

Contents

Abbreviations	XIII
A. Introduction	1
I. Plastid Numbers in Relation to the Whole: Scope of Presentation	1
1. Purpose and Design	1
2. Rationale of the Approach	2
II. Historical Overview	4
B. Survey of Known Plastid Numbers per Cell	5
I. Introduction	5
II. Methods of Counting	7
1. General Remarks	7
2. Observation of Living and Unstained Material	8
3. Fixation and Storage	9
4. Maceration	10
5. Staining	11
6. Handling for Microscopy	13
7. Remarks on Statistics and Reliability	14
III. <i>Phycophyta</i>	15
IV. <i>Bryophyta</i>	16
1. <i>Hepaticae</i>	16
2. <i>Musci</i>	17
V. <i>Pteridophyta</i> and Gymnosperms	18
VI. <i>Dicotyledoneae</i>	21
1. Proplastids in Meristem Cells	21
2. Chloroplasts in Guard Cells	21
3. Chloroplasts in Epidermal Cells	23
4. Chloroplasts in Mesophyll Cells	26
5. Plastids in Other Cells	29
6. Patterns of Plastid Numbers	29
a) Cell Specificity Patterns	29
b) Position of Cells in the Leaf	32
c) Leaf Type Patterns	34

VII. <i>Monocotyledoneae</i>	36
1. Proplastids in Meristem Cells	36
2. Chloroplasts in Guard Cells	36
3. Plastids in Epidermal Cells	37
4. Chloroplasts in Mesophyll Cells	38
5. Patterns of Plastid Numbers	38
VIII. Comparison of Dicotyledons With Monocotyledons	40
IX. Summary	41
C. Developmental Genetics of Plastid Populations	41
I. Plastid Division and Cell Cycle	41
1. Are Plastid Divisions Connected Directly to Cell Divisions?	41
2. Evidence Against a Direct Connection	42
3. Possible Influence of Amount of Nuclear DNA	44
II. Nuclear Ploidy and Chloroplast Number	45
1. Introduction	45
2. Euheteroploidy of Whole Plants	47
a) Autopolyploidy and Haploidy of Different Origins	47
b) Induced Allopolyploidy	49
c) Polyploid Plants From Nature	49
3. Endopolyploidy	53
a) Occurrence and Characteristics	53
b) Numbers of Chloroplasts	54
4. Elimination of Ploidy Effects in Comparisons	55
III. Aneuploidy and Chloroplast Number	56
1. Trisomic Plants	56
a) Single Trisomic Plants	56
b) Double Trisomic Plants	58
2. Other Aneuploid Plants	60
IV. Other Genetic Differences Possibly Affecting the Chloroplast Number	61
1. Gene Differences and Heterozygosity	61
a) Selection and Single-Gene Effects	61
b) Hybridization Response	63
2. Differences in the Basic Amount of Nuclear DNA	64
3. Non-Mendelian Genetic Influences on the Replication of Plastids	65
V. Summary	67
D. Correlations, Regeneration and Compensatory Divisions	68
I. Introduction	68
II. Chloroplast Size, Cell Size and Chloroplast Number	69
1. Chloroplast Size	69
a) General Remarks	69
b) Some Effects of Environment	69
c) Nuclear and Plastid DNA and Chloroplast Size	71
d) Cell Specificity	74
2. Cell Size and Chloroplast Size	76

3. Cell Size and Chloroplast Number	76
4. Chloroplast Size and Chloroplast Number	79
a) Inhibited Division and Continued Growth	79
b) Division Without Growth	82
c) Correlation Between Number and Size	83
III. Compensatory Divisions of Plastids	84
1. Readjustment of Plastid Numbers After Ontogenetic Deviations From the Standard	84
2. Increasing Chloroplast Numbers With Hypertrophic Growth of Cells	86
IV. Summary	87
E. Influences of External Agents on Plastid Number	88
I. Introduction	88
II. Light	89
1. General Remarks	89
2. Light and Darkness	90
3. Intensity of Light	92
4. Quality of Light	96
III. Temperature	98
IV. Water and Mineral Salts	99
1. Role of Water	99
2. Major Elements	99
a) Effect of Endopolyploidy Prevalent	99
b) Effect of Endopolyploidy not Prevalent	102
3. Minor Elements	103
V. Carbon Dioxide	104
VI. Organic Compounds	104
1. Sugars and Related Compounds	104
2. Phytohormones	105
3. Antibiotics	109
4. Various Other Organic Compounds	110
VII. Various Other Factors	113
VIII. Summary	114
F. Continuity of Plastids and Formation of Patterns	116
I. Introduction	116
II. Multiplication of Plastids	116
1. Multiplication in Meristematic and in Differentiating Cells	116
2. Multiplication in Peculiar Environments	118
3. General Considerations and Results	119
III. Minimum Number of Plastids Needed for Continuity	121
1. Allocation of Plastids to Daughter Cells	121
a) General Considerations	121
b) Unequal Cell Divisions	122
c) Plastid Allocation—A Random Process?	123

2. Minimum Numbers	124
a) General Considerations	124
b) Numbers Required and Numbers Found	125
c) Cell Size, Ploidy, and Minimum Number	129
d) Is There a Need for Plastids in All Plant Cells	129
3. Monoplastidic Stages: Facts and Implications	130
a) Monoplastidy as a Transitory Stage	130
b) Major Problems in Monoplastidy	131
IV. Patterns of Chloroplast Reproduction	133
1. Introduction	133
2. Duplication Waves	135
3. Ploidy Prepattern	138
4. Other Prepatterns	140
5. Shifts in Patterns	142
6. General Remarks. Basic Numbers	145
V. Appendix: Plastid Fusions	146
VI. Summary	147
G. Applications, Inferences and Conclusions	147
I. Applications	147
1. Significance of Chloroplast Numbers in Differentiation Studies	147
2. Chloroplast Numbers in Taxonomy	150
3. Applications in Plant Breeding	152
II. Considerations on Evolution	154
1. Monoplastidy Versus Polyplastidy	154
2. Brief Comparison With the Behavior of Symbionts	156
3. Evolution of Patterns	158
III. Inferences and Conclusions	158
1. Major Results	158
2. Lines of Future Research	160
Bibliography	163
Glossary	192
Subject Index	195