Cyanogenic glycosides, trefoils and snails | 84 |
| A. Occurrence of cyanogenic glycosides in plants | 84 |
| B. Polymorphism of cyanogenesis | 85 |
| C. Other protective roles of cyanogens | 89 |
| IV. Cardiac glycosides, milkweeds, monarch butterflies and blue-jays | 90 |
| V. Pyrrolizidine alkaloids, ragworts, moths and butterflies | 93 |
| A. Pyrrolizidine alkaloids in moths | 93 |
| B. Pyrrolizidine alkaloids in butterflies | 94 |
| VI. Utilization of plant toxins by animals | 98 |
| VII. Summary | 100 |
| Bibliography | 101 |

4. Hormonal Interactions Between Plants and Animals

| | |
|--|-----|
| I. Introduction | 104 |
| II. Plant oestrogens | 105 |
| III. Insect moulting hormones in plants | 111 |
| IV. The fruit-fly-cactus interaction | 114 |
| V. Insect juvenile hormones in plants | 117 |
| VI. Pheromonal interactions and the pine bark beetle | 120 |
| VII. Summary | 124 |
| Bibliography | 125 |

5. Insect Feeding Preferences

| | |
|---|-----|
| I. Introduction | 128 |
| II. Biochemical basis of plant selection by insects | 130 |
| A. Co-evolutionary aspects | 130 |
| B. Plant chemicals as defence agents | 131 |
| C. Insect feeding requirements | 132 |

| | |
|--|-----|
| III. Secondary compounds as feeding attractants | 134 |
| A. General | 134 |
| B. The silkworm—mulberry interaction | 134 |
| C. Glucosinolates as feeding attractants in the Cruciferae | 138 |
| D. Other feeding attractants | 140 |
| IV. Secondary compounds as feeding deterrents | 142 |
| A. The winter moth and oak leaf tannins | 142 |
| B. The Colorado beetle and <i>Solanum</i> alkaloids | 146 |
| C. Leaf-cutting ants | 148 |
| D. Other feeding deterrents | 149 |
| V. Feeding of slugs and snails | 152 |
| VI. Oviposition stimulants | 155 |
| VII. Summary | 157 |
| Bibliography | 158 |

6. Feeding Preferences of Vertebrates, Including Man

| | |
|---|-----|
| I. Introduction | 162 |
| II. Domestic animals | 164 |
| A. Responses to individual chemicals | 164 |
| B. Responses to chemicals present in plants | 165 |
| C. Feeding preferences | 168 |
| III. Wild animals | 168 |
| IV. Birds | 172 |
| V. Man | 173 |
| A. The choice of plant foods | 173 |
| B. The chemistry of flavours | 174 |
| C. The chemistry of sweetness | 178 |
| D. Flavour potentiators and modifiers | 182 |
| VI. Conclusions | 183 |
| Bibliography | 183 |

7. The Co-evolutionary Arms Race: Plant Defence and Animal Response

| | |
|--|-----|
| I. Introduction | 186 |
| II. Static plant defence | 187 |
| A. The cost of chemical defence | 187 |
| B. Evolution of feeding deterrents | 189 |
| C. Localization of toxins in the plant | 192 |
| D. Timing of toxin accumulation | 197 |
| E. Variability in palatability within the plant | 198 |
| III. Induced plant defence | 199 |
| A. <i>De novo</i> synthesis of proteinase inhibitors | 199 |

| | |
|---|-----|
| B. Increased synthesis of toxins | 200 |
| C. Release of predator-attracting volatiles | 201 |
| IV. Animal response. | 202 |
| A. Insects | 202 |
| B. Kangaroos | 204 |
| C. Rats and man | 206 |
| V. Conclusion. | 207 |
| Bibliography | 207 |

8. Animal Pheromones and Defence Substances

| | |
|-------------------------------------|-----|
| I. Introduction | 211 |
| II. Insect pheromones | 213 |
| A. Sex pheromones | 213 |
| B. Trail pheromones | 218 |
| C. Alarm pheromones | 220 |
| III. Mammalian pheromones | 222 |
| IV. Defence substances | 226 |
| A. Distribution | 226 |
| B. Terpenoids | 227 |
| C. Alkaloids | 232 |
| D. Phenols and quinones | 235 |
| V. Conclusion. | 238 |
| Bibliography | 239 |

9. Biochemical Interactions Between Higher Plants

| | |
|---|-----|
| I. Introduction | 243 |
| II. The walnut tree | 245 |
| III. Desert plants | 247 |
| IV. Allelopathy in the Californian chaparral | 249 |
| A. Volatile terpenes and the fire cycle | 249 |
| B. Water-soluble inhibitors | 252 |
| V. Other allelopathic agents | 255 |
| VI. Ecological importance of allelopathy | 256 |
| VII. Biochemistry of host-parasite interactions | 258 |
| VIII. Conclusions | 260 |
| Bibliography | 262 |

10. Higher Plant-Lower Plant Interactions: Phytoalexins and Phytotoxins

| | |
|---|-----|
| I. Introduction | 264 |
| II. Biochemical basis of disease resistance | 266 |

| | |
|--|-----|
| A. Pre-infectional compounds. | 272 |
| B. Post-infectional compounds: post-inhibitins | 275 |
| C. Post-infectional compounds: phytoalexins | 285 |
| III. Phytotoxins in plant disease | 285 |
| A. The pathotoxin concept | 287 |
| B. Pyridine-based pathotoxins | 289 |
| C. Helminthosporoside and victorin | 291 |
| D. Macromolecular toxins | 292 |
| E. Other effects of phytotoxins | 292 |
| IV. Conclusion | 292 |
| Bibliography | 294 |
| Subject Index | 298 |
| Index of Plant Names | 310 |
| Index of Animal Species | 316 |