

# Contents

<b>1</b>	<b>Artificial life</b>	<b>1</b>
1.1	Overview . . . . .	1
1.2	Philosophy . . . . .	1
1.3	Organizations . . . . .	2
1.4	Software-based - “soft” . . . . .	2
1.4.1	Techniques . . . . .	2
1.4.2	Notable simulators . . . . .	2
1.5	Hardware-based - “hard” . . . . .	2
1.6	Biochemical-based - “wet” . . . . .	2
1.7	Open problems in ALife . . . . .	3
1.8	Related subjects . . . . .	3
1.9	History . . . . .	3
1.10	Criticism . . . . .	3
1.11	See also . . . . .	3
1.12	References . . . . .	3
1.13	External links . . . . .	4
<b>2</b>	<b>OpenWorm</b>	<b>5</b>
2.1	Background: <i>C. elegans</i> . . . . .	5
2.1.1	NemaLoad . . . . .	5
2.2	OpenWorm project . . . . .	5
2.2.1	Progress . . . . .	6
2.3	Related projects . . . . .	6
2.4	Open science . . . . .	6
2.5	References . . . . .	6
2.6	External links . . . . .	7
<b>3</b>	<b>3D Virtual Creature Evolution</b>	<b>8</b>
3.1	Settings . . . . .	8
3.2	Simulation . . . . .	8

3.3	Creatures . . . . .	9
3.4	References . . . . .	9
<b>4</b>	<b>Agent-based model</b>	<b>10</b>
4.1	History . . . . .	10
4.1.1	Early developments . . . . .	10
4.1.2	1970s and 1980s: the first models . . . . .	10
4.1.3	1990s: agent-based modeling expands . . . . .	11
4.1.4	2000s and later . . . . .	11
4.2	Theory . . . . .	12
4.2.1	Framework . . . . .	12
4.3	Applications . . . . .	12
4.3.1	ABM in biology . . . . .	12
4.3.2	ABM in business, technology and network theory . . . . .	13
4.3.3	ABMs in economics and social sciences . . . . .	13
4.3.4	Organizational ABM: agent-directed simulation . . . . .	13
4.4	Implementation of ABMs . . . . .	14
4.5	Verification and validation of ABMs . . . . .	14
4.6	See also . . . . .	14
4.7	References . . . . .	15
4.8	External links . . . . .	18
<b>5</b>	<b>Animat</b>	<b>20</b>
5.1	See also . . . . .	20
5.2	Further reading . . . . .	20
5.3	References . . . . .	21
5.4	External links . . . . .	21
<b>6</b>	<b>Artificial chemistry</b>	<b>22</b>
6.1	Formal definition . . . . .	22
6.2	Types of artificial chemistries . . . . .	22
6.3	Important concepts . . . . .	22
6.4	History of artificial chemistries . . . . .	23
6.5	Important contributors . . . . .	23
6.6	Applications of artificial chemistries . . . . .	23
6.7	See also . . . . .	23
6.8	External links and references . . . . .	23
<b>7</b>	<b>Artificial creation</b>	<b>24</b>
7.1	Origins . . . . .	24

7.2	Issues . . . . .	24
7.3	References . . . . .	25
7.4	Conferences . . . . .	25
<b>8</b>	<b>Artificial Life (journal)</b>	<b>26</b>
8.1	Abstracting and indexing . . . . .	26
8.2	External links . . . . .	26
<b>9</b>	<b>Artificial life framework</b>	<b>27</b>
9.1	External links . . . . .	27
<b>10</b>	<b>Artificial life organizations</b>	<b>28</b>
10.1	International Society of Artificial Life . . . . .	28
10.2	Biota.org . . . . .	28
10.3	Grey Thumb Society . . . . .	28
10.4	Notes . . . . .	28
10.5	External links . . . . .	28
10.6	References . . . . .	28
<b>11</b>	<b>Artificially Expanded Genetic Information System</b>	<b>29</b>
11.1	References . . . . .	29
<b>12</b>	<b>Astrochicken</b>	<b>30</b>
12.1	See also . . . . .	30
<b>13</b>	<b>Autocatalytic set</b>	<b>31</b>
13.1	Formal definition . . . . .	31
13.1.1	Definition . . . . .	31
13.1.2	Example . . . . .	32
13.2	Probability that a random set is autocatalytic . . . . .	32
13.3	Formal limitations . . . . .	32
13.4	Linguistic aspects . . . . .	32
13.5	Non-autonomous autocatalytic sets . . . . .	32
13.6	References . . . . .	33
13.7	See also . . . . .	33
<b>14</b>	<b>Avida</b>	<b>34</b>
14.1	Design principles . . . . .	34
14.2	Use in research . . . . .	34
14.3	See also . . . . .	34
14.4	References . . . . .	34

14.5 External links . . . . .	35
14.5.1 Scientific publications featuring Avida . . . . .	35
<b>15 Boids</b> . . . . .	<b>36</b>
15.1 See also . . . . .	36
15.2 References . . . . .	36
15.3 External links . . . . .	37
<b>16 Byl's loop</b> . . . . .	<b>38</b>
16.1 Details . . . . .	38
16.2 See also . . . . .	38
16.3 References . . . . .	38
16.4 Further reading . . . . .	38
16.5 External links . . . . .	39
<b>17 Clanking replicator</b> . . . . .	<b>40</b>
17.1 Basic concept . . . . .	40
17.2 History of the concept . . . . .	40
17.2.1 Advanced Automation for Space Missions . . . . .	41
17.2.2 Other references . . . . .	41
17.3 Prospects for implementation . . . . .	42
17.4 Etymology . . . . .	42
17.5 In fiction . . . . .	42
17.5.1 Replicators as weapons . . . . .	42
17.6 See also . . . . .	43
17.7 References . . . . .	43
<b>18 Codd's cellular automaton</b> . . . . .	<b>44</b>
18.1 History . . . . .	44
18.1.1 Comparison of CA rulesets . . . . .	44
18.2 Specification . . . . .	44
18.3 Universal computer-constructor . . . . .	45
18.4 See also . . . . .	45
18.5 References . . . . .	45
18.6 External links . . . . .	45
<b>19 Code of the Lifemaker</b> . . . . .	<b>46</b>
19.1 Plot summary . . . . .	46
19.2 References . . . . .	46
<b>20 Creatures (video game series)</b> . . . . .	<b>47</b>



20.1 Overview . . . . .	47
20.2 History . . . . .	48
20.3 Gameplay . . . . .	49
20.3.1 Species . . . . .	49
20.3.2 User Interface . . . . .	51
20.3.3 Environment . . . . .	51
20.4 Games in the series . . . . .	51
20.4.1 <i>On Albia</i> (later re-released as <i>Creatures: The Albion Years</i> ) . . . . .	51
20.4.2 <i>After Leaving Albia</i> (later re-released as <i>Creatures Exodus</i> ) . . . . .	52
20.4.3 <i>Creatures Online</i> . . . . .	52
20.4.4 <i>Younger Children's Games</i> (later re-released as <i>Creatures Village</i> ) . . . . .	53
20.4.5 Console games . . . . .	53
20.5 Later bundled releases . . . . .	53
20.6 Reception . . . . .	54
20.7 References . . . . .	54
20.8 Further reading . . . . .	58
20.9 External links . . . . .	58
<b>21 Creatures 2</b>	<b>59</b>
21.1 Gameplay . . . . .	59
21.2 Development . . . . .	59
21.3 See also . . . . .	60
21.4 External links . . . . .	60
<b>22 Creatures 3</b>	<b>61</b>
22.1 See also . . . . .	61
22.2 External links . . . . .	61
<b>23 Critterding</b>	<b>62</b>
23.1 Simulation . . . . .	62
23.2 Vision . . . . .	62
23.3 Environment . . . . .	62
23.4 External links . . . . .	62
<b>24 Darwin among the Machines</b>	<b>63</b>
24.1 <i>Book of the Machines</i> . . . . .	63
24.2 <i>Evolution of Global Intelligence</i> . . . . .	65
24.3 See also . . . . .	65
24.4 Notes . . . . .	66
24.5 References . . . . .	66

24.6 External links . . . . .	66
<b>25 DigiHive</b>	<b>67</b>
25.1 See also . . . . .	67
25.2 References . . . . .	67
25.3 External links . . . . .	67
<b>26 Digital organism</b>	<b>68</b>
26.1 History . . . . .	68
26.2 See also . . . . .	68
26.2.1 Related topics and overviews . . . . .	68
26.2.2 Specific programs . . . . .	68
26.3 References . . . . .	69
26.4 Further reading . . . . .	69
<b>27 Evolve 4.0</b>	<b>70</b>
27.1 External links . . . . .	70
<b>28 Evolving digital ecological networks</b>	<b>71</b>
28.1 Overview . . . . .	71
28.2 History . . . . .	72
28.2.1 Coreworld . . . . .	72
28.2.2 Tierra . . . . .	72
28.2.3 Avida . . . . .	72
28.3 Implementation . . . . .	73
28.3.1 Digital organisms . . . . .	73
28.3.2 Digital interactions . . . . .	73
28.4 Research directions . . . . .	75
28.5 References . . . . .	76
<b>29 Flocking (behavior)</b>	<b>78</b>
29.1 Flocking rules . . . . .	78
29.2 Measurement . . . . .	79
29.3 Algorithmic complexity . . . . .	79
29.4 Applications . . . . .	79
29.5 See also . . . . .	80
29.6 References . . . . .	80
29.7 Other sources . . . . .	81
29.8 External links . . . . .	81
<b>30 Framsticks</b>	<b>82</b>

30.1 Bodies . . . . .	82
30.2 Brains . . . . .	82
30.3 World . . . . .	82
30.4 See also . . . . .	82
30.5 External links . . . . .	82
<b>31 Grey goo</b>	<b>83</b>
31.1 Definition . . . . .	83
31.2 Risks and precautions . . . . .	84
31.3 Ethics and chaos . . . . .	84
31.4 In popular culture . . . . .	84
31.5 See also . . . . .	85
31.6 References . . . . .	85
31.7 Further reading . . . . .	85
31.8 External links . . . . .	85
<b>32 History of artificial life</b>	<b>87</b>
32.1 Pre-computer . . . . .	87
32.2 1950s–1970s . . . . .	87
32.3 1970s–1980s . . . . .	88
32.4 2000s . . . . .	89
32.5 See also . . . . .	89
32.6 References . . . . .	89
32.7 External links . . . . .	89
<b>33 Langton's ant</b>	<b>90</b>
33.1 Rules . . . . .	90
33.2 Modes of behavior . . . . .	90
33.3 Universality . . . . .	91
33.4 Extension to multiple colors . . . . .	91
33.5 Extension to multiple states . . . . .	91
33.6 Extension to multiple ants . . . . .	91
33.7 See also . . . . .	92
33.8 References . . . . .	92
33.9 External links . . . . .	92
<b>34 Langton's loops</b>	<b>93</b>
34.1 History . . . . .	93
34.2 Specification . . . . .	93
34.2.1 Colonies . . . . .	93

34.2.2	Encoding of the genome . . . . .	94
34.3	Comparison of related CA loops . . . . .	94
34.4	References . . . . .	94
34.5	See also . . . . .	94
34.6	External links . . . . .	95
<b>35</b>	<b>MASON (Java)</b>	<b>96</b>
35.1	Development . . . . .	96
35.2	Applets . . . . .	96
35.3	See also . . . . .	96
35.4	References . . . . .	96
35.5	External links . . . . .	96
<b>36</b>	<b>Mycoplasma laboratorium</b>	<b>97</b>
36.1	<i>Mycoplasma</i> . . . . .	97
36.2	Other genera . . . . .	97
36.3	Minimal genome project . . . . .	98
36.4	Bacterial genome transplantation . . . . .	99
36.5	Bacterial chromosome synthesis . . . . .	99
36.6	Synthetic genome . . . . .	99
36.6.1	Watermarks . . . . .	100
36.7	Concerns and controversy . . . . .	100
36.7.1	Press coverage . . . . .	100
36.7.2	Utility . . . . .	100
36.7.3	Intellectual property . . . . .	101
36.8	JCVI-syn3.0 . . . . .	101
36.9	Similar projects . . . . .	101
36.10	References . . . . .	101
36.10.1	Primary sources . . . . .	101
36.10.2	Popular press . . . . .	102
36.11	External links . . . . .	103
<b>37</b>	<b>Noble Ape</b>	<b>104</b>
37.1	The Simulation . . . . .	104
37.2	Technology . . . . .	104
37.3	References . . . . .	104
37.4	External links . . . . .	104
37.4.1	Official Links . . . . .	104
37.4.2	Additional Links . . . . .	105



<b>38 Pacrat</b>	<b>106</b>
38.1 See also	106
38.2 References	106
<b>39 Polyworld</b>	<b>107</b>
39.1 External links	107
<b>40 Santa Claus machine</b>	<b>108</b>
40.1 Origin	108
40.2 Discussion	108
40.3 See also	108
40.4 References	109
40.5 External links	109
<b>41 Self-replicating machine</b>	<b>110</b>
41.1 History	110
41.1.1 von Neumann's kinematic model	111
41.1.2 Moore's artificial living plants	111
41.1.3 Dyson's replicating systems	111
41.1.4 <i>Advanced Automation for Space Missions</i>	111
41.1.5 Lackner-Wendt Auxon replicators	112
41.2 Recent work	112
41.2.1 Self-replicating rapid prototypers	112
41.2.2 NIAC studies on self-replicating systems	113
41.2.3 Cornell University's self-assembler	113
41.2.4 New York University artificial DNA tile motifs	113
41.2.5 Self-replication of magnetic polymers	113
41.2.6 Self-replication of neural circuits	113
41.3 Partial construction	114
41.4 Self-replicating spacecraft	114
41.5 Other references	114
41.6 In fiction	114
41.6.1 In literature	114
41.6.2 In film	114
41.6.3 On television	115
41.6.4 In video games	116
41.6.5 Other	117
41.7 Prospects for implementation	117
41.8 See also	117

41.9	References	117
41.10	Bibliography	120
41.11	External links	120
<b>42</b>	<b>Self-replicating spacecraft</b>	<b>121</b>
42.1	Theory	121
42.2	Implications for Fermi's paradox	121
42.3	Applications for self-replicating spacecraft	122
42.3.1	Von Neumann probes	122
42.3.2	Berserkers	122
42.3.3	Replicating seeder ships	122
42.4	In fiction	123
42.4.1	Von Neumann probes	123
42.4.2	Berserkers	123
42.4.3	Replicating Seeder Ships	126
42.5	See also	127
42.6	References	127
<b>43</b>	<b>Self-replication</b>	<b>128</b>
43.1	Overview	128
43.1.1	Theory	128
43.1.2	Classes of self-replication	128
43.1.3	A self-reproducing computer program	129
43.1.4	Self-replicating tiling	129
43.1.5	Applications	129
43.2	Mechanical self-replication	130
43.3	Fields involving study of self-replication	130
43.4	Self-replication in industry	130
43.4.1	Space exploration and manufacturing	130
43.4.2	Molecular manufacturing	131
43.5	See also	131
43.6	References	131
<b>44</b>	<b>Sugarscape</b>	<b>133</b>
44.1	Origin	133
44.2	Principles	133
44.3	Model implementations	133
44.3.1	Ascape	133
44.3.2	NetLogo	133

44.3.3	SugarScape on steroids . . . . .	134
44.3.4	Mathematica . . . . .	134
44.3.5	MASON . . . . .	134
44.4	References . . . . .	134
44.5	External links . . . . .	134
<b>45</b>	<b>Synthetic mycoides</b>	<b>135</b>
45.1	References . . . . .	135
<b>46</b>	<b>Synthetic Organism Designer</b>	<b>136</b>
46.1	References . . . . .	136
<b>47</b>	<b>Tierra (computer simulation)</b>	<b>137</b>
47.1	Simulations . . . . .	137
47.2	See also . . . . .	137
47.3	References . . . . .	138
47.4	Additional reading . . . . .	138
47.5	External links . . . . .	138
<b>48</b>	<b>Turmite</b>	<b>139</b>
48.1	History . . . . .	139
48.2	Relative vs. absolute turmites . . . . .	139
48.3	Specification . . . . .	140
48.4	Examples . . . . .	140
48.5	Turmites and the Busy Beaver game . . . . .	140
48.6	Other grids . . . . .	140
48.7	See also . . . . .	140
48.8	References . . . . .	140
48.9	External links . . . . .	141
<b>49</b>	<b>Von Neumann universal constructor</b>	<b>142</b>
49.1	Purpose . . . . .	142
49.2	Implementation . . . . .	143
49.2.1	Comparison of implementations . . . . .	143
49.3	Practicality . . . . .	143
49.3.1	Computational cost . . . . .	144
49.3.2	Evolvability . . . . .	144
49.4	Animation gallery . . . . .	144
49.5	See also . . . . .	144
49.6	References . . . . .	144

49.7 External links . . . . .	145
<b>50 Weasel program</b>	<b>146</b>
50.1 Overview . . . . .	146
50.2 Implications for biology . . . . .	147
50.3 More complex models . . . . .	148
50.4 Example algorithm . . . . .	148
50.5 See also . . . . .	149
50.6 References . . . . .	149
50.7 External links . . . . .	149
50.8 Text and image sources, contributors, and licenses . . . . .	150
50.8.1 Text . . . . .	150
50.8.2 Images . . . . .	155
50.8.3 Content license . . . . .	158