?J2=E*%(!<%8%'%s%H=8CD$NF0E*4D6-$X$NE,1~

:4!9LZ 5.9(!=j ??M}M:

%^%k%A%(!<%8%'%s%H7OK*1k%(!<%8%'%s%H$N4D6-$X
$NE,1~$O!$?J2=O@$+iNN`?d$K4p$E$-!$8DBNKh$k@8B8
FbGN!V3X=,!W$H=8CD$Khk@Ber$^$?$$$@!V?J2=!W$H
$$$C$?0[$J$kFs2aDx$NAjJdE*JbNH7FB*$($ilk!#
K\9FGO!$%@!<%&%#%s7?$"$k$$$O%i%^%k%/7?$N0dEA5!9=
$r;}$D=8CD$N?J2=$N2aDx$r:F8=$7!FCKF0E*$J4D6-2<$G
N=l>lN=8CD$NE,1~@-$K$D$$$FI>2A$*$h$S5DO@$r9T
$=$N7k2L!$%@!<%&%#%s7?$N=8CD$NJ}$,!$@EE*4D6-2<$G$O
8zN(E*$J%i%^%k%/7?$N=8CDhj$b4D6-$NJQF0KBP7$F@0
Dj7?5sF0$r<($9P+jGJ/!$@$BerDL8$FF0E*4D6
<+BN$KE,1~$7$F$$$/3H$,2DG=$G$"$k3H$r<($9!#

1 O8aK

%^%k%A%(!<%8%'%s%H7ONh$&$J3+J|7?J,;64D6-K*$1
FO!$7OA4BN$N>uBVrCNk3H$d!$$=$NF0E*$GJ#;($J5s
F0$r40A4$KM=B,9k3H$OIT2DG=$G$"$k!#%3$&$7$?4D6
2<$G8m$jJ/F0:n9k40A4$J%(!<%8%'%s%H$r:G=i$+$i9=
C[9k3H$O:$FqG"$k!#$=3G?w7?E*JbNr$$$/$D
$+MQ0U$7$F!$8e$O“*Generate and Test*”7?$N%"%W%m!<
%A$G3F!9$r4D6-KBP7$F=@Fp$K$+$DF0E*$KE,1~?J2=$5$;

$6$$$/$H$$$C$??J2=E*E,1~%(!<%8%'%s%H$N35G0$,M-MQ$K
JCF/kH;Wol$k!#
!VHeNGX7JNbHK!$6aG/!$<+A33&$N%7%9%F%`$KFb:_
9k@8$%$J$_%/%9$r%b%G%kH7$F!$=@Fp$J>pJs=hM}$N2D
6-9rLO:w9k8&5f$,@9$sKJ5l$F$$$k!#Nc$($P!$?M
9)@8L?[9] $HAm>N$5lk8&5fJ,LnKBP9$k4X?4$,9b$^$C
$F$$$k!#%<+A33&$N@8J*($"$k$$$O$=$N=8CD)$O!$?M9)J*$H
OA$,$/0[Jk@_7W!&F0:n86M}$N>e$K@.N)7F$$$J$,$i$b!$
<BP$B&$H$$$&F0E*G+$DM=B,ITG=$JJ#;($J5sF0$r<($9
$4D6@-!&Hs@~7A@-$N6/$$4D6-KBP7$F6K$a$F=@Fp$KE,1~
7F$$$k!#%7?$,$C$F!$3+J|7?J,;64D6-$GF0:n$9$k%(!<
%8%'%s%HJI$N>pJs=hM}5!9=$r9M;!9kK"$?$C$F!$$3
li$N;EAH$_$+$i3XV3HOB?$$!#
K9FGO!$$3Nh$&$J%(!<%8%'%s%H$N4D6-$X$NE,1~2a
D$J5s$$@8J*3X$d?J2=O@$JI+iNN`?d$K4p$E$-!$0J2<$K
$4D6$k0[Jk%l%Y%kK*1kFsDN2aDx$NAjJdE*$JbN
H7$FB*$($k!#
• $D(!<%8%'%s%H8DBN%l%Y%k$G$N@836$N4V$N!V3X=,!W
• %(!<%8%'%s%H=8CD%l%Y%kGN@Ber$^$?$0!V?J2=!W
3N>2aDx$N2M$166$rC4$&N,!V0dEA!W$N5!9=$G$"$k!%
0J2<GO!$?J2=E*%(!<%8%'%s%H$N4D6-XNE,1~2aDx$NB&
LL$KCmL\$7!$$=$N:G>.8B$N@-<A$rCj=P$7$F9=C[$7$?%b%G
%k>eGN%7%_%e%l!<%7%g%sI>2A$r9T$&!%6qBNE*KO!$3X
=,9k8D!9$N%(!<%8%'%s%H$r%K%e!<%i%k%M%C%H%o!<%/[14]
H7$FCj>]2=$7!$?J2=!&0dEA$N86M}$rLOJo$7$?0dEAE*%"
%k%4%j%:%`[5] $rMQ$$$F%(!<%8%'%s%H=8CD$N4D6-$X$NE,
1~2aDx$r:F8=$9$k!%$J$*!$0dEA5!9=H7FO%@!<%&%#%s
7?$H%i%^%k%/7?$NbN$r9M$($k!%$=7F!FCK3l$^$G
$"$^$j5DO@$5lk3HNJ$+$C$?F0E*$J4D6-$N2<$G!$$=

Adaptation of Evolutionary Agents toward the Dynamic Environment

Takahiro Sasaki, 7DXf5A=NBg3XBg3X1!M}9)3X8&5f2J7W;;5!2J3X@196, Department of Computer Science, Faculty of Science and Technology, Keio University.

Mario Tokoro, 7DXf5A=NBg3XM}9)3XIt / %=%K!<%3%s%T%e!<%?%5%$%(%s%98&5f=j, Faculty of Science and Technology, Keio University / Sony Computer Science Laboratory Inc.

%3%s%T%e!<%?%=%U%H%&%'%", Vol.14, No.4(1997), pp.33–46.
1996 G/ 7 7n 1 F|<uIU.

l>lN5!9=$N2<$K$*$1$k3X=,$N8z2L$,!$%(!<%8%0%s%H

=8CD$NE,1~@-!$4h7r@-$KM?$($k1F6A$K$D$$$F$NI>2A$r9T

$$!$$=$NFC@-$rL@i+K9$k!%

0J2<!$Bh 2>O$G$OGX7J$H7F!$3X=,$H?J2=$K4XO"$9$k

$F%i%^%k%-%:%`$H%@!<%&%#%K%:%`$N9M$(J}$r35@b7?

$K!$$3li$N@8J*3XE*CN8+$r>pJs=hM}H7FN4QE@$+

B*$(D>$7$?=>Mh$N4vD+$N8&5fNc$r5s2k!%Bh 3>OGO

3&7?=>Mh$^$G$N8&5f$NIT==J,$JE@$r5s2?>e$G!$K\

5f$NL\E*$rhjL@3NK9$k!%$=7F!$Bh 4>O$GK\9FGN

%7%_%e%l!<%7%g%s$NOHAH$K$D$$$F=R$Y!$Bh 5>O$GI>2A$H

7k2L$N9M;!$r9T$$!$Bh 6>O$G3l$K4X$7$F5DO@$9$k!%:G

8e$K!$Bh 7>O$G7kO@$r=RYk!%

2 GX7J!' 3X=,$H0dEA!&?J2=

2.1 @8J*3X!&?J2=O@E*$JGX7J

@8J*$N4D6-$X$NE,1~$K$O!$3X=,$H?J2=$H$$$&FsDNBg

LL$,$"$k!%$^$:!$@8J*$N?6$kIq$$$OCB@8;~$N>uBV$NM9

8GDj5l$F$$$ko1GO$J$$!%2w3Z$dMx1W$rb?i9

0xHJ$k9TF0$G$"$lP=lr7+jJV7!$5U$K4m81$d6l

$rH<$&9TF0rHr1$k798~$r6/ak!%@8J*$O4D6-$H$NAj

:nMQ$H$$$&<+iN7P83rDL8$F!$@8B8$KM-Mx$HJk$h

K=$N4D6-$KE,1~ — 3X=, — 7F$$$/!%0lJ}!$@8J*$O

BN$OA4$/$NGr;f>uBV$GCB@8$7$F$/$ko1GO$J$$!%<k

$N?6$kIq$$$r7hDj9kG>$N4pK\E*9=B$$r4^a?@8J*$ND

$O!$N>?F$+$i0z$-7Q$0 0dEA;R$N>pJs$K4p$E$$$FH/@8$9

3Nh&$K!$@8J*$O?F$+$i;R$XH=$NFCD'$,0z$-7Q$,

$F$$$/0dEA$H$$$&FC@-$r;}$D$,!$A4FN;R$,?F$HA4$/F

$8@-<A$r;}Do1GOJ$$!%B>$N8DBN$KHfYFB?>/Gb

@8B8$KM-Mx$K?6kIq&8DBN$r9=C[$9$k0dEA;R$O!$<!@$Be

Kh$jB?$/$NJ#@=$r;D9$3$H$,$G$-$k!%3&7?NRQ$E

$J<+A3EqBA$N2aDx$r7P$F$F0dEAE*$JJQ0[$,@Q$_=EJk

$G!$@8J*=8CD$O4D6-$KE,1~ — ?J2= — 7F$$$/!%

H3mG!$?J2=O@$NNr;KK*$$$F!$?J2=$N86F0NOH

EA8=>]$K4X$7$F%i%^%k%-%:%`$H%@!<%&%#%K%:%`$H8F$P

kFsDNBg-$J;WA[$NN.l,B8:_9k!%A0<T$NCf?4E

35G0$O!V3MF@7A<A$N0dEA!WG"$j!$3X=,JI$N4D6-$K

9k1~EzH7$F@8J*8DBN$N@836$N4V$K@8$8$?E,1~E*$J

2=$,!$0dEA;R$K2?$i$+$N7AGAH_9~$^$l$F;RB9$NJQ0

J}8~@-$rM?$(k3HG?J2=$,?d$7?Jailk$H$$$&9M$(

J}G"$k!%0lJ}!$8e<T$NCf?4E*$J35G0$O!V%i%s%@%`$JJQ

0[$H<+A3EqBA!W$G$"$j!$JQ0[<+BN

AK$OJ}8~@-$OJ//!$$?$^$?$^E,1~E*$JJQ0[$r;}$C$F@8$8

$?8DBN$,<+A3EqBA$N2aDx$G@8$-1d$S$FHK1I$9kH$$$&9M

$(J}$G$"$k!%D^$j!$$?H(@8J*8DBN$N@836$N4V$KE,1~

E*$JJQ2=$,@8$8$?H7Fb!$$=$N8z2L$,0dEA;RKAH_9~

$^$lk3HO$J$$/!$JQ0[<+BN$O$"$/$^$G$b%i%s%@%`$G$"

kH9k!%:#F|$N@8J*3X$d?J2=O@K*$$$F<gN.$r@j$a$k

NO8e<T$N%@!<%&%#%K%:%`$G$"$j!$%i%^%k%-%:%`$OO[C<

Jb$N/$O8mjH9k8+J}$,BgH>$G$"$k!%

2.2 @8J*$NE,1~2aDx$H>pJs=hM}

@8J* (=8CD) $N;}$D6KaF=@Fp$JE,1~G=NO$KCeA[$rF@

$F!$$=$N@8J*3XE*CN8+$r>pJs=hM}$N4QE@$+$iB*$(D>7?

8&5f$O@9$s$K0Y$5lF$$$k!%$=$NCf$G!$3X=,$H?J2=$K4X

9k8&5f$N4v$D$+$NBeI=Nc$r0J2<$K5s2k!%

@L?8=>]$N7W;;E*B&LL$+i=$N86M}$rC5m&H9$k

@8L?8&5fH7FNN)>l$+$i$O!$<g$K%@!<%&%#%s7?$N

0dEA5!9=$N2<$G$N3X=,$H?J2=$NN>2aDx4V$NAj8_:nMQ$K

4X9k5DO@$,Cf?4E*$K0Y5lF-$?!%Nc$($P!$Hinton

$H Nowlan Kh$kC1=c$J%b%G%k>eGN5DO@[4] rO8a

H7$F!$3X=,9k%K%e!<%i%k%M%C%H$rF,G>$H7F;}$D?M

9)@8L?BN$,4D6-$KBP7FE,1~7F$$$/2aDx$r:F8=$7$?

Ackley $H Littman $N8&5f[1] $d Parisi iN8&5f[13]

JI$,$"$k!%$3li$N8&5f$G$O!$3MF@7A<A$,0dEA

9k3HNJ$$%@!<%&%#%s7?$N0dEA5!9=$N2<Gb!$8DBN

$N3X=,$,?J2=$N3X=,$,;RB9$N?J2=$KJ}8~@-$rM?$(F=$NB.EY$r

2C$($k8z2L$r;}$D3H[†1]$,<($5lF$$$k!%Nc$($P!$

$=$N8=>]$,@8$8k3H,Js9p5l$F$$$k!%

$=$liN8&5fN&AN$$$/D+$O!$?7%@!<%&%#%s7?

$N0dEA5!9=$N2<GN3X=,$H?J2=$NAj8_:nMQ$r2r@O$7$?

8&5fN&AN$$$/D+ra0C$F!$Nc$($P!$

SAMUEL $H8F$Plk%W%m%0%i%`%7%9%F%`$K$$$/

D+$NFC<l$J3X=,A':n$r2C$($F!$$3liKhCF=$@5$5

lk!$B'72$r%i%^%k%/E*$K0dEA$5$;$k5!9=$rF3F~$7$?

Grefenstette Kh$kBeI=E*$J8&5fNc[3] N[$+$K$b!$%m

%K%C%HNOSN50F;@@.KBP7$F%i%^%k%/E*$J0dEAE*A':n

rE,MQ7$?8&5fNc[2] JI$,$"$k!%

[†1] 4pK\E*$J9M$(J}<+BN$O 1890 G/Be$K$^$GALk,!$<B:]$K3N8z2L$,@8$8k+H]$+$K$D$$$F$O3NG'$9$k=Q$,J+C?!%

$k!%$^$?!$%K%e!<%i%k%M%C%HKh$kO"A[5-21%b%G%k
%^%k%/7?$N5!9=$rF3F~9k3H$G5-21MFNL$JINLLGN
@-G=$,Cx$7$/8~>e$9k3HbJs9p5l$F$$$k[6]!%

3 F0E*4D6-XNE,1~

0J>e$K=R$YF-$?$h$&$K!$?M9)@8L?E*$JN)>l$+$i$N8&
5fNc$NB?$/$O%@!<%&%#%s7?$N0dEA5!9=$K4p$E$/$bNG$"
jG$"$C$?$,!$9)3XE*1~MQ$NN)>l$+$i$O%i%^%k%/7?$N
9=$rF3F~$7F=$NFC@-$rI>2A7?8&5fNcb"$k!%$7$+$7!$
$$$:lNN)>l$N8&5f$K$*$$$F$bN><T$N%b%G%k4VGN
E*$JHf3SI>2A$r9TC?bN$O>/$J$$!%$=$NM}M3$O!$A0
$NN)>l$K$*$$$F$O@8J*3XE*$JGX7JKhkbNG$"$j!$8e
<T$NN)>l$K$*$$$F$O%i%^%k%/7?$N5!9=$NJ}$,8zN(E*G"
lF$$$k3H$,<+L@$G$"$k$+$Nh&$K;W$(k+iG$"$k
$&!%$7$+$7!$0J2<$K=RYkh&$K$$$:lNN)>lbIr+EP
G"kH8@$($k!%

$^$:Bh0l$K!$<B:]$N@8J*3&$K$*$$$F$b!$>/?tG"kH
$O8@$(!$%i%^%k%/E*$JJQ2=$r<($9Nc$,Js9p$5lF$$$k$3
H,5s2ilk!%Nc$($P!$%_%8%s%3$OJa?)<T$NB?$$4D
K*$$$F;I$rH/C#$5$;$k3H$,$"$j!$$3$NE,1~E*$JJQ2=
$,0lEY5/$3kHMqrDL8$F;R$K<u$17Q$,lk$H$$$&8=
>]$,$"$k[15]!%$3$N860x$O0dEA;RH/8=5!9=$NJQ2=$K$"$j!$
$$$ofkDL>o$N?J2=$N%W%m%;%9K*1k DNA $N1?4p
G[Ns<+BN$NJQ2=$KhkbNGO$J$$$3H,H=L@7F$$$k
$,!$$$$:lK$;$h@8J*3XE*$JN)>l$+ib3N%i%^%k%/E*
$J?J2=$N2aDx$NB8:_$rL5;k9ko1KO$$$+$J$$!%

<!$K!$<g$K8e<T$N9)3XE*N)>l$+$i$N8&5f$K4X9kLdBj
E@G"$j!$$^$?K\9F$NCf?4E*$JO@E@$K$b7R$,$k99$K=EMW
$JLdBjE@$H7F$b5s$2ilkN$,!$=>Mh$N8&5f$N$[$H$s
I,@EE*$J<B834D6-$N>eGN$_$NI>2A$*$h$S9M;!$K4E
$/$bNG$"$j!$F0E*@-<A$r;}$D4D6-$N>eGN5DO@$,FK
0Y5lF3J+C?3HG"$k!%@h$K$b5s$2$?9)3XE~
MQ$rL\;X$7$?%7%9%F%`[12][2][3][6] K7Fb Ackley $j
$N?M9)@8L?BN[13][1] K7Fb!07C$F$$$kLdBjNN0h$O@E
E*JbNG$"$j!$%(!<%8%'%s%H$O$=$N@EE*$J4D6-$KBP$7
$FE,1~$9k@1G$h$$!%bAms!$$3li$N8&5fNc$,A[
Dj9k@_Dj2<K*$$$F$b!$4D6-Fb$r%(!<%8%'%s%H$,F0$-
$^$oC?j9k3HG%(!<%8%'%s%HXNF~NO?.9fJI$O
JQ2=$7F@$k!%$=$lGb!$%(!<%8%'%s%H$N3X=,9Y$-5,B'$,
— Nc$($P!V%_%5%$%k$+iN%lh!%W$d!VFy?)=C$+iN%$l

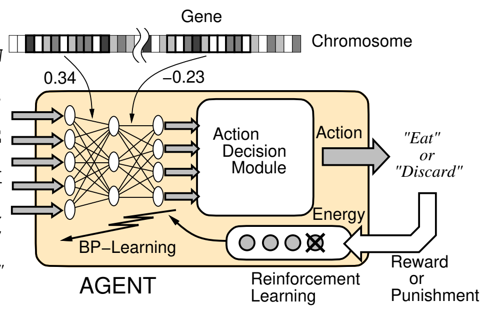
%AK%?)NHKO6aE1!%W — <+BN$OIaJWE*$G$"$j!$$3$N0U
GNEE*G"kH$3$3GO8@$$$?$$$NG"$k!%
7+$7!$%^%k%A%(!<%8%'%s%H7OJI$NJ#;($GM=B,IT2D
G=$J5sF0$r<($93+J|7?J,;64D6-$K$*$$$F$O!$%(!<%8%'%s
%H$N3X=,$9Y-5,B'$,ITJQ$G$"$kHO8Bi:!$$=$l<+BN
$NJQ2=$7F7$^$&2DG=@-b"$k!%$3Nh$&$JF0E*$J4D6-
K*1k%(!<%8%'%s%H$N?J2=$N2aDxK*$$$F$O!$=>Mh
NN&$K!V$Il@$1FCDj$N4D6-$KE,1~$G$-$k$+!W$H$$$&
3H$K2C$($F!$!VIl$@$14D6-$NJQ2=$KDI=>9k3H$,
G-k+!W$H$$$&3H$b=EMW$KJCF/$k!%

$3$3GO!$$3li$NLdBjE@$rF'$^$($?>e$G!$?J2=E*
%(!<%8%'%s%H$NE,1~E*$J2aDx$NB&LL$KCmL\$7!$$=$N:G>.
$N@-<A$@1rCj=P7?%b%G%k$rMQ$$$F!$%@!<%&%#%s7?
$H%i%^%k%/7?$N0dEA5!9=$K4p$E$/=8CD$N?J2=$N2aDx
$r=E$9=9k!%FC$KF0E*4D6-2<$G$N%@%$%J%_%/%9$r4Q;!$9
k3HGN><T$NFC@-$rHf3S7F$$$/!%

4 %7%_%e%l!<%7%g%s$NOHAH

4.1 A[Dj7F$$$k%(!<%8%'%s%H$N@$3&

$K9=F$G$O!$3F%(!<%8%'%s%H$O4D6-$+$i<u$1<hC?F~NO
$r85$K9TF0$r7hDj$9$k3,AX7?$N%K%e!<%i%k%M%C%H$o!<%/
$r;}$D8DBNG"kH9k (?^ 1)!%3N%K%e!<%i%k%M%C%H
$O4p$3F7k9g$N6/EY$r0dEA;RH7$FId9f2=$7$?$ (D^$jIb
F0$$?tE@$NG[Ns$H7FI=8=5l$?) @w?'BN$+$iD>@\%(%s
%3!<%I!<%I![12][16] KhCF@8@.5l$k!%



?^ 1 %(!<%8%'%s%H$N9=B$

3F8DBN$O%K%e!<%i%k%M%C%H$N=PNOCM$K1~$8$F9TF0$r7h
5l$k!$$=$N7k2L$Khj3X=,$r9T$&!%3X=,$NJ}K!$H7F$O!$
$1%M%C%H$N=$@5K!$H7F0lHLE*$J8m:95UEAGEK!

(0J2< BP K!) [14] $N>e$K6/2=3X=,$NOHAH$rHo$;$?bN$G MQ$$$k!%BP K!N_$@$H>o$KM}A[=PNO$r<(7F$/$lk, ;U$NB8:_$,I,MWHJk,!$$3$3$GA[Dj7F$$$k%(!<%8%' %s%H$N@$3&K*$$$F!$;vA0$KAx6x$7F@$kF~NOH=lKBP 9k@5$7$$9TF0NAHrDj5A$7MQ0U$9k3HOG-$J$$!% 0lJ}!$@8J*$OM}A[E*$J65;U$,B8:_7J$/$H$b!$2w3Z$dMx 1W$rb?i99TF0G"lP$=$l$r7+$jJV$9$3Hr3X=, $7!$4m81$d6lDK$rH<$&9TF0$G$"$lP=lr2sHr9k3H $r3X=,$9$k!%$=3G%b%G%kH7FNBEEv@-$r;}$?$;$k$? aK!$>e5-$Nh&$J6/2=3X=,$NOHAH$rF3F~$9kNG"$k!% 3l$O!$9TF0$N7k2L$H7F4D6-$+$i<u$1<h$kJs=7?.9f$r bH$K!$$=$N>u67$KBP7F!VE,@Z$J9TF0!W$G$"$C$?$+$I $&$+$r3X=,$7$F$$$/J}K!G"$k!%<B9T$7$?9TF0$KhC$F Js=7$,b?i5l?JiP=NH$-$NF~NOKBP7$FF1$8 =PNO$,F@$ilkh&$K!$5U$KD(H3$r<u1?JiP=Nh $&$J=PNO$r=P$5J/Jkh&$K BP K!$,E,MQ5l$k!%K\ 9F$G$O!$E57?E*$J!VF~NO%;%s%5 − 9TF0=PNO!WD>7k7?$N %"!<%-%F%/%A%c$N>e$KJs=7!&D(H3$K4pE/6KaFC1=c$J 6/2=3X=,$NOHAHrHo;$?$@1NbN$rMQ$$$?$,!$%K%e!< %i%k%M%C%HKh$k6/2=3X=,$N<B8=K!KOB>KbMM!9Jb N,9M$($i$l!$%j%+%l%s%H%M%C%H%o!<%/$rMQ$$$k3H$G ;~7ONsE*$J=hM}rI,MWH9kJ#;($J%?%9%/$N3X=,$r9T$($k Lin iNhj@vN}5l$?%"!<%-%F%/%A%c [10] JIb" $k!%$J$*!$%K%e!<%i%k%M%C%H$N=$@5$K:]$7FO0J2<$N<0 $rMQ$$$k!%

$$w(t+1) = w(t) - \eta \left.\frac{\partial E(w)}{\partial w}\right|_{w=w(t)} + \alpha \Delta w(t) \quad (1)$$

$3$3$G!$Dj?t η!$$\alpha$ O=l>$l3X=,78?t!$47@-78?tG" $k!%$^$?!$$w(t)$ $O3X=,$N t %9%F%C%WL\$K$*$1$k%M%C%H %o!<%/Fb$N3F7k@~$N6/EY$r@.J,H9$k7k9g6/EY%Y%/%H%k G"$j!$$E(w)$ $O%M%C%H%o!<%/$N=PNO8m:94X?tG"$k!% H3mG!$%(!<%8%'%s%H$O%K%e!<%i%k%M%C%H$N=PNO$ r=N^^FCDjN9TF0$K<LA|$9kNGOJ/!$$=NCM 1~8?3NN($G3NDj=PNO$r;;=P9k9TF07hDj%b%8%e!<%k$N =PNO$KhC$F:G=*E*$J9TF07hDj$r9T$&!%3Nh&$J3NN(E*$J5!9=$O!$%(!<%8%'%s%H$,0lEYM-Mx$J9TF0Q?!<%s$r 3MF@$7$?8e$G$b!$$=lhjb5i$KM-Mx$J9TF0Q?!<%s $r3X=,$9$k2DG=@-$r$$$/i+GbJ];}9k$?$aKI,MWG bNG"$k!%9TF07hDj%b%8%e!<%k$G$O!$3F=PNO%K%e!<%m Nr<h$jF@$k9TF0N=l>lKBP1~E1$F!$$3li$N=P NOCM$N6/5K1~8F0J2<$N<0$G7W;;5l$k%\%k%D%^%s3N N($Khj[K7$?$,CF9TF0$rA*Br$9$k!%

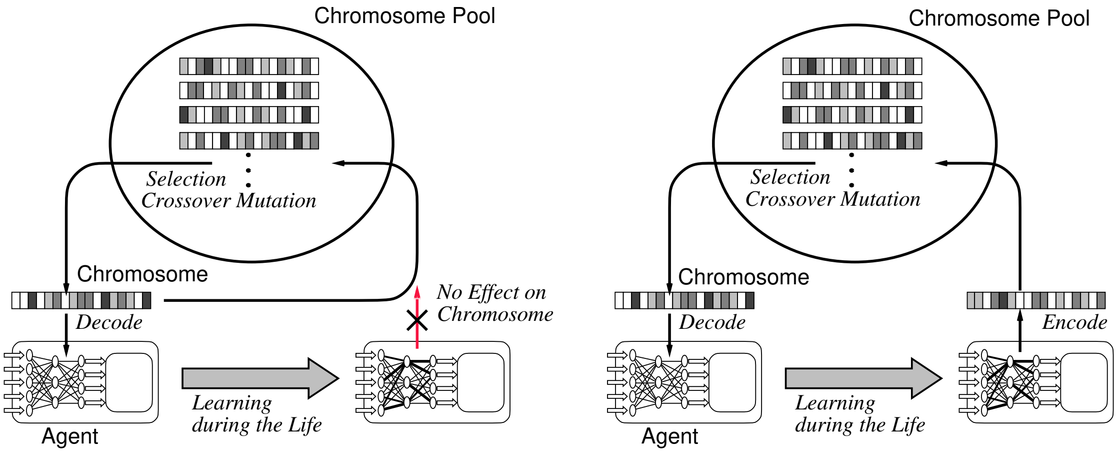
$$p(a_i|s) = \frac{\exp(o_i/T)}{\sum_{j \in possible\_actions} exp(o_j/T)} \quad (2)$$

$3$3$G!$$p(a|s)$ $O>u67 s K*$$$F9TF0$a<h$k3NN($r I=$7F*$j!$$o$ $O9TF0 a $KBP1~$E$1$5l?=PNO%K%e!< %m%s72$N9g7W=PNOCM$G$"$k!%$^$?!$$T$ $O%(!<%8%'%s%H$N KA81EY$rI=$929EYDj?tG"$k!%$T$ $,>.$5$$$H%(!<%8%'%s %H$O2a5n$N7P83$rH?1G$7$?%K%e!<%i%k%M%C%H%o!<%/$N=P NOCM$K4p$E$$$FJ]<iE*$J9TF0$r<h$j!$5U$K T $,Bg$-$$ $H2a5n$N7P83$K0x$ol:$KMM!9$J9TF0$rKA81E*$K;n$_$k 798~$r6/$/<(9h$&$KJk!%

$"$k4|4VH7FDjail$?@836$r=*$($?8DBN$O!$2?$i $+$NI>2A4p=`$K$h$j;;=P$5$l$?E,1~EY$K1~$8$?3NN($GA* Br$5$l!$@w?'BN$N8r:5!&FMA3JQ0[$J$I$N0dEAE*A`:n$,;\ 5l$?>e$G!$<!@BeN;R$r:n$k!%3N:]$K!$%@!<%&%#%s 7?$N0dEA5!9=$r;}$D%(!<%8%'%s%H$O!$?^ 2a $K<($9h& $K!$@836$N4V$K=$@5$5l?7k9g6/EY$r<!@$BeKEA(k3 HOJ/!$<+J,$N?F$+$i<u$17Q$$$@0dEA;Rr=N^$^<! @$Be$N;R$r:n$k:]$N0dEA;RH7$F0dEAE*%"%k%4%j%:%` $N%W%m%;%9$KEO$9!%0lJ}!$%i%^%k%/7?$N0dEA5!9=$r;}$D %(!<%8%'%s%H$O!$?^ 2b $K<($9h&$K!$@836$N4V$K=$@5 5l$?7k9g6/EY$r:FId9f2=7F0dEA;R$r:n$jD>$9!%

4.2 NcBj

<!$K!$D>4QE*$JM}2r$r=u1k$?$a$KK\9F$GMQ$$$k6q $JNcBj$K$D$$$F=RYk!%8DBNG"$k%(!<%8%'%s%H$, $$=l>l"$k0lDj$NCM$r=i4|CM$H9k@8L?%(%M %k%<$r;}$C$F@$3&$KCB@8$9$k!%@$3&KO!$@8L?%(%M%k $r0lDjNLA}2C$5$;$kM-1W$J?)NH$H$=$N5U$K@8L?%(%M <$r0lDjNL8:>/5;$kM-32$JFGJ*$H$$$&Fs<oN`$N MAK,;6:_$7!$$=l>l,FCD'E*$J7A>u (%S%C%H%Q%?!< $N;}$D!%3F8DBN$OJ*<A$N%Q%?!<%s$r%K%e!<%i%k%M%C <%/$KF~NO7F!$$=$N=PNOCM$K1~8F!V?)Yk!W$+ J5Fk!W$N$$:l+$N9TF0$r3NN(E*$K7hDj$9$k!%?) *<A$,?)NHG"C?>l9gKO@8L?%(%M%k%.!<$,A}2C $7!$$=$N%Q%?!<%s$KBP7F!V?)Yk!W9TF0rH$k 9kh&$J3NN($G!$9b$/Jkh&JCMr%K%e!<%i%k%M%C%H%o!<%/$,=P



(a) Darwinian Genetic Inheritance (b) Lamarckian Genetic Inheritance

?^ **2** %@!<%&%#%s7?$H%i%^%k%/7?$N0dEA5!9=

NO9kh&$K3X=,$r9T$&!%5U$K$=$1$,FGJ*$G$"$C$?>l KO@8L?%(%M%k%.!<$,8:>/$9kN$G!$$=$N%Q%?!<%s$K 7F$O!V<N$F$k!W9TF0$rHk3NN($,9b$/Jkh&$K =PNO$9kh$&$K3X=,$r9T$& (?^ 1)!%J*!$J*<A$r!V<N$F $?!W$H$-$K$O3X=,$O9Tol$J$$!%?)NH$HFGJ*$r<1JL9k $?$aKI,MWJCN<1$r!V5,B'!W$H8FV3HK9k$H!$%(%8%'%s%H$O<+$i$,9TF0$r5/$3$9$3$HKhCF!$$3$N5,B' $r3X=,$7$F$$$/3HKJ$k!%3F8DBN$O!$?)NH$"$k$$$OFG J*$rI=$9%S%C%H%Q%?!<%sr"$k7h$ail$?2s?t$@$1D 5l$F6/2=3X=,$r9T$&!%$=$N9g7W2s?t$r8DBN$N!V@836!W $ND9$5H9$k!%@836$r=*$($?%(!<%8%'%s%H$O!$@8L?%(%M %k%.!<$N;DNL$K1~8?3NN($GA*Br$5$l!$%i%^%k%/7?b7 $/$O%@!<%&%#%s7?$N0dEA5!9=$K4p$E$$$?0dEAE*A`:n$ 5l$?>e$G!$<!@$Be$K;RB9$r;D$9!%$D$^$j!$;DB8@8L?%(%M%k%.!<$,$=$N8DBN$NE,1~EY$HJk!%

%7%_%e%l!<%7%g%s$NA4BN$NN.1r$^$Hak$H0J2<$N$h $&$KJk!%

1. =i4|@BeN8DBN$r@8@. ($g=1$)
2. Bh g @BeN8DBN3F!9$,!$$"$k0lDj4|4V9TF0$r7J $,$i3X=, (8DBNH7FN!V@8!W)
3. ;DB8@8L?%(%M%k%.!<$r85$KE,1~EY$NI>2A
4. E,1~EY$r85$K!$A*Br!$8r:5!$FMA3JQ0[$JIN0dEA E*A`:nKhCF $g+1$ @BeN?7$7$$8DBN72$r@8@.
5. $g=g+1$ H7$F!$2.KLak

4.3 $=$NB>$N>\:Y$J@_Dj

KBPF$G9T$C$?<B83$K$*$1$k6&DL$N%Q%i%a!<%?@_Dj$r0J 2<$K5s2k!%

- =8CD$N8DBN?t$O8GDj$G 100 H9$k!%
- $8DBN$N%K%e!<%i%k%M%C%H$O 3 AX9=B$$NbN$rMQ$$!$ 5<b7$/$O 6 8D$NF~NO%K%e!<%m%s!$3 8D$NCf4VAX %K%e!<%m%s!$8 8D$N=PNO%K%e!<%m%s$+$i@.$j!$3FAX 4V$N7k9g$OA47k9g$H9k!%
- <3F%K%e!<%m%s$O!$F~=PNO$N4X78$,%7%0%b%$%I4X?t$G !Dj5l$k%"%J%m%0%K%e!<%m%s$G$"$k!%
- %Mi4|=8CD$N3F%K%e!<%i%k%M%C%H%o!<%/$N7k9g6/EY$O!$ $-0.30 \sim 0.30$ $N4V$N%i%s%@%`JCMG=i4|2=9k!%
- ;¥PNO%K%e!<%m%s$N 8 8D$N$&$A!$H>J,$N 4 8D$:$D$, (?) Yk!W9TF0$H!V<NFk!W9TF0$K4XM?9k!%
- (2) <0K*1k%(!<%8%'%s%H$NKA81EY$r<($9 T $N CM$r 0.3 $K@_Dj$9$k!%
- (1) <0$GI=$5lk BP K!K*$$$F!$3X=,N(η !$47@- 78?t α r=1>$1 0.75!$0.8 $K@_Dj$9$k!%
- 3F8DBN%(!<%8%'%s%H$O=i4|CM 500 $N@8L?%(%M%k%.!< $r;}$C$FCB@8$7!$?)NH$r?)YkKh$K $+10$ $NJs=7!$FG J*$r?)$YkKhK -10 $ND(H3$,M?$($ilk!%
- A3F%(!<%8%'%s%HKO!$?)NH$HFGJ*$NAPJ}$,$=$l$>$l F1$82s?t!$7W 400 2sDs<(5lk3HG@836$N3X=, $r9T$&!%

- 0dEAE*A`:n$K$*$$$F!$8r:5E@$N?t$O 0 ∼ 4 E@!$FM A3JQ0[N($O 5%!$JQ0[$NI}$O ±0.5 $G%i%s%@%`$K7h Dj$9$k!%

J*!$$3$1$i$N%Q%i%a!<%?CM$OM=HwE*<B83K*$$$E;n 9T:x8m$N>e$G7hDj7?bNG"k,!$$3$1$irE,EvJHO 0OFb$GJQ99$9$k8B$jK*$$$F$O!$Dj@-E*$KF1MM$N<B837k 2L$,F@$i1k3H$r3NG'$7$F$$$k!%

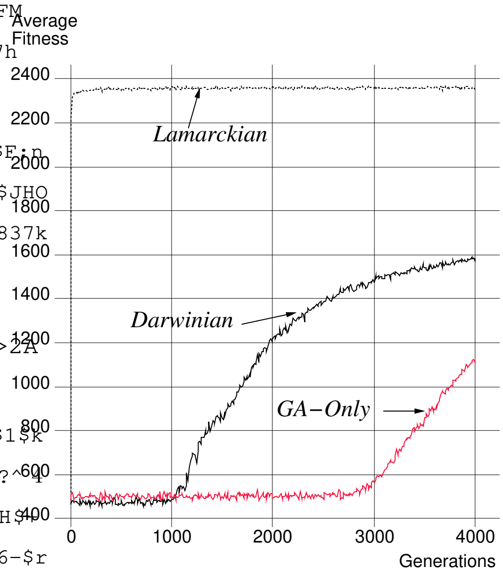
5 %@!<%&%#%s7?$H%i%^%k%/7?$N0dEA5!9=$NI>2A

5.1 M=Hw<B83!'@EE*$J4D6-$G$NE,1~2aDx$NI>2A

$^$:O8aK!$M=Hw<B83$H7F@EE*$J4D6-2<$K$*$1$k $=$1$>$1$N0dEA5!9=$NHf3Sr7F*$/!%$3$3$G$O!$?^4 $N>eJ}$NOHFb$K<($9h&$K!$?)NH$HFGJ*$, 6 %S%C%H$N $i@.$k%Q%?!<%sG=1>$1FCD'$E1i1kh&$J4D6-$r 9M$($k!%$$$^$O!$?^ 4 $NB>$NItJ,$OA4$FL5;k7F!$>eJ} NBg-$JOHFb$@1KCmL\$7$FM_$7$$!%Gr$*$h$S9u$GKd$a i1$?%^%9O=1>$l "0"!$"1" $rI=$7!$"*" $N5-9f$O "0" $H "1" $N$$$:1NCMGb$h$$$3Hr0UL#9k!%D^ $j!$?)NHG"k+FGJ*G"k+$N5,B'$O 6 %S%C%HCf$N>e 0L$N 3 %S%C%H$N4X78$KhC$F7h$ai1F*$j!$;DjN 3 %S%C%H$O;(2;%S%C%H$G$"$kH9$k!%$bAm$s3F%(!<%8%' %s%H$O!$$I$N%S%C%H$,;(2;G"kN$+$r:G=i$+$iCNCF $$$ko1GO$J$$!%%(!<%8%'%s%H$O!$;(2;0J30$N 3 %S%C %H$rFCDj$7!$$5iK$3$1$i 3 %S%C%H$N%Q%j%F%#LdBj$r2r $/$NKI,MWJ5,B'$r3X=,$7$F$$$/3HKJ$k!%

3N4D6-2<K*$$$F!$3F8DBN$N@836$r 400 %9%F%C%W (?^ 4 $N>eJ}$N4]OHFb$K<($7$? 8 DN%Q%?!<%s$r=gHV$K 50 2s!$7W 400 2sDs<() H7$?$H$-$NJ?6QE,1~EY$N?d0\ $NE57?E*$JNc$r?^ 3 $K<($9!%J*!$3X=,%9%F%C%W$, 400 G"k3Hh$j!$%(!<%8%'%s%H$N<h$jF@$k:GBg$NE,1~EY $O 2500 G"$k!%

?^ 4 GOHf3SBP>]H7$F *GA-Only* $H$$$&=8CD$NE,1~ EY$N?d0\$bJ;$;$FI=<(7F$$$k!%GA-Only $N=8CD$K$* 1k%(!<%8%'%s%H$O!$@836$N4V$N3X=,$r9To:$K(9J oA%K%e!<%i%k%M%C%H$N7k9g6/EY$rA4$/=$@5$9$k3H$J $/) 01@8$r2a$4$9!%D^$j!$@8F@E*$K;}$D$K%e!<%i%k%M%C %H$NA1$70-$7$@$1$,E,1~EY$KD>7k9k!%%@!<%&%#%s7?$N =8CD$H GA-Only $N=8CD$H$NHf3S<+BN$OK\9F$N<gBj$H$O D>@\4X78$7$J$$$bNG$"$k$,!$8DBN$N3X=,$,=8CD$N?J2=



?^ **3** [M=Hw<B83] J?6QE,1~EY$N?d0\

$KM?$($k1F6A$K$D$$$F$OK\9F$N0J8e$NItJ,$G$N=EMW$JO@ E@$N01$DGb$"$kNG!$$3$3$Gdd>\:Y$K?($1F*$/!% %@!<%&%#%s7?$N%(!<%8%'%s%HGO!$3F8DBN$,01@8$N4V$K 3X=,7?7k2L$OD>@\;RB9$KEA$($i1k3H$,$J$$$N$G!$ 0dEA5!9=$=$NbN$O GA-Only $HA4$/F1EyG"$k!%$7$? $,$C$F!$D>4QE*KO$%@!<%&%#%s7?$H GA-Only $N=8CD$K $*$$$FE,1~EY$N>e>:$,;O$^$kNO$[$\F1;~4|KJk3$H $,A[A|$5$1$k!%H3m,!$<B:]$K$O?^ 3 $+$i$bJ,$+kH $*$j!$GA-Only $N=8CD$G$O 3000 @$BeL\JU$j$+iG$J $$$HE,1~EY$N>e>:$,;O$^$i$J$$$NBP7F!$%@!<%&%#%s7? =8CD$G$O 1000 @$BeL\JU$j$+$i>e>:$7$;O$a$k!%$D$^$j!$ 3MF@7A<A$,D>@\;RB9$KEA$($i1k3HNJ$$%@!<%&%#%s 7?$N=8CD$K$*$$$F$b!$8DBNKh$k3X=,$,=8CD$N?J2=$KJ} 8~@-$rM?$($F?J2=$NB.EY$rB%?J$9k+Nh$&$J5?;w%i%^ %k%/8z2L$,@8$8kNG"$k!%$3$1$,, 2.2 @aGb=RY? %\!<%k%I%&%#%s8z2L$H8F$P1kbNG"$k!%$3Nh$&$J 8z2L$,@8$8$k860x$O0J2<Nh$&$K9M$($i1k!%%K%e!<%i %k%M%C%H$N7k9g6/EY%Y%/%H%k6u4V$K$*$$$F!$$[$\F1DxEY $N@-G=$r<($97k9g6/EY%Y%/%H%k$OJ#?t$"$jF@k,!$$=$1 $>$1$N%Y%/%H%k$rI=$9E@$N<~0O$N>u67$OF101G"kH$O 8B$i$J$$!%D^$j!$7k9gCM$N01ItJ,$ro:$+$KJQ2=5; k@1G@-G=$,HtLvE*$K8~>e9kh&$J8e@$BeKBP7$F M-K>$J7k9g6/EY%Y%/%H%kb"1P!$B?>/$NJQ99$r;\$7$F

$b@-G=$,$[$HsI>e>:7J$$$h$&$JbNb"$k!%$H3m
$,!$$=1i$N7k9g6/EY%Y%/%H%k<+BN$O$$$:1bF1DxEY$N
@-G=$r<($9$?$a!$$3$1$i$NE@$N$_$r8+$F$$$k GA-Only
$N=8CD$K$*$$$F$O!$<+A3EqBA$N5!9=$OM-K>JbNrA*$S
=P$9$3H,=PMh$J$$!%0lJ}!$@836$N3X=,KhCF7k9g6/
EY$,JQ99$5$1$kh&J@!<%&%#%s7?$N=8CD$N>l9gKO!
@8F@E*$KM?$(i1$?7k9g6/EY%Y%/%H%k$N<~JU$r6I=jE*$K
C5:w9k3H$GM-K>$JbN$rA*JL$9k3H,G-$k!%$=
N?$a!$0dEAE*$J5!9=<+BN$OF1$8$G$b?J2=$NB.EY$K:9$,
=PkNG"$k!%

5F!$$3$3$G3NG'7F$*$/Y-3H$O!$@EE*$J4D6-2<
GO%i%^%k%/7?$N=8CD$NJ}$,%@!<%&%#%s7?$N=8CDhj$b
05E]E*$K8zN($,NI$$$3HG$"$k!%%i%^%k%/7?$N=8CD$G$O!$
20 @$BeL\JU$jGAa/$bE,1~EY$, 2000 $rD6$(kN$KBP
7F!$%@!<%&%#%s7?$N=8CD$NE,1~EY$N2aDx$O4KK}$G$"$k!%
$3$1$O!$%i%^%k%/7?$N=8CD$G$O<wL?$Khj?F$,ESCf$GBG
$A@Z$C$?3X=,$r;R$,7QB3$9$k7A$G3X=,$r?J$ak3H,$G
$-$kNKBP7F!$%@!<%&%#%s7?$N=8CDGO@Be,Beok
$?$S$K;R$O3X=,rd$jD>$5J/FOJi$J$$$+iG$"$j!$
D>4QE*KbM}2r$7F@$k7k2LG"$k!%$7$+$7!$$3$N7k2L$h
$jD>$A$K%i%^%k%/7?$N0dEA5!9=$NJ}$,%@!<%&%#%s7?$N5!
9=hj$bM%$1$F$$$k$H7kO@$E1kNOAa5^G"$k!%

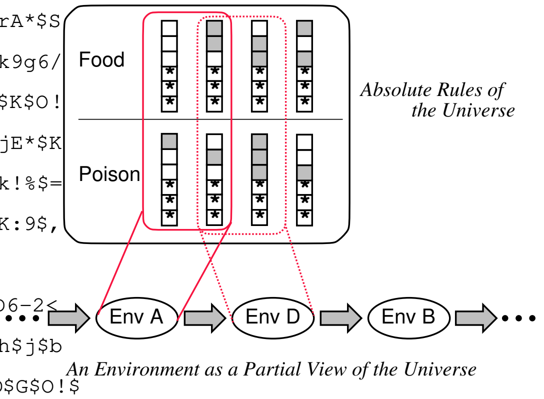
5.2 F0E*$J4D6-$X$NE,1~2aDx$NI>2A

3+J|7?J,;64D6-2<$G3hF0$9$k%(!<%8%'%s%H$O!$<+A3EqBA
K*1k@8J*$HF1MM$K!$J#;($KJQ2=9k4D6-KBP7$F@i4|
Fp$KBP1~$7J/FOJi$J$$!%$=$3GO!$%(!<%8%'%s%H
$N3X=,$,9Y$-5,B'$,ITJQG"kH$O8B$i$J$$!%0J2<GO!$
3 DN0[JkF0E*FC@-$N%l%Y%k$r;}$D4D6-$rA[Dj7F!$
$=$3GNE,1~2aDx$NI>2A$r9T$&!%

5.2.1 <B83 **1**!'MxMQ2DG=$J>pJs$KItJ,@-$,$"$k4D6-

$^$:$O!$F0E*FC@-$N%l%Y%k$H7F$O:G$bDc$$4D6-H7$F!$
$F!$IaJWE*$J5,B' — !V?)NH$G$"$k$+FGJ*$G$"$k$+
<+BN$OJQ2=$7$J$$$,!$$=1r=,F@9kNKI,MW$J4D6-$+iN
>pJsNAH,F1;~KOF@i1kH$O8B$i$J$$$h$&$J>u67$r
$r9M$($k!%$=7F!$%"%/%;%9$G$-$k>pJs$N<oN`$,;BlF*
6&$KJQ2=$9kbNH9k!%$3$1$O!$$"$k;~E@$GB8:_9k
$+$C$?<oN`$NJ*<A$,FMG!8=$1$?$j$$=1^GKB8:_7F
$$$?bN$,>C$($?$j9k$H$$$&>u67$KAjEv$9$k!%$3$3$G
$O!$$=1>1N;~BeK*$$$F4D6-CfKO 4 <oN`$NJ*<A$N

$B8:_$7!$$=N&ANFsD,?)NH$G;D$jNFsD$,FGJ*
G"kh$&$J4D6-$r9M$($k (?^!4)[†2]



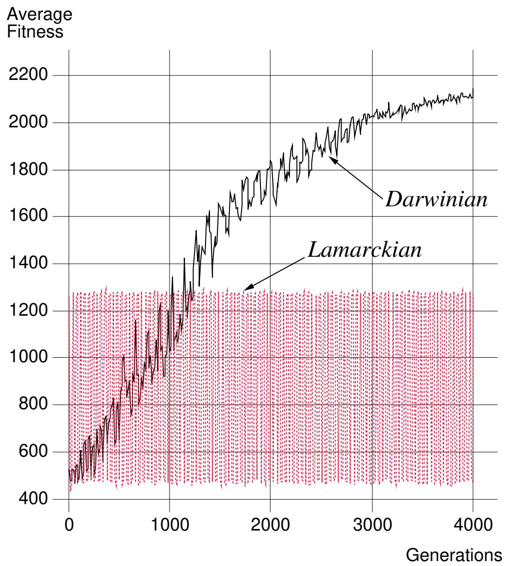
Env A	○	○	×	×	○	○	×	×
Env B	×	×	○	○	×	×	○	○
Env C	○	×	○	×	○	×	○	×
Env D	×	○	×	○	×	○	×	○
Env E	○	×	×	○	×	○	○	×
Env F	×	○	○	×	○	×	×	○

?^ **4** <B83 **1**

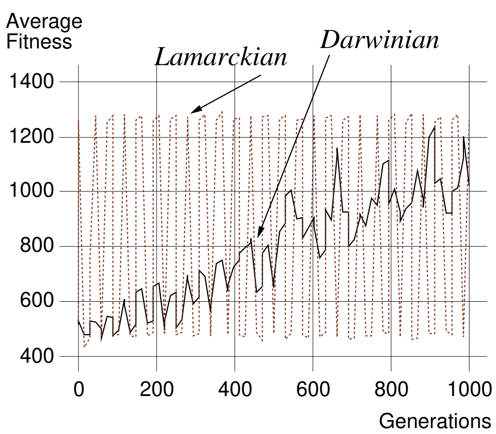
?^ 5!$?^ 6 $K 20 @$BeKh$K4D6-$KB8:_9kJ*<ANAHr
JQ2=5;$?$H$-$N!$E,1~EY$N=8CDJ?6Q$N?d0\$r<($9!%?^
5 $N@i4|@$Be$+$iBh 1000 @Be^GNItJ,$r3HBg$7$?$b
N,?^ 6 G"$k!%$3$1$i$N?^$h$j!$%i%^%k%/7?$N=8CD$G
$O!$4D6-$r9=@.$9$kJ*<A$N<oN`$,JQ2=$9kEYKE,1~EY$,
B?>/$/?6F0$7$F$$$k3H$,3NG'$5$1$k!%0lJ}!$%@!<%&%#
%s7?$N=8CD$G$bE,1~EY$N?6F08=>]$,8+$i1k$,!$%i%^%k
%/7?$N=8CD$N>l9gKHfY$F?6F0$NI}$,>.$5$/0BDj$7$F
$$$k!%9JoA4D6-$NJQF0$KBP9k4h7r@-NLLK$*$$$F
$O!%@!<%&%#%s7?$NJ}$,%i%^%k%/7?$N=8CDhj$bM%$1$F$$$k
$H$$$($k!%

5iK3$3$G%@!<%&%#%s7?$N=8CD$K$*$$$FCmL\$9Y-
3H$O!$4D6-$,JQ2=$9kEYK=8CD$NE,1~EY$,?6$j=P$7$K
Lako1GOJ$/!$?6F0$7$DDb@Be,?J$`$KDl$FA4
$+$C$?

†2 IaJWE*$J5,B'<+BN$,JQ2=7J$$$3Hh$j!$3 @a$G=R$Y$?$h
$&$JOUL#GO!$$3$3$G9M$($F$$$kbN$b40A4$KF0E*$J4D6-
HO8@$($J$$!%



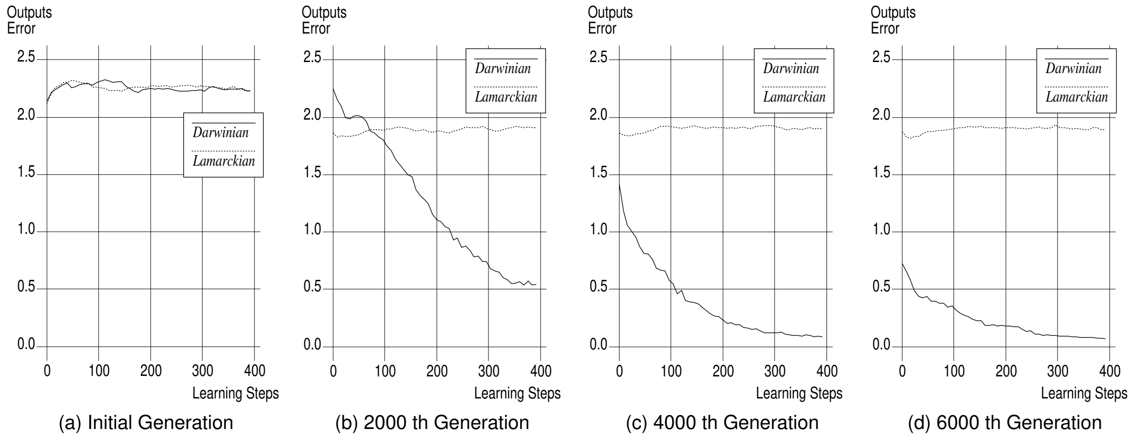
?^ **5** [<B83 **1**] J?6QE,1~EY$N?d0\



?^ **6** [<B83 **1**] J?6QE,1~EY$N?d0\ (01It3HBg)

$^$j?^ 4 >eJ}$N4]OHFb$K<(7?A4%Q%?!<%s$+$i@.$k5, B') $r3X=,$5$;$F$_$?H-$N3X=,FC@-$rI>2A9k!%3N h&K7$FF@$il?3F@BeN3X=,FC@-6J@~$r?^ 7 $K<($9!%?^ 7 K*1k3F%0%i%U$O!$@836FbGN3X=,$N7P2a$K HbJ&%K%e!<%i%k%M%C%H$N=PNO8m:9$NJQ2=$NMM;R$r<(7F$$$k!%=PNO8m:9H7FO!$$=l>lNF~NO%Q%?!<%s KBP9$kM}A[E*$J=PNOCM$H<B:]$N%K%e!<%i%k%M%C%H$N=P NOCM$N<+>h8m:9OB$r<h$C$F$$$k!%$^$:=i4|@BeK$*$$$F $O!$%i%^%k%/7?$H%@!<%&%#%s7?$N%(!<%8%'%s%H=8CD$N$$ $:$l$b3X=,$r$&$^$/9T$($J$$ (?^ 7a)!%2000 @$BeL\$K$J kH!$%i%^%k%/7?$N=8CD$O@8F@E*K"$kDxEY2~A1$5l? =PNOCM$r=P$9%K%e!<%i%k%M%C%H$r;}CF@8$^$lk,!$$= $N8e$K3X=,$r9T$CFb%M%C%H%o!<%/$N=PNO8m:9$O$"$^$j Dc8:$7$J$$!%01J}!$%@!<%&%#%s7?$N=8CD$O!$%i%^%k%/7? $N=8CD$hjb=PNO8m:9NBg-$$%K%e!<%i%k%M%C%H$r;}$C $F@8$^lF$/$k$,!$$=$N8e$N3X=,KhCF=PNO8m:9$O8: >/$9$k (?^ 7b)!%$=7F!$4000 @$BeL\ (?^ 7c)!$6000 @$ BeL\ (?^ 7d) $H@$Be$,?J$`KDlF!$%@!<%&%#%s7?$N0d EA5!9=$N2<$G$O!$85$NA4BN$N5,B'KBP7Fb@5$7$/3X=, $r9T$&3HNG$-$k=8CD$,7A@.$5lF$$$/3H$,J,$+$k!% 01J}!$%i%^%k%/7?$N0dEA5!9=$N2<GO!$%9%F%C%W?t$r@Q sG$bE,@Z$K3X=,$r?J$ak3H,=PMh$J$$$h$&$J=8CD$, 7A@.$5lF7^CF$$$k!%

%i%^%k%/7?$N=8CD$,4D6-$NJQF0$KBP7FIT0BDj$J5sF0 $r<($9M}M3$O!$FC0[E*$J5,B'$KBP7FlEM_$K?<$/E,1~$7 9.F7$^$&$+$iG"$k!%Nc$($P!$?^ 4 K*$$$F!$Env A GO!$$$$:lNJ*<A$b>e$+$i;0$DL\$N%S%C%H$O "0" $G $"$kNG!$$3lrL5;k7F>e0L 2 %S%C%H$N%Q%j%F%#Ld Bj!$$D$^$j XOR LdBj$r2r7h$9$k5,B'$r3X=,9l$P?)NH $HFGJ*$r<1JL9k3H$,$G$-$k!%7+$7!$$"$k;~Be$r6- $K4D6-$, Env A $+$i Env B XH>uBV$,JQ$oC?H9 BNH7$F>e>:$7$F$$$kE@G"$k!%$D$^$j!$3F;~Be$GOt$Env A $G4{$K3MF@:Q$_$N 2 %S%C%H$N%Q%j%F%#Ld J,E*$J>pJs7+MxMQG-$J$$$K$b4X$oi:!$$=lBNK4X9kCN<1$OLrN)$?$J$$$I3m$+ Env B GOA4$/ J,E*$J>pJs$r@$BerDL8$FE}9g7FA4BN$N5,B'$r=@5$BKBPN0UL#$r;}$D3HKJCF7^$&!%%i%^%k%/7?$N 3MF@7F$$$k$+$Nh&$J5sF0$r%@!<%&%#%s7?$N=8CD$OGO!$01@8$N4V$K3X=,$7$?7k2L$rD>@\?F$+$i;RXH 9NG"$k!%$3N3Hr3NG'9k$?$a$K!$$5iK0dEA5$;$F7^$&$?$a!$FCDj$N5,B'$KBP7F?<$/E,1~$7 h&$J<B83$r9TC?!%$^$:!$@h$K=RY?<B83K*$$$F$$$F7^$$!$$=3+$iH4$1=P$9$3H,:FqKJCF7 =i4|=8CD!$2000 @$BeL\!$4000 @$BeL\!$6000 @$BeL\$N$&!%01J}!$%@!<%&%#%s7?=8CDGO!$C;4|E*$K$O8DBN%l =8CD$r$=$l$>$lESCf$G<h$j=P7F$*$/!%$=$7$F!$<h$j=P$$3X=,KhCFFC0[E*$J5,B'$KBP1~7DDb!$D94| 7F$*$$$?3liN=8CDKBP7$F!$85$NA4BN$N5,B'KO=8CD%l%Y%k$GHFMQE*$J2DG=@-$rJ]$C$?$^$^?J2=$K

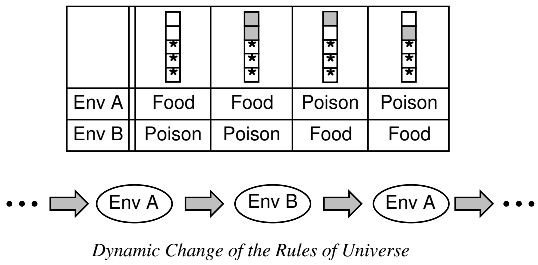


?^ **7** [<B83 **1**] @$Be7P2a$KHbJ&3X=,FC@-$NJQ2=

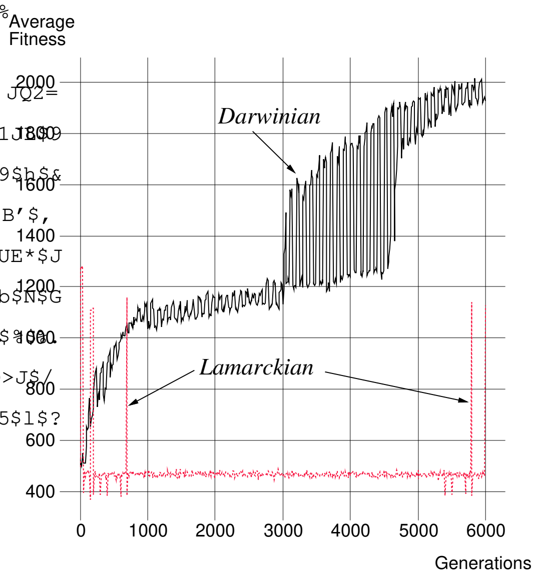
hC$FIaJWE*$J5,B'$r3MF@$7$F$$$/3H$,=PMh$k!%

5.2.2 <B83 **2**!'5,B'<+BN$,JQ2=$9$k4D6- **(1)**

5F!$$h$jF0E*FC@-$N6/$$4D6-GO!$5,B'<+BN$,JQ2=9k3Hb"$jF@$h$&!%$3$3$G$O!$?)NH$HFGJ*$r<1JL9k5,B'<+BN$,Dj$ail$?;~Be$r6-$KH?E>$r7+jJV9h&$J>u67$r9M$($k (?^ 8)!%3Nh&$K@8B8$KM-Mx$J5,B'$,$"$k@Z$C3]$1$r6-$KH?E>9kh&$J>u67$O0l8+Ws0UE*JbNH46$:$k$+$b7l$J$$$,!$<B:]$K5/3jF@kbNG$"$k!%Nc$($P<+A33&K*$$$F@8$8$?8=>]H7FO!$%a%j%9$N2k$N9)6H9u2=$NNc [15] $,M-L>$G$"$k!%>\:Y$O>J$/$,!$$3NNcO8DBN$N@8B8$KM-MxHJ$k5,B'$,8GDj5l$?$bNGOJ$/N.F0E*$G$"$k3H$r<($7$F$$$k!%



?^ **8** [<B83 **2**]

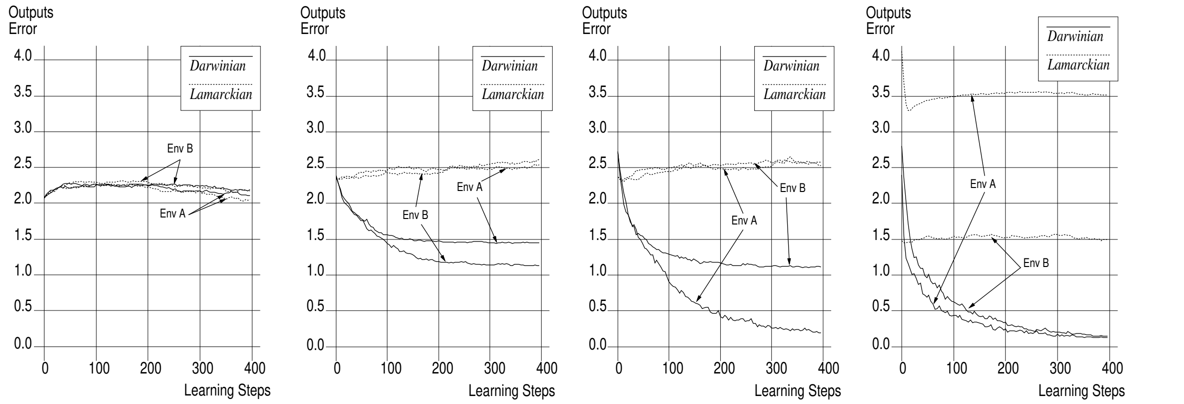


?^ **9** [<B83 **2**] J?6QE,1~EY$N?d0\

H7$FI=$5lk$,!$$=$N5,B'$N0UL#$O;~Be$,?J$`$HHb$KH?E>$r7+jJV9!%?^ 9 $K=8CD$NJ?6QE,1~EY$N?d0\$r<($9!%%i%^%k%/7?$N=8CD$,4D6-$KE,1~G-$J$$$H$$$&7k2L$O6K$a$FD>4QE*$G$"$k!%0lJ}!$$3$3$G$bCmL\$9Y-3H$O!$%@!<%&%#%s7?$N=8CD$NE,1~EY$,?6F0$7J,ib@Ber=EMkKDlF>e>:7F$$$k$H$$$&6KaFH?D>4QE*JbNG$"$k!%$H$$$&Nb!$<B83 1 $N>l9g$H$O0[$J$j!$$3$3$GIaJWE*$J5,B'<+BN$,JQ2=7F$$$k$+$iG"$k!%$3Nh$&$J!$%@!<%&%#%s7?$N0dEA5!9=$N2<$G$O!$

$3$3GO!$?^ 8 $K<($9h&$K!$4D6-$r 50 @$BeK$K Env A $H Env B $N4V$GF~lBX(k3Hr7+jJV9bNH9$k!%?)NH$HFGJ*$r<1JL$9$k5,B'$O 3 %S%C%H$N%Q%j%F%#LdBj (XOR LdBj) H7F3$N2<$GF~lBX(k3Hr!$4D6-$NH9$k!%

2;ItJ,$r=|$1$P!$2 %S%C%H$N%Q%j%F%#LdBj (XOR LdBj) 3liN7k2Lhj!$%@!<%&%#%s7?$N0dEA5!9=$N2<$G$O!$



(a) Initial Generation (b) 2000 th Generation (c) 4000 th Generation (d) 6000 th Generation

?^ **10** [<B83 **2**] @$Be7P2a$KHbJ&3X=,FC@-$NJQ2=

Env A!$Env B $N$$$:lN4D6-KBP7Fb$&$^$/E,DL$N9=B$$r3MF@7F$$$/2DG=@-$r9M$(k3HbG-$k!%
G-kh$&$J=8CD$,7A@.$5lF$$$/3H$,J,$+$k!%$3NP!$$3$3$G9M$($F$$$k4D6- (?^ 8) GN5,B'$NJQ2=$O
3H$r99$K3NG'9k$?$a$K!$>e5-$N<B83$K$*$$$FEVGP$G!W$H$$$&bNG"$k!%$D$^$j!$?)NH$G$"$k$+FGJ*$G
<h$j=P$7F*$$$?!$=i4|=8CD!$2000 @$BeL\!$4000 @BeL+OHb+$/!$0lHVL\$HFsHVL\$NFsDN%S%C%H$N4X
L\!$6000 @$BeL\$N=8CDN=l>lr Env A $H Env B KhCF!$>/J/HbJ*<A$rFsDN%0%k!<%W$KJ,1k
$NN>J}$N5,B'$N2<$G3X=,$r9T$o$;$?H-$N3X=,FC@-$rHQ,=PMh$k!%=8CD%l%Y%k$G$O!$$3$N!V%0%k!<%WJ,$1!W
;!7?!%$=$N7k2L$r?^ 10 $K<($9!%$^$:!$=i4|@$Be$N=8CD$&Cj>]EY$N%l%Y%k$,9b$$5,B'$@$1$r?J2=E*$K3MF@$7
KD$$$F$O!$%@!<%&%#%s7?$H%i%^%i%/7?$$$:lN=8CD$b-!$$=$N>e$G3F8DBN%l%Y%kGN3X=,KhCFIA$i
;W$&$h$&$K3X=,$r?J$ak3H,G-$J$$ (?^ 10a)!%N0%k!<%W$,?)NH$G$"$jFGJ*G"k+$r<1JL$9$k>\:Y$J
m,!$2000 @$BeL\$KJkHAa/$bN><T$NAj0c$,L@$i$+$KBP1~7F$$$/$H$$$&6Z=q$-$G$"$k!%7+$7!$<!$K
KJCF$/$k!%%@!<%&%#%s7?$N0dEA5!9=$N2<GO!Envk<B83 3 Kh$j!$>e=R$N6Z=q$-0J30KbB>$NM}M3$,
A $H Env B $N$$$:lN5,B'rb!$$"$kDxEY3X=,$9k3j=$&$J3H$,J,$+$k!%
HN=PMh$k=8CD$,7A@.5lO8aF$$$k (?^ 10b)!%**5.2.3** <B83 **3**!'5,B'<+BN$,JQ2=$9$k4D6- **(2)**
iK!$@$Be?t$r=E$M$F 6000 @$BeL\ (?^ 10d) $K;j$k$H!$8e$K!$<B83 2 hj$b99$KF0E*FC@-$,6/$$4D6-H7
%@!<%&%#%s7?$N0dEA5!9=$N2<GO!$$$$:lN5,B'$$b$?^ 11 $K<($9h&$K?)NH$HFGJ*$r6hJL$9$k5,B'$,40
@Z$K3X=,$9k3H,=PMhkh$&$J=8CD$,7A@.$5lF$$$kT$5,B'$KJQ2=9k>u67$r9M$($k!%J*<A$rI=$9%S%C%H
0lJ}!$6000 @$BeL\$N%i%^%k%/7?$N=8CD$G$O!$Env A$QH?!<%s$O 3 %S%C%H$N;(2;$r4^$` 5 %S%C%H$+$i@.$j!$?)
Env B N=l>lN5,B'$r3X=,$5$;$?H-$N3X=,FC@-HFGJ*$r<1JL9kNK0lHVL\$HFsHVL\$N%S%C%H$,4XM?
$,Bg$-$/0[$J$j!$F@0U$J5,B'$HITF@0U$J5,B'$H$,L@9N$K%7+$7!$$=$N5,B'$K$O<B83 2 Nh$&$K 2 %S%C%H
J,N%7F7^CF$$$k!%7+$b!$$=$NF@0U$JJ}$N5,B'$Nj%F%#LdBjNh$&$J9=B$$OL5$/!$$=$NAH9g$;$,A4$/
3X=,FC@-G5$(!$%@!<%&%#%s7?$N=8CD$NbNhj$b5,B'E*$KJQ2=9kNG!$%(!<%8%'%s%H$KHCFO5i
$F$$$k!% $K87$7$$4D6-G"kH8@$($k!%

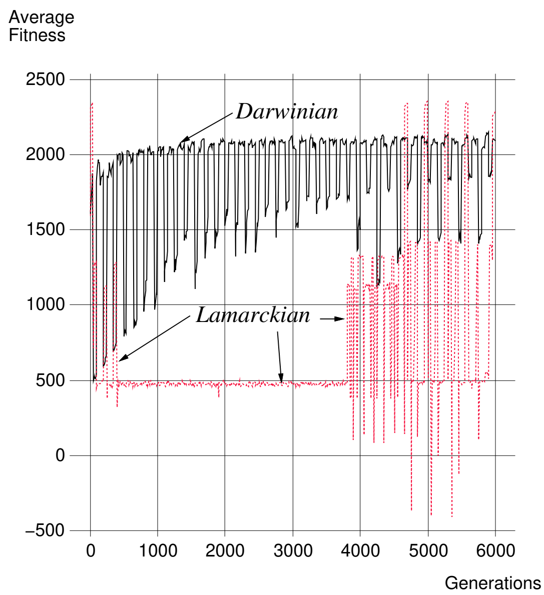
IaJWE*$J5,B'<+BN$,JQ2=7F$$$kKb4Xoi$:!$%@3Nh$&$J>u67$N2<$G!$5,B'$r 50 @$BeKh$KJQ2=5;
%&%#%s7?$N=8CD$,$$$:lKBP7F$bE,@Z$J3X=,r?H-$N=8CD$NJ?6QE,1~EY$N?d0\$r4Q;!7?(?^ 12)!%D>
%K%e!<%i%k%M%C%H$r3MF@$G$-$kM}M3$N0l$DH7$F!$4KO$$$:lN=8CDb&$^$/E,1~G-$J$$$h$&$K;W$(
%&%#%s7?$N=8CD$,N><T$N5,B'$N4V$K1#$5l?2?i+NNN@$,!$?^ 12 $r8+$F$_$k$H!$$3$3$G$b%@!<%&%#%s7?

Env A	Food	Food	Poison	Poison
Env B	Poison	Poison	Food	Food
Env C	Food	Poison	Food	Poison
Env D	Poison	Food	Poison	Food
Env E	Food	Poison	Poison	Food
Env F	Poison	Food	Food	Poison

Dynamic Change of the Rules of Universe

?^ **11** <B83 **3**

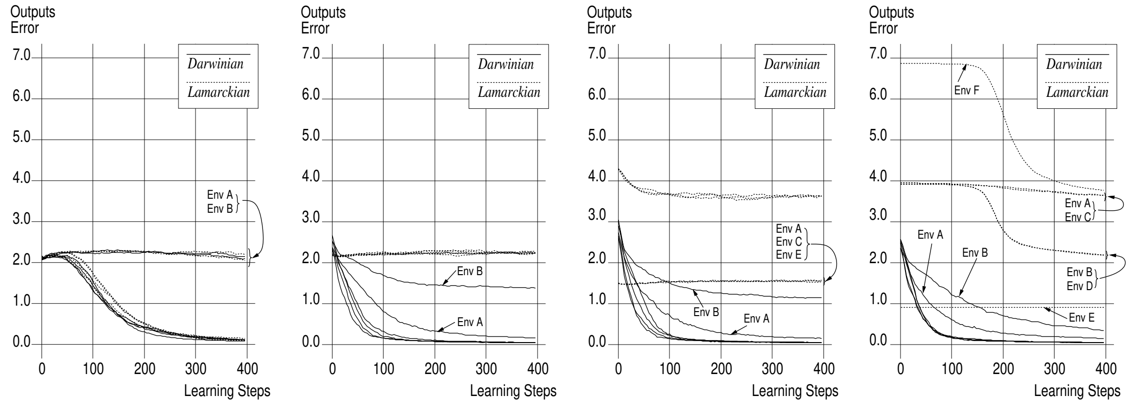
=i4│=8CD!$2000 @$BeL\!$4000 @$BeL\!$6000 @$BeL\$N=8
CDN=1>1KBP7F!$?^ 11 $G<($7$?$=1>1N5,B'
$N2<$G3X=,$r9T$o$;$?H-$N3X=,FC@-6J@~$r?^ 13 $K<(
$9!%$^$:!$=i4│@BeN=8CDKD$$$F$N3X=,FC@-(?^ 13a)
hj!$$$$:1N=8CDKHCF$b Env A $H Env B $N5,
B'$r3X=,$9k3HOFq7/!$$=N[$+$O3X=,$,MF0W$G%9
%F%C%W$N7P2a$KHbJC$F%K%e!<%i%k%M%C%H$N=PNO8m:9
$,B.$d$+$K8:>/7F$$$/3H$,J,$+$k!%$3$1$O!$Env A
$H Env B $N5,B'$, 2 %S%C%H$N%Q%j%F%#LdBj$G$"$j@~7A
J,N%ITG=$H$$$&@-<A$r;}$C$F$$$k$+$iG"k,!$$3$3$G
=EMWJN$O5,B'$N0c$$$Khk3&7?3X=,FC@-$NAj0c$G
OJ$/!$$=1>1N5,B'KBP7$F%@!<%&%#%s7?$H%i%^%k
$N=8CD$NE,1~EY$N?6F0$NI}$,@$Be$r7P$kK7$?$,CF$NN><T$,F1Ey$J3X=,FC@-$r<(9H$$$&3HG"$k!%
5/JC$F$$$-!$$5iKA4BNH7$F>e>:798~$r<(7F$$$m$,!$2000 @$BeL\$KJk$HMM;R$,JQ2=7F$/$k(?^
k3H,3NG'G-$k!%$3$3$G9M$($F$$$k4D6-KO!$5B2) 13b)%@!<%&%#%s7?$N=8CDGO!$Env A $H Env B $N
@a$N8eHx$G=RY?h&$J!V%0%k!<%WJ,$1!WNh$&$JqC$$$bNr4^a?$=$1$>$1$N5,B'$KBP9k3X=,FC@-
>]EY$N9b$$%1%Y%kK*1k9=B$E*$J5,B'5(B8:_$;$$$$$i$+8~>e$5$1$?bNHJ$k!%01J}!$%i%^%k%/7?$N
5,B'$OA4$/%i%s%@%`$KJQ2=$9$k!%$3Nh$&$J6KaF8CD$O!$$$$:1N5,B'KBP7Fb3X=,$,;W$&h&$K?J$^
IT2DG=$J>u67$K$*$$$F5(!$%@!<%&%#%s7?$N0dEA5$9$$$OJ$k!%$5iK!$4000 @$Be (?^ 13c)!$6000 @$Be (?^
2?i+$N;EAH$_$GM-1W$J>pJs$r;RB9$KEA$($F$$$k!13d) $H@$Be$r=E$MkKD1$F!$%@!<%&%#%s7?$N=8CD$K$*
$$$F$O!$$$$:1N5,B'KBP7Fb3X=,FC@-$N5$iJk8~
>e$,8+$i1k!%01J}!$%i%^%k%/7?$N=8CDGO!$$=1>$1
$N5,B'$KBP9k3X=,FC@-$,Bg$-$/0[$J$j!$F@0U$J5,B'$H
ITF@0U$J5,B'$H$,L@3N$KJ,N%7F$/$k!%$3$3Gb!$%@!<
%&%#%s7?$N%(!<%8%'%s%H=8CD$,!$$$$:1N5,B'rbE,@Z
$K3X=,$9k3H,2DG=$J=@Fp$J%K%e!<%i%k%M%C%H$r3MF@
7F$$$/?J2=$N2aDx$,:F8=$5$1$F$$$k!%



?^ **12** [<B83 **3**] J?6QE,1~EY$N?d0\

5.3 $^$H$a

8DBN$N3X=,$H=8CD$N?J2=$N2aDx$rL)$KM;9g7?%i%^%k
%/7?$N0dEA5!9=$r;}$D=8CD$O!$FCDj$N4D6-XNE,1~$,B.
$$$?$a!$@EE*$J4D6-2<$K$*$$$F$O%@!<%&%#%s7?$N=8CD$K
HfYF05E]E*$KM-Mx$G$"$k!%H3m,!$%i%^%k%/7?$OFC
Dj$N4D6-$KBP7F1EM_$K?<$/E,1~$7$9$.$F7^$&$N$G!$
$=$3$+$i:F$SH4$1=P$9$3HOHs>o$K:$FqHJ$k!%$7$?
$,$C$F!$4D6-$,F0E*$KJQF0$9$kh&$J>u67$K$*$$$F$O!$
$=$NJQF0$K9g$o$;$FE,1~EYbBg-$/?6F0$7!$6K$a$FIT0B
Dj$J5sF0$r<($9!%01J}!$%@!<%&%#%s7?$N=8CD$O!$4D6-$,
JQF0$7$F$b%i%^%k%/7?$N=8CD$[$I5sF0$,IT0BDj$KJk$3
<!$K!$>e5-$N<B83$K$*$$$FESCf$G<h$j=P7F$*$j$^$9!%



(a) Initial Generation (b) 2000 th Generation (c) 4000 th Generation (d) 6000 th Generation

?^ **13** [<B83 **3**] @$Be7P2a$KHbJ&3X=,FC@-$NJQ2=

8DBN$K3X=,$r9To;kH!$3X=,7k2L$,0dEA9k3H$,$F?(lF$*$/Y-3H$,0lE@$"$k!%IaJWE*$J5,B'<+J/Hb%\!<%k%I%&%#%s8z2LKhCF=8CD$N?J2=$,B%?JQ2=7J$$<B83 1 K*$$$F$O!$@8F@E*$J%M%C%H%o!<$5lk3H$r=R$Y$?!%$^$?!$$3$N5?;w%i%^%k%/E*8z2L$,PNO8m:9$,@$Be$r=E$MkKDl$F8:>/$7$F$$$k (?^ @8$8$k860x$O!$8DBN$N9T$&3X=,KhCF!$@8F@E*$J%M%C$^$j!$@8$^lD$-E,$7$?9TF0%Q%?!<%s$r<hkh$&%H%o!<%/$N7k9g6/EY%Y%/%H%k$N<~JU$,6I=jC5:w5lkDN,@8$8$k!%0lJ}!$5,B'<+BN$,JQ2=7F7^$&<B83 iG$"$k3H$b=RY?!%F0E*$J4D6-K*$$$F!$J#?t$N<B83 3 K*$$$F$O!$$'7m@8F@E*$J%M%C%H%o!<%/$N B'$N2<$GE,@Z$J9TF0%Q%?!<%s$r@8$8$5$;$kh&$J%KPNO8m:9$O@Ber=EMkKDlFA}2C7F$$$k (?^ 10!$ %i%k%M%C%H$,B8:_$7$J$$!$$b7/$O3MF@$,:FqG$?$k13)!%3N3H$O!$F0E*FC@-$N6/$$4D6-GO!$FCDj$N 9gKO!$$3$N6I=jC5:w$,Hs>o$K=EMW$JLr3d$r2L$?$9,B'<B<$GE,@Z$K?6$kIq$&$3Hhjb!$MM!9$J5,B'$r3X=, :]$K!$@836$N3X=,$,9T$olJ$$ GA-Only $N=8CD$O3N-kh$&$J=@Fp$J@-<A$NJ}$,=EMW$G$"$k3H$r0UL#$7 h&$JF0E*4D6-2<$G$OA4$/$&$^$/5!G=$7$J$$$3H,B%G$k!%$D$^$j!V&$^$/9TF0G-$k!WFC@-$r0dEA7h$& 5l$F$$$k!%H3mG!$$3$3$G6=L#?<$$$N$O!$8DBN$N9XkD>@\E*$J%i%^%k%/7?$N0dEA$GOJ$/!V$&$^$/3X=, =,7k2L (D^$j6I=jC5:w$N7k2L) $rM[$K0dEA5;kh$&$J$k!WFC@-$,0dEA7F$$$/%\!<%k%I%&%#%s8z2LKh$k %i%^%k%/7?$N0dEA5!9=$bF0E*4D6-2<$GO&$^$/5!G=7E*$J5!9=$NJ}$,=EMW$JLr3d$r;}$D!% $$$3HG$"$k!%3Nh&$JF0E*$J>u672<GO!$8DBN$N3X =,$H=8CD$N?J2=$N2aDx$rL@3N$KJ,N%$7$F!$3F8DBN$N%I%Y

6 5DO@

%kGO3X=,KhCF>\:Y$J5,B'$KBP1~7DDb!$=8CD$N%<%8%'%s%H=8CD$N?J2=$N2aDx$r:F8=$9k?aKK\9F BNH7FO$"$kDxEY$NHFMQE*$J2DG=@-$rJ]$C$?$^$$GMQ$$$?%b%G%k$O!$@8L?$N86M}$KCeA[$rF@$?bNGO$" $KE,1~$7$F$$$/%@!<%&%#%s7?$N0dEA5!9=$NJ}$,0BDj@-!$@8J*3XE*$K=EMW$J$$$/D+$NB&LL$r4JN,2=7?6K 4h7r@-NLLGM%lk!%5i$KFCI.$9Y-3H$O!$%G$FCj>]EY$N9b$$$bNHJC$F$$$k!%Nc$($P!$@w?'BN$+ %&%#%s7?$N=8CD$O!$F0E*FC@-$N6/$$4D6-2<$G0BDj$7$8DBN$N%K%e!<%i%k%M%C%H%o!<%/$r@8@.$9kK$"$?CF F0$r<($9$@$lGJ$/!$@Be,?J$`$KDl$FE,1~EY$D>@\%(%s%3!<%I$K!$rMQ$$$F$-$?$,!$<B:]$N@8J*$NG>GO 5;$F$$$kE@G"$k!%$D$^$j%@!<%&%#%s7?$N=8CD$K$O%K%e!<%m%s4V$N7k9g$N6/EY$,D>@\E*$K0dEA;R$+$i7hDj E*$J4D6-KBP7FNE,1~G=NOrHw($F$$$k!% 5l$F$$$kHO9M$($K$/$$!%$?9)3XE*$JN)>l$+$i$b!$ >e=RN3HH4XO"7F!$<B83 1!$<B83 2!$<B83 3 K*$jBg5,LO$J%K%e!<%i%k%M%C%H%o!<%/$r?J2=E*$K3MF@$9 1k@$BeKh$N3X=,FC@-$NJQ2= (?^ 7!$?^ 10!$?^ 13)$K3H$r9M$($?$H$-$K$O!$$3$3$GMQ$$$?D>@\%(%s%3!<%I

K!GOIT==J,G"$k!%$3$N:]$K$O!$Kitano $,Ds<($7%E,?J$^$J$$$3Hb$"$k$H$$$&@-<A$r;}$C$F$$$k!%$3
$$$k%0%i%U=q-49(5,B'$r:F5"E*$KMQ$$$kJ8K!%(%$1$1$N@-<A$O!$3+J|7?J,;64D6-$Nh&$JJ#;($J4D6-2<$G
%IK![8] Nh$&$J5!9=$,M-MQ$KJk3H$O3N$+G"$kN%$(!<%8%'%s%H$N3X=,$N2aDxrE,EYK%b%G%k2=G-kb
$?!$$=$N5!9=$O@8J*$NH/@8$N%a%+%K%:%`Kh$j6a$$NDGWolk,!$K\9F$GF@il$??CN8+$,$=$N$^$^B>$N3X
%kGb$"$k!%7+$7!$$3N3HOK\9FK*1k3X=,HQi%@%$%`$KBP7F$b@.$jN)D+I&$+$N3NG'KD$$
2=$K4X$9$k5DO@$NK\<A$rJ$$9bNGO$J$$!% FO:#8e$N2]Bj$KJC$F$$$k!%$^$?!$K\9F$GMQ$$$?%b%G
0J>e=RYF$-$?h&$K!$$3$3$GF@il$?CN8+$rD%$D!$4D6-Cf$K%(!<%8%'%s%H$N?)NHHJ$kJ*;q$,==J,$K
N^$^@8J*3X$K%U%#!<%I%P%C%/9k3HOFq7$$$$!$5U$8Bil$??)NH$ra0CF$N%(!<%8%'%s%H4V$N6%Ah
$KCj>]EY$N9b$$%b%G%k>eGN5DO@$O%^%k%A%(!<%8%$H$$$C$?D>@\E*$J%(!<%8%'%s%H4V$NAj8_:nMQ$r9MN8$KF~
7O$N9=C[K!$JINMM!9$JOCBj$K$^$G1~MQHO0O$r9-$2$$$$bNHJC$F$$$J$$!%7+$7!$<B:]$N@8J*$N@$3&$d
$k2DG=@-$b$"$k!%%(!<%8%'%s%HKh$kLdBj2r7h$"$K$$$O!4D6-JI$r9MN8$9kH!$8B$il?;q8;$r=d$C$F@8
$=$N$?$a$N8z2LE*$J@oN,3MF@$N2aDx$H$$$&4QE@$+$t$dTW;;%5%V%7%9%F%`$,6%9g9k3H$,>o$G$"$k!%5i
K\9F$GMQ$$$?!V3X=,!W$H!V?J2=!W$H$$$&MQ8lN=$$$K$$(!<%8%'%s%H4V$NAj8_:nMQ$H$O>e5-$Nh&$J6%Ah$K
$O!$3F8DBN$,FH<+$K9T$&C5:w$H=8CDA4BN$,9T$&6(D4B5C$?$bNP$+$jGO$J$$!%%(!<%8%'%s%HF1;N$O!$8_$$
$HB*$(D>$9$3HbG-$k!%$3NH$-$K!$$=l>lNMMxWr>e2k$?$a$K6(D4$9k3Hb$"$k[11]!%3N$h
$N2M$l66 — >pJs$NEAC#$*hS8r49 — $NLr3d$rC4$&$N9-$$0UL#GN%(!<%8%'%s%H4V$NAj8_:nMQ$r9MN8$KF~
$,!V0dEA!W$N5!9=G"$k!%Nc$($P!$J#?t$N%(!<%8%$1$?%b%G%k$rMQ$$$?I>2AbI,MWKJCF/$k!%$^$?!$$3
$,8_$$$K>pJsNd$j<h$jr9$k:]$K!$$INh$&$J8$497A?%(!<%8%'%s%H4V$KAj8_:nMQ$N%M%C%H%o!<%/$,B8:_
BV$,7k2L$H7F:G$bNI$$8z2L$r@8$_=P$9$3HKJk9kHl9g!$7OA4BN$N5sF0Oh$jJ#;($J%@%$%J%_%/%9$rDh
$$$C$?LdBj$JIKBP7F$3$3$GF@$il?CN8+$O2?$$9kNG"m&[7]!%3N?6$kIq$$$rM}2r9kNK!$%+%*%9
<(:6$rM?$(F@$k!%$^$?!$JL$N6=L#?<$$OCBjH7$F!$JPNJ#;(7O$N2J3X$K4p$E$$$?2r@ObI,MWKJCF/$k
G>JI$N?M9)E*$JCNE*%7%9%F%`9=C[$NMxE@$N0lDH7Fol$k[17]!%
<wL?$N@)Ls$,B8:_7J$$$3H,7P7P5s2ilk$,!$
K\9F$GF@$il?CN8+O3$NAGKQ$JD>4QKBP7$F:F9M$rB%7kO@
$9!%K\9F$G9M$($F$$$k%i%^%k%/7?$N0dEA5!9=$G$O!$<+A2FGO!$F0E*$GM=B,ITG=$J?6$kIq$$$rDh9k3+J|7?
EqBA$d0dEA;R$N8r:5$dFMA3JQ0[$JIN8z2LO"k,$N4D6-$K$*$$$F$O?J2=E*%(!<%8%'%s%H$N35G0$,=EMW$K
$N!$?F$N3X=,7k2L$r;R$,$=N^$^<u$17Q0H$$$&BJKDH$NN)>l$+$i!$3X=,$N8z2L$H0dEA5!9=$,%(!<%8%'%s
$J0UL#$G$O!$8+J}rJQ(kH<wL?$rL5$/$73X=,$r1?H=8KD$N?J2=$KM?$($k1F6AKD$$$F!$%K%e!<%i%k%M%C%H
B3$1$k3H$r2DG=$K9k;EAH$_$H7FB*$($k3HbPMh/$H0dEAE*%"%k%4%j%:%`$rMQ$$$?Cj>]E*$J%b%G%k$r
$k!%$H3m$,K\9F$G$N<B837k2L$Khk$H!$F0E*$J4DMQ$2$?%7%_%e%l!<%7%g%s$KhjI>2A7?!%F@il$?7k2L
GO3&7??M9)E*$J%7%9%F%`$K<wL?$,B8:_$7$J$$$3HakH!$0J2<$NH*jKJk!%
$O5Q$C$FITMx$HJjF@k3H,M=A[5l$k!%$`7mEl.E@EE*$J4D6-$N2<GO!$%@!<%&%#%s7?$N0dEA5!9=$h
$K@$Be8rBe$r7+$jJV$9$3H,=EMWG"$j!$$7$+$b$=$Nhj$b%i%^%k%/7?$N5!9=$NJ}$,8zN(NI$/4D6-$KE,1~$G
$N>pJs$NEAC#$O%@!<%&%#%s7?$N5!9=$K4p$E$$$?bNGJ$k!%
1lPJiJ$$!% 2. F0E*$J4D6-$N2<GO!$%@!<%&%#%s7?$N0dEA5!9=$N
0lJ}$G!$K\9F$GMxMQ$7F-$?%b%G%k$N0lHL@-$dBEEJ$}$,%i%^%k%/7?$N5!9=KHfY$F!$4D6-$NJQF0$KBP$7
@-$K4X$9$k8!>Z$O=EMWG"$k!%Nc$($P!$K\9FGO!$%($F0BDj7?5sF0$r<($7!$4h7r@-$KM%lk!%
%8%'%s%H$N3X=,$N2aDxH7$F%K%e!<%i%k%M%C%H%o!<%3.$N5iK!$F0E*$J4D6-$N2<$G$O!$%@!<%&%#%s7?$N0d
%b%G%k$rMQ$$$?!%%K%e!<%i%k%M%C%H%o!<%/$N3X=,$N?J$EA5!9=$O4h7r@-$KM%$lkP$+$jGJ$/!$=y!9$KJ?6Q
J}$OA2?JE*$G$"$j!$;~$H7F6I=j2rKJaolF<sHxNI$/$JE,1~EY$r>e>:$5$;$F$$$-!$F0E*$J4D6-<+BNXN

E,1~@-$r;}$C$F$$$k!%

K\8&5f$N:GBg$N9W8%$O!$$3l^G"$^$j0Y5lF3J+C?F0E*$J4D6-2<$G$N%@!<%&%#%s7?$H%i%^%k%/7?$N0dEA5!9=$NHf3SI>2A$r9T$C$F!$$=$NFC@-$rL@i+K7$?$3HG$"$k!%

J8CfGO@8J*3XE*$JMQ8l$rB?MQ7F$$$k$,!$K\<AE*ON$O!V>pJs$N<}=8!&3hMQ!&EAC#!W$N2aDx$G$"$k!%7W;;5!$N@$3&N_Ji$:!$<B@$3&$NIN%l%Y%k$N7O$b!$F0E*$J3+J|7?J,;64D6-H7FNMMAjrDh9$k!%$7$?$,CF!$$3$3$GF@il$?CN8+$O!$%=%U%H%&%'%"%(!<%8%'%s%H$N9=C(K!$d%(!<%8%'%s%H4V$G$NCN<1$NEAC#$*$h$S6&M-$NJ}K!$H$$$C$?OCBj$N$_$Ji:!$3+J|7?J,;64D6-2<$G1?MQ5l$kMM!9$J%7%9%F%`$N9=C[K!$K$D$$$F9MN8$9$k:]Kb!$2?$i$+$NM-1W$J<(:6$rM?$($kbNG"kH9M$($k!%

<U<-

K\8&5f$K4X$7$^$7$F!$%=%K!<%3%s%T%e!<%?%5%$%(%s%98&5f=j$NBgBt1Q0l;a!$BgJ?E0;a!$KLLn9(L@;a!$C+=_;a$h$j5.=E$J$k%3%a%s%H$rD:$-$^7?!%?4$+$i46<UCW7^$9!%

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