

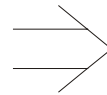
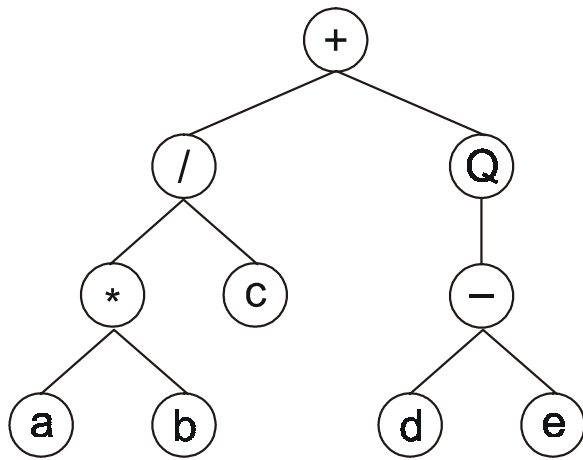
# **GENE EXPRESSION PROGRAMMING IN PROBLEM SOLVING**

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<http://www.gene-expression-programming.com>

# REPRESENTATION

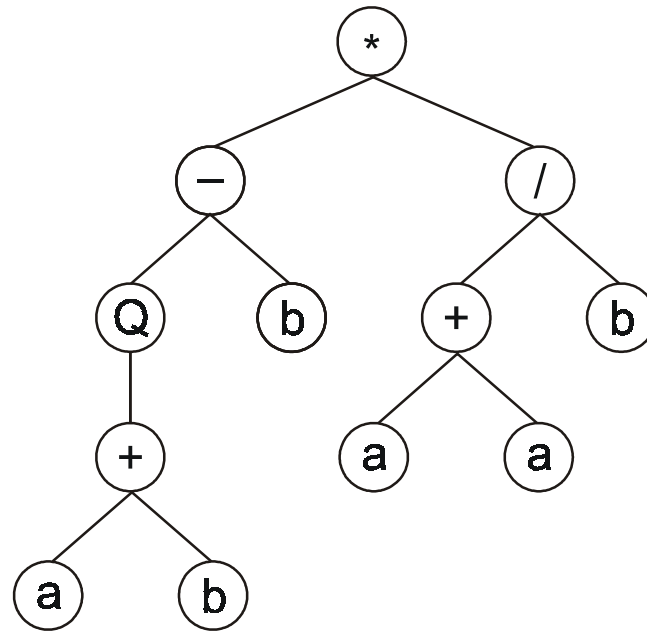
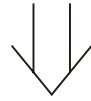
$$\frac{a \cdot b}{c} + \sqrt{d - e}$$



0123456789  
+ / Q \* c - a b d e

# K-EXPRESSIONS OR ORFs

012345678901  
\* - / Q b + b + a a a b

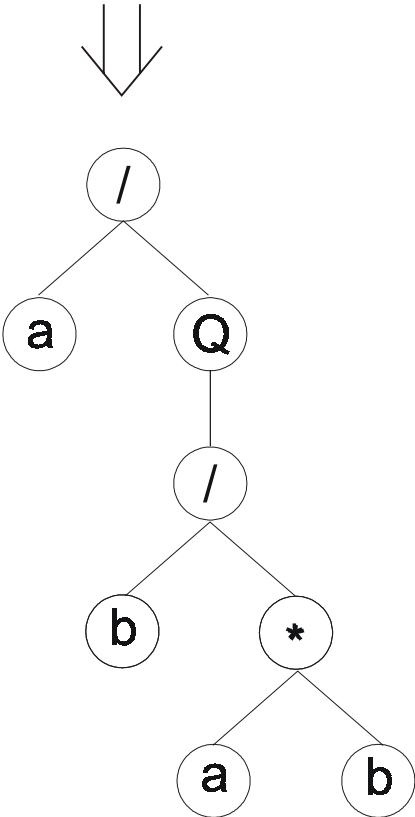


# GEP GENES

012345678901234**5678901234567890**  
/aQ/b\*ab/Qa\*b\***-ababaababbabbba**

head

tail



$$t = h(n-1) + 1$$

*h* - head

*t* - tail

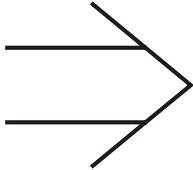
*n* - max arity

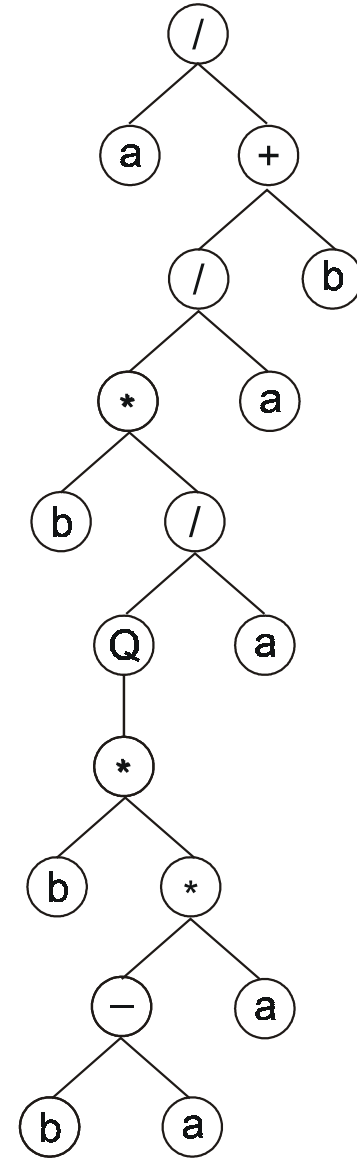
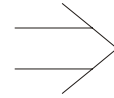
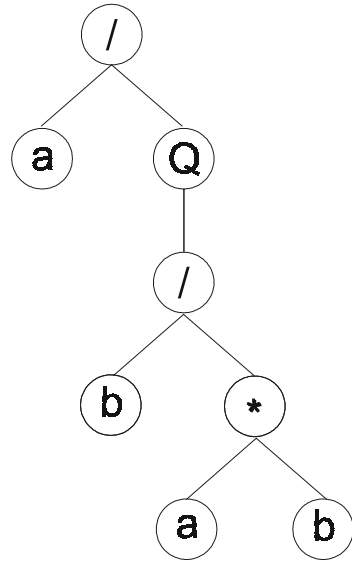
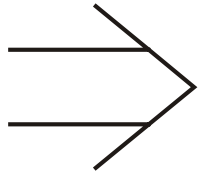
# PLASTICITY OF GEP GENES

0123456789012345678901234567890  
/aQ/b\*ab/Qa\*b\*-ababaababbabbba



0123456789012345678901234567890  
/a+/b\*ab/Qa\*b\*-abaabaababbabbba



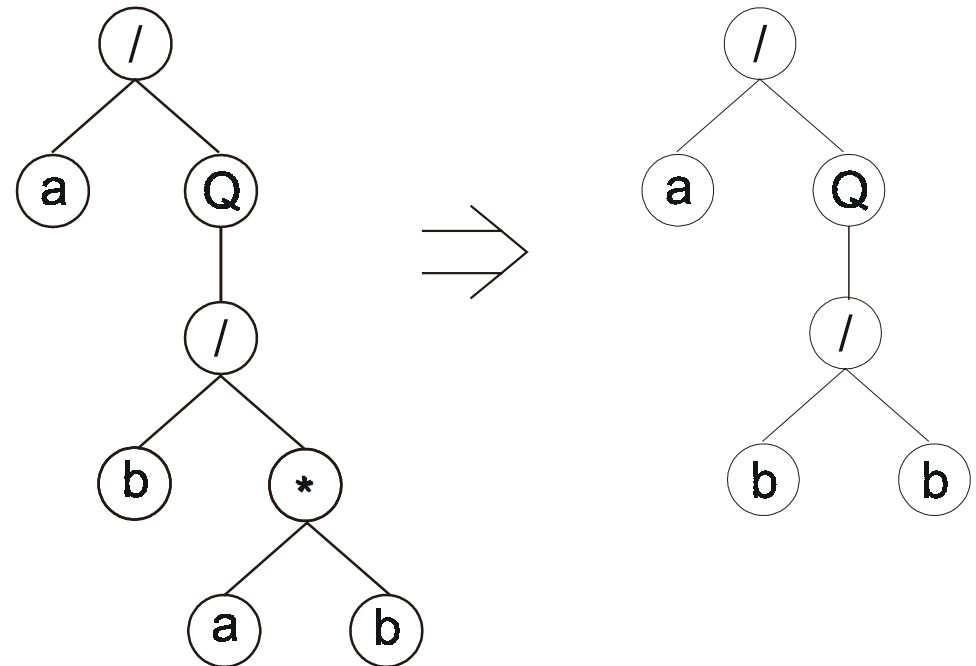
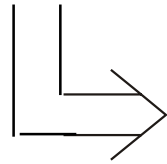


# PLASTICITY OF GEP GENES

0123456789012345678901234567890  
/aQ/b\*ab/Qa\*b\*-ababaababbabbba



0123456789012345678901234567890  
/aQ/bbab/Qa\*b\*-ababaababbabbba

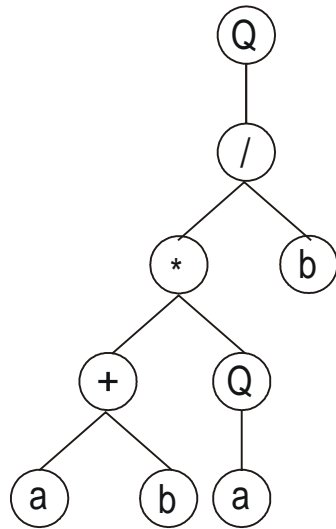


# TRANSLATION

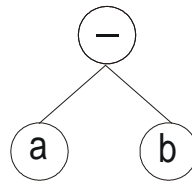
012345678901234012345678901234012345678901234  
Q/\*b+Qababaabaa-abQ/\*+bababbab\*\*-\*bb/babaaaab



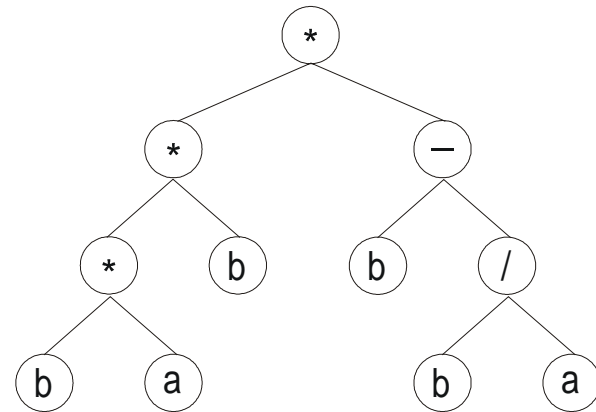
Sub-ET<sub>1</sub>



Sub-ET<sub>2</sub>



Sub-ET<sub>3</sub>

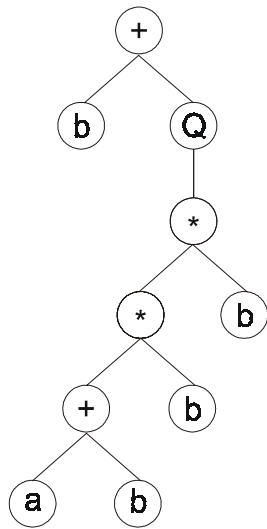


# EXPRESSION OF ALGEBRAIC MULTIGENIC CHROMOSOMES

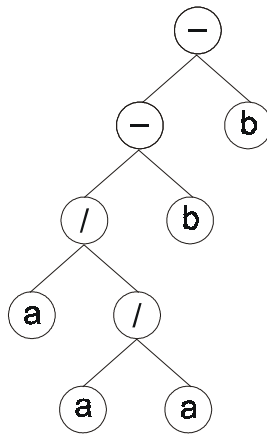
012345678901234012345678901234012345678901234

+bQ\*\*b+bababbbb-b/ba/aaababab\*Q\*a\*-/abaaaaab

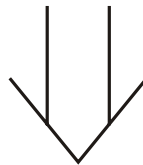
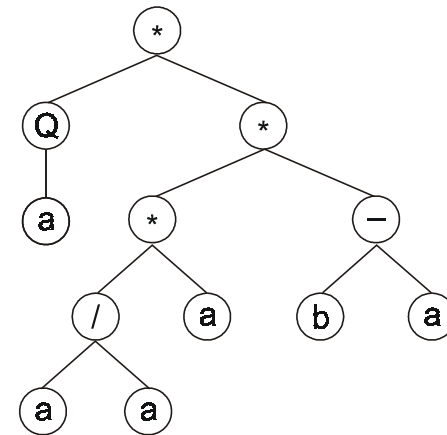
⇓  
Sub-ET<sub>1</sub>

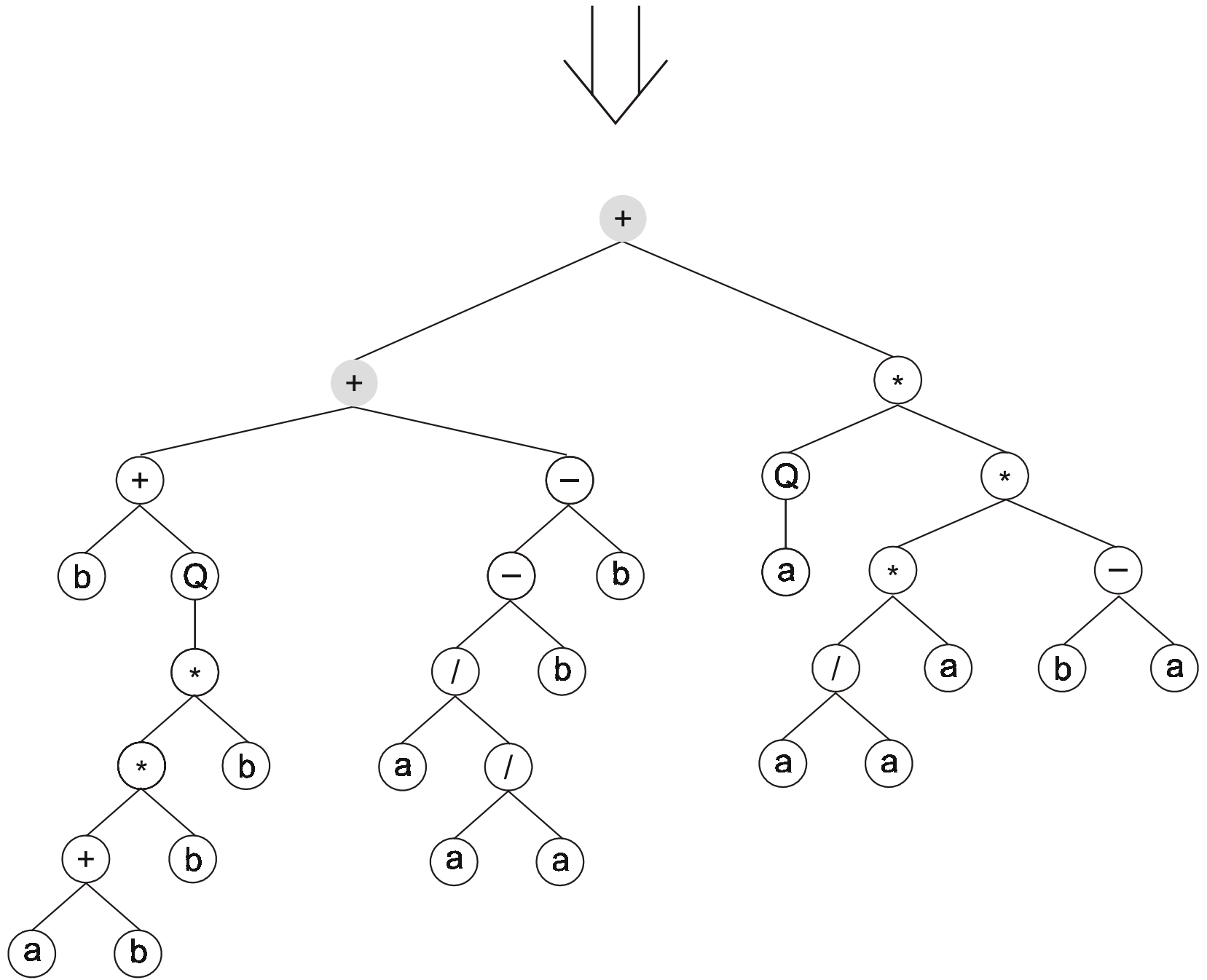


⇓  
Sub-ET<sub>2</sub>



⇓  
Sub-ET<sub>3</sub>



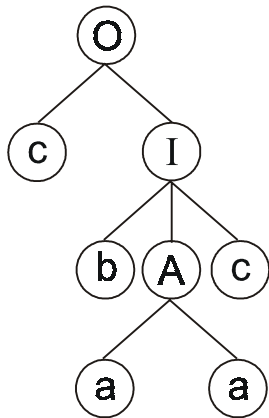


# EXPRESSION OF BOOLEAN MULTIGENIC CHROMOSOMES

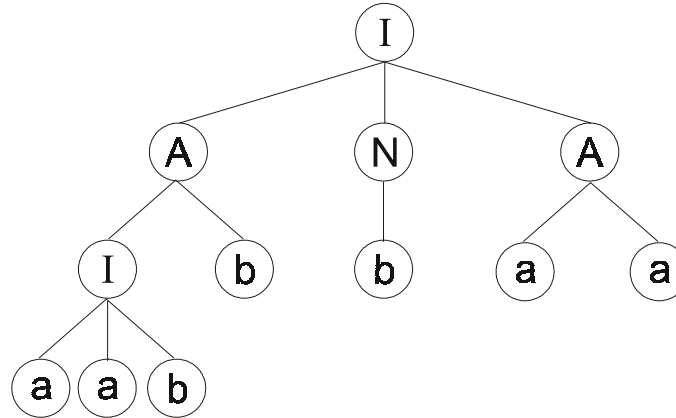
012345678901234501234567890123450123450123456789012345  
OcIbAcaabc**bc**caaaIANAI**bb**aaaabaaab**Acb**cIcaaaacaccaa



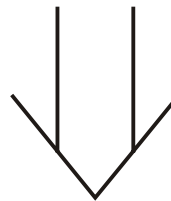
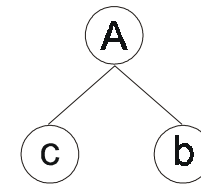
Sub-ET<sub>1</sub>

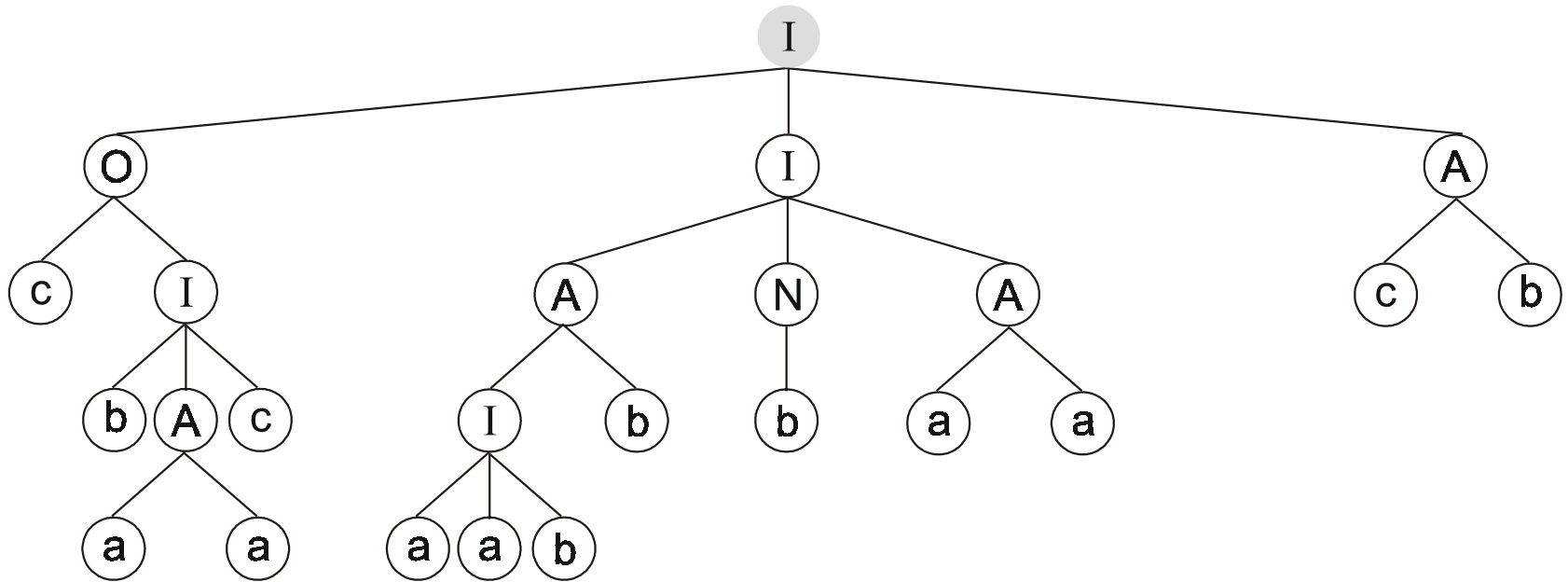
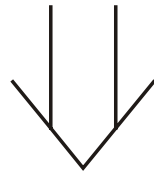


Sub-ET<sub>2</sub>



Sub-ET<sub>3</sub>





# SELECTION AND REPLICATION

Generation N: 0

\*+-/a\*aaaaaaa//+\*aaaaaaa-[0] = 10.64033  
-/a//aaaaaaa+\*+a/+aaaaaaa-[1] = 16.2117  
\*+a-+aaaaaaa---///aaaaaaa-[2] = 13.81953  
+a\*/-aaaaaaa\*\*+a\*aaaaaaa-[3] = 18.32701  
\*-+a/-aaaaaaa/aa+a/aaaaaaa-[4] = 11.13926  
+\*/a/aaaaaaa---aa-aaaaaaa-[5] = 13.88255  
\*-\*-\*aaaaaaa/-a///aaaaaaa-[6] = 7.777691  
/++a-\*aaaaaaa/+a\*+-aaaaaaa-[7] = 13.14786  
//+\*aaaaaaa\*+/---aaaaaaa-[8] = 7.713599  
-\*\*+-/aaaaaaa\*//aa/aaaaaaa-[9] = 8.73985

Generation N: 1

\*+a-+aaaaaaa---///aaaaaaa-[0] = 13.81953  
-/a//aaaaaaa+\*+a/+aaaaaaa-[1] = 16.2117  
\*-+a/-aaaaaaa/aa+a/aaaaaaa-[2] = 11.13926  
+\*/a/aaaaaaa---aa-aaaaaaa-[3] = 13.88255  
+a\*/-aaaaaaa\*\*+a\*aaaaaaa-[4] = 18.32701  
-\*\*+-/aaaaaaa\*//aa/aaaaaaa-[5] = 8.73985  
-\*\*+-/aaaaaaa\*//aa/aaaaaaa-[6] = 8.73985  
//+\*aaaaaaa\*+/---aaaaaaa-[7] = 7.713599  
/++a-\*aaaaaaa/+a\*+-aaaaaaa-[8] = 13.14786  
-/a//aaaaaaa+\*+a/+aaaaaaa-[9] = 16.2117

# GENETIC DRIFT

(...)

Generation N: 8

/-/a//aaaaaaaa+\*+a/+aaaaaaaa-[0] = 16.2117

/-/a//aaaaaaaa+\*+a/+aaaaaaaa-[1] = 16.2117

/-/a//aaaaaaaa+\*+a/+aaaaaaaa-[2] = 16.2117

/-/a//aaaaaaaa+\*+a/+aaaaaaaa-[3] = 16.2117

/-/a//aaaaaaaa+\*+a/+aaaaaaaa-[4] = 16.2117

/-/a//aaaaaaaa+\*+a/+aaaaaaaa-[5] = 16.2117

/-/a//aaaaaaaa+\*+a/+aaaaaaaa-[6] = 16.2117

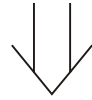
/-/a//aaaaaaaa+\*+a/+aaaaaaaa-[7] = 16.2117

/-/a//aaaaaaaa+\*+a/+aaaaaaaa-[8] = 16.2117

/-/a//aaaaaaaa+\*+a/+aaaaaaaa-[9] = 16.2117

# MUTATION

012345678900123456789001234567890  
Q+bb\*bbbaba-\*\*-abbbaaQ\*a\*Qbbbaab



012345678900123456789001234567890  
Q+bb/bbbbabaQ\*\*-abbbaaQ+\*Qbbbaab

# IS TRANSPOSITION

0123456789012345601234567890123456  
-ab**a+Q**-baabaabaabQ\*+\*+ - / aababbbaaaa



0123456789012345601234567890123456  
-ab**a+Q**-baabaabaabQ\*+**a+Q**\*+aababbbaaaa

# RIS TRANSPOSITION

0123456789012345601234567890123456  
\*-bQ/++/babbbabba//Q\*baa+bbbabbbb



0123456789012345601234567890123456  
Q/+\*-bQ/babbbabba//Q\*baa+bbbabbbb

# GENE TRANSPOSITION

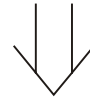
012345678901201234567890120123456789012  
/+Qa\*bbaaabaa\*a\*/Qbbbbabb/**Q-aabbaaabb**



012345678901201234567890120123456789012  
**/Q-aabbaaabb**/+Qa\*bbaaabaa\*a\*/Qbbbbabb

# 1-POINT RECOMBINATION

0123456789012345601234567890123456  
+\* -b-Qa\*aabbbbbaaa-Q-//b/\*aababbab  
**++//b//-bbbbbbbbbb-\* -ab/b+bbbaabbaa**



0123456789012345601234567890123456  
+\* -b-Q/ -bbbbbbbbbb-\* -ab/b+bbbaabbaa  
**++//b/a\*aabbbbbaaa-Q-//b/\*aababbab**

# 2-POINT RECOMBINATION

0123456789012345601234567890123456  
\* - + Q / Q \* Q a a b b b b a b Q Q a b \* + + - a a b b a b a a b  
**Q / - b - + / a b a a b b b a a b / \* - a Q a \* b a b b a b b a b b**



0123456789012345601234567890123456  
\* - + Q / + / **a b a a b b b a a b / \* - a Q a \*** - a a b b a b a a b  
**Q / - b - Q \* Q a a b b b b a b Q Q a b \* + + b a b b a b b a b b**

# GENE RECOMBINATION

012345678901201234567890120123456789012  
/+/ab-aabbbb-aa\*\*+aaabaaa-+--babbbbaab  
**+baQaaaabaaba\* -+a-aabbabb/ab/+bbbabaaa**



012345678901201234567890120123456789012  
/+/ab-aabbbb\***-+a-aabbabb**-+--babbbbaab  
**+baQaaaabaaba**-aa\*\*+aaabaaa/ab/+bbbabaaa

# SOLVING A SIMPLE PROBLEM

TEST FUNCTION:

$$y = 3a^2 + 2a + 1$$

FITNESS CASES

a	f(a)
-4.2605	46.9346
-2.0437	9.44273
-9.8317	271.324
2.7429	29.0563
0.7328	4.07659
-8.6491	208.123
-3.6101	32.8783
-1.8999	8.02906
-4.8852	62.8251
7.3998	180.071

# SETTINGS

FITNESS FUNCTION:

$$f_i = \sum_{j=1}^{C_t} \left( M - |C_{(i,j)} - T_j| \right)$$

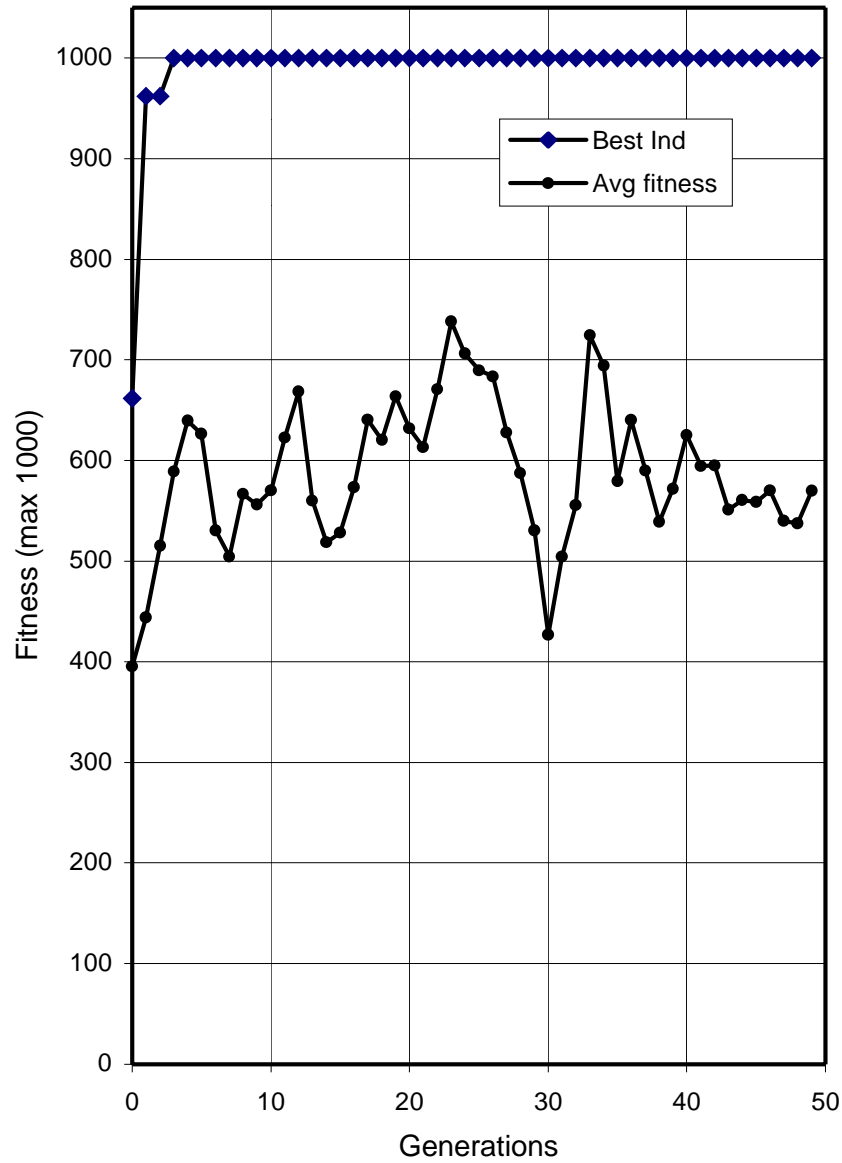
GENERAL SETTINGS

---

Number of generations	50
Population size	20
Number of fitness cases	10 (Table 1)
Function set	+ - * /
Gene length	13
Number of genes	3
Linking function	+
Chromosome length	39
Mutation rate	0.051
1-Point recombination rate	0.3
2-Point recombination rate	0.3
Gene recombination rate	0.1
IS transposition rate	0,1
IS elements length	1,2,3
RIS transposition rate	0.1
RIS elements length	1,2,3
Gene transposition rate	0.1
Selection range	100
Precision	0.01

---

# EVOLUTIONARY DYNAMICS



# INITIAL POPULATION

Generation N: 0

012345678901201234567890120123456789012  
+\*\*/\* / aaaaaaaaa / +a / a \* aaaaaaaaa / a - \* a + aaaaaaaaa - [ 0 ] = 577.3946  
--aa++aaaaaaaa+- / a \* / aaaaaaaaa / --a - aaaaaaaaa - [ 1 ] = 0  
/ \*\*\* / + aaaaaaaaa \* + / + - aaaaaaaaa + + aa / aaaaaaaaa - [ 2 ] = 463.6533  
- / + / + + aaaaaaaaa + - / / + / aaaaaaaaa + - / a / \* aaaaaaaaa - [ 3 ] = 546.4241  
++a / \* aaaaaaaaa + - + a \* - aaaaaaaaa - a / - \* aaaaaaaaa - [ 4 ] = 460.8625  
\* + \* a - \* aaaaaaaaa \* a / aa / aaaaaaaaa / + \* a / aaaaaaaaa - [ 5 ] = 353.2168  
\* / \* \* + aaaaaaaaa + a / \* \* + aaaaaaaaa - - - - + / aaaaaaaaa - [ 6 ] = 492.6827  
\* aa - + - aaaaaaaaa + a / - + / aaaaaaaaa \* \* \* / - \* aaaaaaaaa - [ 7 ] = 560.9289  
+ / - \* / / aaaaaaaaa \* + \* / / + aaaaaaaaa - / \* \* + \* aaaaaaaaa - [ 8 ] = 363.4358  
--a + \* / aaaaaaaaa + a + + - - aaaaaaaaa + a + aa + aaaaaaaaa - [ 9 ] = 386.7576  
+ - \* - \* \* aaaaaaaaa \* / - + \* \* aaaaaaaaa \* + - - + + aaaaaaaaa - [ 10 ] = 380.6484  
/ a - \* \* / aaaaaaaaa / - a / a / aaaaaaaaa + / a / - \* aaaaaaaaa - [ 11 ] = 0  
+ - - + / / aaaaaaaaa + \* + / \* - aaaaaaaaa / \* - a - + aaaaaaaaa - [ 12 ] = 551.2066  
- a / + a / aaaaaaaaa \* / - - / aaaaaaaaa \* - + / a + aaaaaaaaa - [ 13 ] = 308.1296  
/ + / - + - aaaaaaaaa + - a / aaaaaaaaa \* \* + - \* - aaaaaaaaa - [ 14 ] = 0  
/ / - \* + / aaaaaaaaa / / \* a + aaaaaaaaa / a + + a \* aaaaaaaaa - [ 15 ] = 489.5392  
\* a - a \* - aaaaaaaaa + \* + - a / aaaaaaaaa \* / \* aa \* aaaaaaaaa - [ 16 ] = 399.2122  
- a + + \* / aaaaaaaaa + / aa - \* aaaaaaaaa - - - / \* \* aaaaaaaaa - [ 17 ] = 317.6631  
--a / \* aaaaaaaaa + + \* + - aaaaaaaaa + - / \* + - aaaaaaaaa - [ 18 ] = 597.8777  
**\* + + + - / aaaaaaaaa / - - / / aaaaaaaaa + - + aaaaaaaaa - [ 19 ] = 661.5933**

# BEST OF GENERATION 0

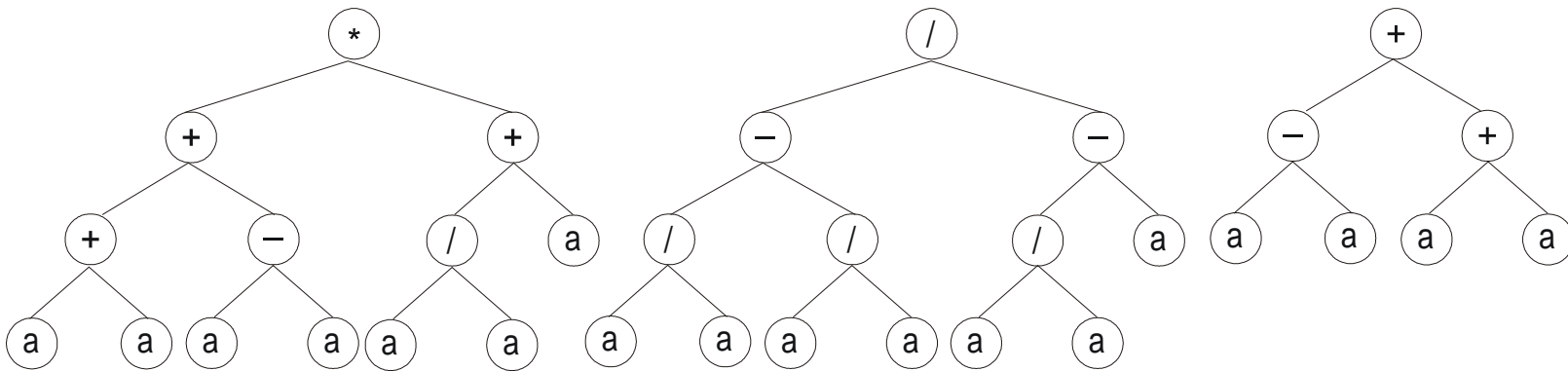
012345678901201234567890120123456789012  
 \*+++ - / aaaaaa / - - / / / aaaaaa + - + aaaaaaaaaa



Sub-ET<sub>1</sub>

Sub-ET<sub>2</sub>

Sub-ET<sub>3</sub>



$$y = (2a^2 + 2a) + (0) + (2a)$$

# GENERATION 1

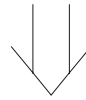
Generation N: 1

012345678901201234567890120123456789012

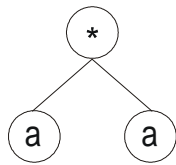
\*+++-/aaaaaaaa/--///aaaaaaaa+--+aaaaaaaa-[ 0 ] = 661.5933  
-a++\*/aaaaaaaa+//a--aaaaaaaa---/\*\*aaaaaaaa-[ 1 ] = 0  
+--\*\*\*/aaaaaaaa\*/-+\*\*\*/aaaaaaaa\*+--+aaaaaaaa-[ 2 ] = 380.6484  
+--\*\*\*/aaaaaaaa\*/-+\*\*\*/aaaaaaaa\*/a\*\*\*/aaaaaaaa-[ 3 ] = 356.9471  
+--+aaaaaaaa\*+++-/aaaaaaaa/--///aaaaaaaa-[ 4 ] = 661.5933  
\*aa-+-aaaaaaaa+a//+//aaaaaaaa\*\*\*+-\*aaaaaaaa-[ 5 ] = 567.9289  
\*a-a\*-aaaaaaaa+/\*-a/aaaaaaaa\*+-\*+aaaaaaaa-[ 6 ] = 449.802  
**\*aa-+-aaaaaaaa+a/-+/aaaaaaaa\*+--+aaaaaaaa-[ 7 ] = 961.8512**  
/\*\*\*/+aaaaaaaa\*+/+-aaaaaaaa-a/-\*aaaaaaaa-[ 8 ] = 470.5862  
+--+//aaaaaaaa+\*+/\*-aaaaaaaa/\*-a-+aaaaaaaa-[ 9 ] = 551.2066  
\*+++-/aaaaaaaa-//--/aaaaaaaa+--+aaaaaaaa-[10] = 0  
--+a\*-aaaaaaaa++a/\*aaaaaaaa-a/-\*aaaaaaaa-[11] = 487.3099  
-a++\*/aaaaaaaa+aa-\*aaaaaaaa---/\*\*aaaaaaaa-[12] = 317.6631  
++a/\*aaaaaaaa+--+a\*-aaaaaaaa+aa/aaaaaaaa-[13] = 451.464  
+--+/-aaaaaaaa+a/\*\*+aaaaaaaa-----+/aaaaaaaa-[14] = 493.5336  
\*/-a++aaaaaaaa+aa-\*aaaaaaaa---/\*\*aaaaaaaa-[15] = 356.4241  
+/-\*//aaaaaaaa\*a//+aaaaaaaa-/+\*\*+aaaaaaaa-[16] = 493.9218  
\*/\*\*+aaaaaaaa+\*+/\*aaaaaaaa\*\*\*/-\*aaaaaaaa-[17] = 448.4805  
+--\*\*\*/aaaaaaaa\*/-+\*\*\*/aaaaaaaa\*+--+aaaaaaaa-[18] = 380.6484  
++a/\*aaaaaaaa+--+a\*+aaaaaaaa--/-\*aaaaaaaa-[19] = 380.8585

# BEST OF GENERATION 1

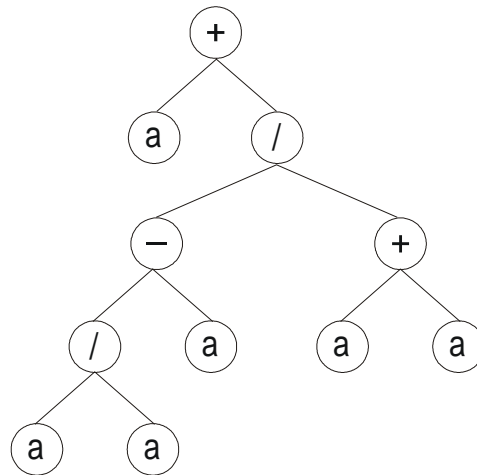
012345678901201234567890120123456789012  
 \*aa-+-aaaaaaaa+a/-+/aaaaaaaa\*+--++aaaaaaaa



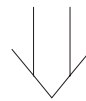
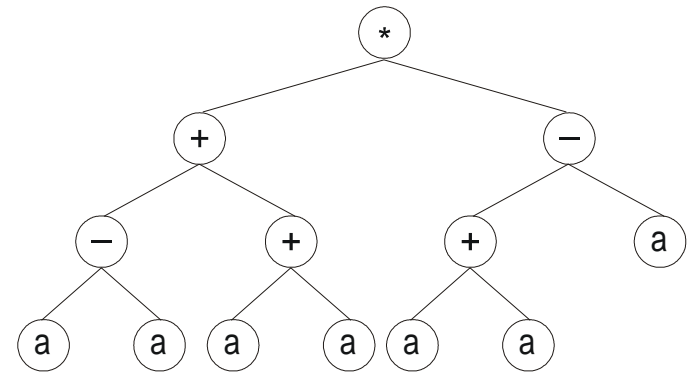
Sub-ET<sub>1</sub>



Sub-ET<sub>2</sub>



Sub-ET<sub>3</sub>



$$y = (a^2) + \left( a + \frac{1-a}{2a} \right) + (2a^2)$$



# GENERATION 3

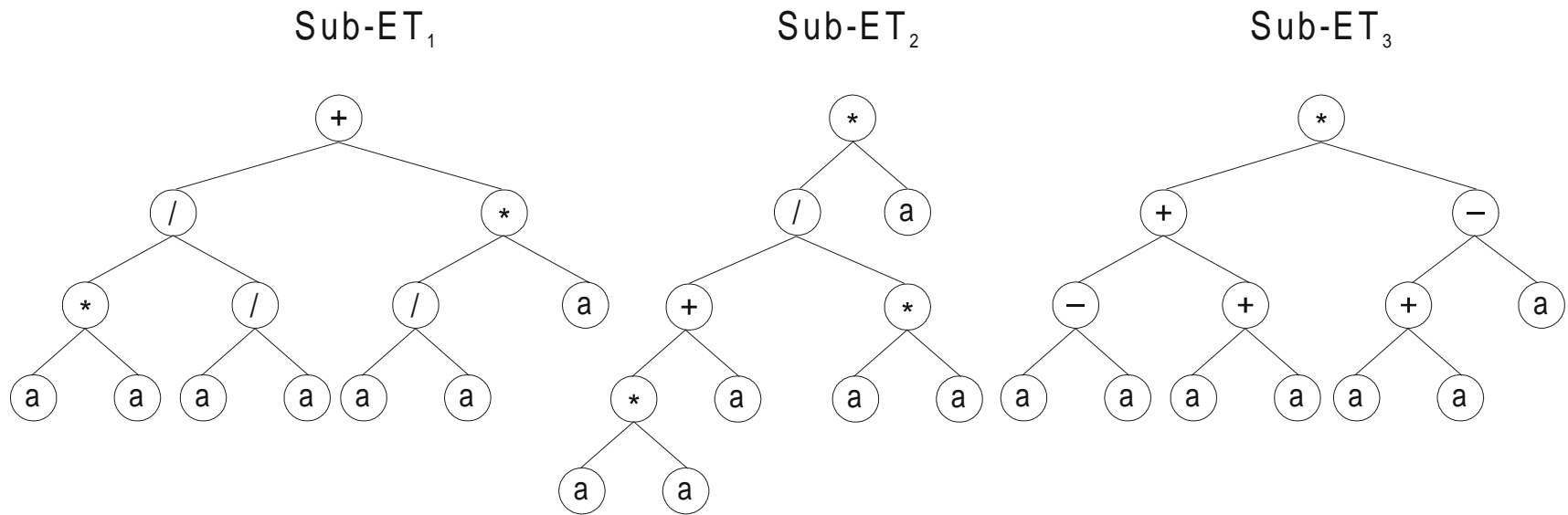
Generation N: 3

012345678901201234567890120123456789012

\*aa+\*/aaaaaaaa+a/-+/aaaaaaaa\*+--+aaaaaaaa-[ 0 ] = 961.8512  
\*aa-+-aaaaaaaa+a/-+/aaaaaaaa/--//aaaaaaaa-[ 1 ] = 560.9289  
\*aa-+-aaaaaaaa-++/+-aaaaaaaa-a/-\*aaaaaaaa-[ 2 ] = 558.2066  
\*+++/+aaaaaaaa\*a+/-+aaaaaaaa+--+aaaaaaaa-[ 3 ] = 569.0469  
/+++/+aaaaaaaa\*++/+-aaaaaaaa-a/-\*aaaaaaaa-[ 4 ] = 699.5153  
+-+aa/aaaaaaaa++++-/aaaaaaaa\*\*\*+\*aaaaaaaa-[ 5 ] = 466.1533  
\*aa-+-aaaaaaaa--\*aaaaaaaa\*+--+aaaaaaaa-[ 6 ] = 957.9443  
--++\*-aaaaaaaa\*a+/\*-aaaaaaaa+aa+aaaaaaaa-[ 7 ] = 337.7807  
\*aaa\*/aaaaaaaa+a-+/aaaaaaaa\*+/-+aaaaaaaa-[ 8 ] = 953.9443  
/\*\*\*/-aaaaaaaa\*+/-+aaaaaaaa-a--\*aaaaaaaa-[ 9 ] = 0  
\*aa-+-aaaaaaaa+a/-+/aaaaaaaa\*/--+aaaaaaaa-[10] = 560.9289  
\*aa-+-aaaaaaaa+a/+/aaaaaaaa/--//aaaaaaaa-[11] = 567.9289  
+-+a-aaaaaaaa/\*\*\*-/aaaaaaaa\*+--+aaaaaaaa-[12] = 676.0663  
**+/\*\*//aaaaaaaa\*/a+\*\*aaaaaaaa\*+--+aaaaaaaa-[13] = 1000**  
\*/-+\*\*aaaaaaaa+\*-+\*+aaaaaaaa\*/a\*\*aaaaaaaa-[14] = 672.877  
/\*\*\*/+aaaaaaaa/+\*+/-+aaaaaaaa-a\*/--aaaaaaaa-[15] = 498.3734  
+/-\*///aaaaaaaa\*/a+\*+\*aaaaaaaa\*+--+aaaaaaaa-[16] = 0  
--\*+--aaaaaaaa\*/a-+-aaaaaaaa/a/-+/aaaaaaaa-[17] = 506.1233  
++a/\*aaaaaaaa+-a-+-aaaaaaaa-a\*-+/aaaaaaaa-[18] = 815.7772  
\*+a//-aaaaaaaa+a/-+/aaaaaaaa-/+\*+\*aaaaaaaa-[19] = 412.5237

# PERFECT SOLUTION

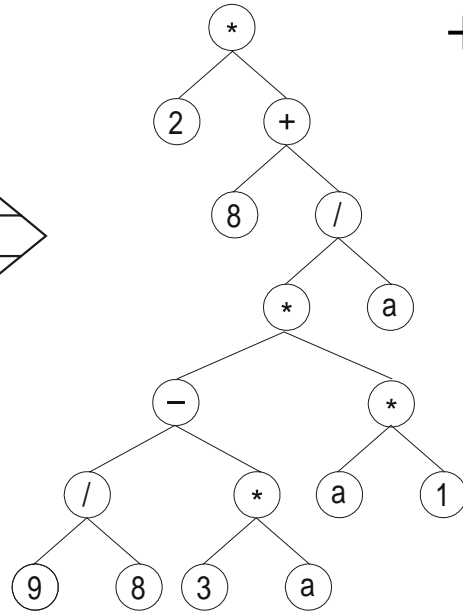
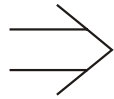
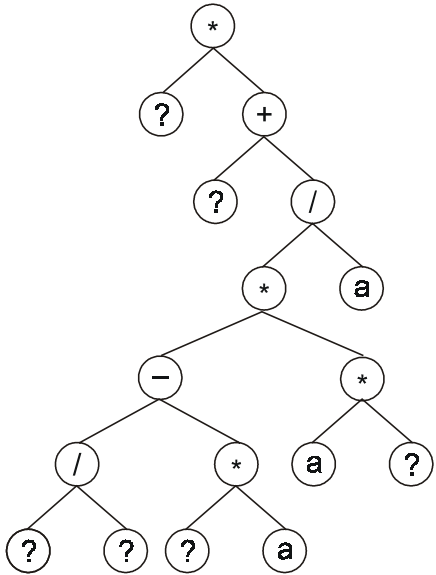
012345678901201234567890120123456789012  
 + / \* \* / / a a a a a a \* / a + \* \* a a a a a a \* + - - + + a a a a a a



$$y = (a^2 + a) + (a + 1) + (2a^2) = 3a^2 + 2a + 1$$

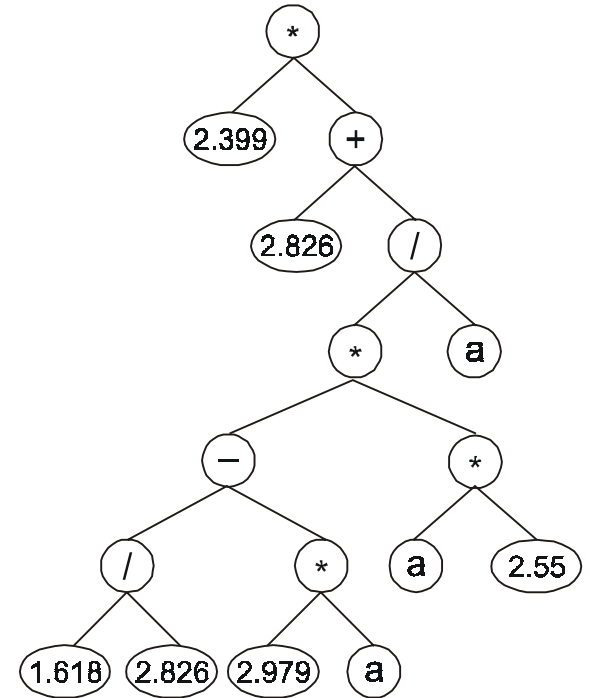
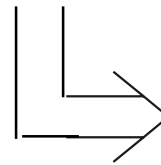
# USING NUMERICAL CONSTANTS

01234567890123456789012345678901234  
 \*?+?/\*a-\*/a????a??a??a**281983874486**



+

- [0] = -2.829
- [1] = 2.55
- [2] = 2.399
- [3] = 2.979
- [4] = 2.442
- [5] = 0.662
- [6] = 1.797
- [7] = -1.272
- [8] = 2.826
- [9] = 1.618



# FINDING THE 'V' SHAPED FUNCTION

TEST FUNCTION:

$$y = 4.251a^2 + \ln(a^2) + 7.243e^a$$

FITNESS FUNCTION:

$$f_i = \sum_{j=1}^{C_i} \left( M - \left| \frac{C_{(i,j)} - T_j}{T_j} \cdot 100 \right| \right)$$

FITNESS CASES

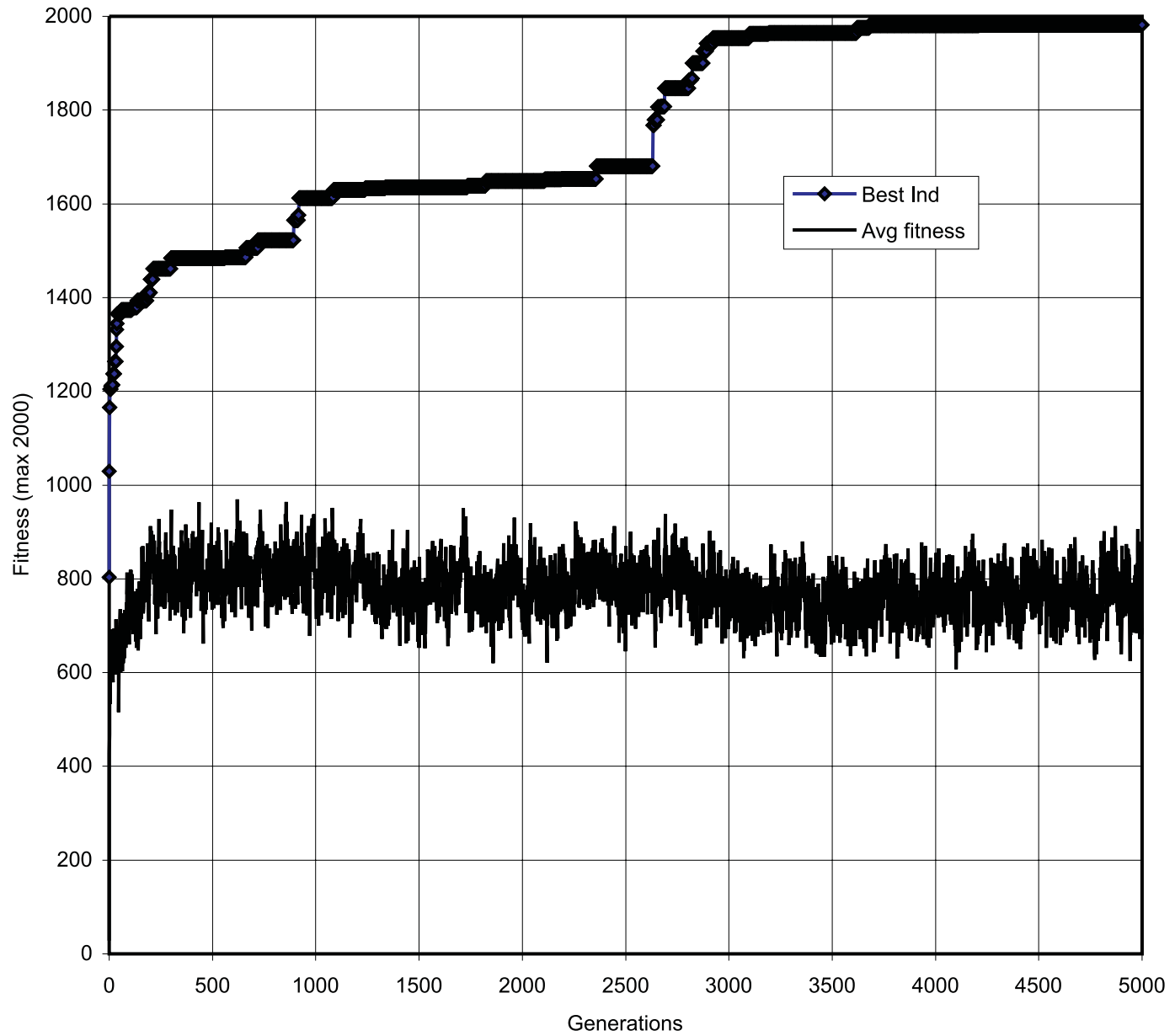
a	f(a)
-0.2639725157548009	3.194980662652764
0.0578905532656938	1.990520017259985
0.3340252901096346	8.396637039972868
-0.2363345775644623	3.070889769728257
-0.8557443825668047	5.879467636957033
-0.0194437136332785	-0.7753263223284588
-0.1921343881833043	2.834702257744086
0.5293079101246271	12.21547266421373
-0.007889741187284598	-2.498039834186359
0.4389698049506311	10.40717348588088
-0.1075592926980396	2.094136356459081
-0.2745569943771633	3.239272780108398
-0.05953332196045281	1.197012847673475
0.3844929939583523	9.355807691898551
-0.8749230207363339	6.006424530013026
-0.236546636250546	3.071897290438372
-0.1678759417045577	2.674400531309863
0.9506821818220914	22.48196398441491
0.9469791595773622	22.37501611873555
0.6393399100595915	14.5701285332337

# SETTINGS

## GENERAL SETTINGS

	<b>With Random Constants</b>	<b>Without Random Constants</b>
Number of runs	100	100
Number of generations	5000	5000
Population size	100	100
Number of fitness cases	20 (Table 3)	20 (Table 3)
Function set	+ - * / L E K ~ S C	+ - * / L E K ~ S C
Head length	6	6
Number of genes	4	5
Linking function	+	+
Chromosome length	80	65
Mutation rate	0.044	0.044
1-Point recombination rate	0.3	0.3
2-Point recombination rate	0.3	0.3
Gene recombination rate	0.1	0.1
IS transposition rate	0.1	0.1
IS elements length	1,2,3	1,2,3
RIS transposition rate	0.1	0.1
RIS elements length	1,2,3	1,2,3
Gene transposition rate	0.1	0.1
Rand. const. mut. rate	0.01	--
Dc specific IS transp. rate	0.1	--
Dc specific IS elements length	1,2,3	--
Selection range	100%	100%
Precision	0.01%	0.01%
Average best-of-run fitness	1850.476	1934.619

# EVOLUTIONARY DYNAMICS



# MODEL EVOLVED WITH RANDOM CONSTANTS

Gene 0: **L\*~\*+/aa?a??a2132990**

$$A_0 = \{0.565, 0.203, 0.613, 0.219, 0.28, 0.25, 0.48, 0.427, 0.821, 0.127\}$$

Gene 1: **E-+-\*?aaaaaaaa7332660**

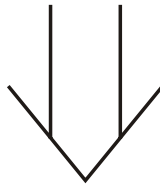
$$A_1 = \{0.031, 0.046, 0.696, 0.643, 0.528, 0.417, 0.978, 0.811, 0.637, 0.988\}$$

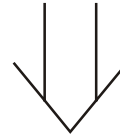
Gene 2: **~Saaa+??aa??a9109969**

$$A_2 = \{0.515, 0.466, 0.254, 0.219, 0.425, 0.942, 0.306, 0.619, 0.821, 0.262\}$$

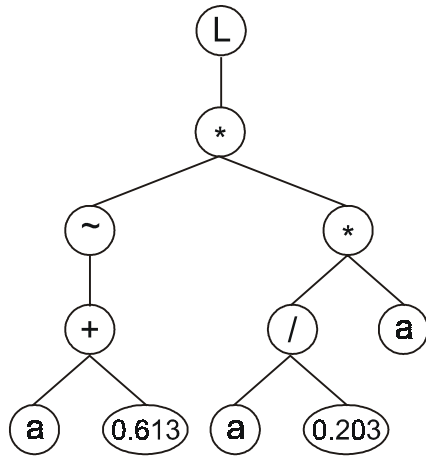
Gene 3: **~SSaES?????aa5420661**

$$A_3 = \{0.595, 0.547, 0.525, 0.219, 0.297, 0.387, 0.508, 0.695, 0.728, 0.415\}$$

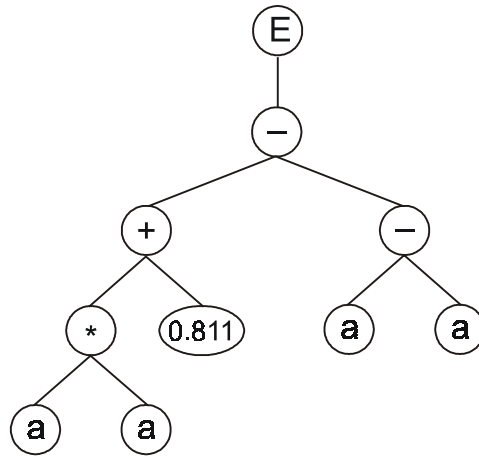




Sub-ET<sub>1</sub>



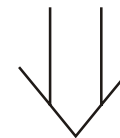
Sub-ET<sub>2</sub>



Sub-ET<sub>3</sub>

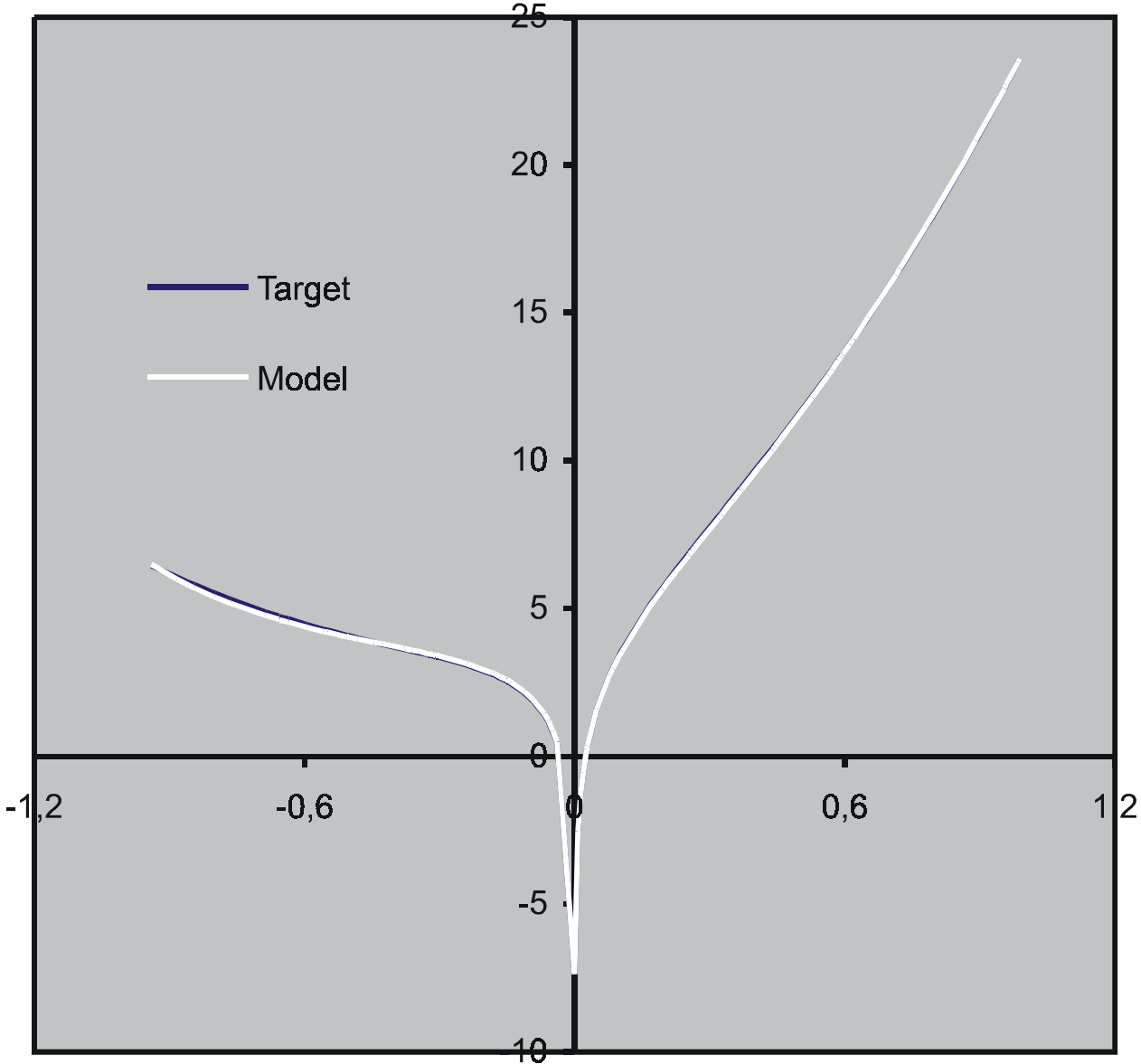


Sub-ET<sub>4</sub>



$$y = \left[ \ln \left( 10^{(a+0.613)} \cdot \frac{a^2}{0.203} \right) \right] + \left[ e^{(a^2+0.811)} \right] + \left[ 10^{\sin(a)} \right] + \left[ 10^{\sin(\sin(a))} \right]$$

# PLOT COMPARISON

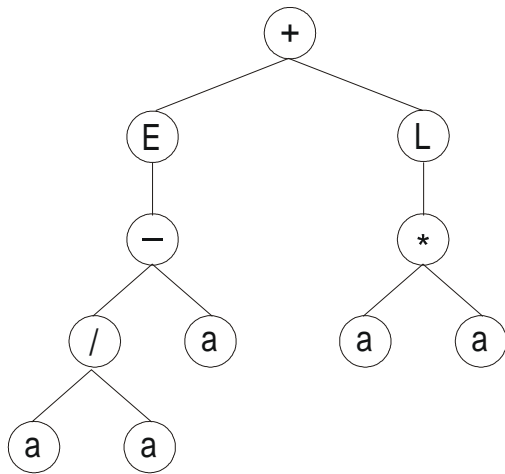


# MODEL EVOLVED WITHOUT RANDOM CONSTANTS

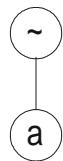
01234567890120123456789012012345678901201234567890120123456789012  
 +EL-\*/aaaaaaaa~a+E/Laaaaaaaa+C+C+Eaaaaaaaa\*C~+aSaaaaaaaa~a-L~+aaaaaaaa



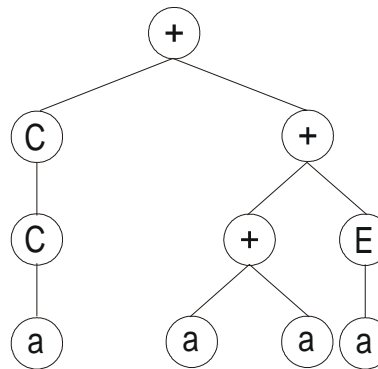
Sub-ET<sub>1</sub>



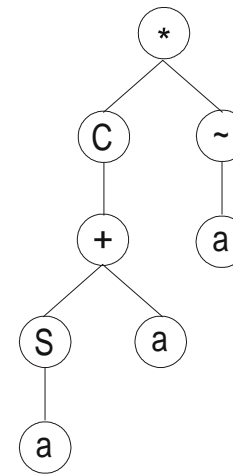
Sub-ET<sub>2</sub>



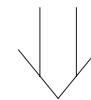
Sub-ET<sub>3</sub>



Sub-ET<sub>4</sub>

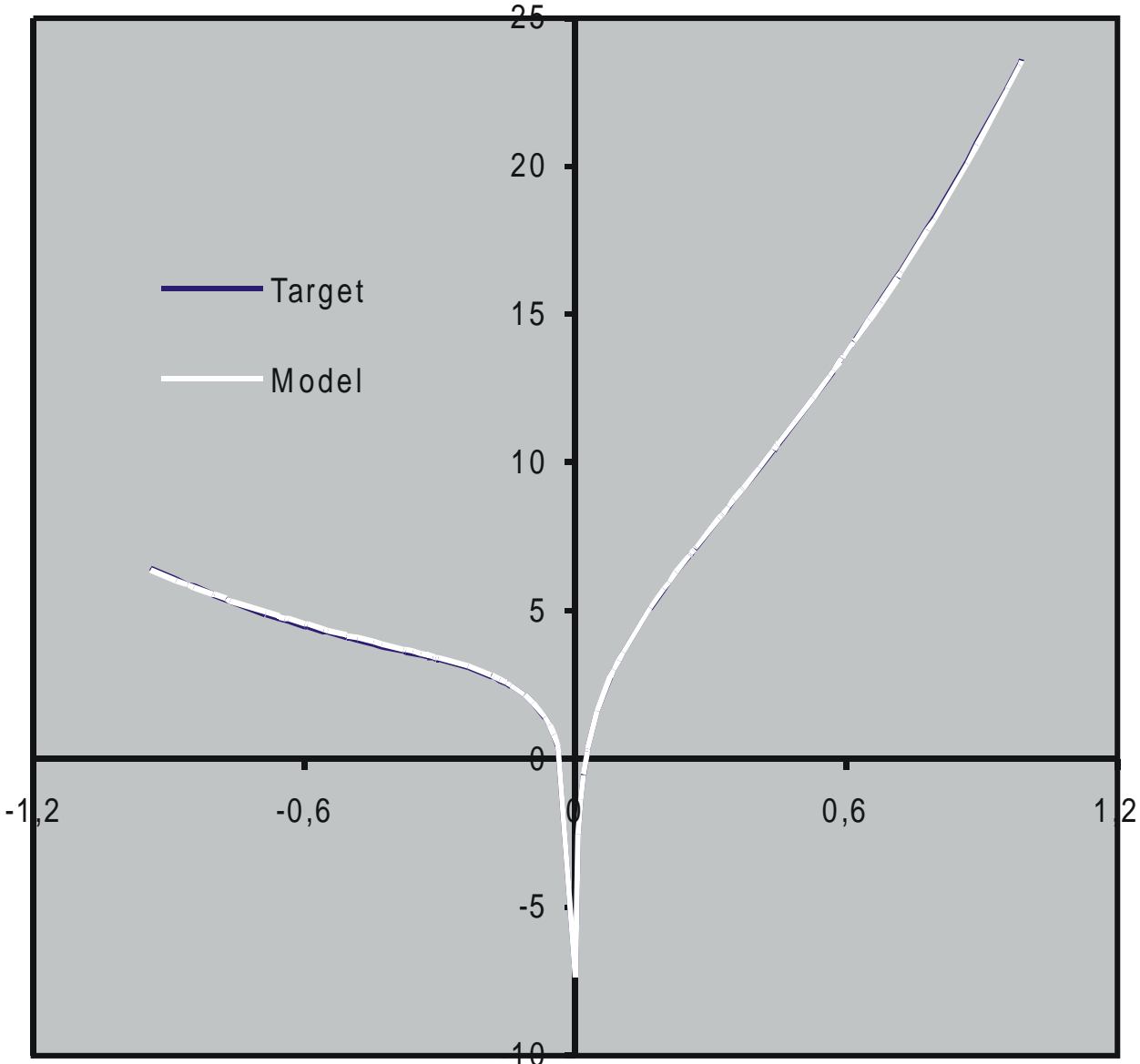


Sub-ET<sub>5</sub>



$$y = [e^{(1-a)} + \ln(a^2)] + [10^a] + [\cos(\cos(a)) + 2a + e^a] + [\cos(\sin(a) + a) \cdot 10^a] + [10^a]$$

# PLOT COMPARISON



# FINDING A 5-PARAMETER FUNCTION

TEST FUNCTION:

$$y = \frac{\sin(a) \cdot \cos(b)}{\sqrt{10^c}} + \tan(d - e)$$

FITNESS FUNCTION:

$$f_i = \sum_{j=1}^{C_i} \left( M - \left| \frac{C_{(i,j)} - T_j}{T_j} \cdot 100 \right| \right)$$

GENERAL SETTINGS

---

Number of generations	1000
Population size	100
Number of fitness cases	100
Function set	+ - * / Q K ~ S C G
Gene length	19
Number of genes	3
Linking function	+
Chromosome length	57
Mutation rate	0.044
1-Point recombination rate	0.3
2-Point recombination rate	0.3
Gene recombination rate	0.1
IS transposition rate	0,1
IS elements length	1,2,3
RIS transposition rate	0.1
RIS elements length	1,2,3
Gene transposition rate	0.1
Selection range	100%
Precision	0%

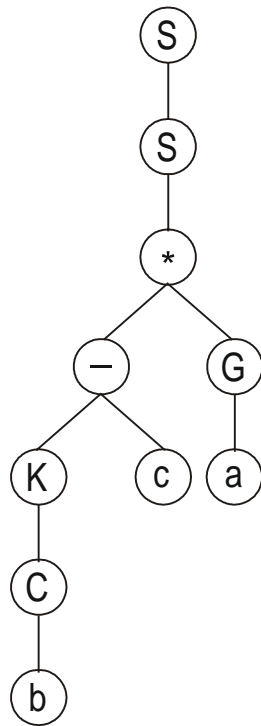
---

# EVOLVED MODEL

012345678901234567801234567890123456780123456789012345678  
SS\*-GKcaCbbccbeabdbaC--SKaeGceadddabadG-de\*add+adedabdeaa



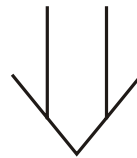
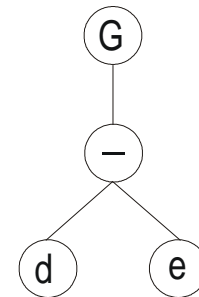
Sub-ET<sub>1</sub>

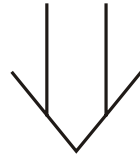


Sub-ET<sub>2</sub>

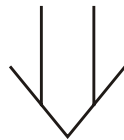


Sub-ET<sub>3</sub>





$$y = [\sin(\sin((\log(\cos(b)) - c) \cdot \tan(a)))] + [a] + [\tan(d - e)]$$



```
double APSCfunction(double d[ ])  
{  
    double dblTemp = 0;  
    dblTemp += sin(sin(((log10(cos(d[1])) - d[2]) * tan(d[0]))));  
    dblTemp += d[0];  
    dblTemp += tan((d[3] - d[4]));  
    return dblTemp;  
}
```