

## TABLE OF CONTENTS

<b>CERTIFICATE OF EXAMINATION</b>	<b>ii</b>
<b>ABSTRACT</b>	<b>iii</b>
<b>ACKNOWLEDGEMENTS</b>	<b>v</b>
<b>TABLE OF CONTENTS</b>	<b>vi</b>
<b>INTRODUCTION</b>	<b>1</b>
<b>Chapter 1 Some Elements of Formal Language Theory</b>	<b>9</b>
1.1 Notation and General Notions . . . . .	9
1.2 Operations on Strings and Languages . . . . .	11
1.3 Chomsky Grammars . . . . .	12
1.4 Normal Forms . . . . .	14
1.5 Finite Automata . . . . .	15
1.6 Register Machines . . . . .	17
1.7 Grammars with Restrictions in Derivation . . . . .	19
1.8 Grammar Systems . . . . .	22
<b>Chapter 2 H Systems</b>	<b>26</b>
2.1 The Splicing Operation . . . . .	26
2.2 Iterated Splicing as a Language Operation . . . . .	29
2.3 Extended H Systems; Generative Power . . . . .	33

<b>Chapter 3 Extended H Systems with Permitting Contexts</b>	<b>35</b>
3.1 Definitions and a Basic Result . . . . .	35
3.2 The Diameter of an H System with Permitting Contexts . . . . .	44
3.3 Generating Context-Free Languages . . . . .	50
<b>Chapter 4 Extended H Systems with Forbidding Contexts</b>	<b>53</b>
4.1 Definitions . . . . .	53
4.2 The Universality of Extended H Systems with Forbidding Contexts . .	54
<b>Chapter 5 Extended H Systems with Targets</b>	<b>59</b>
5.1 Definitions . . . . .	59
5.2 The Universality of Extended H Systems with Target Languages . . .	60
<b>Chapter 6 H Systems with Multisets</b>	<b>64</b>
6.1 Definitions . . . . .	64
6.2 The Universality of H Systems with Multisets . . . . .	65
<b>Chapter 7 H Systems Based on Double Splicing</b>	<b>69</b>
7.1 Definitions . . . . .	69
7.2 The Universality of H Systems Based on Double Splicing . . . . .	70
<b>Chapter 8 Communicating Distributed H Systems</b>	<b>72</b>
8.1 Definitions . . . . .	72
8.2 The Universality of Communicating Distributed H Systems . . . . .	74
8.3 The Generation of Context-Free Languages . . . . .	77
<b>Chapter 9 Time-Varying H Systems</b>	<b>80</b>
9.1 Definitions . . . . .	80
9.2 The Universality of Time-Varying H Systems . . . . .	81
<b>Chapter 10 Complexity Issues in Watson-Crick Finite Automata</b>	<b>88</b>
10.1 Watson-Crick Finite Automata . . . . .	88
10.2 Complexity Measures for WK Automata . . . . .	91
10.3 Decidability Questions . . . . .	91

10.4 Succinctness Questions . . . . .	93
10.5 Connectedness/Triviality Questions . . . . .	97
10.6 A Further Measure . . . . .	99
<b>Chapter 11 Membrane Computing: An Introduction</b>	<b>101</b>
11.1 An Informal Introduction to P Systems . . . . .	101
11.2 A More Formal Definition of a P System . . . . .	104
11.3 Further Features Used in P Systems . . . . .	107
11.4 The Power of the Previous Systems . . . . .	108
<b>Chapter 12 Universality with a Small Number of Catalysts</b>	<b>110</b>
12.1 Using Bi-stable Catalysts . . . . .	110
12.2 Using Mobile Catalysts . . . . .	113
<b>Chapter 13 P Systems with Active Membranes</b>	<b>118</b>
13.1 Motivation . . . . .	118
13.2 Definitions . . . . .	120
13.3 Solving HPP by P Systems with Active Membranes . . . . .	123
13.4 Solving HPP by P Systems of a Restricted Form . . . . .	127
13.5 Universality without Membrane Division . . . . .	130
<b>Chapter 14 P Systems with Symport/Antiport</b>	<b>134</b>
14.1 Preliminary Observations . . . . .	134
14.2 Definition . . . . .	135
14.3 The Symport Rules Suffice . . . . .	139
14.4 A Variant . . . . .	145
14.5 The Antiport Rules Suffice . . . . .	149
14.6 Other Universality Results . . . . .	151
14.7 Controls on the Use of Symport Rules . . . . .	153
14.8 P Systems with Traces . . . . .	159
<b>Chapter 15 Communicating P Systems</b>	<b>162</b>
15.1 Definition of Communicating P Systems . . . . .	162

15.2 The Universality of Communicating P Systems . . . . .	163
15.3 Interpreting Communicating P Systems with Only One Membrane as P Systems with Symport/Antiport . . . . .	167
<b>Chapter 16 Computing in Networks of Membranes</b>	<b>171</b>
16.1 Definition . . . . .	171
16.2 Preliminary Results . . . . .	176
16.3 The Power of Tissue P Systems with Symport/Antiport . . . . .	178
16.4 Less Structured Networks . . . . .	184
<b>Chapter 17 P Systems With Partially Parallel Rewriting</b>	<b>189</b>
17.1 Definitions . . . . .	190
17.2 Universality Results for P Systems With Partial Rewriting . . . . .	191
<b>Chapter 18 P Systems Based on Splicing</b>	<b>198</b>
18.1 Definitions . . . . .	198
18.2 The Universality of Splicing P Systems . . . . .	200
<b>Chapter 19 P Systems With Global Rules</b>	<b>210</b>
19.1 The Power of Global Rewriting P Systems . . . . .	210
19.2 The Power of Global Splicing P Systems . . . . .	214
<b>Chapter 20 Final Remarks</b>	<b>219</b>
<b>REFERENCES</b>	<b>221</b>
<b>VITA</b>	<b>231</b>