Evolution: 123

- Foundations - *evolutionary dynamics*
- Phylogeny and Ontogeny - *evolution of development*
- Frontiers - *Demons, coevolution, niche construction and cultural change*

Big Background Themes...

- Do we need a new statistical mechanics of evolution - demonic dynamics ?
- What are the limits to organismal and ecological complexity?
- What makes for organisms versus communities?
- How do we extend evolutionary theory to encompass cultural change without over-extending metaphors?

The selective parameters we are going to investigate

$$g_i \xrightarrow[\text{Energy} + \text{Resources}]{r_i} 2g_i$$

origins of replicative advantages

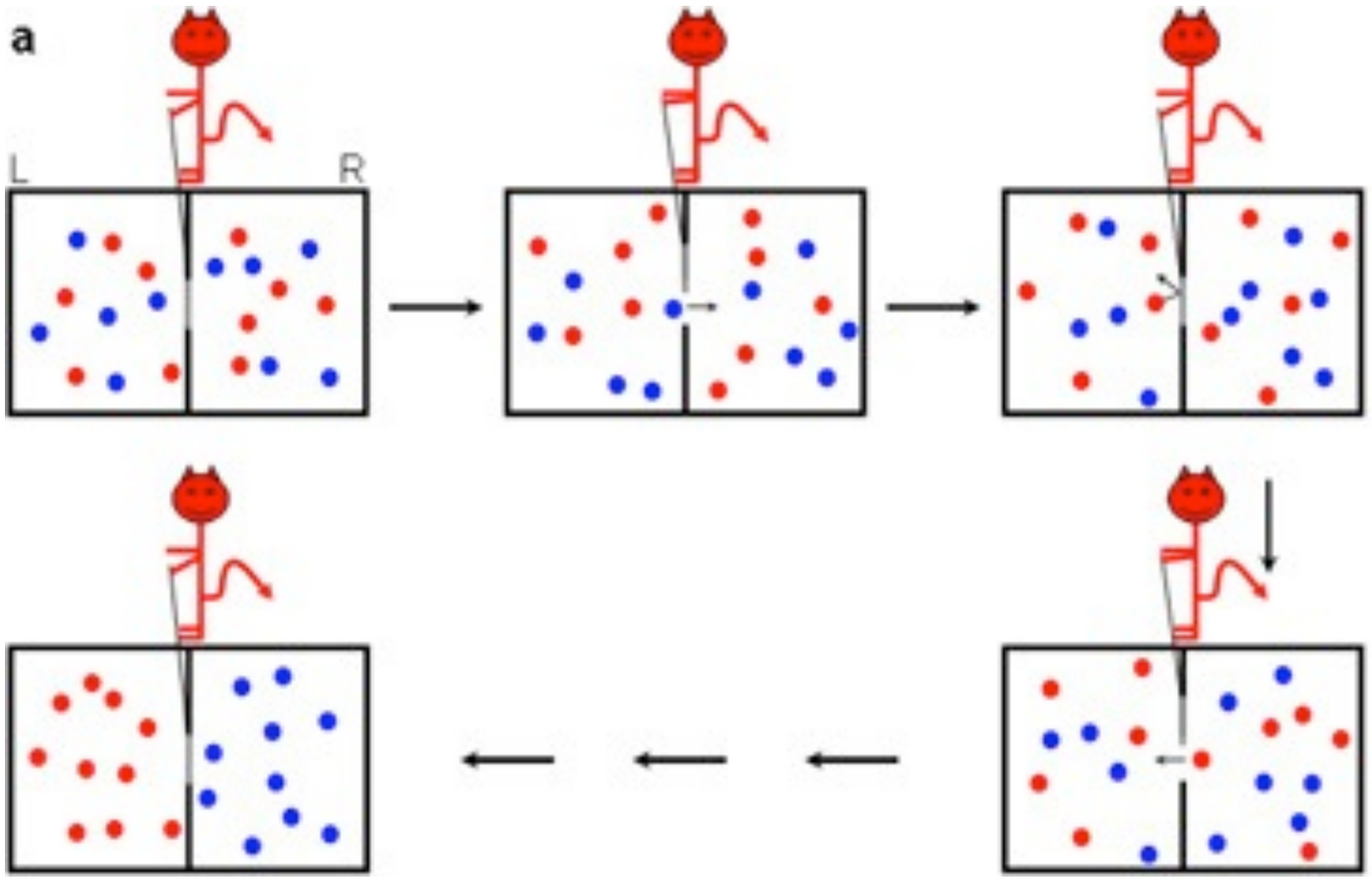
$$g_i + g_j \xrightarrow{c_{ij}} g_j$$

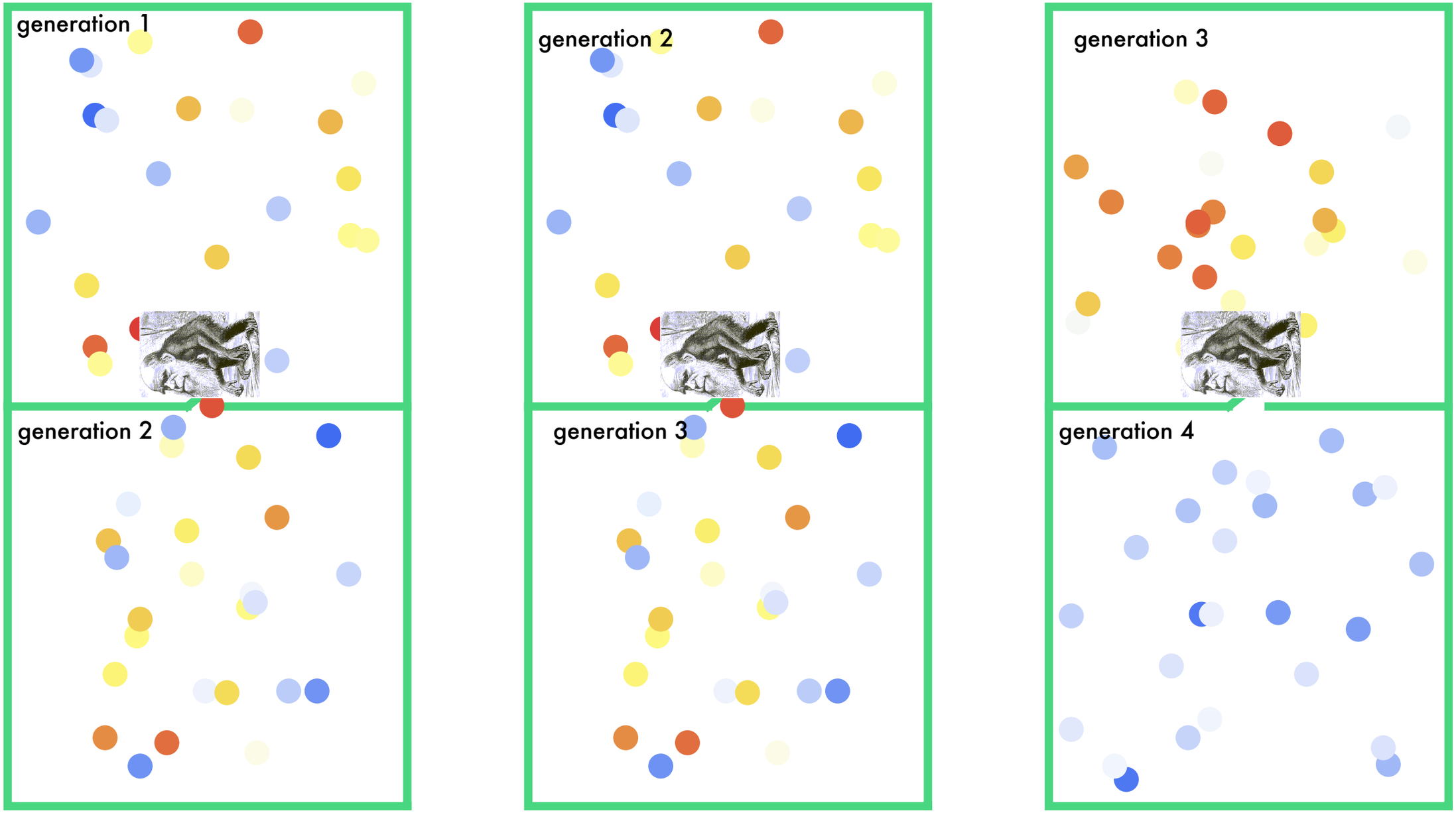
sources of density dependence

$$g_i \xrightarrow{d_i} p_i$$

limitations of genetic models

Maxwell's Demon

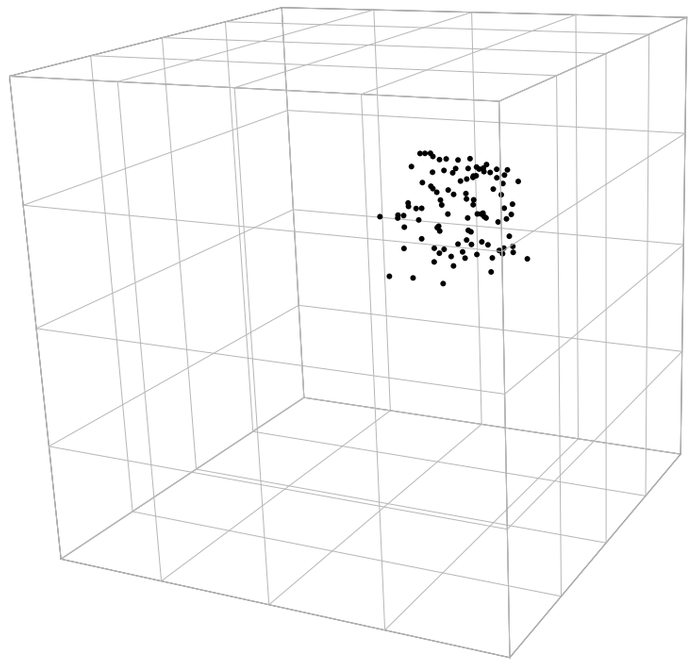



generation 1
generation 2
generation 3
generation 2
generation 3
generation 4

Evolutionary Information Storage

Information Conserved

$$\mu L < 1 < sN$$

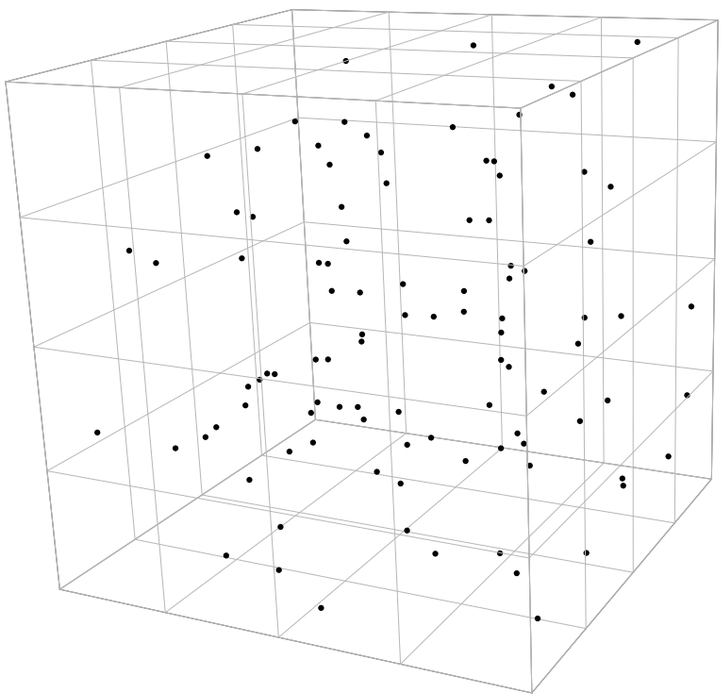


Information Lost

$$\mu L > 1 < sN$$

$$\mu L < 1 > sN$$

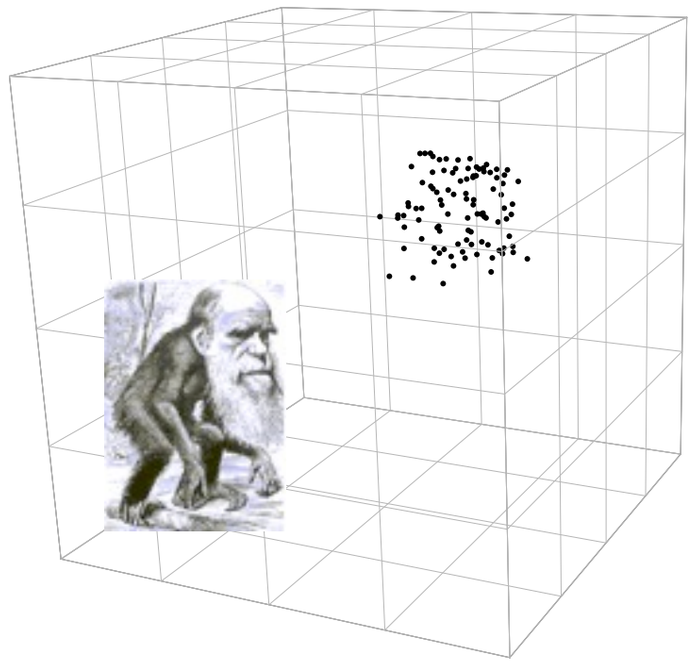
$$\mu L > 1 > sN$$



Evolutionary Information Storage

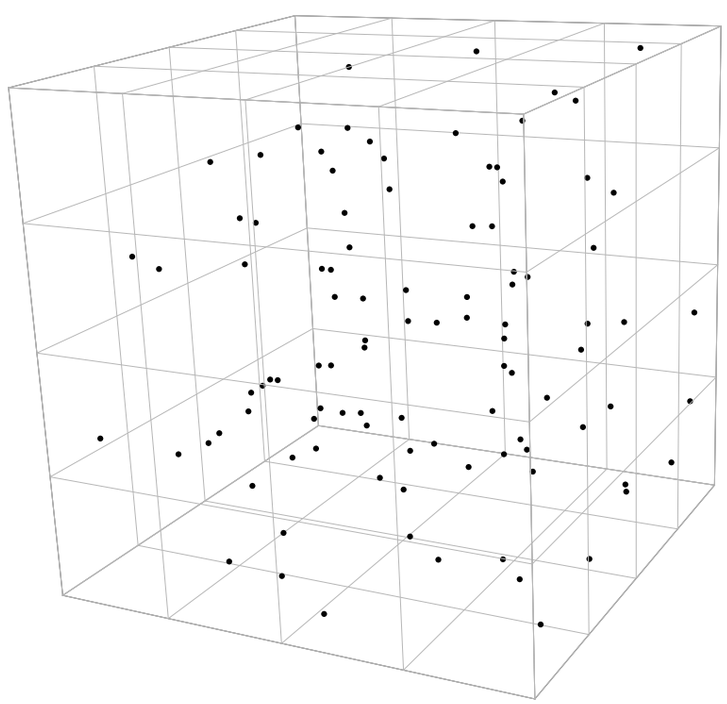
variables localized

$$\mu L < 1 < sN$$



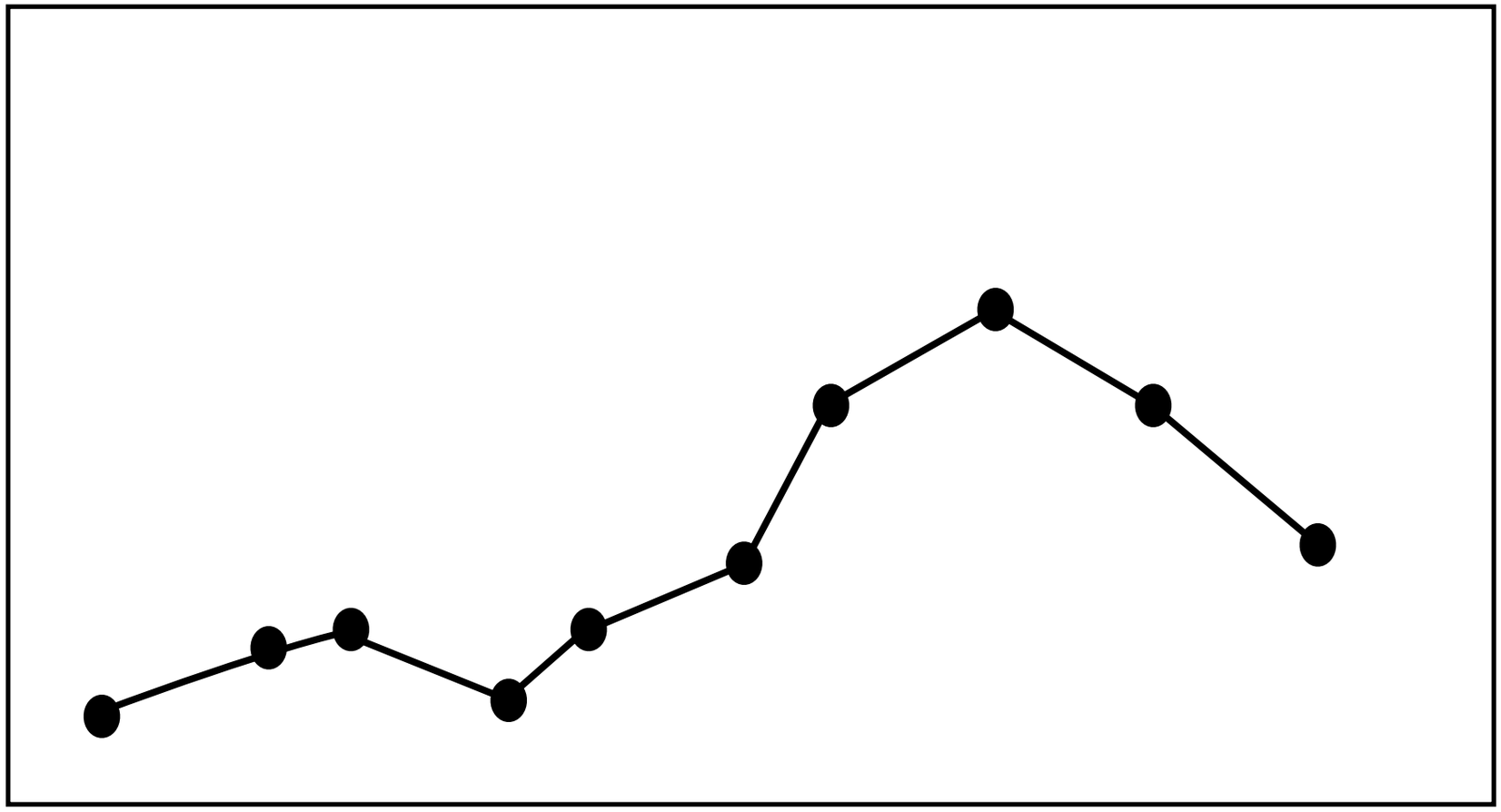
variables Distributed

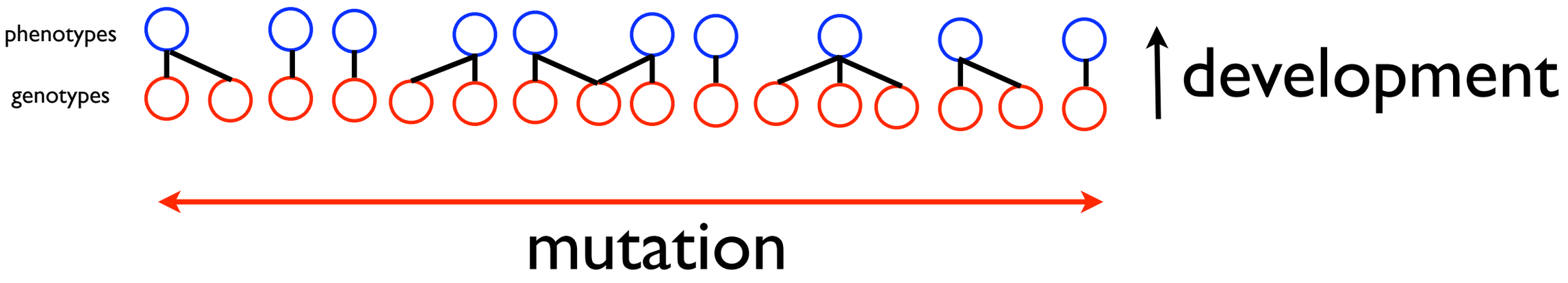
$$\mu L > 1 < sN$$
$$\mu L < 1 > sN$$
$$\mu L > 1 > sN$$

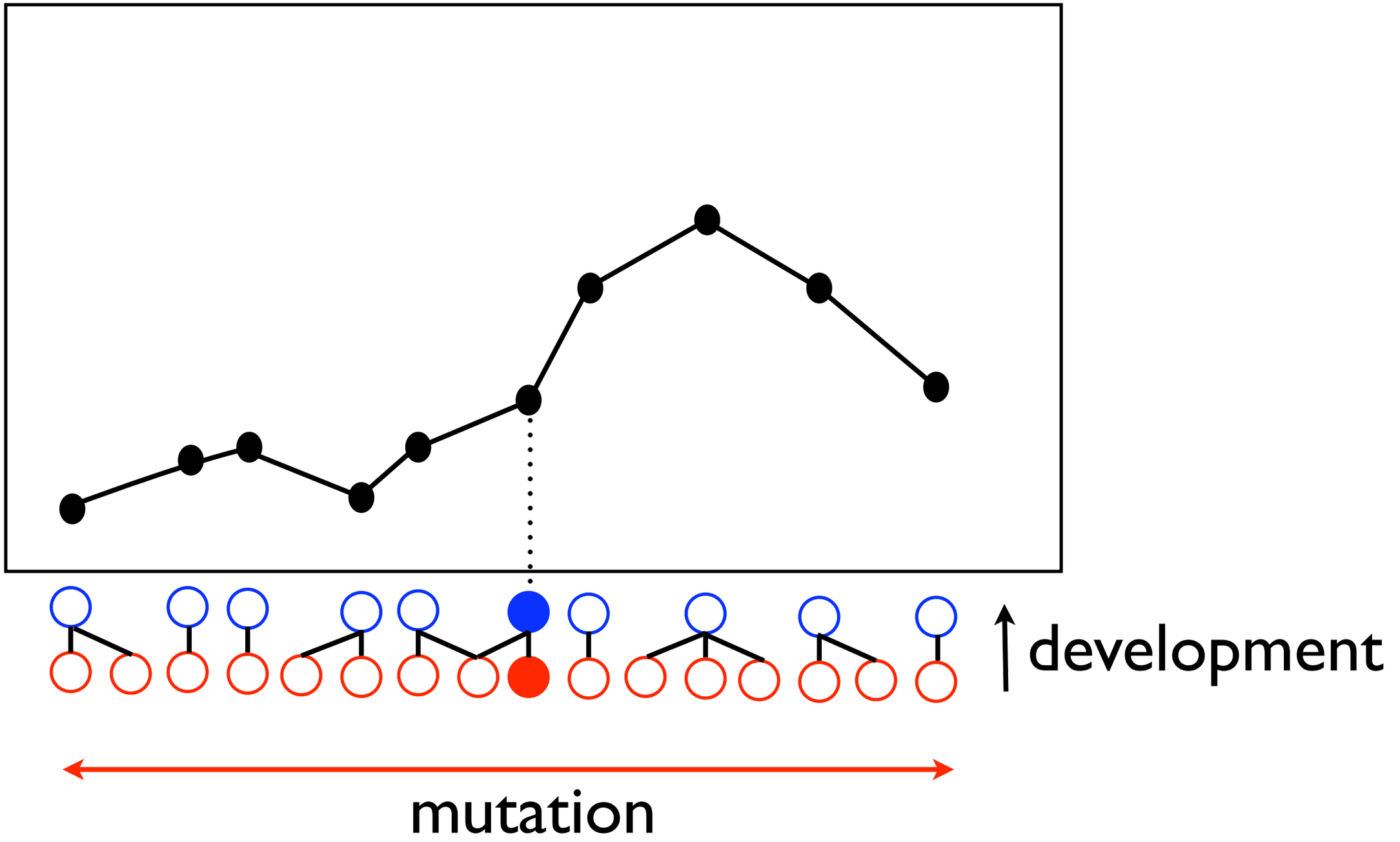


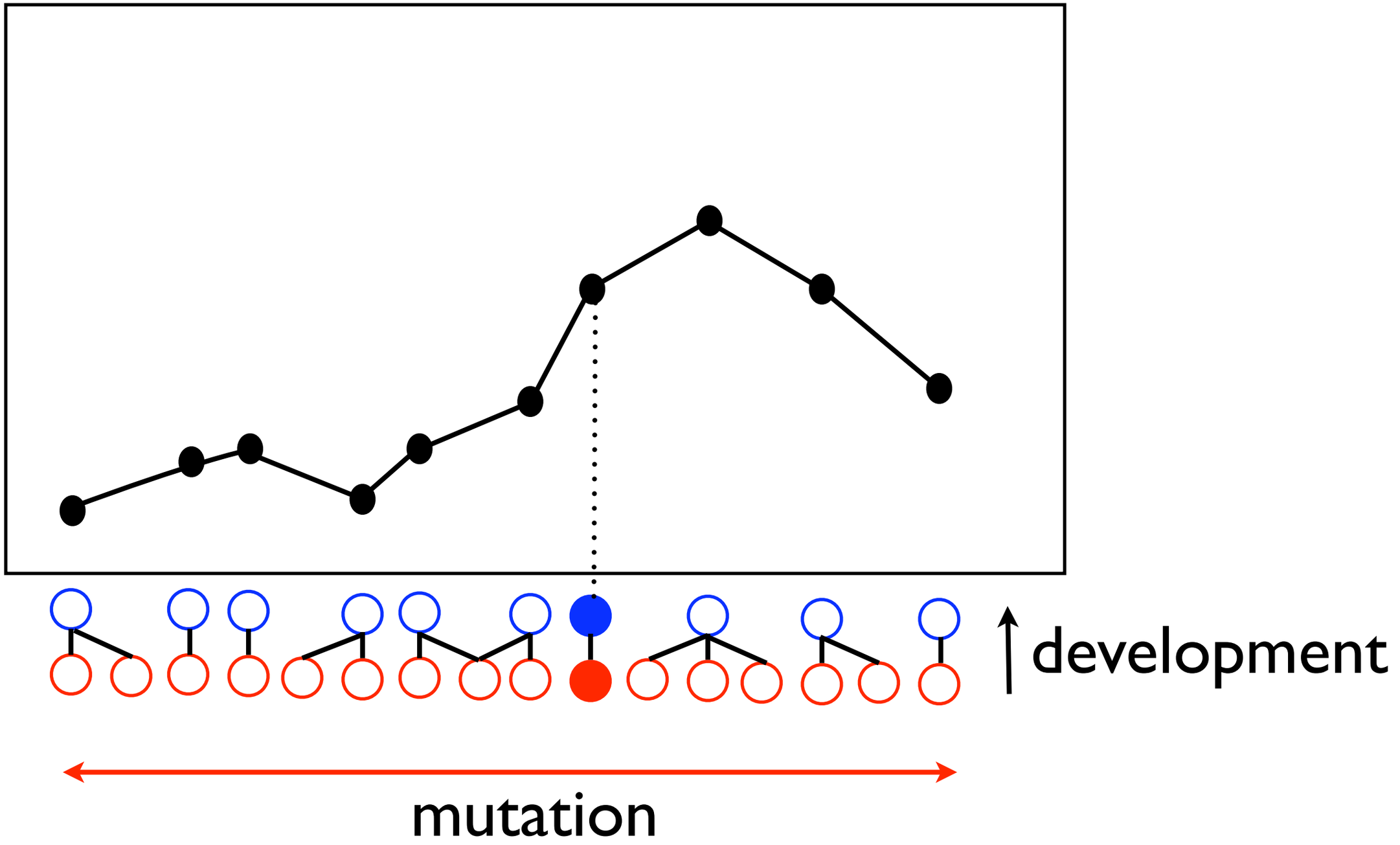
A Demonic Framework

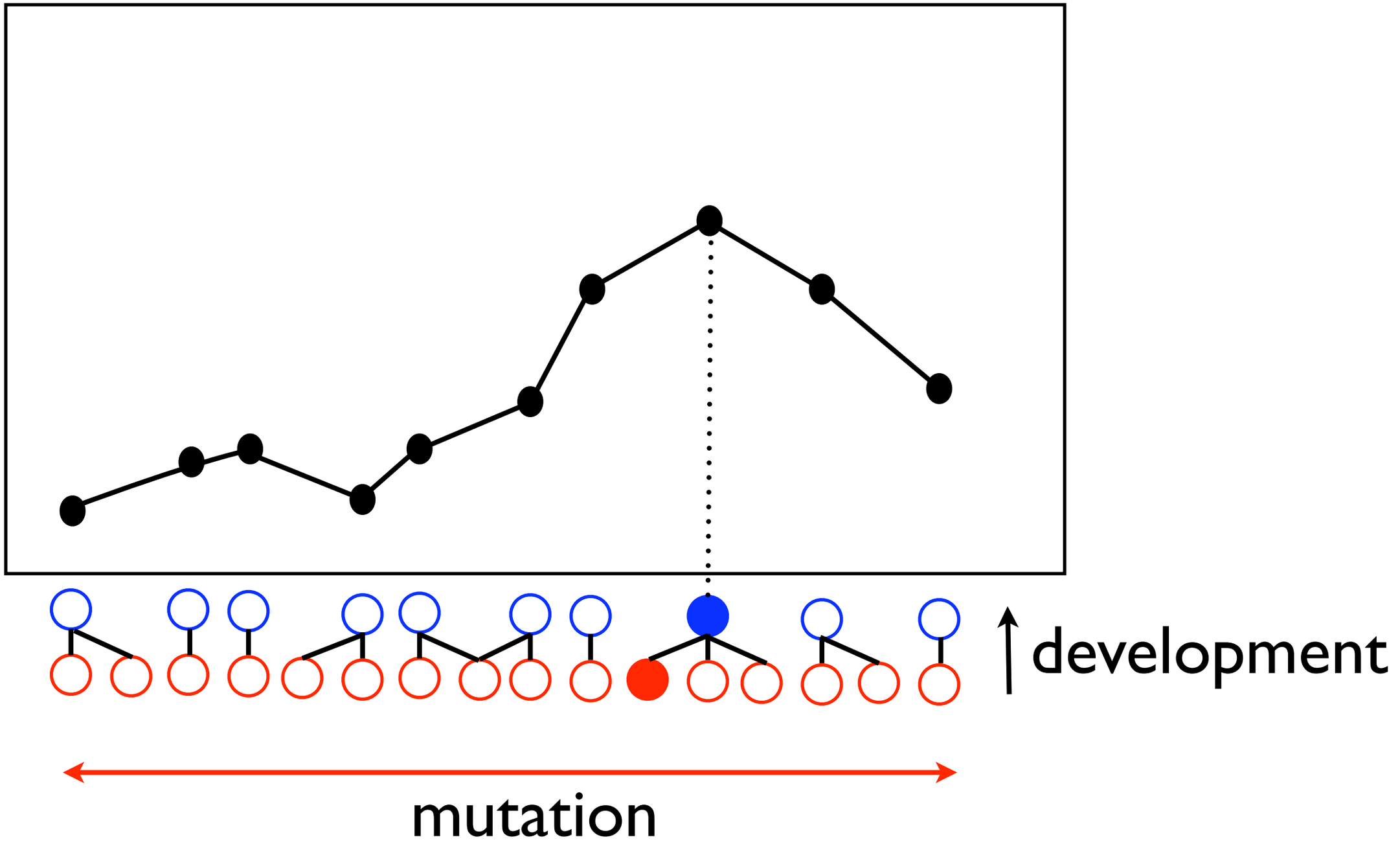
- Organisms as selective environments & internalizing selection
- Organisms creating & externalizing selective environments
- Creating the organism as a selective environment of the genome
- Learning to construct cultural selection

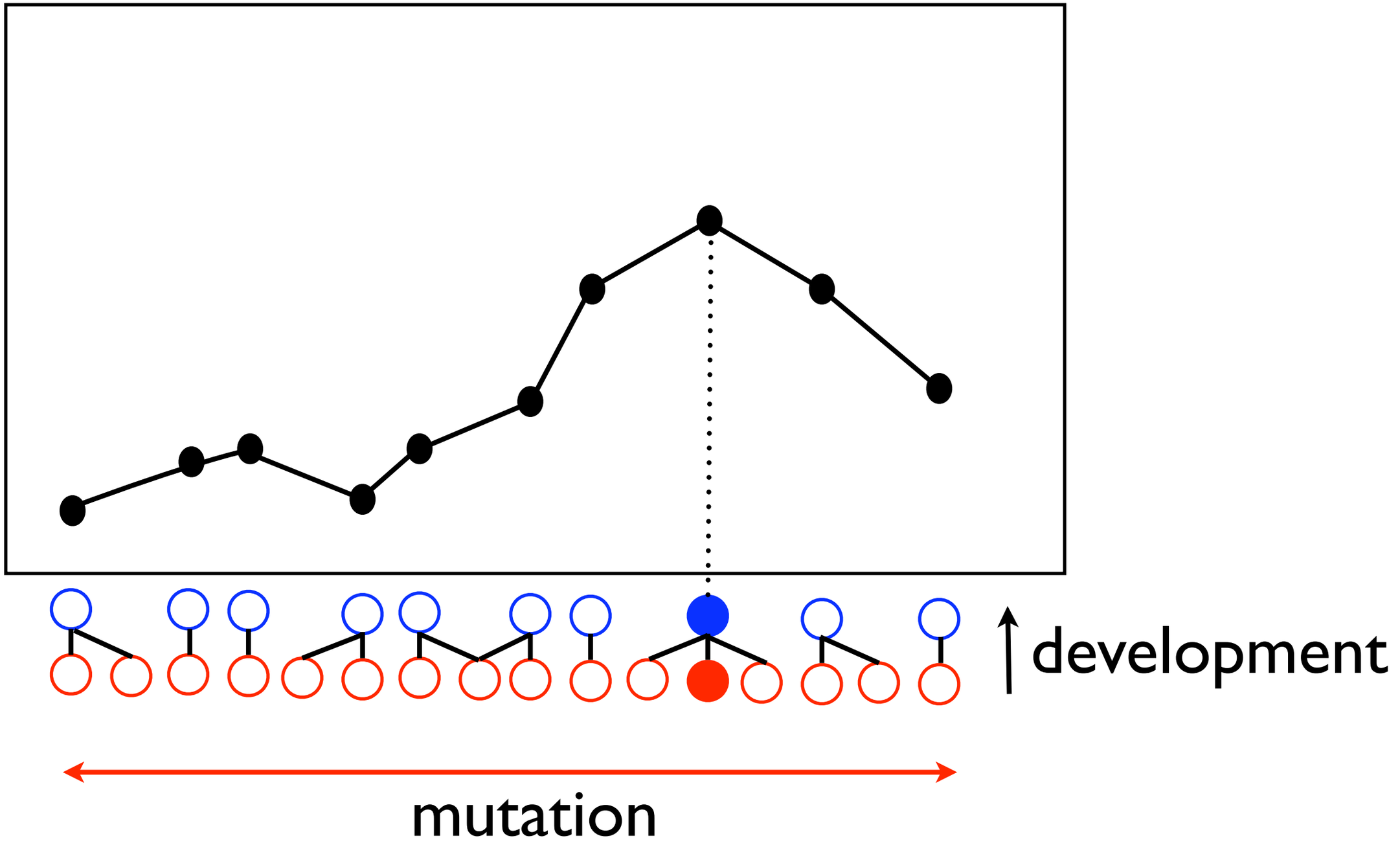



phenotypes
genotypes
development
mutation


development
mutation

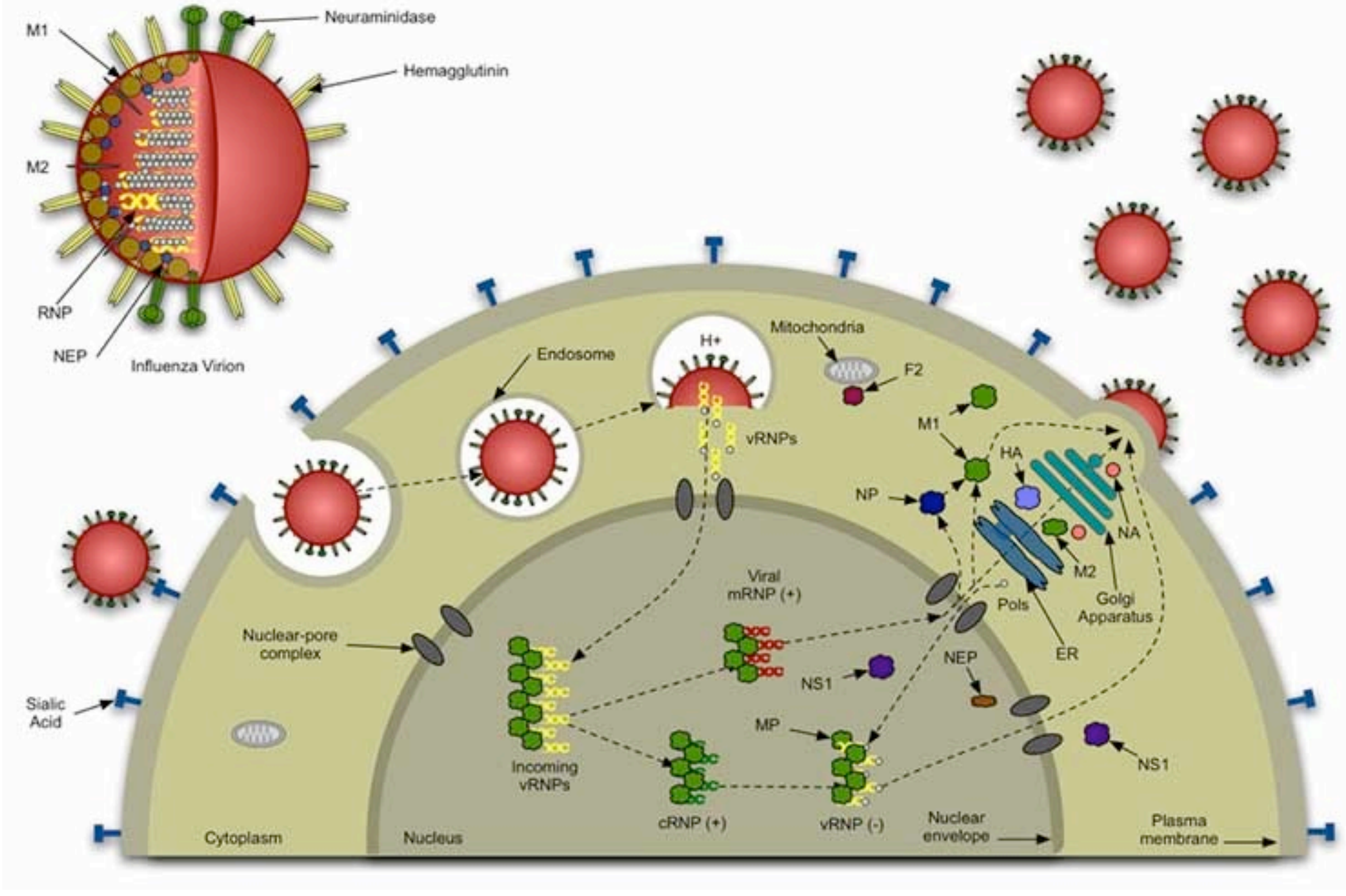

development
mutation


development
mutation


development
mutation

I. Coevolutionary Demons

Organisms as selective environments


M1
Neuraminidase
Hemagglutinin
M2
RNP
NEP
Influenza Virion
Endosome
H+
Mitochondria
F2
vRNPs
M1
HA
NP
NA
M2
Pols
Golgi
Apparatus
ER
Viral
mRNP (+)
Nuclear-pore
complex
NEP
NS1
Sialic
Acid
MP
NS1
Incoming
vRNPs
cRNP (+)
vRNP (-)
Nuclear
envelope
Plasma
membrane
Cytoplasm
Nucleus

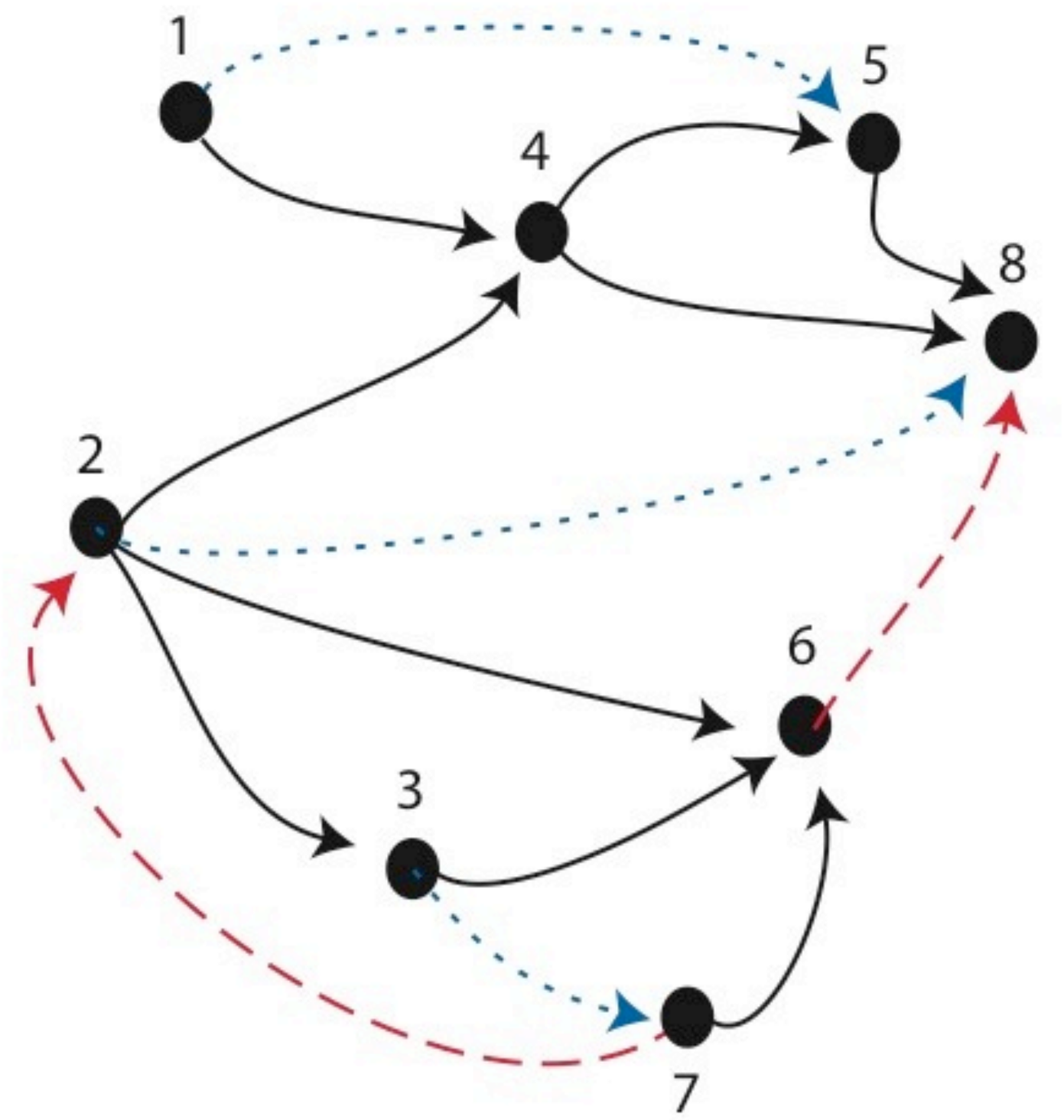
KEY

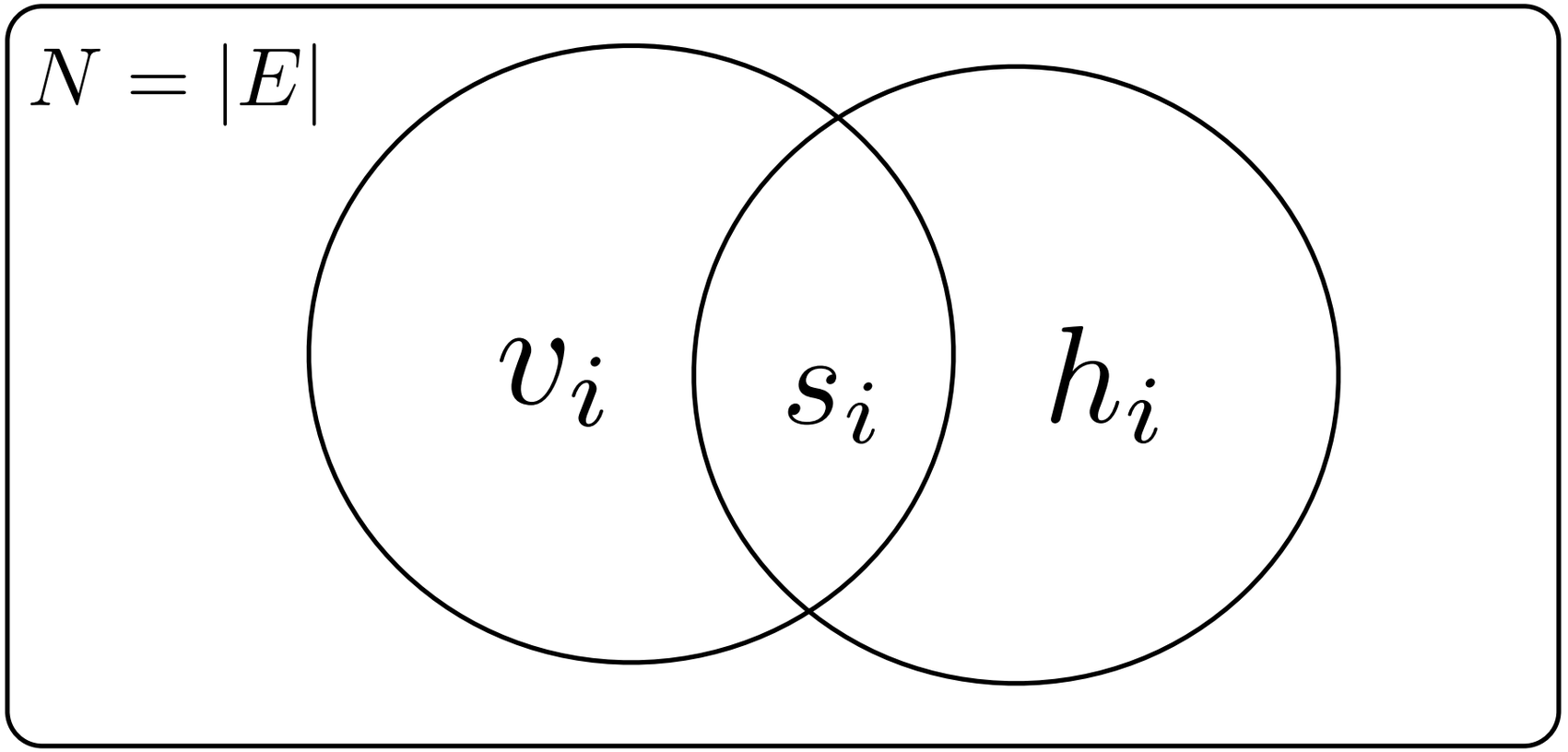
virus catalyzed

host A catalyzed

host B catalyzed

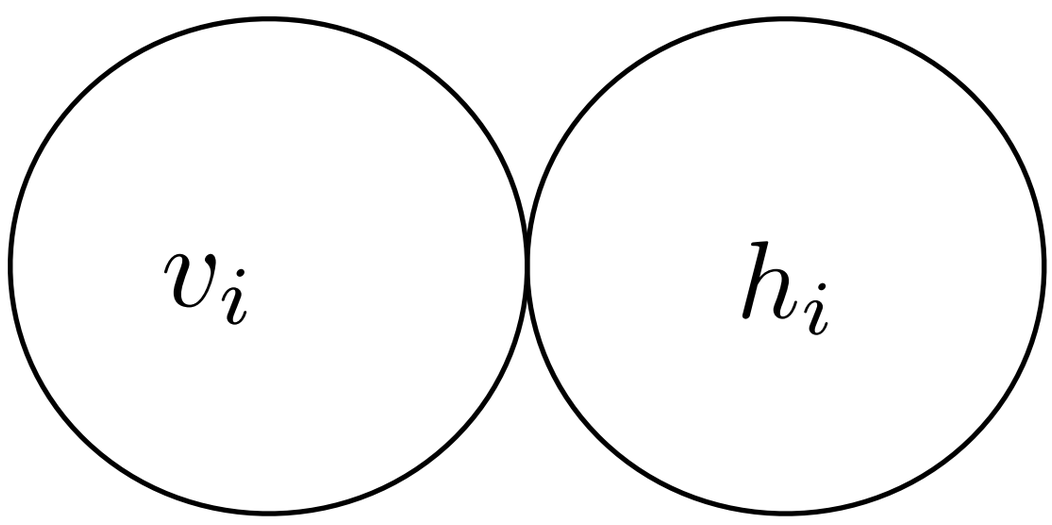
Transmissible Regulatory Networks



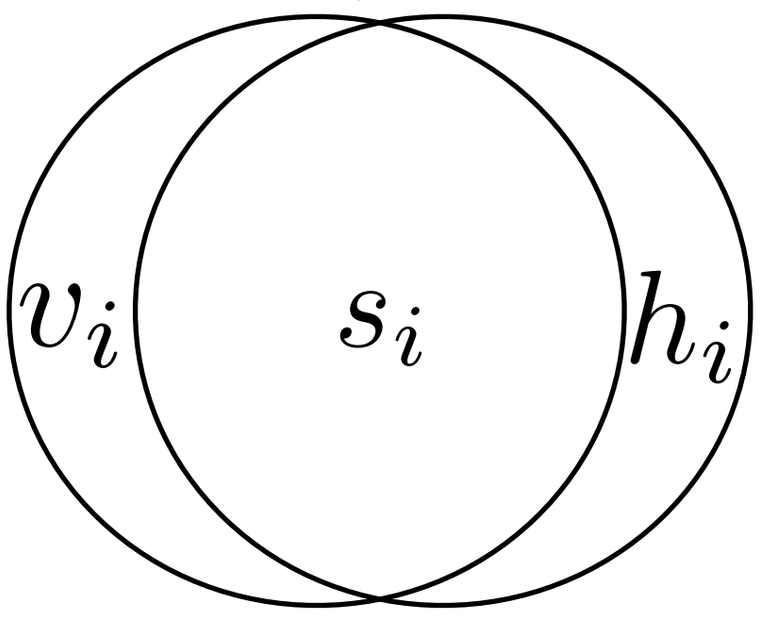


Minimality

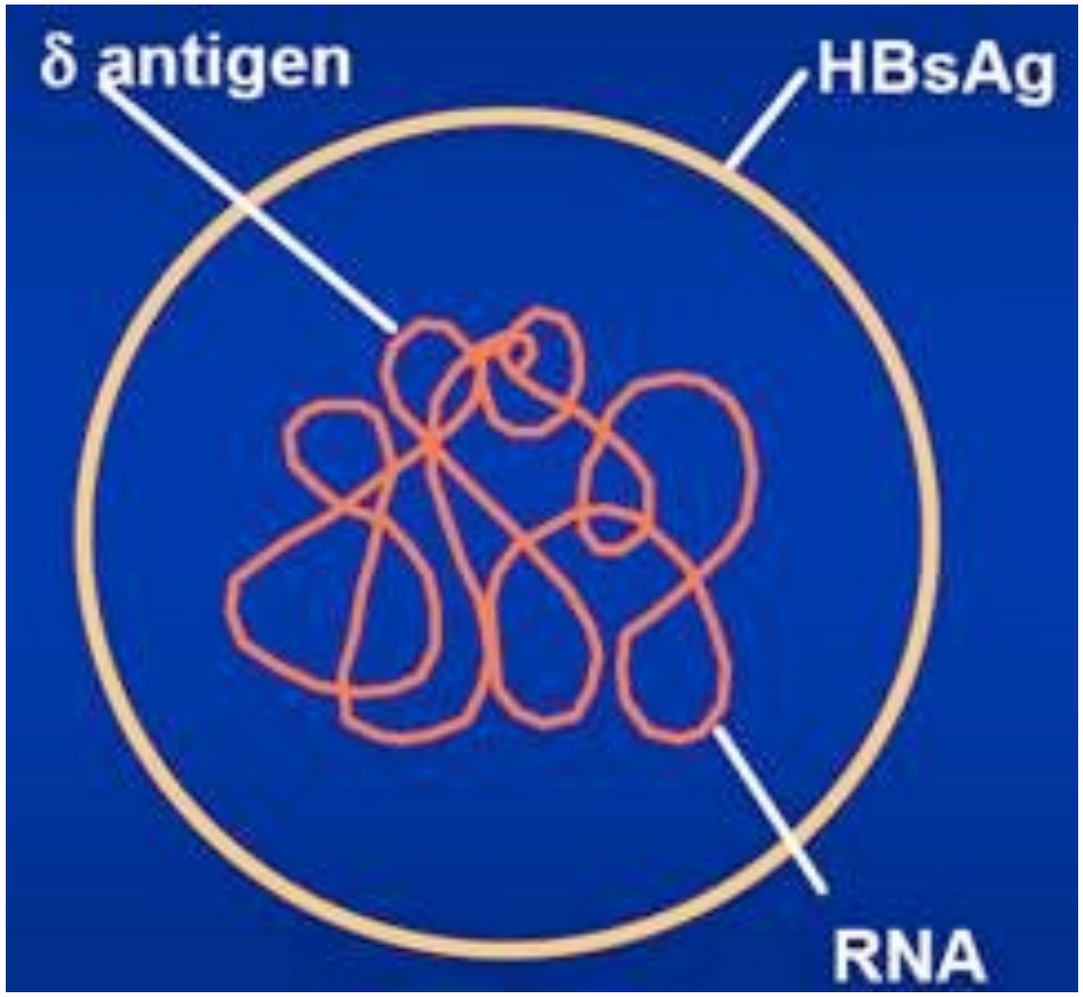
Autonomy

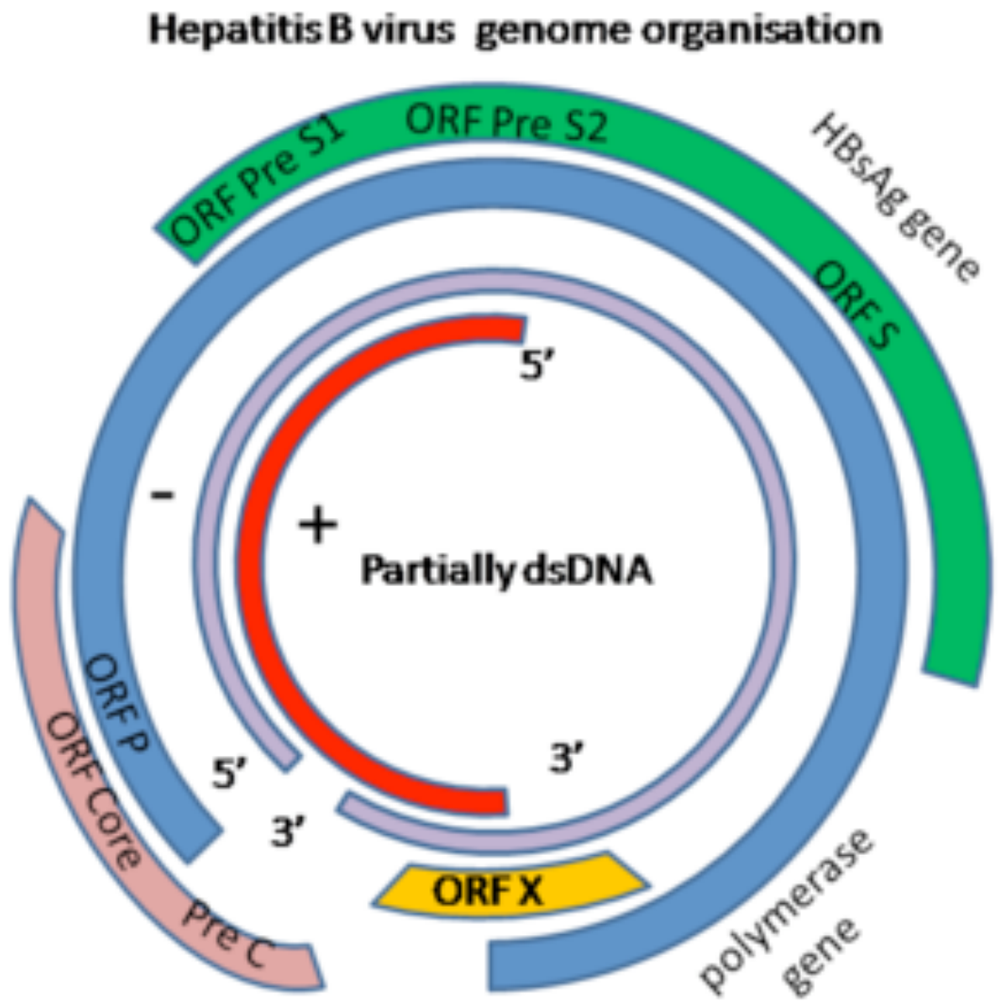


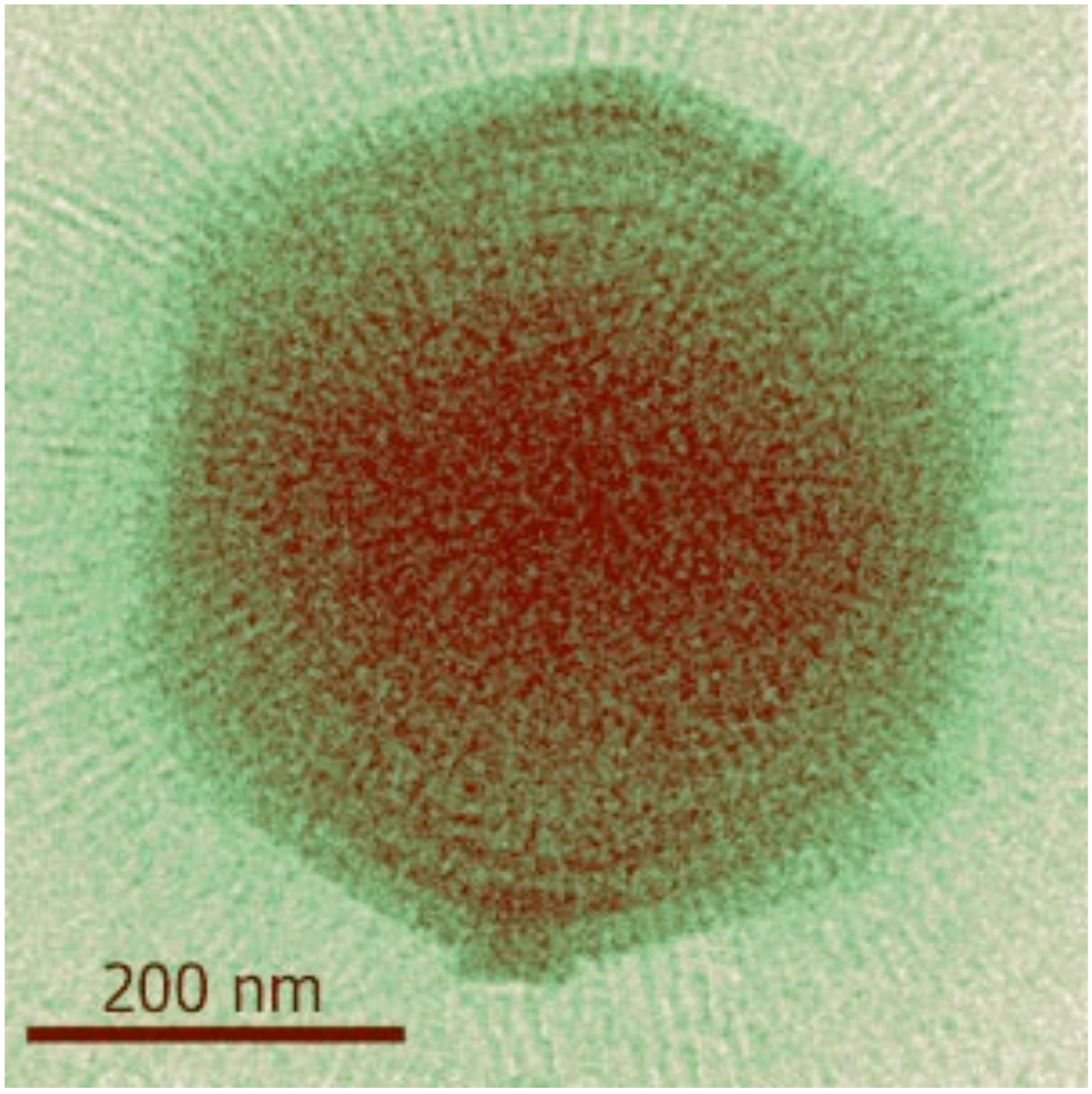
$$|v \cup h| = N$$
$$|v \cap h| = 0$$

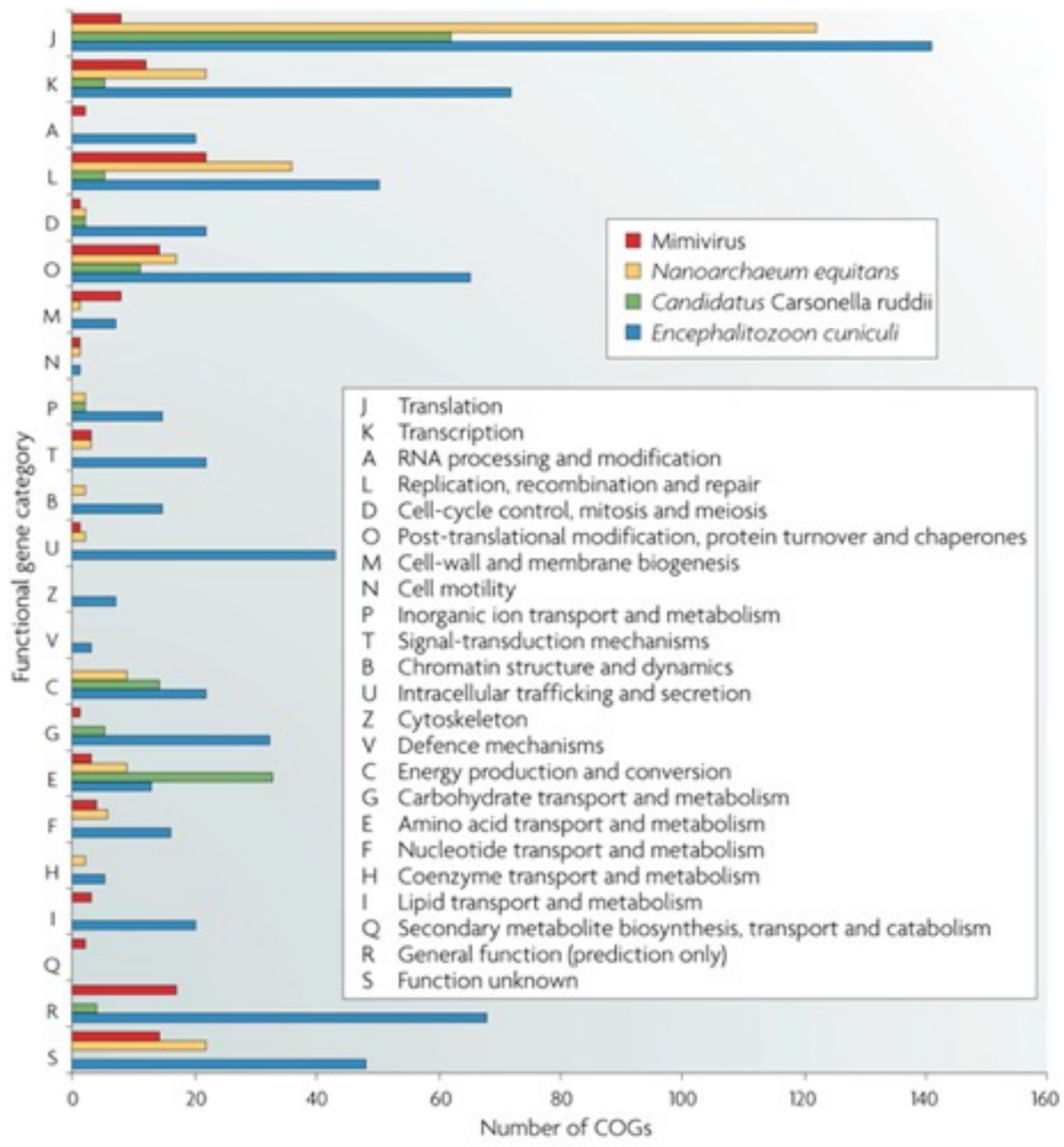


$$|v \cup h| = N$$
$$|v \cap h| \approx N$$


δ antigen
HBsAg
RNA

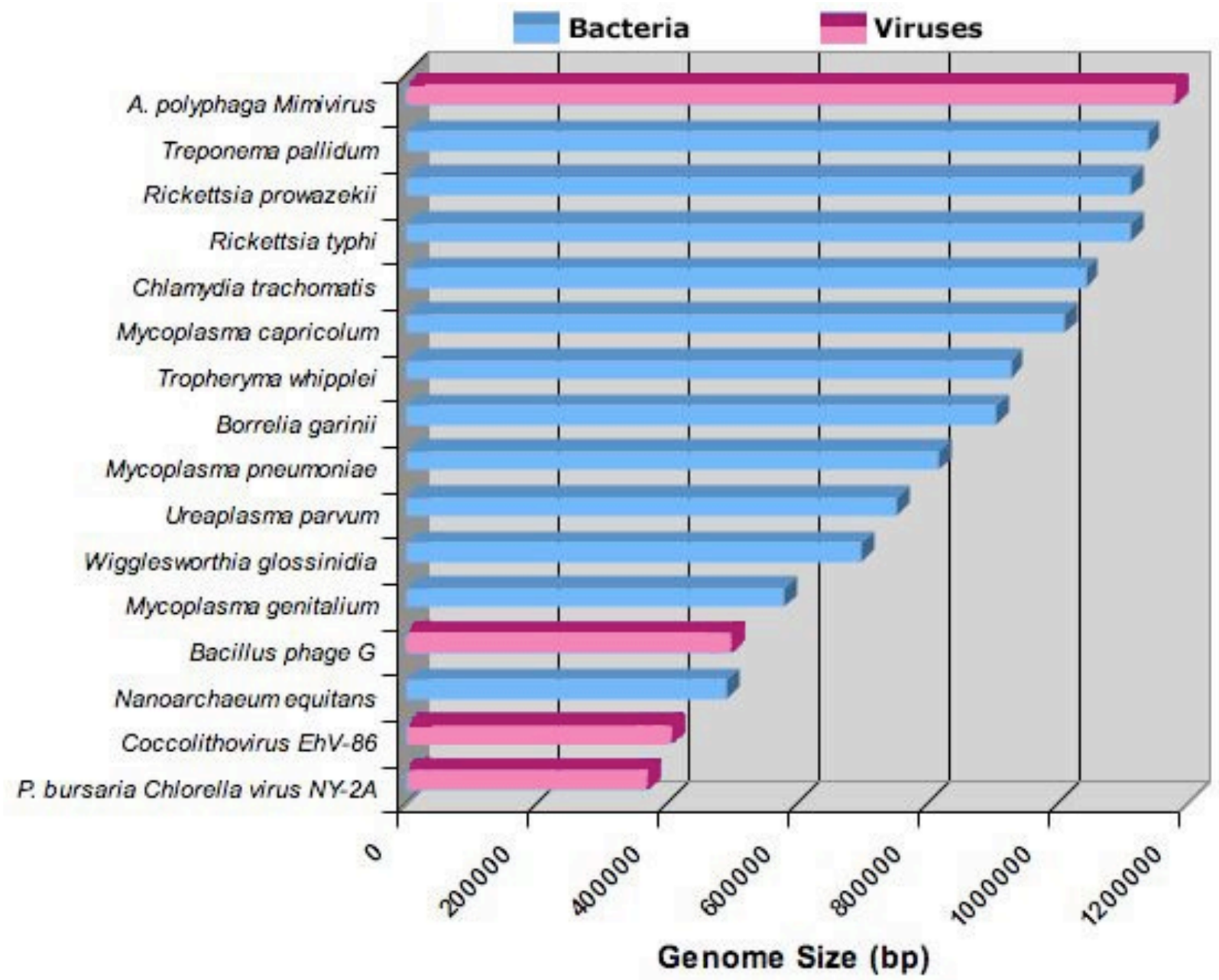

Hepatitis B virus genome organisation
ORF Pre S1
ORF Pre S2
HBsAg gene
ORF S
5'
-
+
Partially dsDNA
ORF P
ORF Core
Pre C
5'
3'
3'
ORF X
polymerase gene





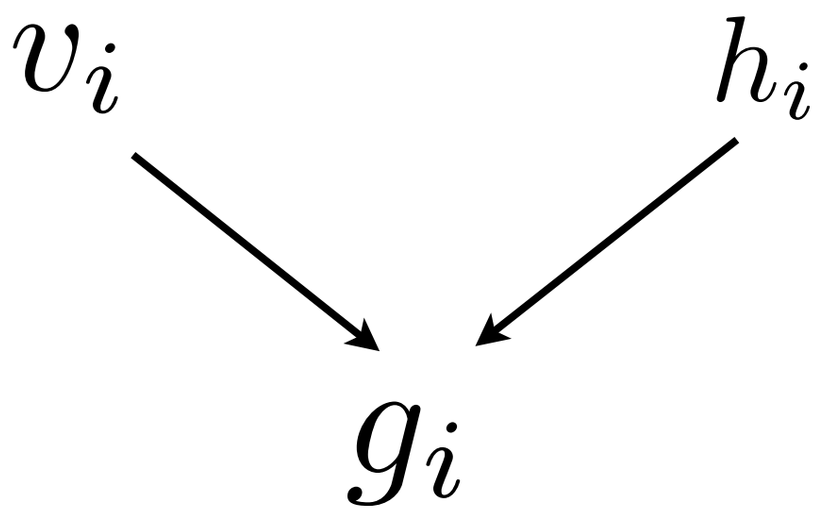
Nature Reviews | Microbiology

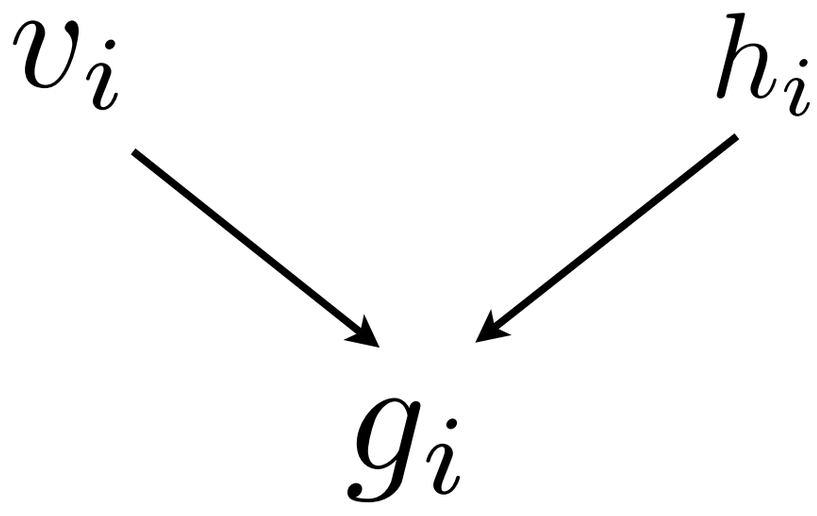
Didier Raoult & Patrick Forterre. (2008)


Bacteria
Viruses
A. polyphaga Mimivirus
Treponema pallidum
Rickettsia prowazekii
Rickettsia typhi
Chlamydia trachomatis
Mycoplasma capricolum
Tropheryma whipplei
Borrelia garinii
Mycoplasma pneumoniae
Ureaplasma parvum
Wigglesworthia glossinidia
Mycoplasma genitalium
Bacillus phage G
Nanoarchaeum equitans
Coccolithovirus EhV-86
P. bursaria Chlorella virus NY-2A
0
200000
400000
600000
800000
1000000
1200000
Genome Size (bp)

$$w = \prod_{i \in E} f(g_i) \sum_{j \in NE} h(g_j)$$

$$w_E = \prod_{i \in E} f(g_i)$$





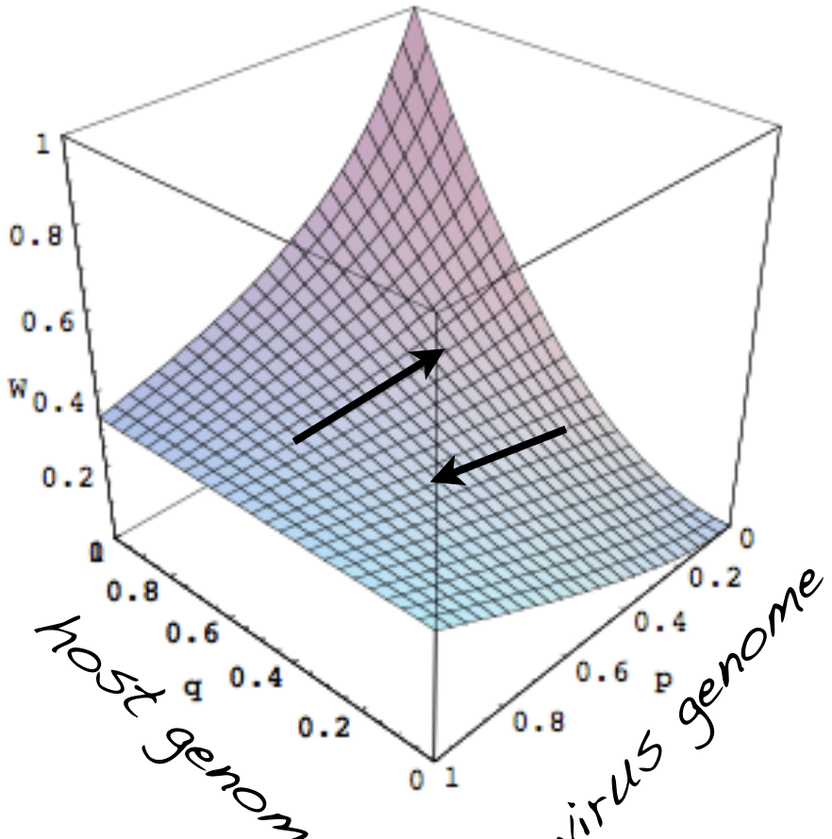
$$g_i = h_i \vee v_i$$

$$Prob(h_i = 1) = q \qquad Prob(v_i = 1) = p$$

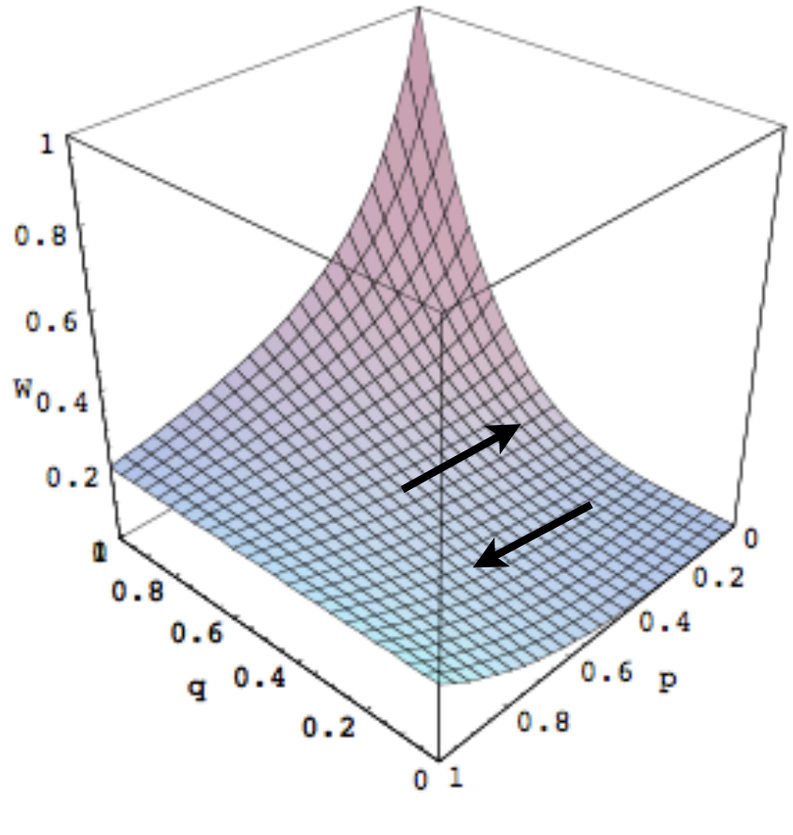
$$L_v = \sum_i v_i, \qquad < L_v >= pN$$

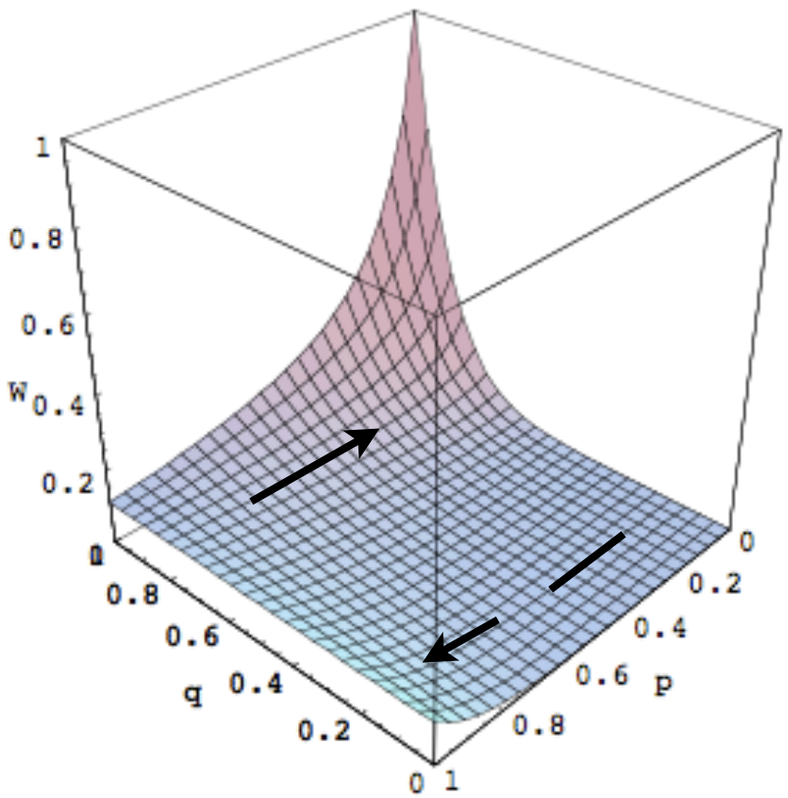
$$w = \frac{\prod_{i \in N} g_i}{(1 + L_v)} \qquad < w >= \frac{(q + p - qp)^N}{1 + pN}$$

N=4

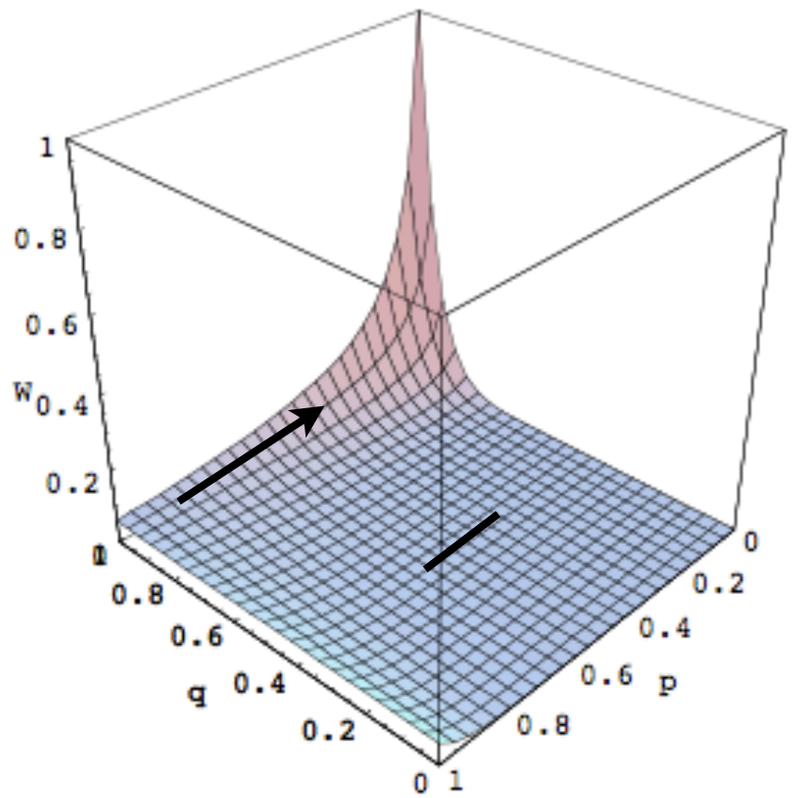

1
0.8
0.6
W 0.4
0.2
0
0.8
0.6
q 0.4
0.2
0
1
0.8
0.6 p
0.4
0.2
0
host genome
virus genome

N=8


1
0.8
0.6
W 0.4
0.2
0
0.8
0.6
q 0.4
0.2
0
1
0.8
0.6 p
0.4
0.2
0

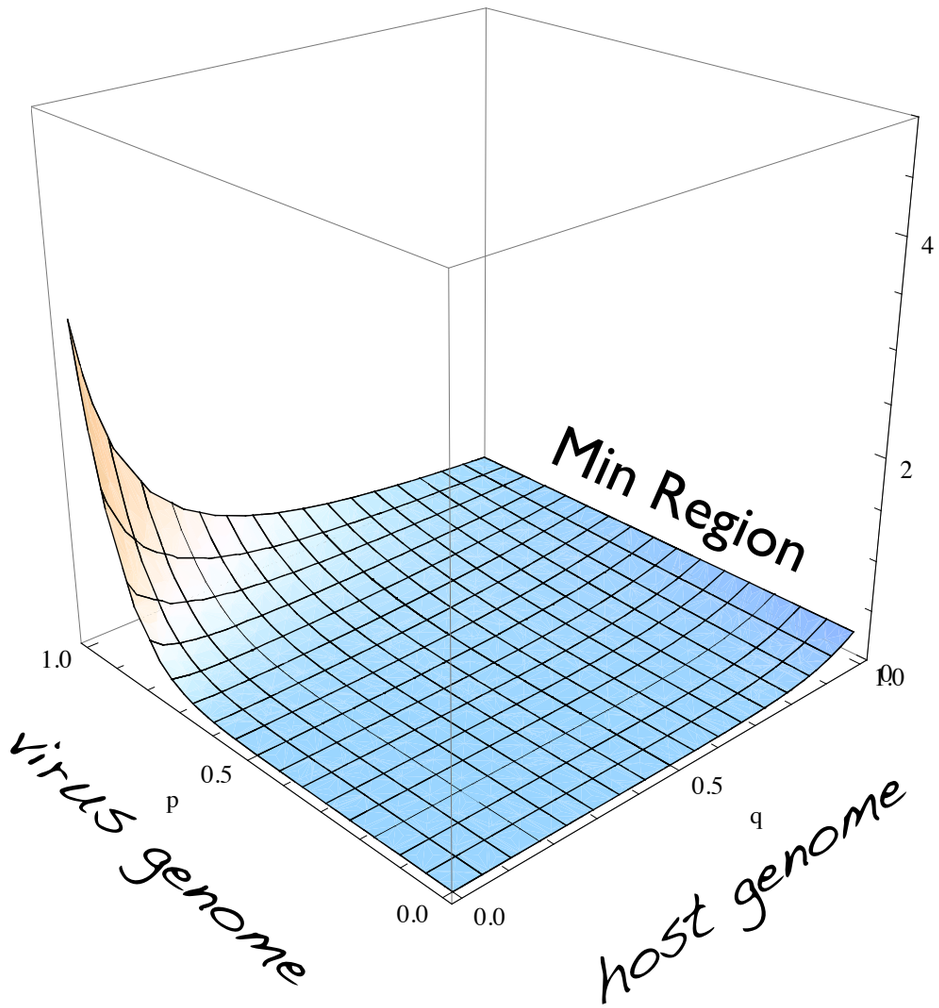

1
0.8
0.6
W 0.4
0.2
0
0.8
0.6
q 0.4
0.2
0
1
0.8
0.6 p
0.4
0.2
0

N=16

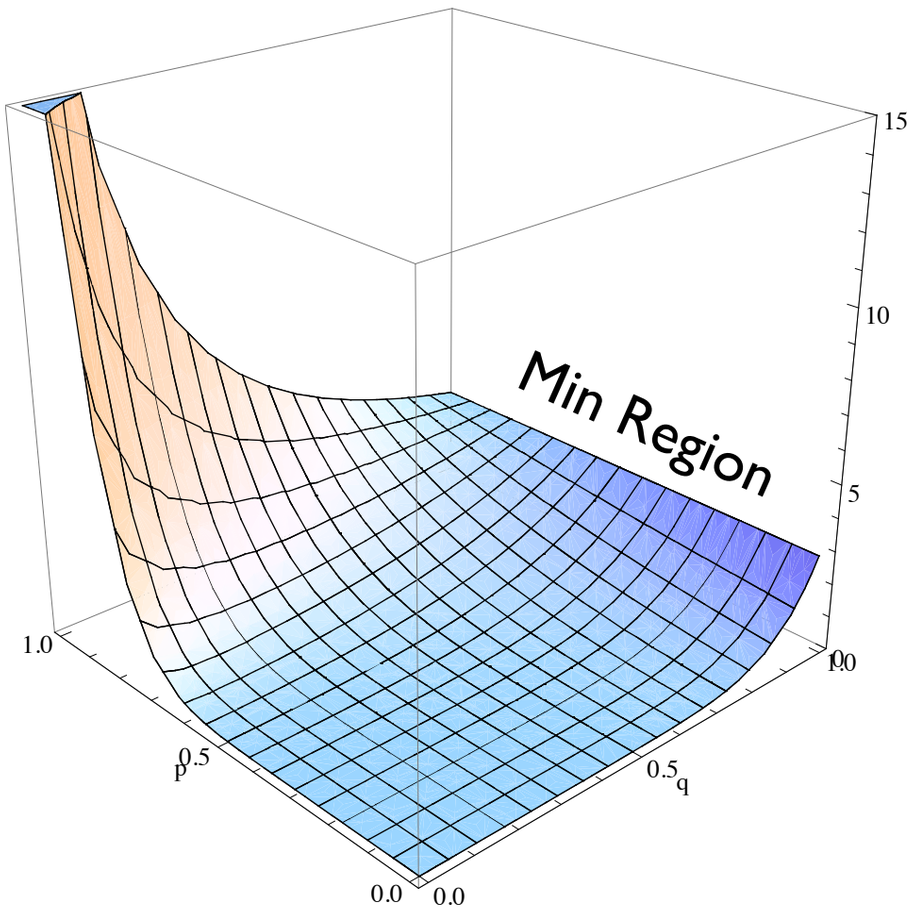

1
0.8
0.6
W 0.4
0.2
0
0.8
0.6
q 0.4
0.2
0
1
0.8
0.6 p
0.4
0.2
0

N=32

$$\langle w \rangle = \frac{N^k (q + p - qp)^N}{1 + pN}$$



k=0.5



k=1.5

II. Niche Constructing Demons

Organisms creating selective environments

STRUCTURE AND DISTRIBUTION

OF

CORAL REEFS.

BEING THE FIRST PART OF
THE GEOLOGY OF THE VOYAGE OF THE BEAGLE,
UNDER THE COMMAND OF CAPT. FITZROY, R.N.
DURING THE YEARS 1832 TO 1836.

BY

CHARLES DARWIN, M.A., F.R.S., F.G.S.,
NATURALIST TO THE EXPEDITION.

Published with the Approbal of the Lords Commissioners of
Her Majesty's Treasury.

LONDON:
SMITH, ELDER AND CO., 65, CORNHILL.
1842.

THE FORMATION

OF

VEGETABLE MOULD,

THROUGH THE

ACTION OF WORMS.

WITH

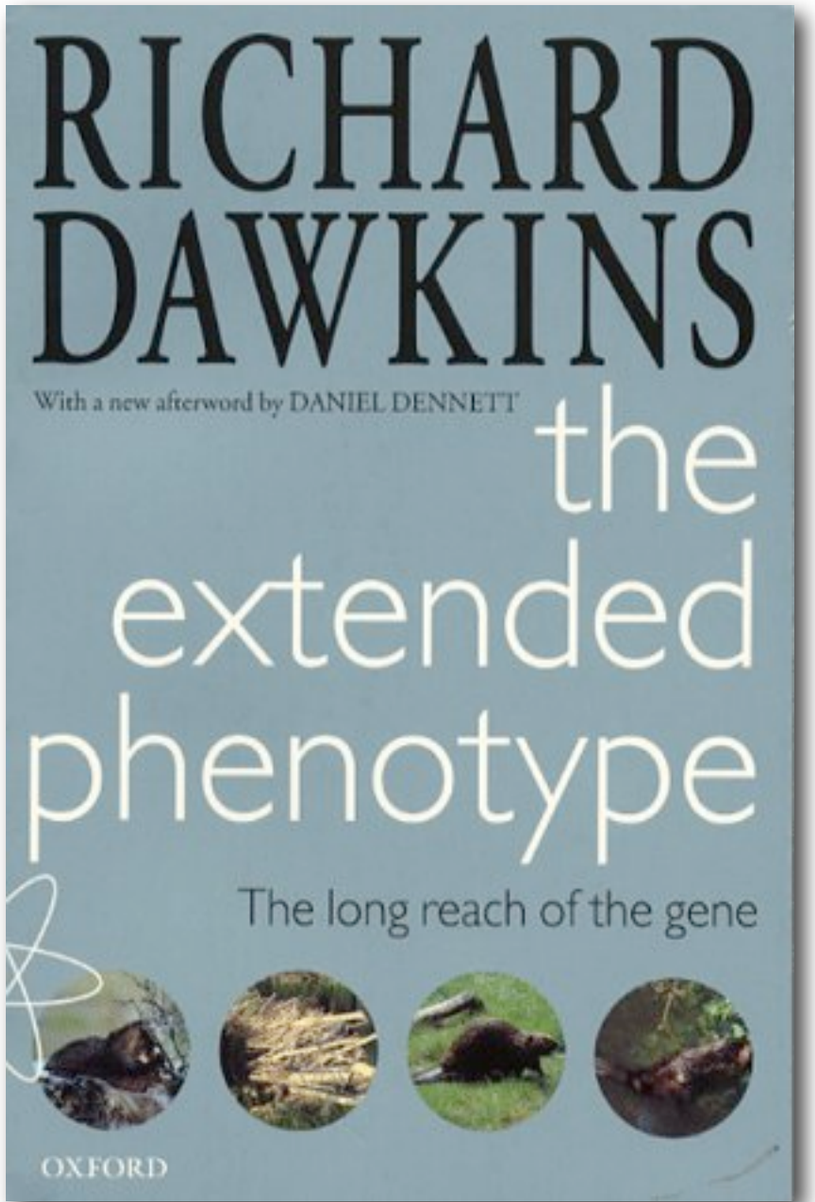
OBSERVATIONS ON THEIR HABITS.

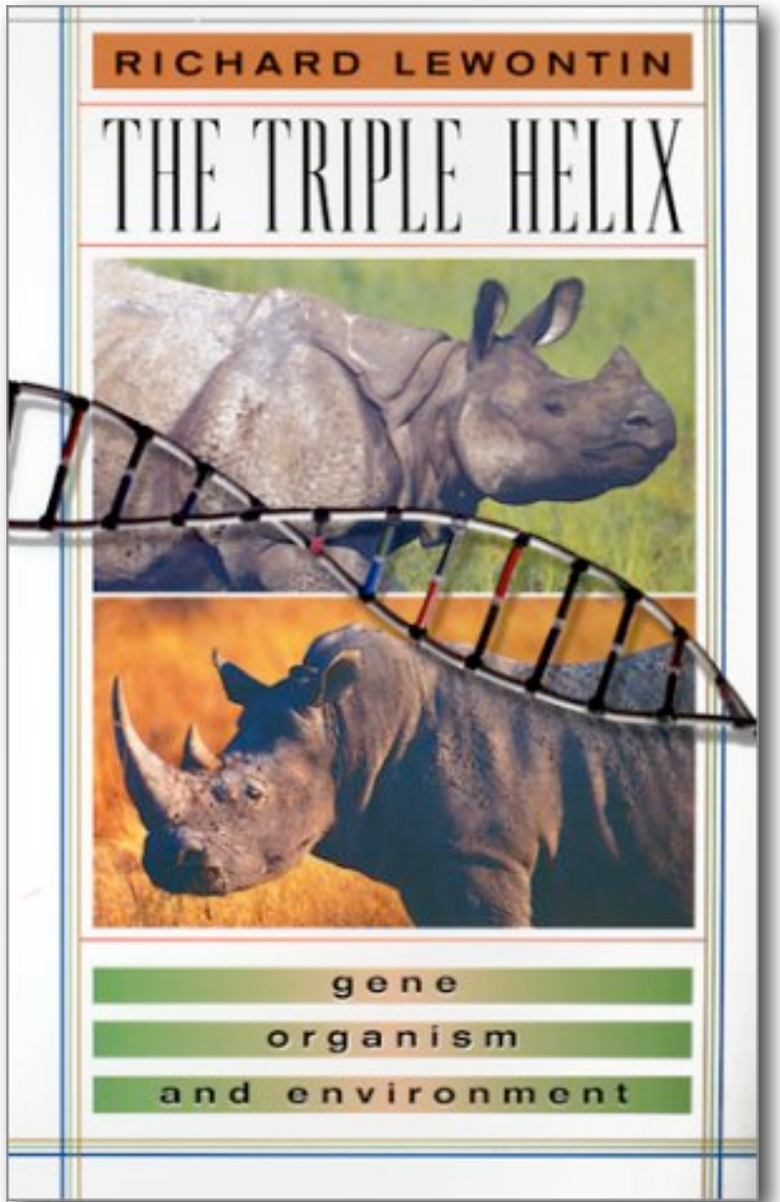
By CHARLES DARWIN, LL.D., F.R.S.

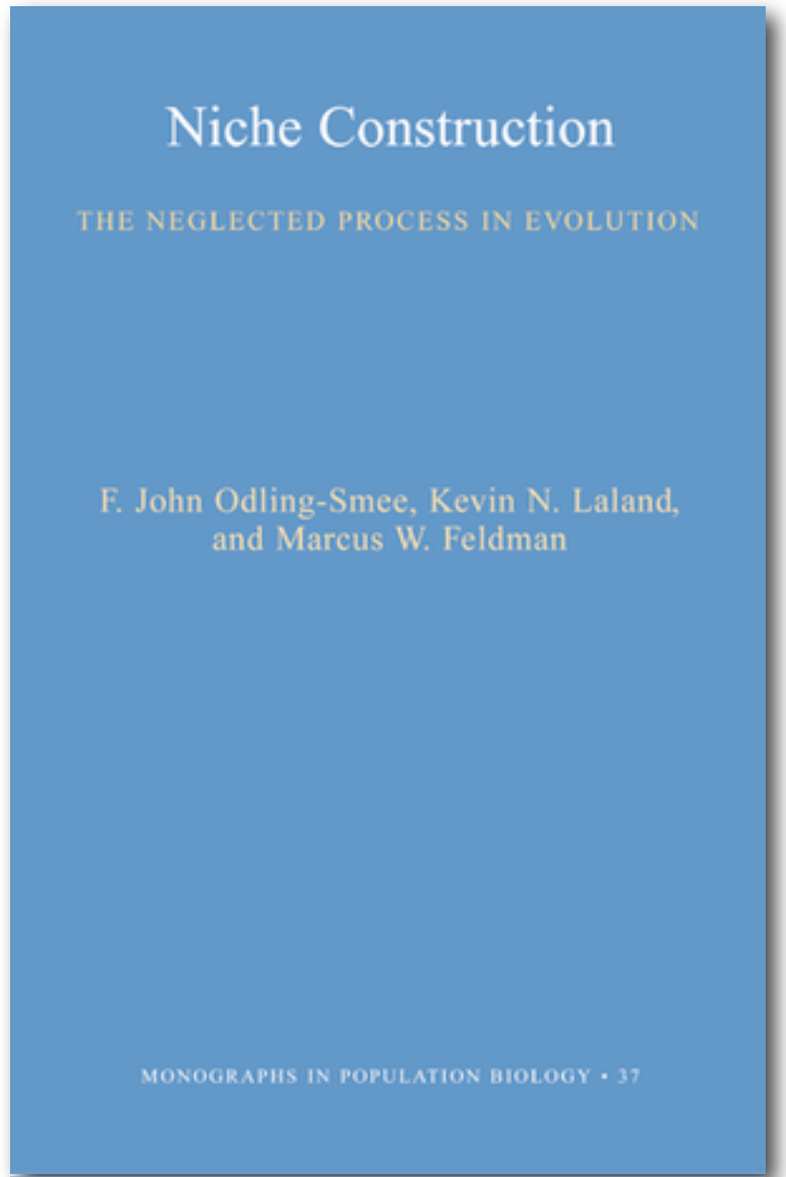
WITH ILLUSTRATIONS.

SEVENTH THOUSAND (CORRECTED)

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1882.


RICHARD
DAWKINS
With a new afterword by DANIEL DENNETT
the
extended
phenotype
The long reach of the gene
OXFORD


RICHARD LEWONTIN
THE TRIPLE HELIX
gene
organism
and environment


Niche Construction
THE NEGLECTED PROCESS IN EVOLUTION
F. John Odling-Smee, Kevin N. Laland,
and Marcus W. Feldman
MONOGRAPHS IN POPULATION BIOLOGY • 37

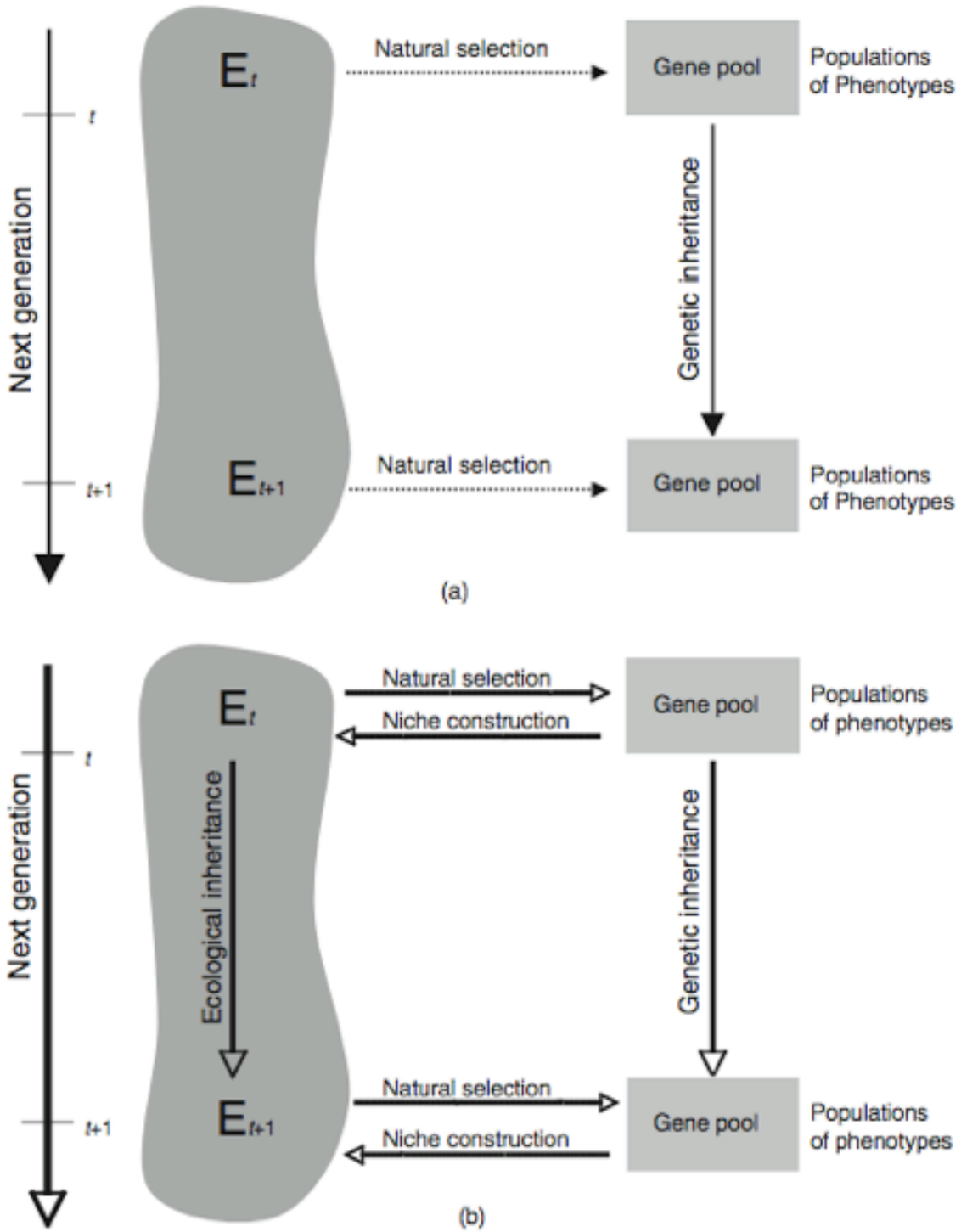
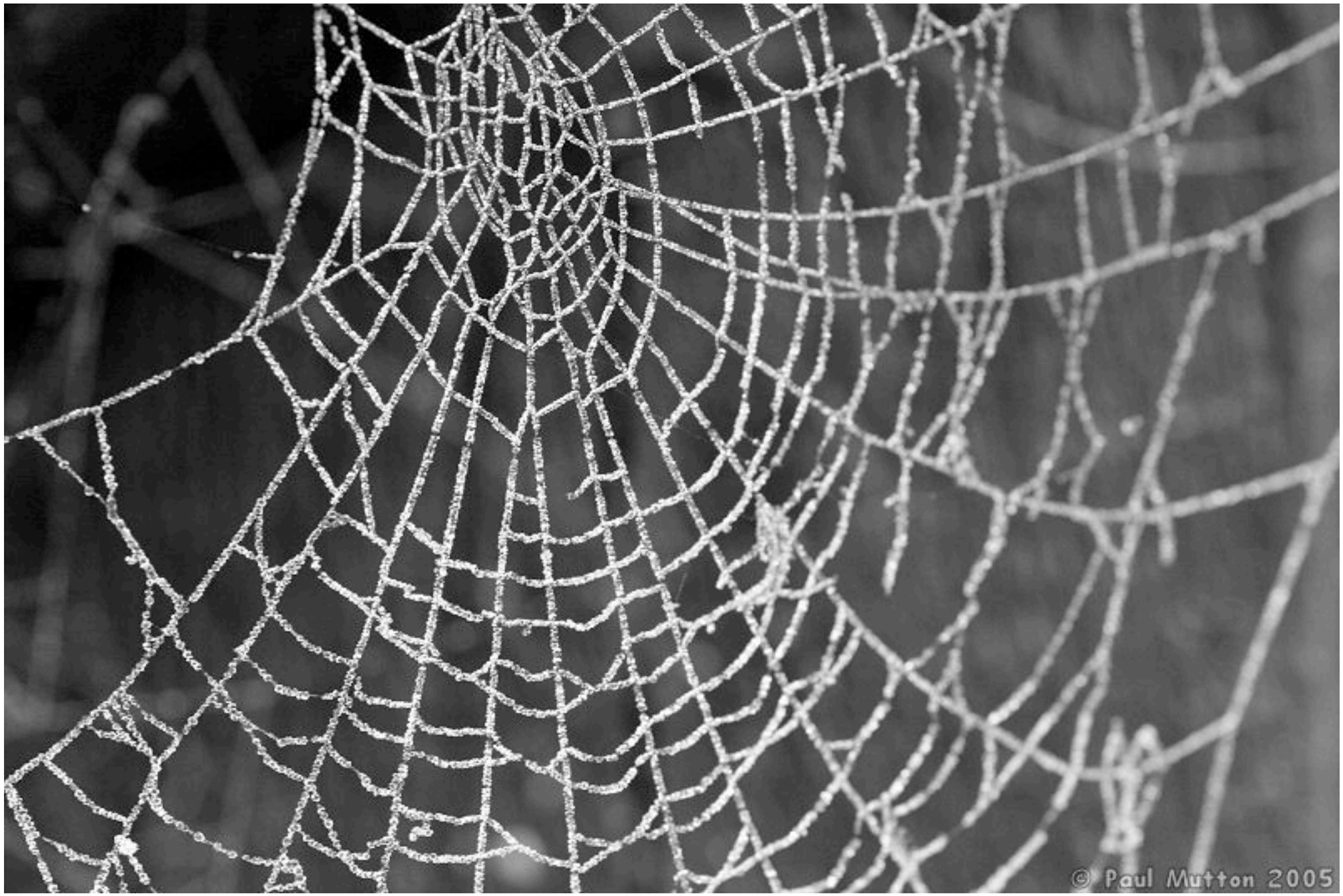


Figure 1.
a. Standard evolutionary theory. b. Extended evolutionary theory.

From: Odling Smee. Biol. Theor. 2007

The Niche

- Grinnel (1917) - many environmental variable foraging recess *(den. dep)*
- Elton (1927) - Grinnel + inclusion of interactions among species *(freq. dep.)*
- Hutchinson (1959) - high dimensional space of combined organism-environment interactions
- Niche Construction - how the adaptive complement of above come into existence



Wednesday, 24 June 2009

Niche Construction

- Does not assume selection is an adiabatic invariant
- Relatively rapid change of selective environment - entropic - and adaptive.
- Single genome modifies success of multiple organisms in this environment when shared
- Selection (not only traits) partly encoded in genomes

Recursive Adaptation

- An alteration or adjustment in structure or habits, often hereditary, by which a species or individual improves its condition in relationship to its environment.

- An alteration or adjustment in structure or habits, often hereditary, by which a species or individual improves its condition in relationship to its (*structure or habits, often hereditary, by which a species or individual improves its condition in relationship to its environment*).

- An alteration or adjustment in structure or habits, often hereditary, by which a species or individual improves its condition in relationship to its (structure or habits, often hereditary, by which a species or individual improves its condition in relationship to its (*structure or habits, often hereditary, by which a species or individual improves its condition in relationship to its environment*)).

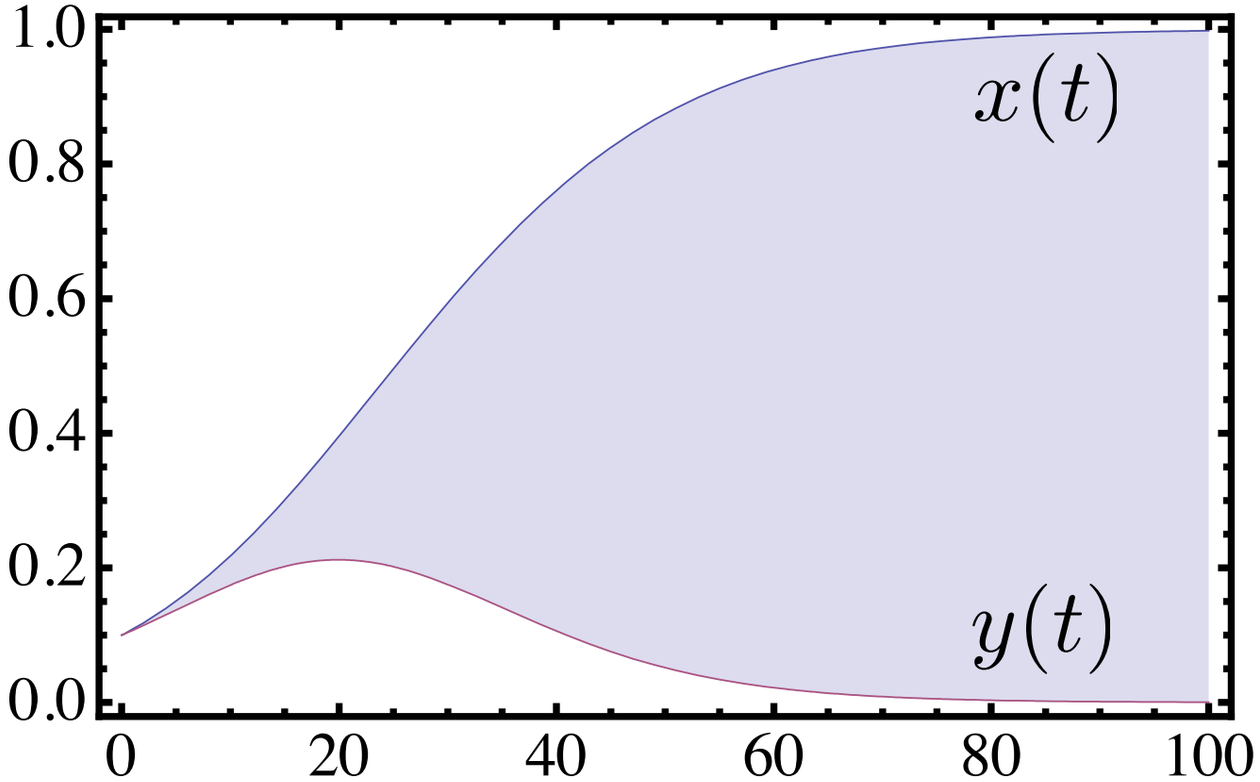
Niche constructing an extended phenotype

Developing a morphological phenotype

Ecological Dynamics

$$\dot{x} = c_x x - x\frac{x + b_{yx}y}{k_x}$$

$$\dot{y} = c_y y - y\frac{y + b_{xy}x}{k_y}$$



$$b_{yx} < b_{xy}$$

competition

mortality

fecundity

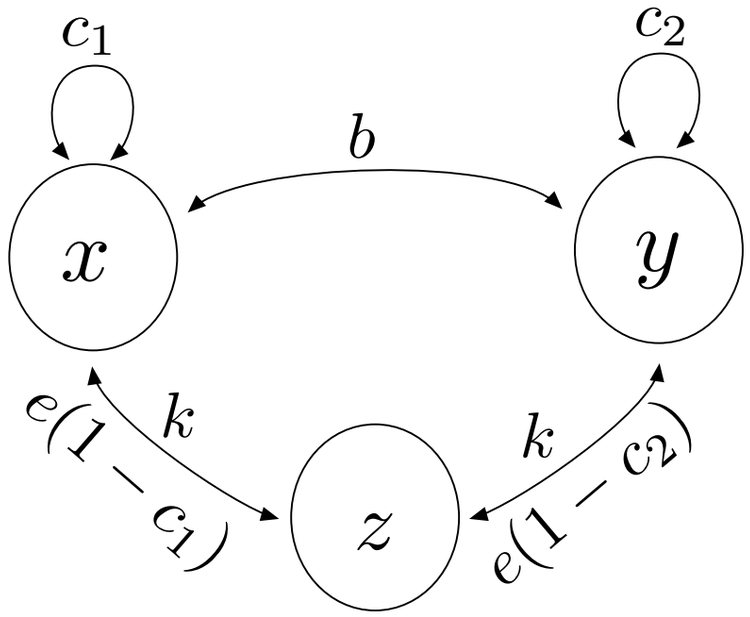
$$\dot{x} = c_x x - x\frac{x + b_{yx}y}{k_x}$$

carrying capacity

$$\dot{y} = c_y y - y\frac{y + b_{xy}x}{k_y}$$

Wednesday, 24 June 2009

Carrying Capacity Construction



$$\dot{x} = c_x x - x\frac{x + b_{yx}y}{k_x z} \tag{1}$$

$$\dot{y} = c_y y - y\frac{y + b_{xy}x}{k_y z} \tag{2}$$

$$\dot{z} = p + (1 - c_x)\frac{ex}{x + y + z} + (1 - c_y)\frac{ey}{x + y + z} - dz. \tag{3}$$

Niche Constructing Diversity

$$B > b_{yx} - b_{xy} > 0 \qquad K > k_x - k_y > 0$$

$$\dot{x} = c_x x - x\frac{x + b_{yx}y}{k_x z} \tag{1}$$

$$\dot{y} = c_y y - y\frac{y + b_{xy}x}{k_y z} \tag{2}$$

$$\dot{z} = p + (1 - c_x)\frac{ex}{x + y + z} + (1 - c_y)\frac{ey}{x + y + z} - dz. \tag{3}$$

Construction Dilemma

$$\dot{x} = cx - x\frac{x+w}{kz},$$

$$\dot{w} = c'w - w\frac{w+x}{kz},$$

$$\dot{z} = p + (1-c)\frac{ex}{x+w+z} + (1-c')\frac{ew}{x+w+z} - dz.$$

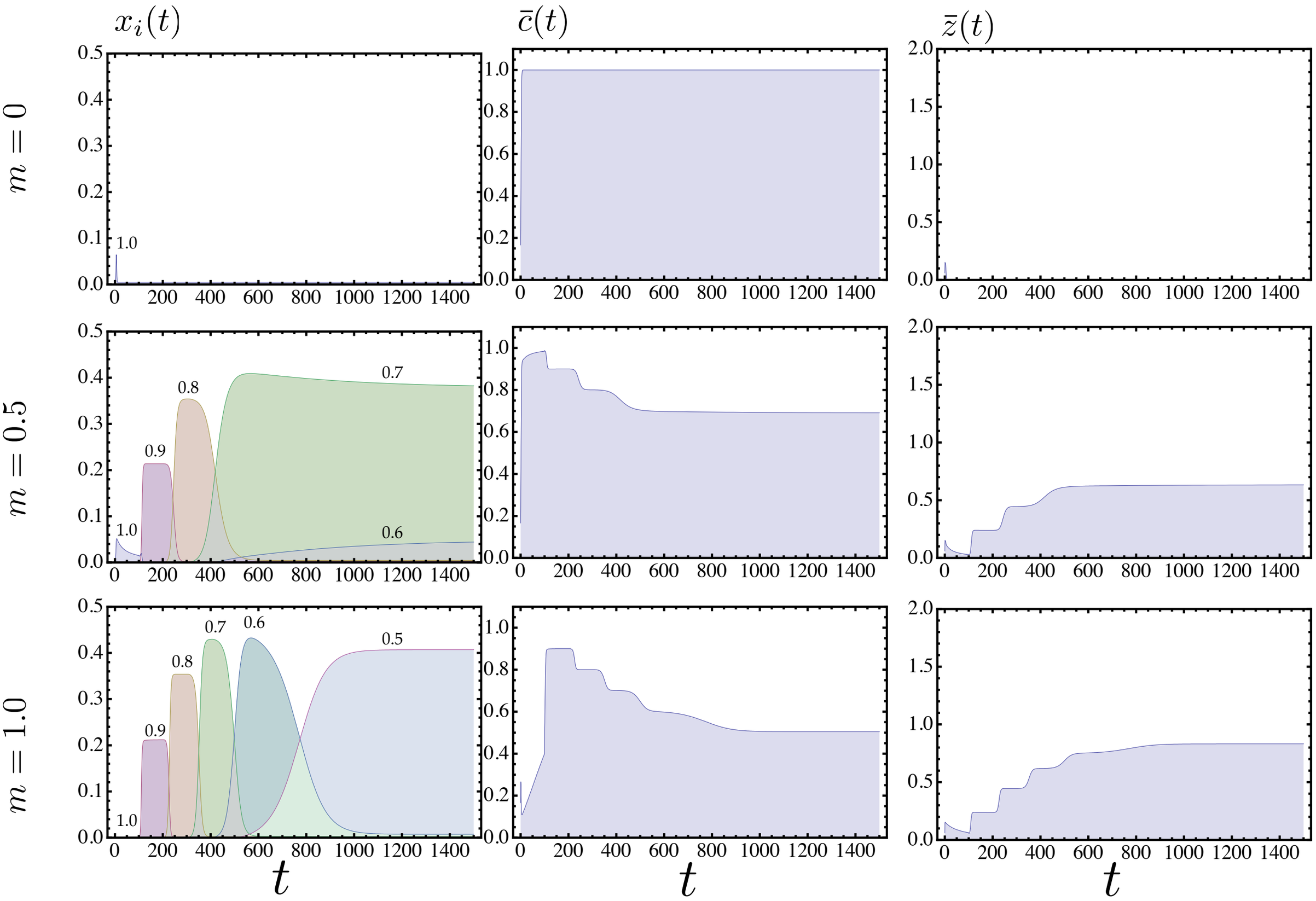
$$\frac{\dot{w}}{w} = \frac{\dot{x}}{x} + (c'-c)$$

$$\frac{w}{w(0)} = \frac{x}{x(0)}e^{(c'-c)t}.$$

Niche monopolies subvert dilemmas

$$z_x \approx z_x m + z_x(1-m)$$

N-strain niche construction dynamics



Allopatric versus Sympatric Niche Construction

$$c_i = \frac{1}{m+1}$$

$$c_j = \frac{1}{m+1}$$

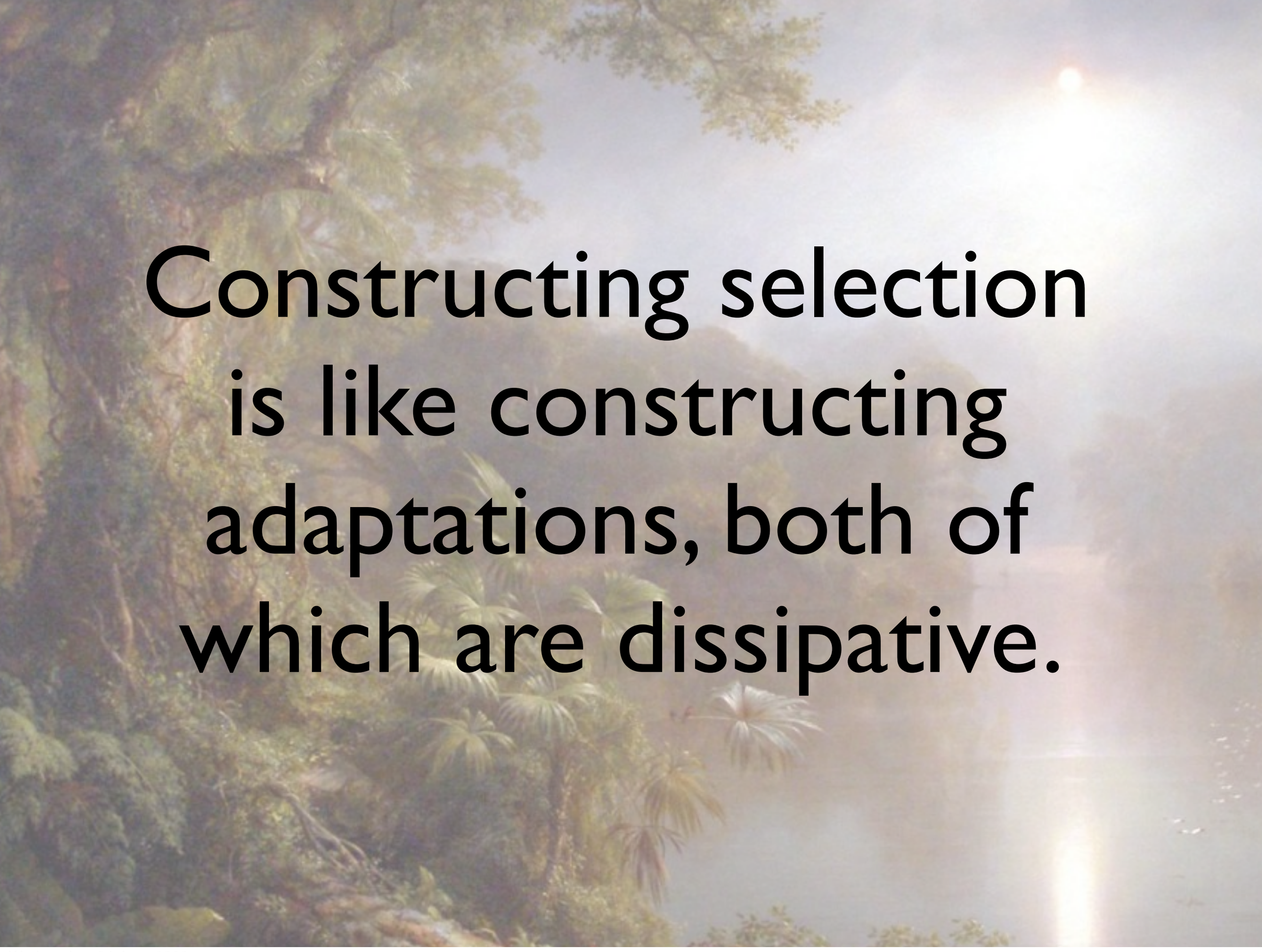
Ecological dynamics

$$c_i = c_j = \frac{1}{m+1}$$

$$c_i = c_j = \frac{1}{m+1}$$

Evolutionary dynamics

$$c_* = \frac{(1 + z_i/z_j)(1-m) + m(i/j)}{1 + m + (1-m)(z_i/z_j + m(i/j)} < \frac{1}{1+m}$$

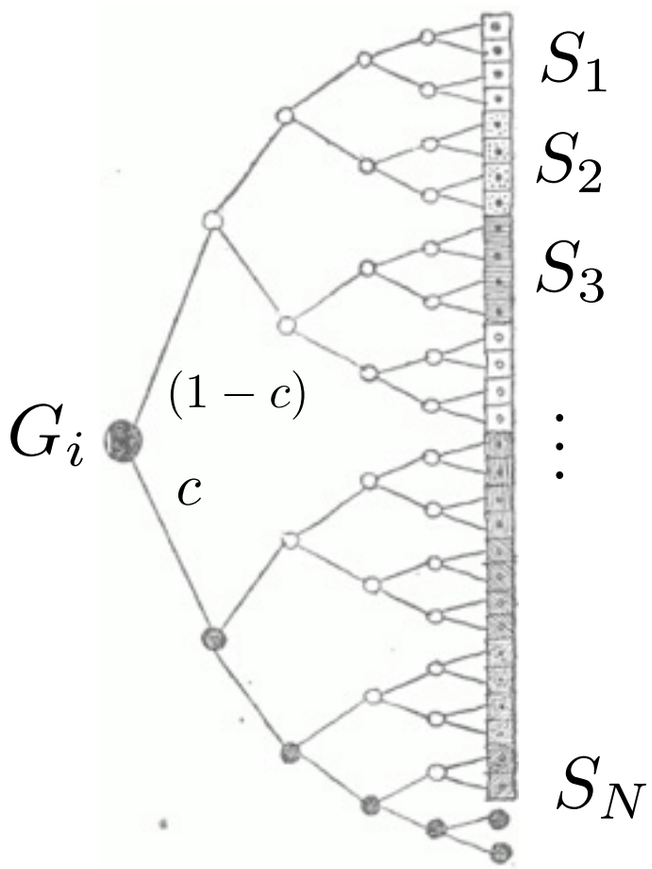

Constructing selection
is like constructing
adaptations, both of
which are dissipative.

III. Developmental Demons

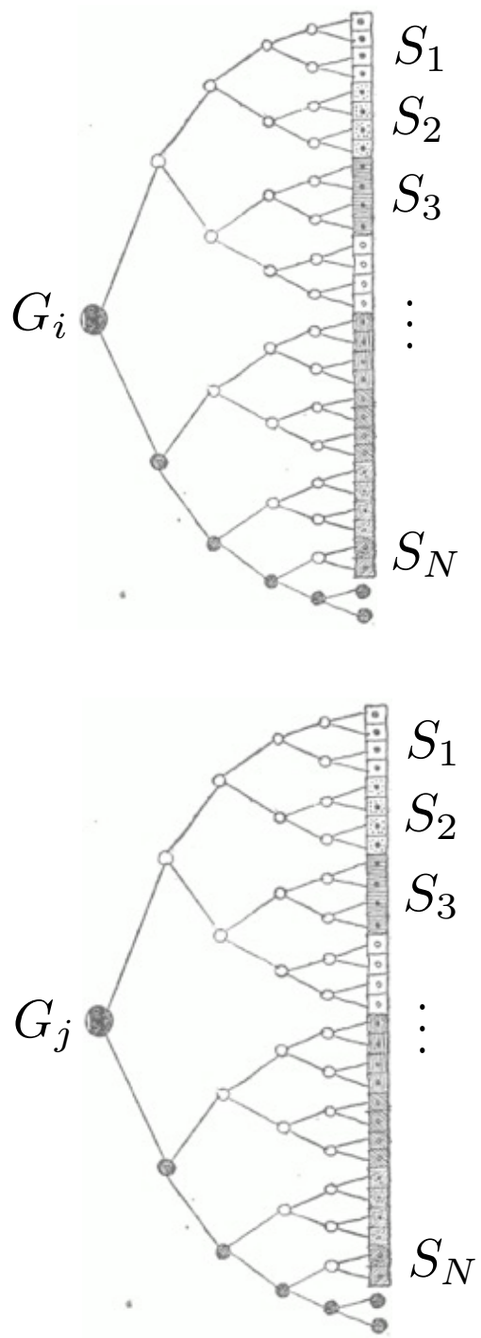
Creating the organisms as a selective environments

Organismal development

Population selection



$f(\mathbf{S}, E)$



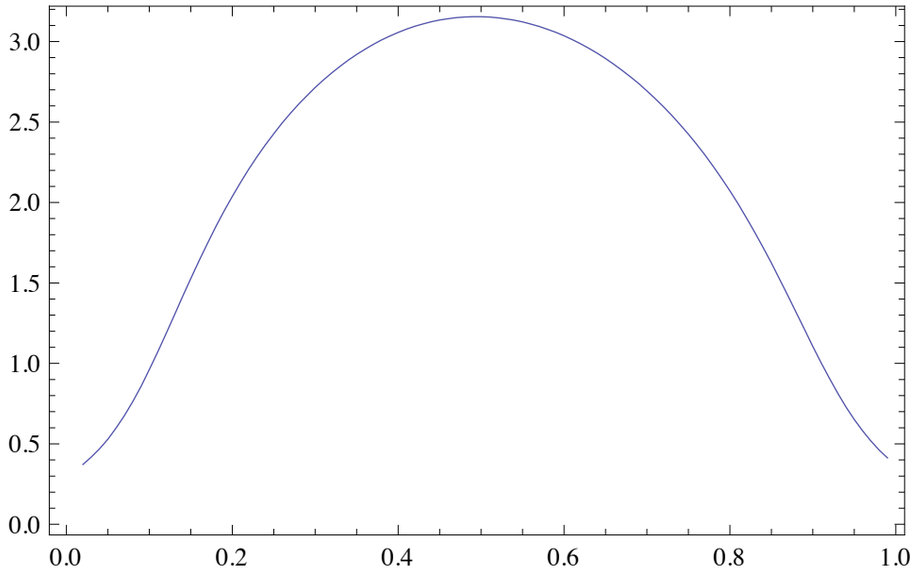
$$G + R \xrightarrow{r + pkS} 2G$$

$$G + R \xrightarrow{(1-p)k} G + S$$

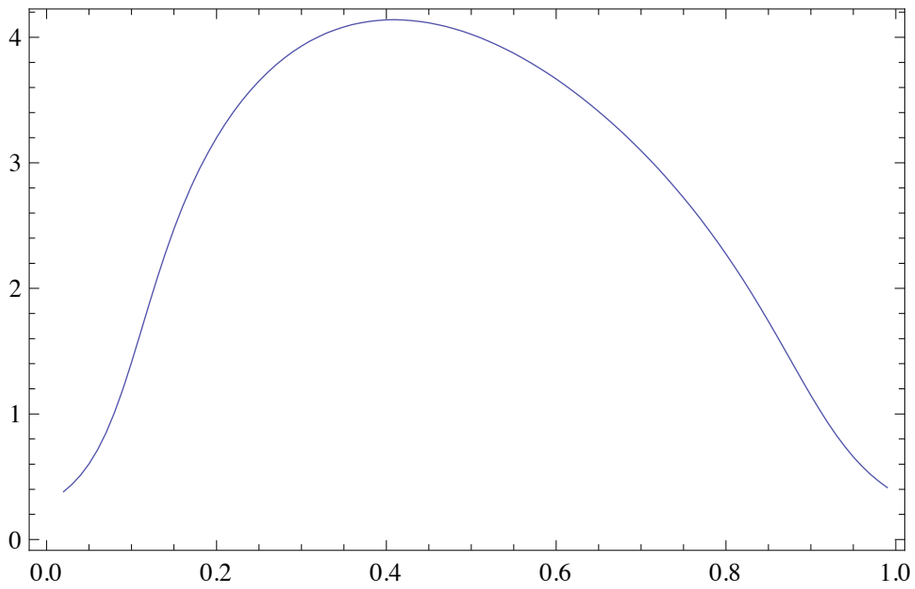
$$2S \xrightarrow{c} S$$

$$\theta \xrightarrow{k + nS} R \qquad R \xrightarrow{d} 0$$

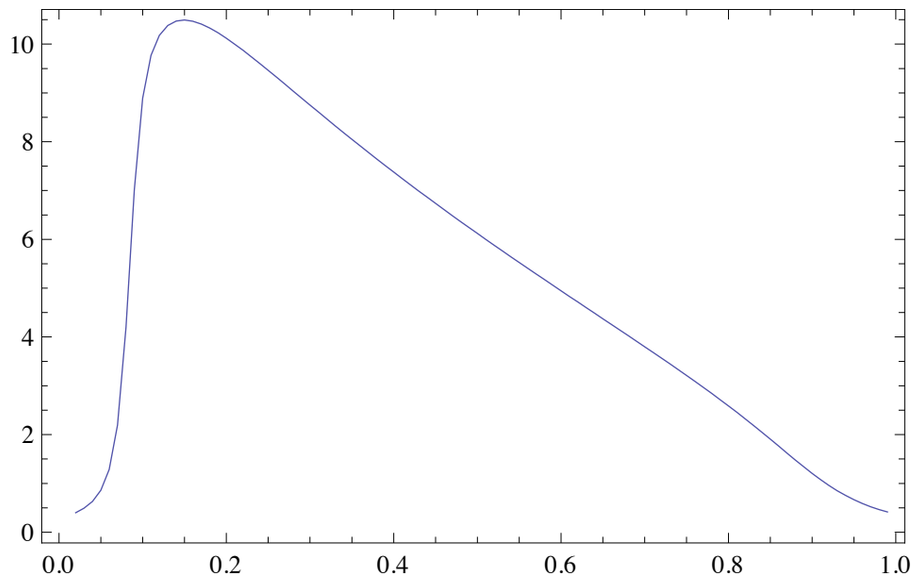
small *n*



mid *n*



large *n*

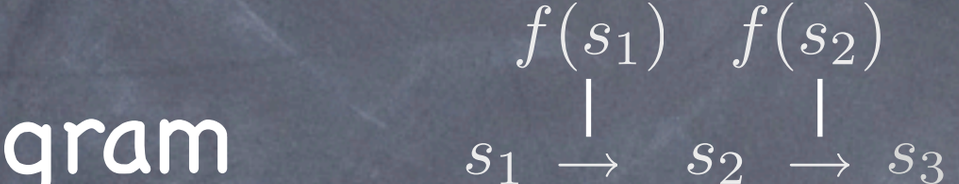


Symmetric division

Asymmetric division

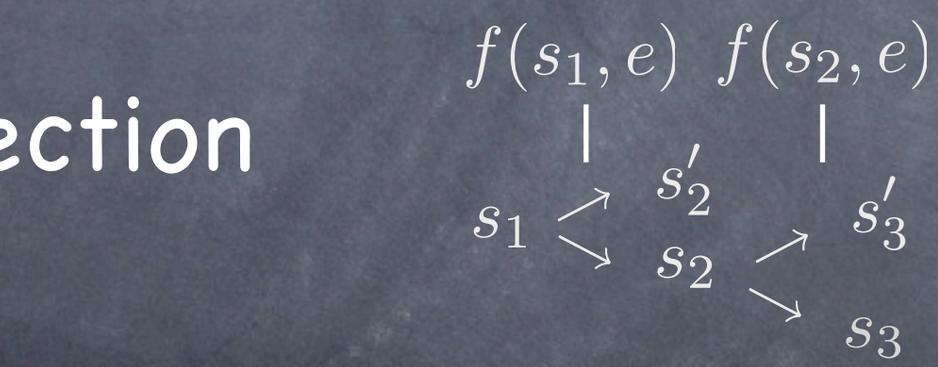
Why does development appear more programmed than evolution?

Program



deterministic
internal control

Selection



noisy
+ external control

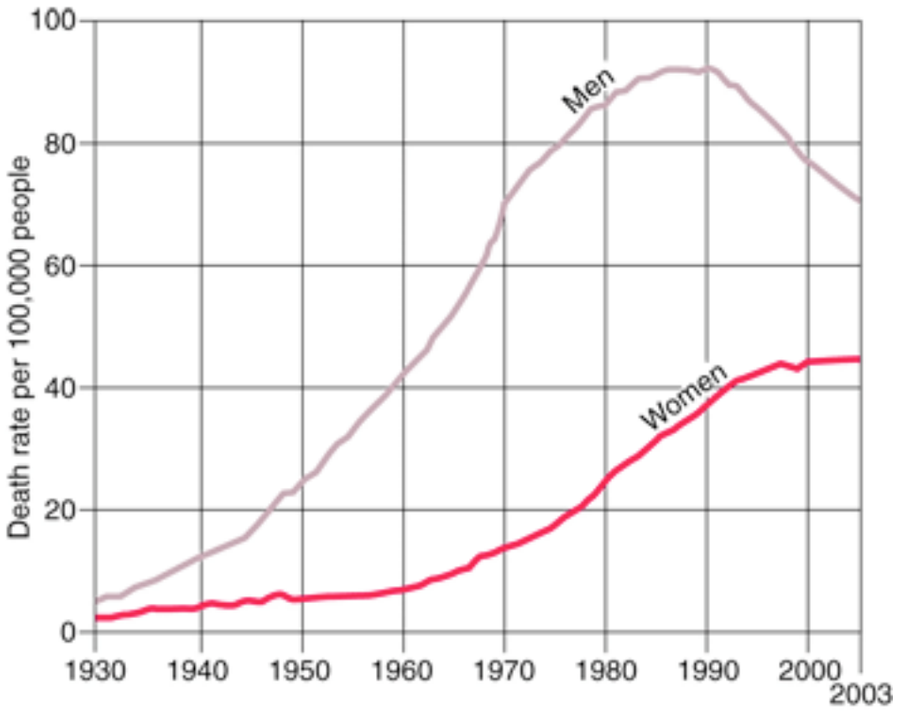
Niche construction $e \rightarrow 0$

IV. NC, learning & cultural change

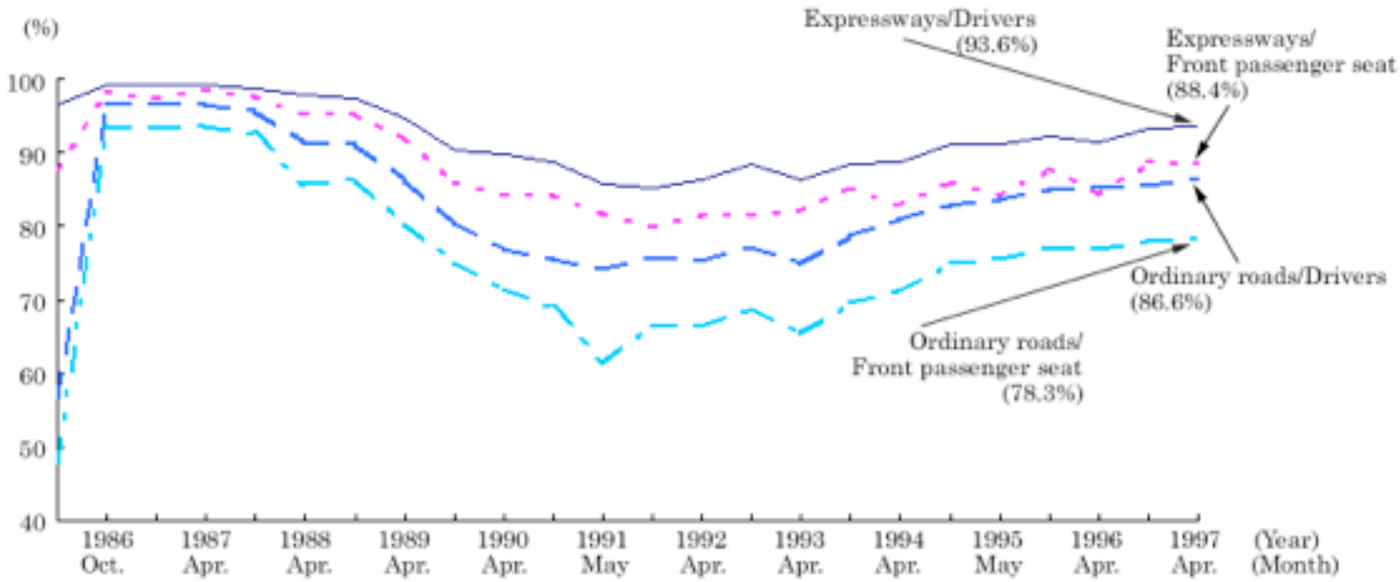
learning to construct cultural selection

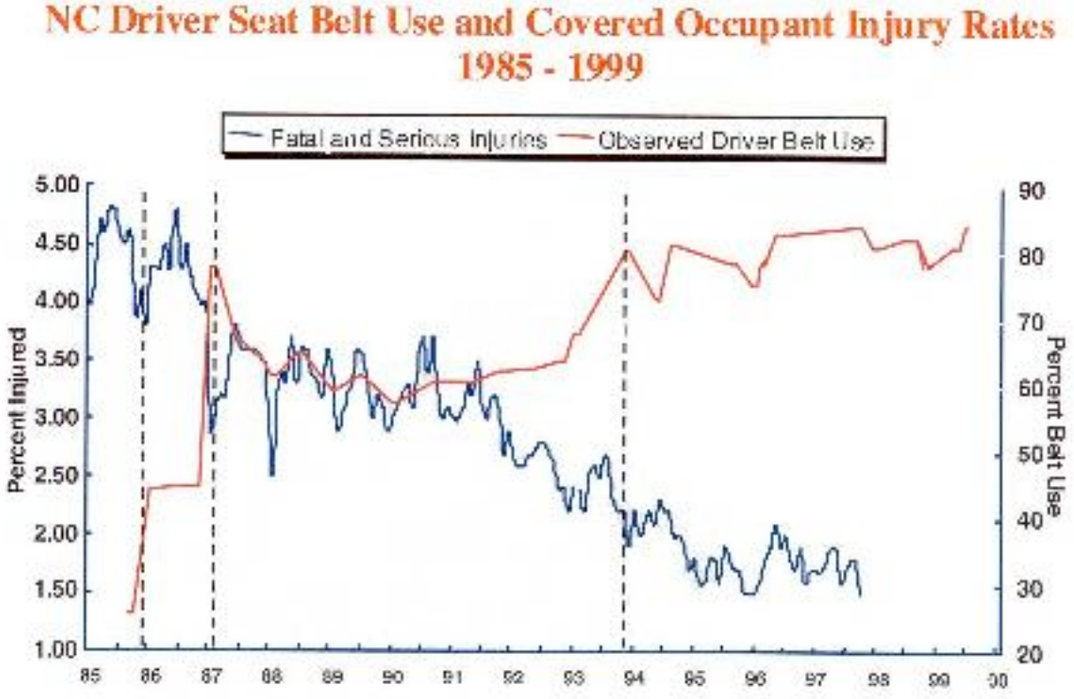
Wednesday, 24 June 2009

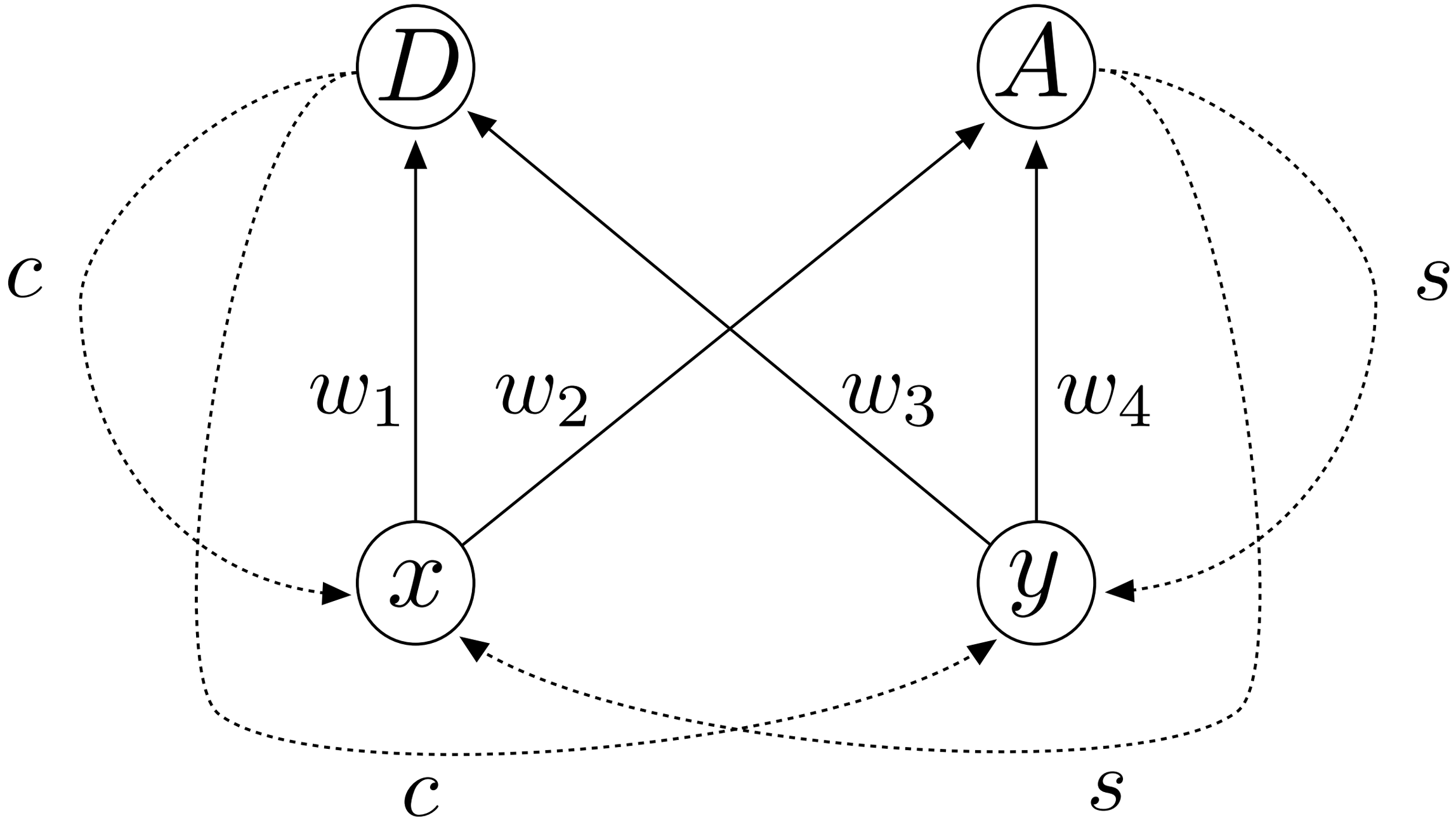
Smoking related deaths



Seat belt usage






D
A
c
s
w_1
w_2
w_3
w_4
x
y
c
s

Mind the Gap.

I did not cover this so I have omitted these slides.

Key Implications of Demons & NC

- The construction of multiple overlapping time scales - selective boundary conditions.
- The feed-forward construction is as important as the feedback selection
- The organism-environment dichotomy is challenged
- Provides an approach to dealing with questions of hierarchy/complexity in nature

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