

Contents

Contents	vii
Introduction	ix
1 Preliminaries	1
1.1 Alphabets and languages	1
1.2 Multisets	3
1.3 Graphs and trees	4
1.4 Recursive functions	5
1.5 Diophantine sets	8
1.6 Turing machines	8
1.7 Complexity classes	11
I Computational completeness	13
2 Cellular computing systems with membranes	15
2.1 From cell to P systems	15
2.2 Formal scheme of a P system	21
3 P systems with external output	25
3.1 Membrane structures	25
3.2 Syntax of P systems with external output	26
3.3 Semantics of P systems with external output	29
3.4 Variants of P systems with external output	36
4 P systems as accepting devices	37
4.1 Language accepting P systems	37
4.2 Computational completeness through Turing machines	39
4.3 Formal verification	51
5 P systems as language generating devices	75
5.1 Language generating P systems	75

5.2	Computational completeness through formal languages . . .	77
5.3	Formal verification	85
6	P systems as computing devices	97
6.1	Function computing P systems	97
6.2	Computational completeness through recursive functions . .	99
7	P systems as set generating devices	115
7.1	Set generating P systems	115
7.2	Computational completeness through Diophantine sets . . .	116
II	Computational complexity	125
8	A Complexity Theory in P Systems	127
8.1	Preliminary definitions	127
8.2	Complexity classes in P systems	129
9	P Systems and the $P = NP$ problem	139
9.1	Simulation of Turing machines by P systems	140
9.2	Simulation of P systems by Turing machines	148
9.3	Characterization of the $P \neq NP$ relation through P systems	156
10	P systems with active membranes	159
10.1	Syntax of P systems with active membranes	159
10.2	Semantics of P systems with active membranes	161
11	Linear solutions of the SAT and VALIDITY problems in systems with active membranes	171
11.1	P systems with active membranes as accepting devices . . .	172
11.2	Resolution of SAT problem	174
11.3	Resolution of VALIDITY problem	193
	Conclusions and future work	205
	Bibliography	209