Contributo	rs			xv
Foreword l	by Ke	nneth V. Thimann		xvii
Preface	0		х	xvii
1 The	Phen	nomena of Senescence and Aging		
L. D. I	Noodé	n		
I.	Em	ergence of Senescence as a Concept		2
II.	Cor	ncepts		3
	Α.	Senescence versus Aging		3
	Β.	The Basic Units of Senescence		4
	C.	Death and Death Processes		4
	D.	The Senescence Syndrome: An Outline		6
JII.	Exp	perimental Analysis of Senescence		14
	-	Why Study Senescence?		14
	Β.	Measures of Senescence		15
	C.	Correlative Controls		16
	D.	Attached versus Detached Structures		19
	E.	Hormonal Controls		20
IV.	Pat	terns of Senescence		22
	Α.	Overview		22
	Β.	Cellular Patterns		23
	C.	Tissues		26
	D.	Organs		31
	E.	Organisms		32
	F.	Relationship between Stress and Senescence		34
	G.	Nonsenescence Processes		36
		References		38
2 The	Mole	cular Basis for Membrane Deterioration		
	NOIC	vulai basis ivi menintane belenvialivit		

during Senescence

- J. E. Thompson
 - I. Introduction

52

Contents

II.	Senescence of Microsomal and Plasma Membranes	52
	A. Increased Production of Free Radicals	53
	B. Changes in the Molecular Organization	
	of Lipid Bilayers	55
	C. A Tentative Model for Senescence	
	of Microsomal Membranes	65
III.	Thylakoid Membrane Senescence	69
	A. Free Radical Production	70
	B. Loss of Thylakoid Membrane Integrity	71
IV.	Mitochondrial Membranes	75
V.	Modulation of Membrane Senescence	75
VI.	Conclusions	76
	References	77

3 Photosynthesis

4

Shimon Gepstein

I.	Introduction	85
II.	Senescence of Chloroplasts	86
	A. Ultrastructural Changes in Chloroplasts during	
	Senescence	86
	B. Autonomous Degradation of Chloroplasts	87
III.	Chlorophyll Degradation	89
IV.	Changes in Lipids during Chloroplast Senescence	92
V.		
	Senescence	93
VI.	Changes in the Components of the Chloroplast	
	Thylakoid Membranes during Foliar Senescence	95
VII.		99
VIII.	Leaf Conductance and CO ₂ Assimilation in	
	Senescing Leaves	102
IX.	Conclusions	103
	References	104
Deen	instian in Concessing Plant Organou	
	iration in Senescing Plant Organs:	
	ature, Regulation, and Physiological Significance	
Ineopi	hanes Solomos	
I.	Introduction	112
II.	Patterns of Respiration in Detached Plant Organs	112
	A. Fruit	112
	B. Leaves	113

B.	Leaves		
C.	Flowers		

113

		Contents	vii
	III. IV. VI. VII. VIII. IX. XI. XII. XII	Causes of the Climacteric Rise in Respiration Mode of Action of Ethylene on Plant Respiration Regulation of Plant Respiration Glycolysis Pentose Pathway Tricarboxylic Acid Cycle Electron Transport Residual Cellular Organization Physiological Significance of the Climacteric Rise in Plant Senescence Summary References	 113 117 118 119 124 124 126 132 133 134 136 137
5		eic Acid and Protein Synthesis	
	I. II. III. IV.	Introduction Nucleic Acid and Protein Contents A. DNA B. RNA C. Protein Nucleic Acid and Protein Synthesis A. DNA Synthesis B. RNA Synthesis C. Protein Synthesis Senescence Mutants References	147 149 150 152 156 157 157 157 170 171
6	Metal Reall	nterplay between Proteolysis and Amino Acid polism during Senescence and Nitrogen ocation 8. Peoples and Michael J. Dalling	
	I. II.	Introduction Qualitative and Quantitative Description	182
	III.	of Preanthesis Nitrogen Source Protein Degradation A. Generalized Concepts of Proteolysis B. Protein Turnover C. Nature of Protein-Degrading Enzymes	182 185 185 186 187
		D. Generalized Concepts for the Regulation of Protein Degradation	189

0		1.
(0	nter	nts
~~	10001	1000

	IV.	Senescence, Proteolysis, and the Metabolism	
		of Nitrogen: Some Case Histories	195
		A. Root and Nodule Senescence	195
		B. Leaf Senescence	202
	V.	Concluding Remarks	211
		References	212
7	Wate	r Economy of Fruits and Fruiting Plants:	
n Trans Trans		Studies of Grain Legumes	
	J. S. P		
	÷		010
	I.	Introduction	219
	Ш.	Water Balances of Developing Fruit and Seeds	
		and Their Relationships to the Import of Carbon	
		and Nitrogen through the Xylem and Phloem	223
	III.	Diurnal Water Balance of Fruit and the Fruiting	
		Plant	227
	IV.	Structural Features of the Fruit and Their	
		Significance in Terms of Water Relationships	229
	V.	Tracer Studies of the Phloem and Xylem Exchanges	
		of Water and Solutes between Fruit, Peduncle, and	
		the Remainder of the Plant	233
	VI.	General Conclusions	236
		References	238
8	Ethyl	ene and Plant Senescence	
	Autar k	K. Mattoo and Nehemia Aharoni	
	I.	Introduction	242
	II.	Biosynthesis of Ethylene	243
	- VIII	A. Precursors and Pathway	243
		B. Enzyme Systems	244
	III.	Regulation of Ethylene Biosynthesis	246
		A. Methionine Recycling	246
		B. Linkage with Polyamine Biosynthesis	247
		C. Conjugation of ACC	248
		D. Membrance Association and Involvement	210
		of Membrane Function	249
		E. Feedback Controls	250
		F. IAA-Induced Ethylene Production	251
	IV.	Ethylene in Fruit Ripening, Senescence, and Leaf	<u> </u>
	τv.	Abscission	255
		A. Ethylene and Fruit Ripening	255
		B Symptoms of Leaf Senescence	257

C	. Laur La	
COP	itents	

		C. Exogenous Ethylene and Leaf-Blade	
		Senescence	258
		D. Endogenous Ethylene and Leaf-Blade	
		Senescence	259
		E. Interactions between Ethylene and Other Plant	
		Hormones in Leaf-Blade Senescence	261
		F. Exogenous Ethylene and Changes	
		in the Abscission Zone	262
		G. Interactions between Auxin and Ethylene	
		in Abscission	263
		H. Endogenous Ethylene in Abscission	264
		I. Interactions between Ethylene and Other	
		Factors in Natural Abscission	266
	V.	Mechanisms of Ethylene Action	266
	VI.	Conclusions	267
		References	269
9	Cytoł	kinins and Senescence	
	-	es Van Staden, Elizabeth L. Cook, and L. D. Noodén	
	I.	Introduction	282
	II.	Cytokinin Biochemistry and Physiology	282
		A. Cytokinin Structure	282
		B. Sites of Cytokinin Production	284
		C. Cytokinin Transport	285
		D. Cytokinin Metabolism	288
	III.	Evidence to Implicate Cytokinins in the Regulation	
		of Senescence	293
	IV.	Cytokinins and Organ or Organism Senescence	295
		A. Leaves	296
		B. Cotyledons	303
		C. Flowers	305
		D. Fruit and Seed Senescence	306
		E. Whole Plant Senescence	307
	V.	Relationships between Cytokinins	
		and Other Hormones	309
	VI.	Conclusions	310
		References	312
10		sic Acid, Auxin, and Other Regulators	
		nescence	
	L. D. N	oodén	

I. Introduction

330

ix

Contents	
	Contents

331

	II.	Abscisic Acid and Senescence Processes	331
		A. Influence of Exogenous Abscisic Acid	332
		B. Correlation with Endogenous Abscisic Acid	334
		C. Relationships between Abscisic Acid	
		and Other Hormones	335
	III.	Other Promoters of Senescence	338
		A. Fatty Acids	338
		B. Serine	339
		C. Jasmonic Acid and Related Compounds	340
		D. Miscellaneous Promoters	340
		E. Unidentified Promoters	341
		F. Hypersensitive Response	342
	IV.		342
		A. Influence of Exogenous Auxin	343
		B. Correlation with Endogenous Auxin	344
		C. Relationship between Auxin and Other	
		Hormones	344
	V.	Gibberellin and Senescence Processes	348
		A. Influence of Exogenous Gibberellin	348
		B. Correlation with Endogenous Gibberellin	349
		C. Relationship between Gibberellin and Other	
		Hormones	351
	VI.	Other Retardants of Senescence	352
	VII.	Summary	353
		A. What Hormone Is in Control?	353
		B. Hormone Combinations	353
		C. Integrated Hormone Systems	354
		D. New Hormones?	354
		E. Conclusion	354
		References	355
11	Calci	um and Senescence	
		Poovajah	
	I.	Introduction	369
	II.	Calcium and Hormone Interactions	371
	III.	Cytosolic and Apoplastic Roles of Calcium	373
		A. Cell Walls and Membranes	373
		B. Calcium and Calmodulin	376
		C. Protein Phosphorylation	379
	IV.	Role of Inositol Phospholipids in Calcium	
		Messenger System	383
	V.	Conclusion	385
		References	385

12	Whole L. D. N	oodén	
	I.	Introduction	392
	II.	Patterns of Whole Plant Senescence	392
	III.	Correlative Controls	393
		A. Cells and Organs as Components	
		of the Organism	394
		B. Control Centers versus Targets	394
		C. Behavior of the Senescence Signal	398
	IV.	Cessation of Vegetative Growth as a Component	
		of Whole Plant Senescence	398
	V.	Decline in Assimilatory Processes	402
		A. Changes in Assimilation in the Roots	
		and Leaves	402
		B. Metabolic Decline in Plants with Reproductive	
		Structures Removed ("Desinked")	403
	VI.	Partitioning and Redistribution of Assimilates	
		in Relation to Senescence	406
		A. Nutrient Diversion and Redistribution	406
		B. Shift in Photosynthate Partitioning during	107
		Reproductive Development	406
		C. Competition between the Fruits and Leaves for	405
		Mineral Nutrients Assimilated by the Roots	407
		D. Controls of Assimilate Movement	408
		E. Nutrient Redistribution	409
	X 7TT	F. Exhaustion Death: Real or Apparent?	410
	VII.	Hormonal Controls	412
		A. Introduction	412 413
		B. The Senescence Signal	415
	VIII.	C. The Root/Shoot (Leaf) Interaction	419
	V 111.	Senescence of Polycarpic Plants A. Introduction	419
		B. Clonal Growth	419
		C. Causes of Decline in Polycarpic Plants	422
		D. Do Polycarpic Plants Senesce?	425
	IX.	Conclusions	426
	1/1.	References	427
			~~~

### 13 Deterioration of Membranes during Aging in Plants: Evidence for Free Radical Mediation

Bryan D. McKersie, Tissa Senaratna, Mark A. Walker, Edward J. Kendall, and P. Richard Hetherington

I. Introduction

442

xi

Contents	

II.	Evidence for Membrane Deterioraton during Aging	443
	A. Seed Aging	443
	B. Desiccation Tolerance	444
	C. Freezing	445
	D. Ice-Encasement	446
III.	Physical Properties of Microsomal Membranes	447
	A. Phase Properties	448
	B. Freeze Fracture Electron Microscopy	450
	C. Membrane Microviscosity	450
IV.	Lipid and Protein Composition of Microsomal	
	Membranes	452
	A. Membrane Lipids	452
	B. Membrane Proteins	454
V.	Free Fatty Acids and Lipid Phase Properties	454
	Free Radicals	456
	A. Phospholipid De-esterification	456
	B. Free Radical Scavenging Systems	458
	C. Production of Free Radicals	459
VII.	Summary	460
	References	461

## 14 Seed Aging: The Genome and Its Expression

### E. H. Roberts

I.	Intr	oduction	466
II.	His	torical Perspective	467
	Α.	A False Dawn: Old Seeds of Oenothora	
		Contain More "Mutants" Than New Seeds	
		(1901–1931)	467
	B.	Chromosone Aberrations and Gene Mutations,	
		or the Events That Give Rise to Them,	
		Are Induced during Seed Storage (1933–1936)	468
	C.	Accumulation of Chromosome Damage	
		Is a Function of Time, Temperature,	
		and Moisture Content (1933-1939)	468
	D.	Recognition of a Simple Relation between Loss	
		of Seed Viability and the Induction	
		of Chromosome Damage (1967–1985)	469
	E.	The Concept of Repair during Moist Seed	
		Storage (1974–1985)	474

Contents	

F. The Amount of Chromosome Damage

		Associated with a Given Loss of Viability Is	
		Large at Low-Moisture Contents and Is	
		Minimal at High-Moisture Contents (1985)	476
	III.	The Nature of the Damage to the Genome	
		and Its Expression	483
		A. The Classical and Exchange Theories	
		of Chromosome Damage	483
		B. Chromatid-Type and Chromosome-Type	
		Aberration in Seeds: Is the Damage Initiated	
		during Aging or Afterward during	
		Germination?	484
		C. Speculations Concerning DNA Lesions That	
		Result from Seed Aging	488
		D. The Fate of Damage to the Genome	489
		E. Damage to the Cellular Systems That Express	207
		the Genome	491
	IV	Conclusions	492
	1 .	References	493
			4
15	Postl	ude and Prospects	
	L. D. N		
	<u> </u>	Senescence versus Exogenously Driven	100
		Degeneration	499
	II.	What Is Senescence?	501
		A. Required Processes	501
		B. Central versus Peripheral Processes	
		in Senescence	503
		C. The Role of the Chloroplast in Senescence	506
		D. Senescence as Parallel or Loosely Coupled	
		Processes	507
		E. Is Senescence One Process or Several?	509
		F. Future Analyses of Senescence	509
	III.	What Hormone Is in Control?	510
	IV.	Limits on Life	511
	V.	Conclusions and Closing	512
		References	513
		Note Added in Proof	517
T 1			<b>E10</b>
Index	Ç.		519