Contents

INTRODUCTION 11

1 METHODS AND GENERAL ASPECTS OF STUDIES OF EXPERIMENTAL PLANT MORPHOGENESIS 13

1.1 Plant hormones as factors of morphogenesis and structural integrity in plants (M. KUTÁČEK) 13

1.1.1 Indole and non-indole auxin 14

1.1.1.1 Chemical composition of auxin 14

1.1.1.2 Occurrence and identity of auxins in plants 16

1.1.1.3 Auxin biosynthesis 17

1.1.1.4 Regulation of auxin synthesis at genetic and molecular levels 24

1.1.1.4.1 Regulation of auxin synthesis at the genetic level 24

1.1.1.4.2 Regulation of auxin biosynthesis at the molecular level 24

1.1.1.5 Catabolism of auxin 28

1.1.1.5.1 Types of auxin degradation and resulting products 28

1.1.1.5.2 The system of auxin oxidase, its co-factors and inhibitors . . . 31

1.1.2 Gibberellins 32

1.1.2.1 Chemical constitution of gibberellins 32

1.1.2.2 The occurrence of gibberellins in plants 33

1.1.2.3 The biosynthesis of gibberellins and their degradation 35

1.1.3 Cytokinins 38

1.1.3.1 Chemical constitution of cytokinins 38

1.1.3.2 The occurrence of cytokinins in plants 39

1.1.3.3 Biosynthesis of cytokinins and their metabolism 41

1.1.4 Abscisic acid 43

1.1.4.1 Chemical constitution of abscisic acid and related compounds 43

1.1.4.2 The occurrence of ABA in higher plants 44

1.1.4.3 Biosynthesis and degradation of abscisic acid 45

1.1.5. Ethylene 46

1.1.5.1 The chemistry of ethylene 46

1.1.5.2 Ethylene levels in plants 47

1.1.5.3 Ethylene metabolism and its regulation 48

1.1.6 Phenols and other secondary substances 50

1.1.6.1 Aromatic compounds 50

1.1.6.2 Nitrogen compounds 52

1.1.6.3 Aliphatic compounds 52

1.1.7 The possible participation of steroids, prostaglandin-like compounds and polyamines in the regulation of plant growth and development 53
1.1.7.1 Brassinosteroids 53
1.1.7.2 Jasmonic acid 55
1.1.7.3 Polyamines 55
1.2. Principles of the methods for the estimation of growth substances (M. KUTÁČEK) . . 57
1.2.1 Extraction and purification procedures 57
1.2.2 Physico-chemical methods of phytohormone estimation 58
1.2.3 Immunochemical methods 59
1.2.4 Bioassays 60
1.2.4.1 Bioassays for auxin-like substances 61
1.2.4.2 Gibberellin bioassays 62
1.2.4.3 Cytokinin bioassays 62
1.2.4.4 Bioassays of inhibiting substances 63
1.2.4.5 Radionuclide indicator methods 63
1.3 Morphogenesis and phytohormone effects at the molecular, subcellular and cellular level (M. KUTÁČEK) 64
1.3.1 Action of phytohormones at the molecular level 64
1.3.1.1 Primary mechanism of phytohormone action in cell elongation and growth . . 65
1.3.1.1.1 Kinetics of the phytohormonal action on growth 65
1.3.1.1.2 The "cell wall acidification" theory 67
1.3.1.1.3 The gene expression hypothesis – rapid gene regulation by auxin . . 68
1.3.1.1.4 The role of calcium. Calmodulin involvement in phytohormone action 70
1.3.2 Binding sites and phytohormone receptors 71
1.3.2.1 Binding sites and receptors, their determination and methods of study . 71
1.3.2.2 Principles of methods of estimation of binding sites 74
1.3.2.3 Soluble binding sites for auxin 75
1.3.2.4 Binding sites for auxins on cell membranes 75
1.3.2.5 Binding sites for other phytohormones 78
1.3.3 Morphogenesis and phytohormone effects on the cell level 79
1.3.3.1 Protoplast cultures 79
1.3.3.2 Organogenesis in cell explants and phytohormonal balance 80
1.4 Morphogenesis on the level of tissues (Z. SLADKÝ) 81
1.4.1 Methods of tissue culture 81
1.4.1.1 Sterile conditions 83
1.4.1.2 Culture media 83
1.4.1.3 External conditions of cultivation 84
1.4.2 Regeneration capacity of explants 84
1.4.2.1 Organogenesis 85
1.4.2.2 Somatic embryogenesis 85
1.4.2.3 Callus cultures 86
1.4.2.4 Anther cultures 86
1.4.2.5 Cultivation of the endosperm and other tissues 87
1.4.3 Differentiation in tissue cultures 88
1.5 Morphogenesis on the level of organs (Z. SLADKÝ) 90
1.5.1 Methods of classical experimental morphology 90
1.5.2 Cultures of organs *in vitro* 90
1.5.3 The plant as an integral organism (J. ŠEBÁNEK) 91
1.6 Transport of phytohormones 92

1.6.1 Structure of vascular tissues (M. LUXOVÁ) 92
1.6.1.1 Xylem 93
1.6.1.2 Phloem 97
1.6.2 Transport of phytohormones in stem and root (S. PROCHÁZKA) 99
1.6.2.1 Transport of auxins 101
1.6.2.2 Transport of gibberellins 106
1.6.2.3 Transport of cytokinins 109
1.6.2.4 Transport of abscisic acid 111
1.6.2.5 Interactions of growth regulators 117
1.6.2.6 Interactions of growth regulators during transport 117

2 PLANT INTEGRITY IN THE SPHERE OF VEGETATIVE ORGANS 123

2.1 Plant growth correlations 123
2.1.1 Stem/root growth correlations (J. ŠEBÁNEK) 123
2.1.1.1 Inhibiting correlative effect of radicle and root at the onset of germination 123
2.1.1.2 The correlative stimulating effect of the root in later growth stages . . . 125
2.1.1.2.1 Stimulating effect of root in relation to gibberellins 126
2.1.1.2.2 Stimulating effect of root in relation to cytokinins 128
2.1.1.2.3 Stimulating effect of root in relation to auxins 129
2.1.1.3 Growth-correlative effect of plumule at the beginning of germination . . 131
2.1.1.4 Growth-correlative effect of stem on root in later stages of growth . . . 131
2.1.1.4.1 Correlative effects of stem on the formation of lateral roots 131
2.1.1.4.2 Correlative effects of the stem on the root in relation to phytohormones of a stimulating nature 133
2.1.1.5 Correlation between the stem and root systems in relation to inhibiting effects 133
2.1.2 Growth-correlative effects of cotyledons (J. ŠEBÁNEK) 136
2.1.2.1 Age and growth-correlative effects of cotyledons 136
2.1.2.2 Effect of light on the growth-correlative effect of cotyledons 137
2.1.2.3 Dominance among cotylars and growth regulators 138
2.1.2.3.1 Dominance between the cotylars in relation to ABA 138
2.1.2.3.2 Dominance between cotylars in relation to auxin and ethylene 140
2.1.2.3.3 Dominance between cotylars in relation to cytokinins 141
2.1.2.3.4 Dominance between cotylars in relation to gibberellins 142
2.1.2.4 Correlating effect of cotyledons in relation to cotyledonary petioles . . 143
2.1.3 Growth correlating effects of leaves and scales (J. ŠEBÁNEK) 144
2.1.3.1 Correlating effects of leaves on the growth of stem internodes and leaf axillary buds 144
2.1.3.2 Growth-correlative effects of leaves on growth of leaf marginals 148
2.1.3.3 Growth correlative effect of scales 150
2.1.4 Growth correlating effects emanating from tubers and bulbs and substances effects of tuberization (J. ŠEBÁNEK) 152
2.1.4.1 Growth correlating effects emanating from tubers 152
2.1.4.2 Substance effects of tuberization 154
2.1.4.2.1 Tuberization and auxin 154
2.1.4.2.2 Tuberization and inhibiting substances 154
2.1.4.2.3 Tuberization in relation to cytokinins and gibberellins 158

2.1.4.2.4 Tuberization and exogenous effects 158
2.1.4.2.5 Tuberization studied on isolated stem segments of *Solanum tuberosum* (Z. SLADKÝ) 160
2.1.5 Senescence and abscission of leaves as phenomena of plant structural integrity (J. ŠEBÁNEK) 163
2.1.5.1 Leaf senescence as a phenomena of integrity 163
2.1.5.2 Leaf abscission as a phenomenon of plant structural integrity 166
2.1.6 Stem apical dominance (S. PROCHÁZKA) 170
2.1.6.1 Different degrees of stem apical dominance 170
2.1.6.2 Nutritional theory of apical dominance 172
2.1.6.3 Correlative inhibiting effects in apical dominance 172
2.1.6.4 Theory of "direct inhibition" of auxin in apical dominance 173
2.1.6.5 Theory of "indirect inhibition" of auxin in apical dominance 174
2.1.6.6 The "nutrient-diversion" theory, and the other theories 175
2.1.6.7 Role of plant growth substances in apical dominance 176
2.1.6.7.1 Indole-3- acetic acid 176
2.1.6.7.2 Cytokinins 180
2.1.6.7.3 Gibberellins 185
2.1.6.7.4 Abscisic acid 187
2.1.6.7.5 Anti-auxin substances and apical dominance 189
2.1.6.7.6 Ethylene 192
2.1.6.8 Apical dominance and phytohormone-regulated transport of metabolites 193
2.1.6.9 Peculiarities of apical dominance in woody species 197
2.1.6.10 Mechanism of stem apical dominance 199
2.2 Regeneration as the recovery of disturbed plant structural integrity 200
2.2.1 Types of regeneration (J. ŠEBÁNEK) 200
2.2.2 Regeneration of adventitious buds (J. ŠEBÁNEK) 202
2.2.2.1 Correlative effects of adventitious bud formation on the stem and root 202
2.2.2.2 Growth-correlative effects of initiation of adventitious buds on leaves . 204
2.2.3 Regeneration of adventitious roots (M. LUXOVÁ) 206
2.2.3.1 Substance demands for adventitious root formation 206
2.2.3.2 Correlative effects conditioned by the nature of the rooted material . . 211
2.3 Polarity as a phenomenon of plant structural integrity (J. ŠEBÁNEK) 216
2.3.1 Polarity in the shoot 218
2.3.1.1 Division (topophysis) of regulating substances in the shoot 218
2.3.1.2 Polarity in relation to shoot regeneration 221
2.3.1.3 Polarity associated with the different morphogenetic nature of the apex, centre and base of the shoot 225
2.3.2 Polarity in the leaf and cotyledon 226
2.3.3 Polarity in the root 228
2.3.3.1 Distribution of regulating effects in the root 228
2.3.3.2 Polarity in relation to root regeneration 229
2.3.4 Polarity in the tuber 229
2.4 Dormancy of buds, tubers and bulbs as a phenomenon of structural integrity (J. ŠEBÁNEK) 230
2.4.1 Endogenous dormancy of buds and environmental conditions 230
2.4.2 Gradual transition of correlative bud inhibition into bud dormancy 233
2.4.3 Bud dormancy and endogenous phytohormones 233
2.4.4 Bud dormancy and exogenously applied phytohormones 234

2.4.5 Length of bud dormancy in various woody species . . . 237
2.4.6 Endogenous dormancy of tubers and bulbs . . . 239
2.5 Movements of plants as a manifestation of their structural integrity (J. ŠEBÁNEK) . . 241
2.6 Integrity and exogenous effects . . . 254
2.6.1 Radiation (J. ŠEBÁNEK) . . . 254
2.6.1.1 Photomorphogenesis . . . 254
2.6.1.1.1 The effect of light on germination . . . 255
2.6.1.1.2 Etiolation and de-etiolation . . . 256
2.6.1.1.3 Photoperiodism and phototropism . . . 257
2.6.2 Gravity (M. LUXOVÁ) . . . 258
2.6.3 Water and chemical effects (J. ŠEBÁNEK) . . . 264
2.6.3.1 Mineral nutrition . . . 264
2.6.3.2 Water and drought stress . . . 265
2.6.3.3 Stress caused by "acid rain" (sulphuric acid) . . . 268
2.6.4 Temperature and frost stress (J. ŠEBÁNEK) . . . 272
2.6.5 Pathogenic and symbiotic effects of microorganisms (J. ŠEBÁNEK) . . . 273

3 TRANSFORMATION OF THE VEGETATIVE APEX INTO A FLOWER PRIMORDIUM (Z. SLADKÝ) . . . 276

3.1 Morphogenesis and differentiation of hermaphrodite flowers . . . 277
3.1.1 The model of *Papaver somniferum* . . . 277
3.1.2 The model of *Campanula rapunculoides* . . . 283
3.1.3 The model of *Veronica austriaca* . . . 285
3.1.4 The model of *Digitalis purpurea* . . . 288
3.2 Morphogenesis and differentiation of flowers on monoecious plants . . . 288
3.2.1 The model of *Cucumis sativus* . . . 288
3.2.2 The model of *Zea mays* . . . 293
3.2.3 The model of *Juglans regia* . . . 300
3.3 Morphogenesis and differentiation of dioecious plant flowers . . . 304
3.3.1 The model of *Melandrium album* . . . 304
3.3.2 The model of *Mercurialis annua* . . . 307
3.3.3 The model of *Cannabis sativa* . . . 308
3.3.4 The model of *Lemna gibba* . . . 309
3.4 The role of phytohormones in sex differentiation of flowers . . . 310
3.5 Morphological atavisms of flowers and inflorescences . . . 312

4 EXPERIMENTAL MORPHOGENESIS OF SEEDS AND FRUITS . . . 315

4.1 Double fertilization of angiosperms (Z. SLADKÝ) . . . 315
4.1.1 Seed development without fertilization . . . 316
4.1.2 *In vitro* fertilization . . . 318
4.2 Structural integrity of tissues in the seed during embryogenesis (O. ERDELSKÁ) . . . 320
4.2.1 Types of embryo: endosperm correlation . . . 325
4.2.2 Disturbances in the embryo: endosperm correlation . . . 328
4.3 Development of embryo in the seed (O. ERDELSKÁ) . . . 330
4.3.1 Zygote . . . 330
4.3.2 Proembryo . . . 333
4.3.3 Embryo . . . 334
4.4 Embryo development *in vitro* (O. ERDELSKÁ) . . . 336
4.4.1 Correlations in the development of the suspensor and embryo . . . 339
4.4.2 Correlations in the development of the cotyledons (or scutellum) and embryo 340

4.4.3 Determination and regeneration of embryo tissues 341
4.4.4 The use of cultures of isolated embryos 342
4.5 Polyembryony (O. ERDELSKÁ) 344
4.5.1 Induction of polyembryony on the mother plant 345
4.5.2 Induction of polyembryony in excised ovules and seeds 345
4.5.3 Induction of polyembryony in excised embryos 346
4.6 The endosperm *in vitro* (O. ERDELSKÁ) 347
4.7 The origin and development of the fruit (Z. SLADKÝ) 348
4.7.1 The role of growth substances in the initial processes of fruit growth 349
4.7.2 The role of growth substances in fruit ripening 352
4.7.3 Fruit abortion 353
4.8 Dormancy of seeds and fruits (J. ŠEBÁNEK) 355
4.8.1 Dormancy of seeds and fruits and endogenous growth regulators 355
4.8.2 The effect of exogenous growth regulators on the dormancy of seeds and fruits 357

5 THE IMPORTANCE OF STUDIES ON EXPERIMENTAL PLANT MORPHOGENESIS FOR UNDERSTANDING PHYLOGENESIS AND FOR PRACTICAL APPLICATION 359

5.1 Phylogenetic recapitulation and Haeckel's biogenetic law (Z. SLADKÝ) 359
5.2 Concrete examples of leaf atavisms (J. ŠEBÁNEK) 361
5.3 The importance of experimental morphogenesis and plant integrity for practical plant production (J. ŠEBÁNEK) 365

REFERENCES 371

SUBJECT INDEX 404