

The background of the cover is a composite image. On the left, there is a large, detailed image of a flower with many petals, showing a mix of green, yellow, and red colors. On the right, there is a microscopic image of plant cells, showing cell walls and internal structures in shades of purple, pink, and green. The overall color palette is dark and rich.

Molecular Physiology and Biotechnology of Flowering Plants



Alpha
Science

A. Rashid

Contents

<i>Preface</i>	v
1. SEED GERMINATION AND FORMATION OF A SEEDLING: BEGINNING OF AN ESTABLISHMENT	1
Development of a Seed	1
Hormonal Balance of Seed Development	2
Seed Dormancy	3
Embryo Dormancy or Germination : Function of a Balance between ABA and GA	4
Precocious Germination or Vivipary : Inhibition by ABA	5
Release from Seed Dormancy	6
Light Control of Seed Germination	6
Photoreversibility of Phytochrome	7
Regulation of Seed Germination	9
Gibberellin Control of Seed Germination	11
Gibberellin-stimulated Transcription of α -amylase m-RNA	13
Transcription factor regulates expression of α -amylase gene	14
Seedling: An Establishment	15
Gravity Response of Roots	16
Mechanism for Lateral Auxin Redistribution in Root-cap	16
Gravity Sensing is Ca^{+2} - and pH-mediated	16
Root Gravitropism due to Redistribution of Auxin	18
Gravity Response of Coleoptile/Hypocotyl	20
Gravitropism Involves Lateral Redistribution of Auxin	20
Phototropism	21
Involvement and Redistribution of Auxin	21
Specifically, A Blue Light-mediated Response	23
Phototropin-Mediated Blue Light Response	23
Skotomorphogenesis	24

Hook Formation in Dark-grown Dicot Seedlings, an Ethylene-mediated Response	24
Photomorphogenesis	26
Distinction between Blue-light and Phytochrome-mediated Inhibition of Hypocotyl Elongation	27
Cryptochrome-mediated Blue-light Inhibition of Hypocotyl Elongation	28
High Irradiance Response (HIR) in Inhibition of Hypocotyl Elongation	28
Is Phytochrome the Photoreceptor for HIR	29
HIR-action Spectrum in Blue and UV Regions	30
HIR-action Spectrum of Green Plants	30
Are there Different Types of Phytochromes	30
Are there Multiple Molecular Forms of Phytochrome	31
Phytochrome Interactions in Development of Seedlings	32
Phytochrome in Shade Avoidance	32
Evolution of Phytochrome, Form and Function, in Different Plant Groups	35
Is Photomorphogenesis Possible in Dark	36
<i>References</i>	37
2. THE PLANT: VEGETATIVE PHASE	43
Primary Meristems	43
Concept of Stem Cells	43
Shoot Meristem : A Dynamic Structure	44
Cell Differentiation at Shoot Apex	44
Dynamism of Shoot Meristem	45
Cell Fate: Role of Lineage or Position	46
Root Meristem: An Organized Structure	47
Developmental-Domains of a Root	48
Types of Stem Cells in a Root	48
Post-embryonic Meristems	49
Development and Differentiation of a Leaf	49
Organogenesis	49
Development of Suborgan Domains	49
Cell and Tissue Differentiation	50
Apical Dominance	50
Role of Cytokinin	51
Role of Ethylene	51
Role of ABA	52
Movement of Stomatal Guard-cells	52
Blue Light Mediates Stomatal Opening	52
Blue Light Activates Proton Pump at Guard-cell Plasma Membrane	54
Blue Light Activates Ionic and Osmotic Relation of Guard-cells	55

Role of Osmotically Active Sucrose in Stomatal Opening	55
Kinetics of Blue-light Responses and Signal Transduction	56
Blue Light Photoperception in Guard-cells is Mediated by Carotenoid Zeaxanthin	56
Blue Light-stimulated Stomatal Opening Reversed by Green Light	58
Movement of Chloroplasts	58
Movement of Leaf Lamina or Sun Tracking	60
Movement of Leaves and Leaflets	60
Phytochrome in Sleep Movement of Leaves	61
Clock Genes in Arabidopsis	62
Working of Circadian Oscillator by a Transcriptional Negative Feedback Loop	62
Growth of Roots and Laterals	63
Formation of Root Hairs, Stimulation by Ethylene	63
Formation of Root Nodules	63
Nodulation, An Exchange of Signals	63
Nod Factors of Bacterial Origin	64
Nodule Morphogenesis	64
<i>References</i>	65
3. REPRODUCTIVE PHASE: FLOWERING	70
Juvenile, Vegetative and Reproductive Phases	70
Genes for Vegetative Development	71
Floral Evocation: Internal and External Factors	71
Flowering in Response to Photoperiod	73
Daylength is Monitored by Length of Night	73
Night-break Nullifies Effect of Dark Period	74
Phytochrome is the Primary Photoreceptor in Flowering	74
Time-keeping, Function of an Endogenous Circadian Oscillator	75
Circadian Clock in Photoperiodic Time-keeping for Flowering	76
Hormones in Flowering	78
Floral Stimulus	79
Is Floral Stimulus Self-propagating	79
Is There an Inhibitor to Flowering	80
Transmission of Floral Stimulus, Through Phloem	80
Isolation and Characterization of Floral Stimulus Awaited	80
Vernalization, Low Temperature Treatment for Flowering	82
Vernalization, An Epigenetic Change	82
Gene Expression in Flowering	83
Floral-meristem Identity Gene(s)	83
Floral-organ Identity Genes	84

ABC Model of Floral Organ Identity	84
Flowering in <i>Arabidopsis</i> : A Case Study	88
References	90
4. PLANT HORMONES: IN DEVELOPMENT AND DIFFERENTIATION	94
Auxin: Growth Hormone	95
Concept of Auxin	95
Discovery of Auxin	95
Chemistry of Auxin	96
Biosynthesis of Auxin	97
Metabolism of IAA	97
Degradation of Auxin	99
Transport of Auxin	100
Polar Auxin Transport is Chemiosmotic	100
Inhibition of Polar Auxin Transport	101
Flavonoids are Natural Inhibitors of Polar Auxin Transport	103
Regulation of Auxin Transport	103
Long-distance Auxin Transport	103
Physiological Effects of Auxin	105
Cell Elongation	105
Formation of Lateral Roots	106
Formation of Adventitious Roots	107
Induction of Vascular Differentiation	107
Delay of Leaf Abscission	108
Apical Dominance	108
Gibberellins: Hormones for Elongation	108
Gibberellin Concept	108
Discovery of Gibberellic Acid	108
Chemistry of Gibberellins	108
Biosynthesis of Gibberellins	109
Metabolism of Gibberellins	112
Conjugation of Gibberellins	112
Synthesis and Storage of Gibberellins	112
Active Gibberellins	113
Environmental Control of Gibberellin Biosynthesis	113
Photoperiodic Regulation of GA ₁ Biosynthesis	113
Light Control of GA ₁ Synthesis	113
Low Temperature Effect	115
Promotion of Gibberellin Biosynthesis by Auxin	115

Physiological Effects of Gibberellin	116
Cell Elongation and Cell Division	116
Cytokinin: Hormone For Cell Division	118
Concept of Cytokinin	118
Discovery of Cytokinin	118
Structure and Activity of Cytokinins	118
Biosynthesis of Cytokinins	119
t-RNA as Possible Source of Cytokinin	119
Cytokinin Conjugation	120
Active Cytokinin	121
Cytokinin Catabolism	122
Site of Synthesis and Transport	122
Physiological Effects	122
Cell Division and Growth of Shoot and Root	123
Regulation of Cell Cycle	123
Regulation of Morphogenesis	123
Regulation of Apical Dominance	123
Formation of Genetic Tumour	123
Delay of Senescence	124
Differentiation of Chloroplast	124
Cotyledon Expansion	124
Movement of Nutrients	124
Abscisic Acid: Hormone for Growth Inhibition	124
Concept and Discovery of Abscisic Acid	124
Structure and Activity of Abscisic Acid	125
Biosynthesis of Abscisic Acid	125
Conjugation and Oxidation of Abscisic Acid	126
Translocation and Distribution of Abscisic Acid	127
Physiological Effects of Abscisic Acid	127
Abscisic Acid in Bud Dormancy	127
Abscisic Acid in Seed Dormancy	127
Abscisic Acid in Inhibition of Vivipary and Precocious Germination	128
Abscisic Acid in Inhibition of Seed Germination	128
Abscisic Acid in Stomatal Closure in Water Stress	128
Abscisic Acid in Promotion of Root Growth in Water Stress	128
Abscisic Acid in Promotion of Leaf Senescence	128
Ethylene: Gaseous Hormone	128
Concept and Discovery of Ethylene	129
Ethylene-induced 'Triple Response'	129

Biosynthesis of Ethylene	130
Catabolism and Conjugation of Ethylene	131
Inhibition of Ethylene Biosynthesis	131
Role of Hormones In Ethylene Synthesis	131
Inhibition of Ethylene Action	132
Physiological Effects of Ethylene	132
Ethylene in Promotion of Flowering and Change in Sex Expression	132
Ethylene in Promotion of Fruit Ripening	132
Ethylene in Lateral Cell Expansion	133
Ethylene in Maintenance of Hooks in Etiolated Seedlings	133
Ethylene in Breaking of Seed Dormancy	134
Ethylene in Elongation Growth of Submerged Plants	134
Ethylene in Promotion of Root Hair Formation	134
Ethylene in Defence Responses of Plants	134
Ethylene and Stress	135
Oligosaccharins as Plant Hormones	135
Pectic Oligosaccharins	135
Xyloglucan Oligosaccharins	137
Brassinosteroids as Plant Hormones	137
Concept and Discovery	138
Structure and Biosynthesis	138
Physiological Effects	138
Brassinosteroid Receptor and Mode of Action	140
Jasmonic Acid as Plant Hormone	140
Concept and Discovery	140
Biosynthesis	141
Physiological Effects of JA	141
Jasmonate as Systemic Signal	142
Salicylic Acid as Plant Hormone	142
Potential Plant Hormones	145
Systemin	145
Arabinogalactan Proteins	147
Polyamines	149
Thidiazuron: A Phenyl Urea Derivative	151
Fusicoccin	153
Plant Growth Regulators in Agriculture and Industry	153
Auxins	154
Rooting of Cuttings	154
Stimulation of Fruit-set	154

Chemical Thinning of Fruits	154
Prevention of Fruit Drop	155
Herbicidal Action	155
Gibberellins	155
Increase in Fruit Size Of Grapes	156
Increased Yield of Sugar-cane	156
Malting of Barley	156
Breaking Dormancy of Seeds and Tubers	156
Control of Flowering and Sex Expression	156
Cytokinin	157
Ethylene	157
Promotion of Leaf Senescence in Tobacco	157
Promotion of Fruit Abscission and Mechanical Harvesting	157
Promotion of Fruit Ripening	157
Flowering and Sex Expression	158
Increasing Latex Flow in Rubber Trees	158
Growth Retardants	158
<i>References</i>	159
5. TRANSDUCTION OF SIGNALS: HORMONAL AND ENVIRONMENTAL	175
Auxin Signalling	176
Auxin Receptor	176
Signalling Intermediates	177
Transcription Factors	178
Auxin-induced Primary Response Genes Or Early Genes	178
Early Genes for Growth and Development	178
Early Genes for Stress Responses	178
Early Genes for Cell-to-cell Communication and Late Gene Regulation	179
Model for Auxin Signalling	179
Cytokinin Signalling	180
Cytokinin Receptor	180
Expression of Response Regulator Genes	181
Histidine Phosphotransferases Mediate Cytokinin Signalling Cascade	181
Cytokinin-induced Phosphorylation Activates Transcription Factors	182
Model For Cytokinin Signalling	182
Ethylene Signalling	183
Ethylene Receptor	183
Copper Requirement	184
Serine/Threonine Protein Kinase Involvement	184
Gene Expression	184

Order of Ethylene Signalling Components	185
Model for Ethylene Signalling	185
Abscisic Acid Signalling	186
ABA Perception	186
G Protein-coupled Receptor (GCR 1)	187
Signalling Intermediates	187
Activation of Slow Anion Channels	187
Stimulation of Phospholipid Metabolism	188
Role of Protein Kinases and Phosphatases	188
Model for ABA-induced Stomatal Closure	188
Ca ²⁺ Independent Pathway Involvement	188
ABA-regulated Gene Expression In Development	189
Mediation by Transcription Factors	190
Negative Regulators of ABA Response	190
Sugar, Stress and Hormone (ABA and Ethylene) Interactions	190
Gibberellin Signalling	191
Gibberellin Receptors	191
Role of G Protein-dependent and-independent Pathways	192
Signalling Intermediates	192
GA Mutants and Transcription Factors	192
Model for Gibberellin-induced α -amylase Synthesis	194
New Signalling Molecules	195
Oxylipins	195
Extracellular ATP (E-ATP)	195
Reactive Oxygen Species (ROS)	195
Nitric Oxide	196
Red Light Signalling	196
Phytochrome-mediated Gene Regulation	197
Transcription Factor(s) Involvement	198
<i>LHCB</i> Regulation Follows Circadian Rhythmicity	199
Diversity of Phytochrome Responses	199
Movement of Phytochrome to Nucleus	200
What Happens When Phytochrome Moves To The Nucleus	201
Transduction of Phytochrome Signal Through Multiple Intermediates	201
G Protein and Calcium	202
Phosphorylation	202
Model For Phytochrome Signalling	203
Modulation Of Phytochrome by Other Photoreceptor	203
Blue Light Signalling	204

Blue Light Receptors	205
Cryptochromes	205
Phototropins	206
Zeaxanthin	206
Signal/Transduction	207
Cryptochrome	207
Phototropin	208
Zeaxanthin	208
Interaction of Putative Blue Light Receptor/s	209
Stress Signalling	210
<i>References</i>	210
6. STRESS: PERCEPTION AND TOLERANCE	219
Drought Stress	220
Tolerance to Drought Stress	220
Water Stress Classified	221
Slow Dehydration	221
Rapid Dehydration	221
Severe Dehydration	221
Heat Stress	222
Low Temperature Stress	222
Salinity Stress	224
Salinity Stress vs Drought Stress	224
Salinity Tolerance	224
Aquaporins in Response to Drought	227
Accumulation of Osmotin in Salt Stress	227
Genes Induced by Water Stress Responsive to ABA	227
Oxygen Deficiency	228
Water Logging	228
Oxidative Stress	229
Antioxidant Defence	231
Air Pollution and Acid Rain	232
Control Mechanisms in Stress Tolerance	232
Salt Tolerance	232
Tolerance to Freezing and Osmotic Stress	235
Protein Synthesis in Cold Tolerance, Heat Stress and Pathogenesis	235
Cold-induced Gene Expression Regulated by Transcription Factors	236
Heat Shock Protein Production at High Temperature	236
HSP Accumulation Mediated by Transcription Factor	237

Heatshock Proteins Mediate Thermotolerance	237
Heat Stress Acclimation is Calcium Mediated	238
Tolerance to Osmotic Stress	238
Crassulacean Acid Metabolism (CAM)	238
Changes in Gene Expression	239
Regulation of Stress-responsive Genes	240
What Happens When Stress-tolerance Pathways Collide	241
<i>References</i>	241
7. SENESCENCE AND ABSCISSION: PROGRAMMED CELL DEATH	246
Senescence is a Terminal Process	247
Senescence Classified	247
Inflorescence Arrest and Senescence	247
Senescence vs Necrosis	248
Factors Promoting Senescence	248
Phases in Leaf Senescence	248
Cytological and Biochemical Changes During Senescence	249
Pigment Metabolism in Senescence	249
Protein Catabolism in Senescence	250
Senescence-associated Genes (SAGs)	251
Salvage Aspects of Senescence	252
Breakdown of Proteins	252
Degradation of Nucleic Acids	254
Hormones in Promotion of Senescence	255
Ethylene-enhanced Senescence	255
Abscisic Acid-enhanced Senescence, Independent of Ethylene Biosynthesis	257
Sugar and Hormone Correlations in Senescence	258
Delay of Senescence	258
Role of Cytokinin	258
Role of Sucrose	260
Abscission	260
Hormonal Regulation of Abscission	262
Programmed Cell Death (PCD)	262
Programmed Cell Death in Plants and Animals (Apoptosis)	262
Selective Cell Death in Plants for Development and Differentiation	263
Examples of Programmed Cell Death in Plants	264
Death of Aleurone Cells	265
Death of Root-cap Cells	266
Death of Cells in Suspension Culture	267

In Vitro Control of PCD: Differentiation of Tracheary Elements (TEs)	267
Requirements for Differentiation of TEs	268
Stages in Differentiation of TEs	270
Stage I	270
Stage II	271
Transition From Stage II To Stage III	271
Stage III	271
Changes In Cytoskeleton	272
Secondary Wall-specific Proteins	272
Expression of Lignin Biosynthetic Enzymes	272
Programmed Cell Death (PCD)	272
Morphological Aspects of PCD	272
Molecular Aspects of PCD	273
Pathogenesis	273
<i>References</i>	275
8. REGENERATION: TOTIPOTENCY OF PLANT CELLS	280
Micropropagation (Regeneration from Shoot Apical Meristem)	281
Requirements for Regeneration of Shoot-apex	281
Beneficial and Harmful Role of Cytokinin	282
Some Examples of Micropropagation	282
Commercial Applications of Micropropagation	283
Culture of Shoot Apex for Propagation of Orchids	283
Culture of Shoot Apex for Propagation of Virus-free Plants	284
Regeneration from Lateral Meristem	285
<i>Regeneration from Stem Segment</i>	285
Regeneration of Shoot-buds on Stem Segments	285
Regeneration of Somatic Embryos on Hypocotyl Segments	288
Regeneration of Somatic Embryos on Seedlings	288
Regeneration of Somatic Embryos from Zygotic Embryos	288
Regeneration from Leaf Segments	290
Regeneration by Shoot-bud Formation	290
Regeneration of Orchids	291
Leaf Age and Regeneration	291
Regeneration of Tree Species	291
Regeneration of Medicinal Plants	292
Regeneration of Vegetable Plants	293
Regeneration of Ornamentals	293
Regeneration by Somatic Embryogenesis	294

Regeneration from Roots	295
Shoot Regeneration from Hairy-roots	296
Regeneration from Endosperm	297
Regeneration from Cotyledons	298
Regeneration from Cotyledonary Node	300
Regeneration from Thin-layer or Peel Explants	302
Regeneration of Flowers in Tissue Culture	303
Regeneration from Free-cells	304
Regeneration from Protoplasts	304
Regeneration from Microspores	305
Anther Culture for Induction of Haploids	306
Pollen Culture for Induction of Haploids	308
Pollen Culture of Monocot Plants	310
Regeneration from Callus Tissue	312
Organogenesis vs Embryogenesis	312
Regeneration of Callus Tissue by Organogenesis	312
Recalcitrance to Regeneration	313
Regeneration of Callus Tissue by Somatic Embryogenesis	314
Factors Affecting Somatic Embryogenesis	315
Tissue Environment and Somatic Embryogenesis	316
Role of Auxin, Ammonium and pH of Medium	316
Tissue-origin and Somatic Embryogenesis (Somatic Embryogenesis in Cereals, Grasses And Palms)	318
Direct Embryogenesis	321
Ethylene and Polyamines in Somatic Embryogenesis	322
Glycoproteins in Somatic Embryogenesis	324
Gene Expression in Somatic Embryogenesis	326
Stress and Somatic Embryogenesis	327
Cell Programming in Somatic Embryogenesis	327
Molecular Markers of Somatic Embryogenesis	328
Direct and Indirect Somatic Embryogenesis	329
Somatic Embryogenesis on Plantlets, Regenerated <i>in vitro</i> from Callus Cultures	329
Somatic Embryogenesis vs Zygotic Embryogenesis	329
Do Somatic Embryos have a Suspensor	330
Auxin Transport in a Somatic Embryo	330
Polarity in a Somatic Embryo	330
Absence of Maturation in a Somatic Embryo	331
Somatic Embryo to Plantlet	331
Induction of Maturation	331

Beneficial Role of Cytokinin	332
Large Scale Production of Somatic Embryos	332
Synchronization of Somatic Embryo Development	333
Synthetic Seeds or Syn Seeds	334
Problems and Prospects in Somatic Embryogenesis	336
Retention and Regulation of Cell Totipotency	336
<i>References</i>	337
9. NOVEL PLANTS (TRANSGENICS): GENETICALLY ENGINEERED (GE) OR GENETICALLY MODIFIED (GM) CROPS	369
What is Recombinant DNA Technology	370
<i>Agrobacterium</i> , a Genetic Engineer in Nature	371
Methods of Gene Delivery	373
<i>Agrobacterium</i> -mediated Transformation or Agroinfection	374
Protoplast-mediated Cell Transformation	375
Particle Bombardment or Biolistics-mediated Transformation	376
Comparison of Biolistics, Protoplast and Agroinfection	377
Agrolistics, A New Method for Transformation	377
Alternative Methods of Gene Delivery	377
Silicon Carbide Fibre-mediated Delivery of DNA	378
Electroporation	378
Electrophoresis	379
Microinjection	379
Achievements Of Genetic Engineering	380
Herbicide Resistance	380
Pest Control	381
Parasite Control	384
Control of Viral Diseases	384
Coat Protein-mediated Resistance (CPMR)	386
Movement Protein-mediated Resistance (MPMR)	389
Replicase-mediated Resistance	389
c-RNA or Antisense RNA Strategies	389
Sat-RNA Strategy	389
Multiple-protection Strategies	390
Viral Disease Resistance Through Expression of Antibody Sequence	390
Problems and Prospects	390
Induction of Male Sterility	391
Delay of Senescence	391
Combating Stress	394
Combating Iron Deficiency of Soil	396

Improvement of Grain Quality	396
Alteration in Starch Quality	398
Increase in Oil: Quantity and Quality	398
Improvement of Feed Quality	400
Alteration of Plant Morphology and Physiology	400
Transgenics for Generating Vaccines	402
Production of Polyester Cotton	403
Applications of Transgene Silencing	405
Apprehensions about Transgene Technology	408
Terminator Gene Technology	409
Terminator Technology in Self-pollinated Crops	410
Terminator Technology for Hybrid Crops	411
Why Terminator Technology	412
<i>References</i>	412
<i>Index</i>	425
<i>About the Author</i>	434