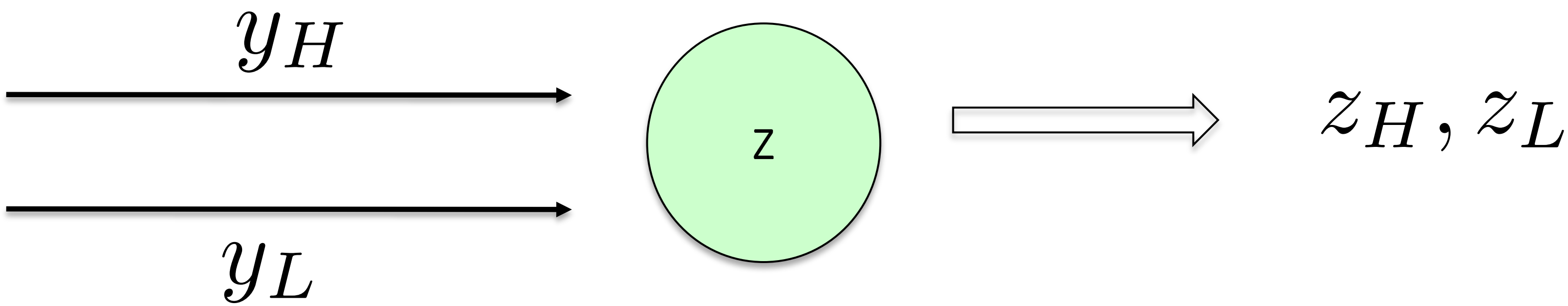
Evolving parameters for genetic regulatory networks

Dominique Chu
School of Computing
University of Kent
CT2 7NF, Canterbury, UK

Motivation

- Design principles of living systems.
  - Abstract models of organisation (autopoiesis, (M,R)-systems etc…
  - "Complex systems" approach (network topology)
- A numerical understanding of organisms:
  - Why is a particular reaction rate k, rather than something else?
  - Why are there N proteins in the cell, rather than twice as many? Half?

Simplest possible model system: binary Gene



$$\dot{z} = \beta \frac{y^h}{y^h + K^h} - \mu z$$

ELSEVIER

Biosystems

Volume 104, Issues 2–3, May–June 2011, Pages 99–108

Optimal parameter settings for information processing in gene regulatory networks

Dominique F. Chu[a], Nicolae Radu Zabet[a], Andrew N.W. Hone[b]

Noise-time trade-off

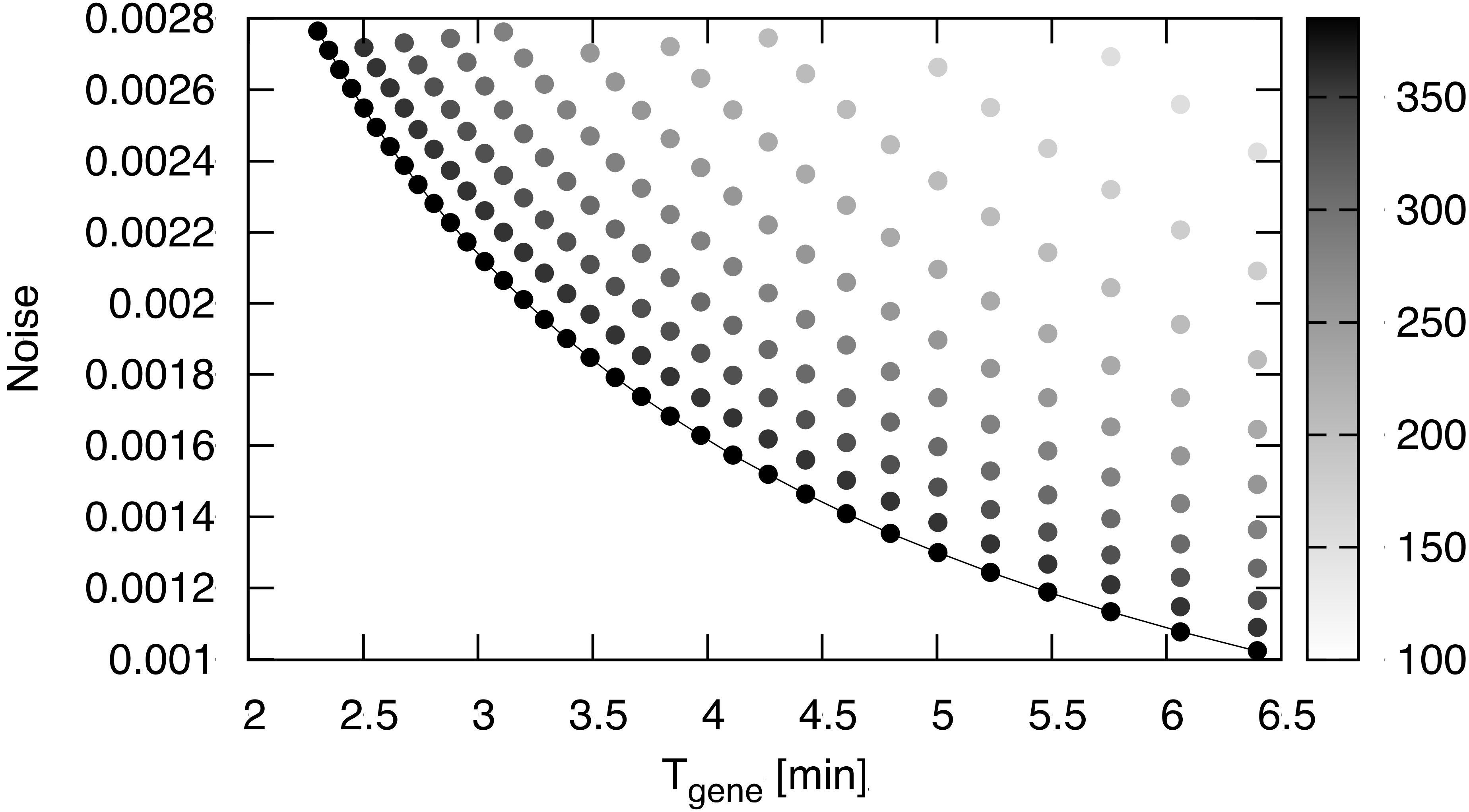
1 gene case:

$$T \sim \frac{1}{\mu} \qquad \mathcal{N} \sim \mu$$

- We have ignored cost so far.
- Define as the number of molecules produced per time unit (at maximum).

$$\dot{z} = \beta \frac{y^h}{y^h + K^h} - \mu z$$

Noise-time-cost trade-off

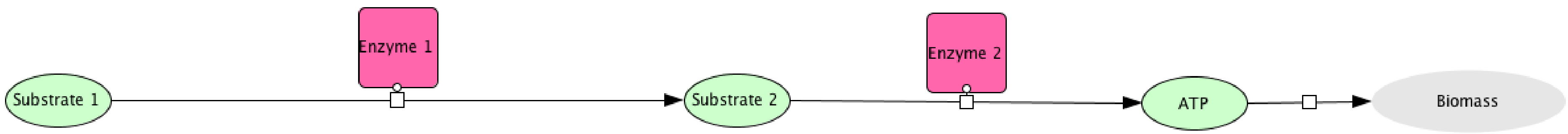


J R Soc Interface. 2010 Jun 6;7(47):945-54. doi: 10.1098/rsif.2009.0474. Epub 2009 Dec 9.

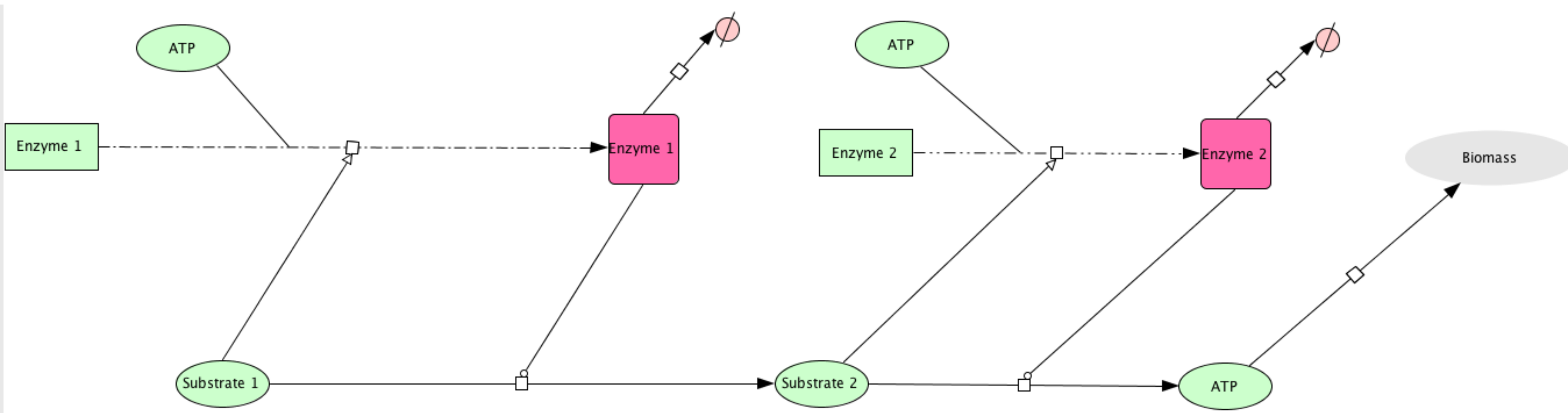
Computational limits to binary genes.

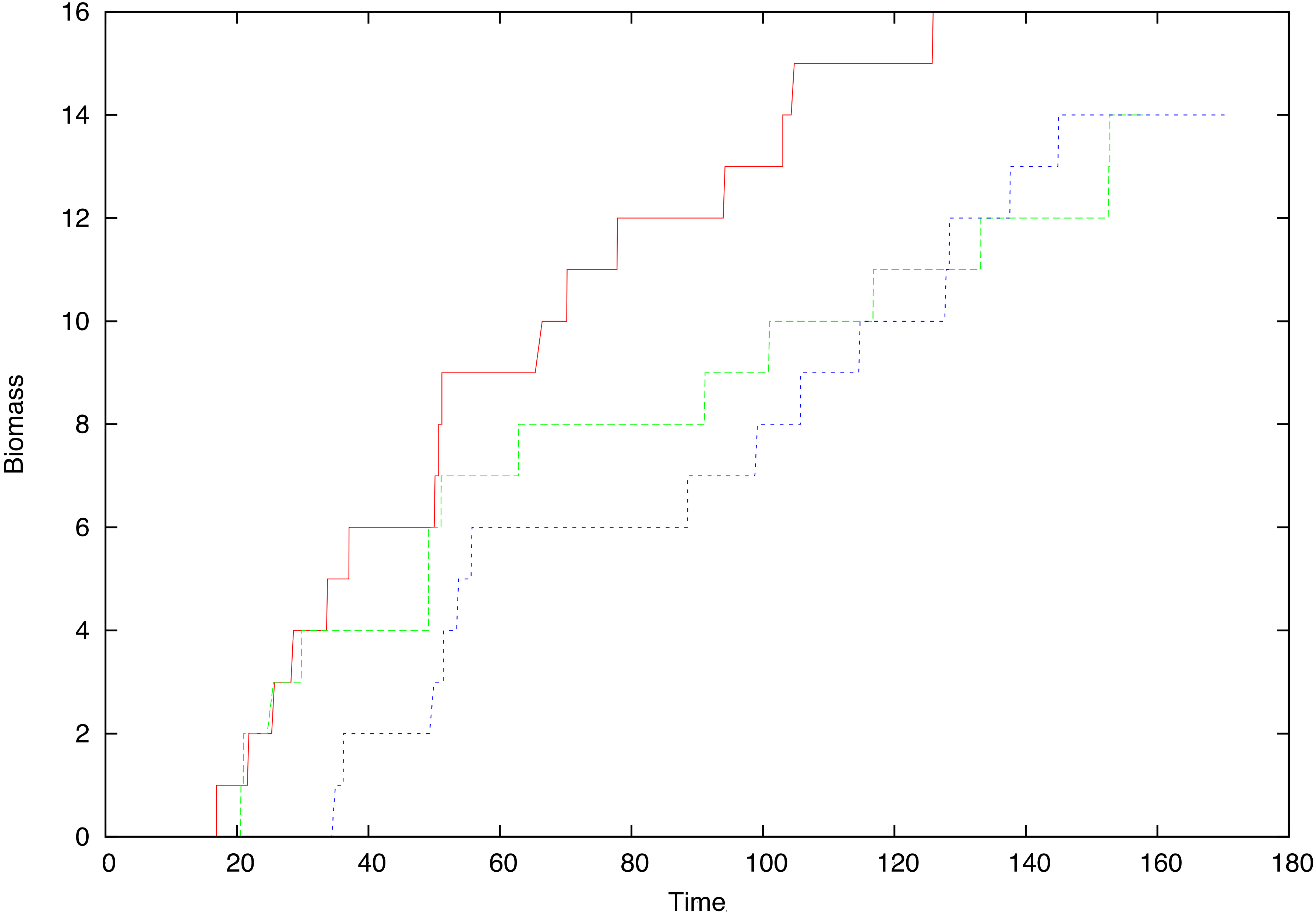
Zabet NR, Chu DF.

A very simple example system (simplified representation)



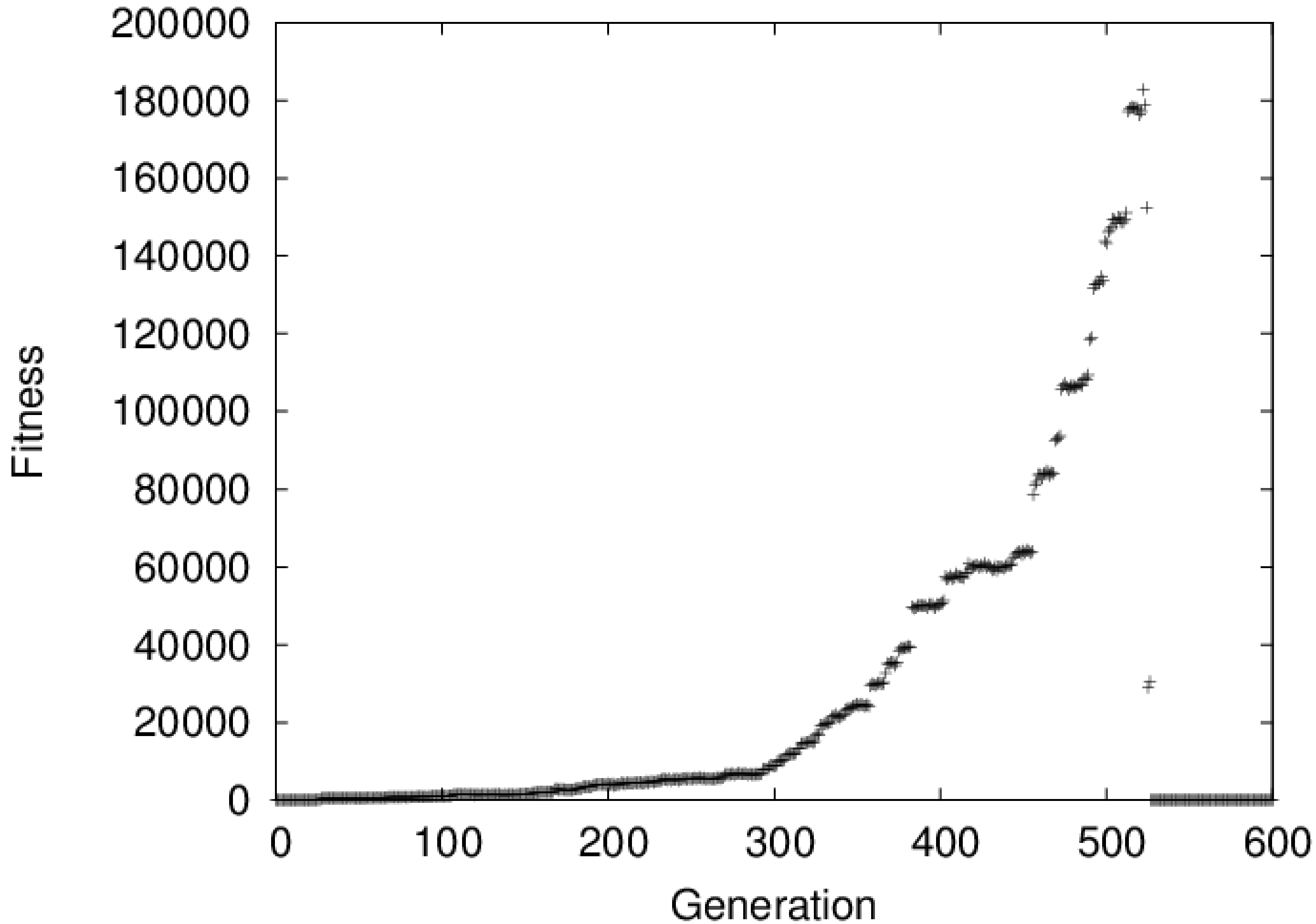
A very simple example system (full representation)




Biomass
Time
0
2
4
6
8
10
12
14
16
0
20
40
60
80
100
120
140
160
180

step	subs1	subs2	enz1	enz2	atp	biomass
0	179	0	0	0	10	0
1	179	0	1	0	9	0
2	179	0	2	0	8	0
3	179	0	3	0	7	0
4	179	0	4	0	6	0
5	179	0	5	0	5	0
6	179	0	6	0	4	0
7	178	0	5	0	4	0
8	178	1	6	0	4	0
9	178	1	6	1	3	0
10	178	0	6	0	3	0
11	178	0	6	1	4	0
12	178	0	7	1	3	0
13	178	0	8	1	2	0
14	178	0	9	1	1	0
15	178	0	10	1	0	0
16	177	0	9	1	0	0
17	177	1	10	1	0	0
18	177	0	10	0	0	0
19	177	0	10	1	1	0
20	176	0	9	1	1	0
21	176	1	10	1	1	0
22	176	1	10	2	0	0
23	176	0	10	1	0	0

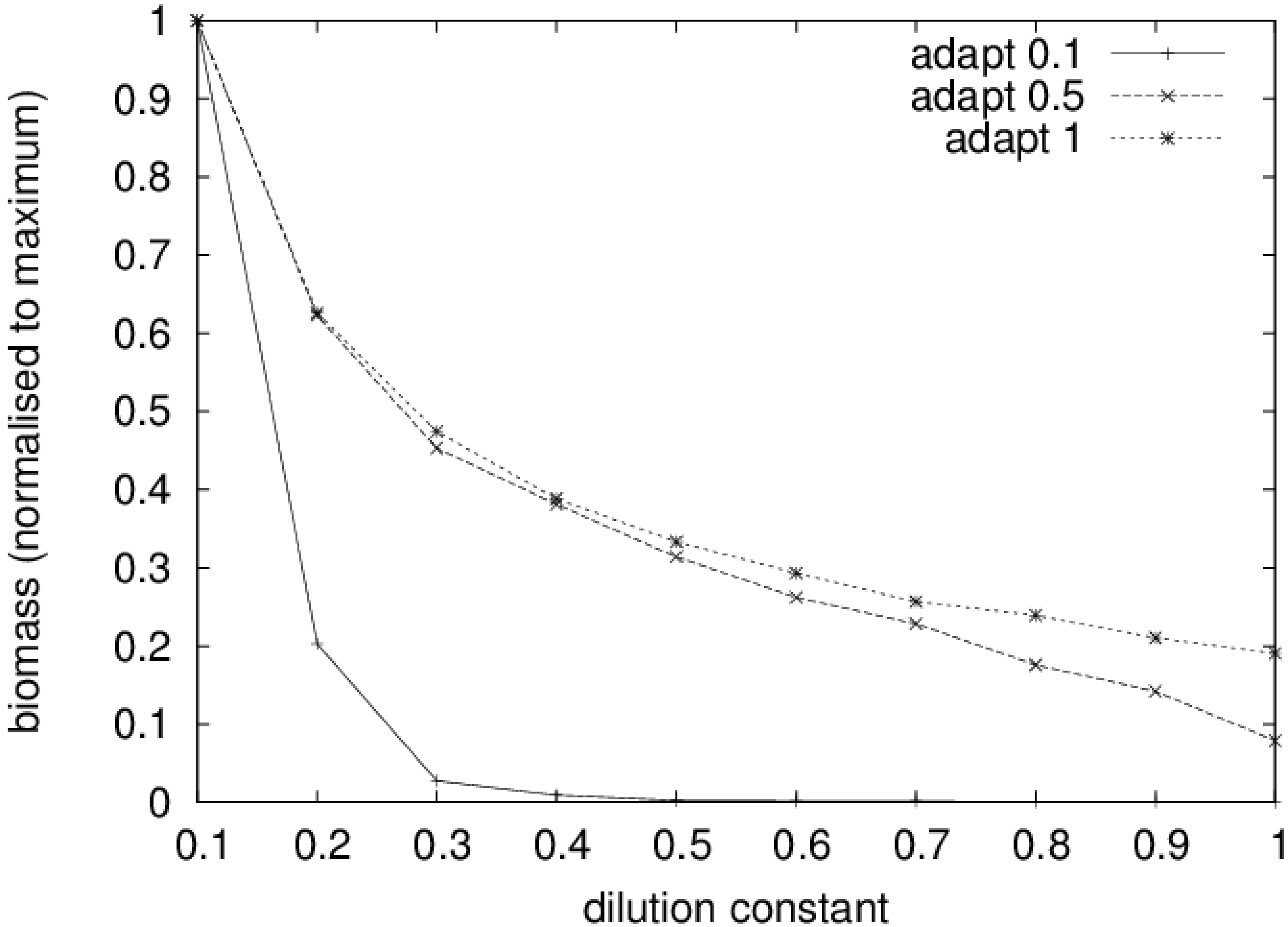
Running an EA



Adapting to 3 environmental conditions

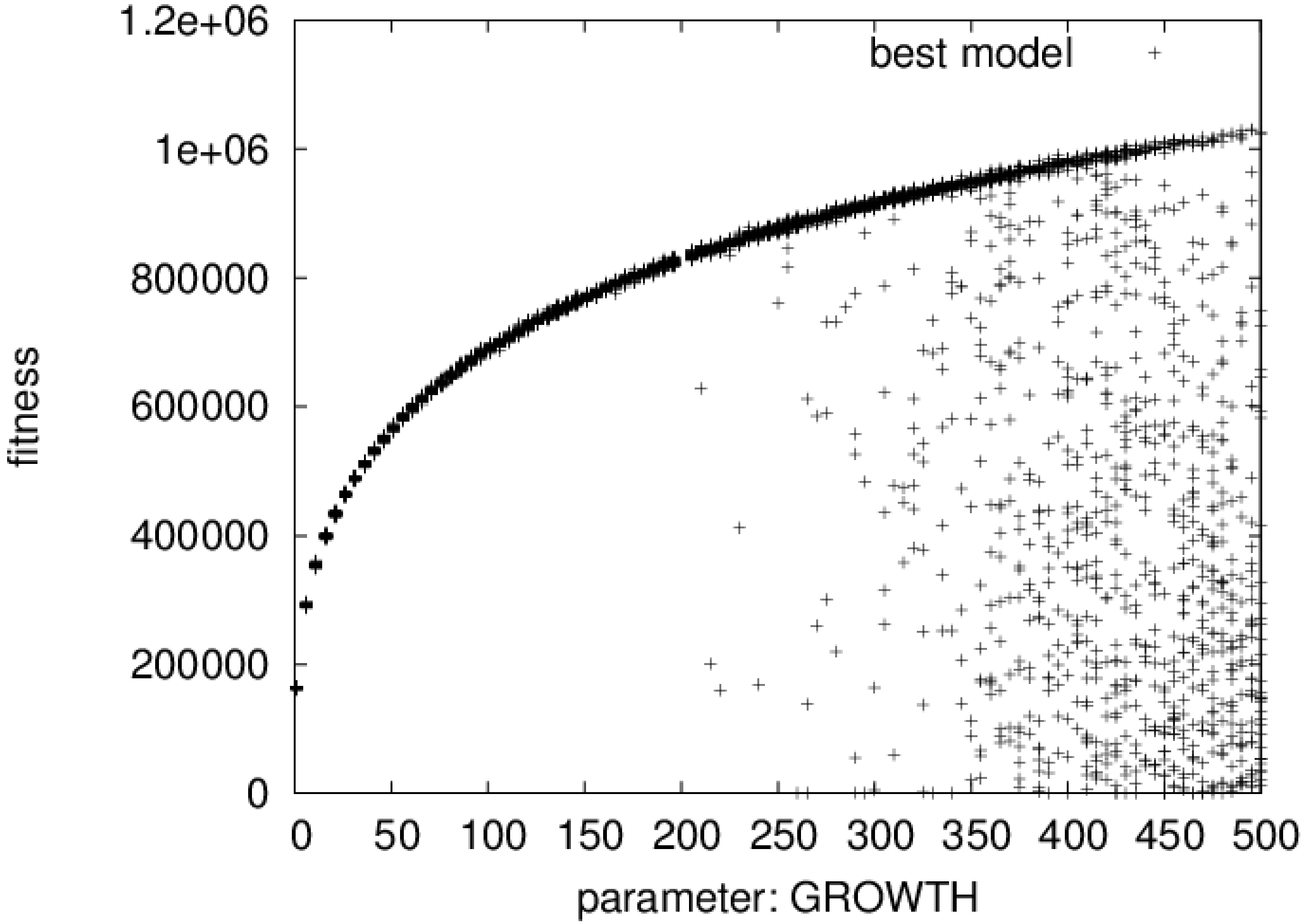
	(i) unlimited		(ii) oscillating		(iii) long break	
Adapted to:	biomass	sd	biomass	sd	biomass	sd
(ii)	221.9	164.898661	48.35	28.8175294	91.85	72.2657923
(ii)	491.65	522.103768	**83.75**	41.5285254	142.5	49.0375796
(i)	**49947**	19618.0107	0.25	0.5501196	0.45	0.51041779
(iii)	700.75	589.922464	30.45	25.7078219	135.4	70.6111666
(iii)	493.7	31.8567517	70.85	8.85720046	**157.75**	10.1560197

Adaptation to different dilution rates.

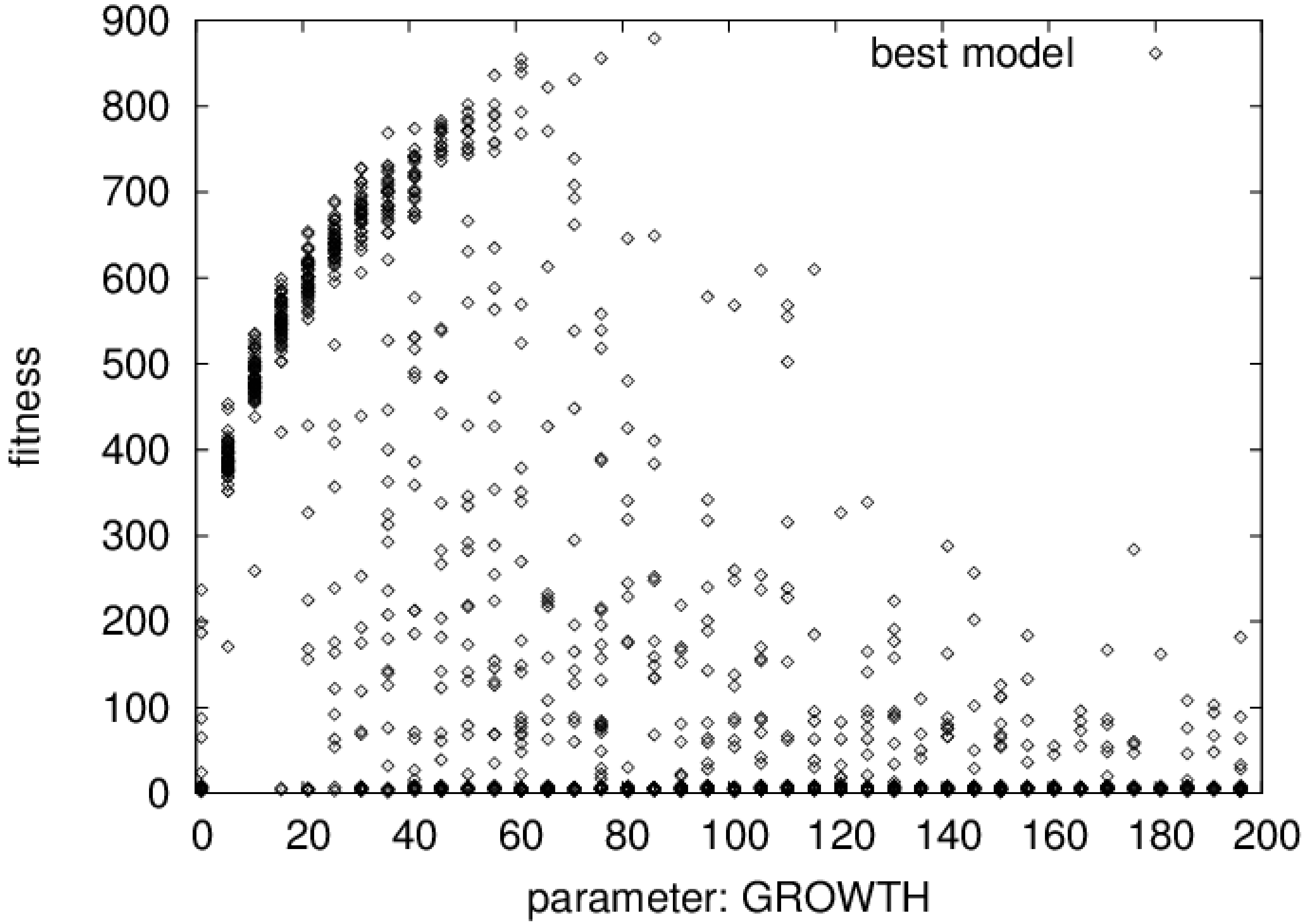


Interesting feature:
Stochastic fitness function

Unlimited nutrient supply



Oscillating nutrient supply



Summary

- The cost/speed trade-off in biological cells is not yet understood.
- Naturally evolved parameters are likely a an adaptation to optimise switching while controlling costs.
- In realistic systems it is difficult to understand how to think about parameters with respect to computational properties.