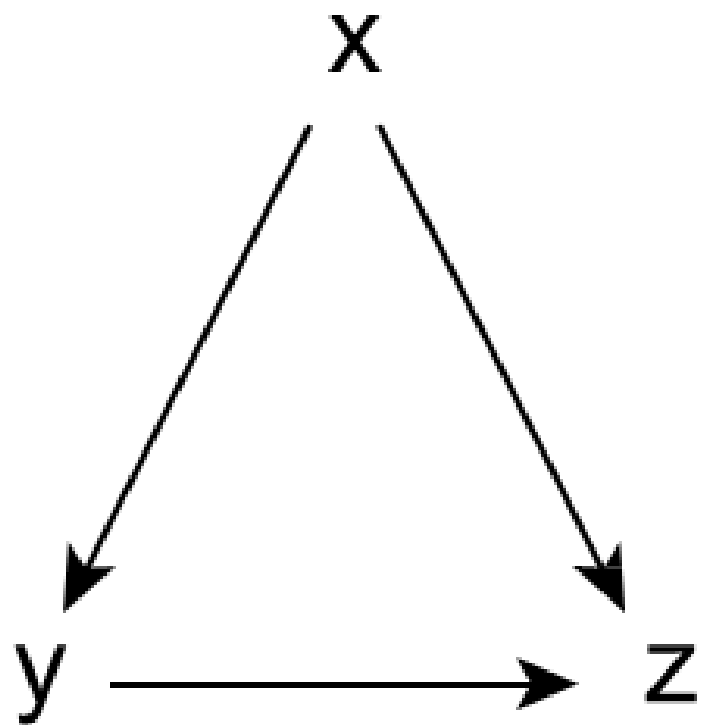
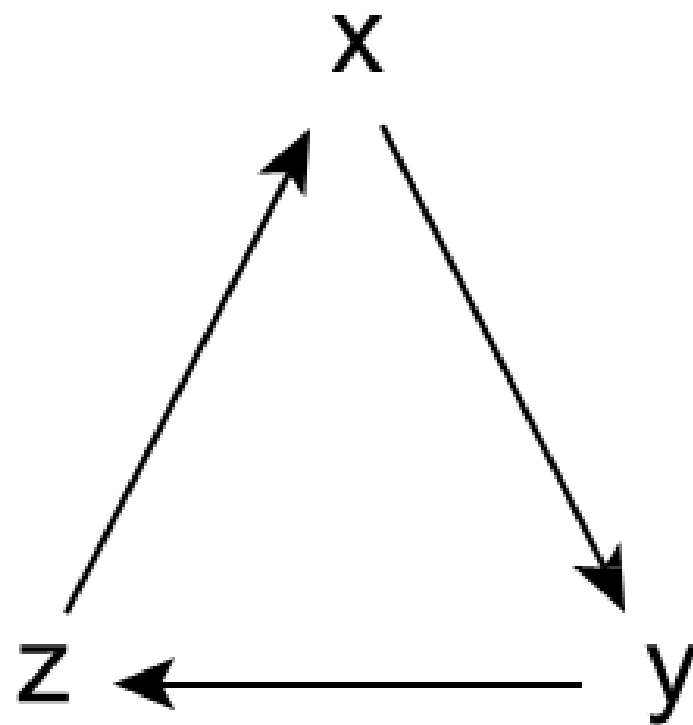


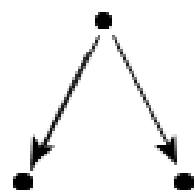
The Feed-Forward Loop Network Motif



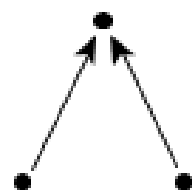
Feedforward Loop
(FFL)



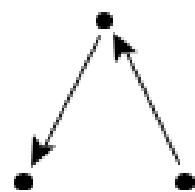
Feedback Loop
(FBL)



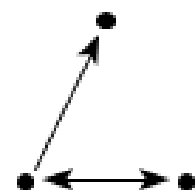
fan
out



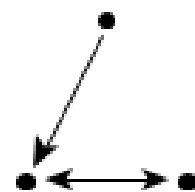
fan
in



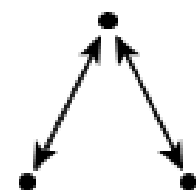
cascade



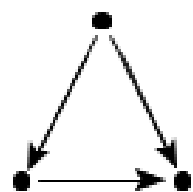
mutual
out



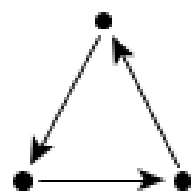
mutual
in



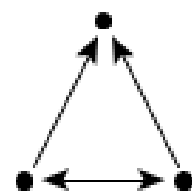
bi-mutual



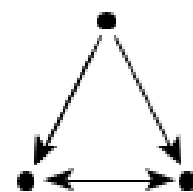
FFL



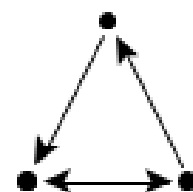
FBL



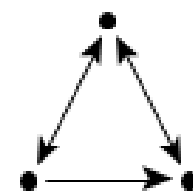
regulating
mutual



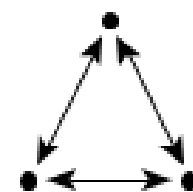
regulated
mutual



mutual
cascade

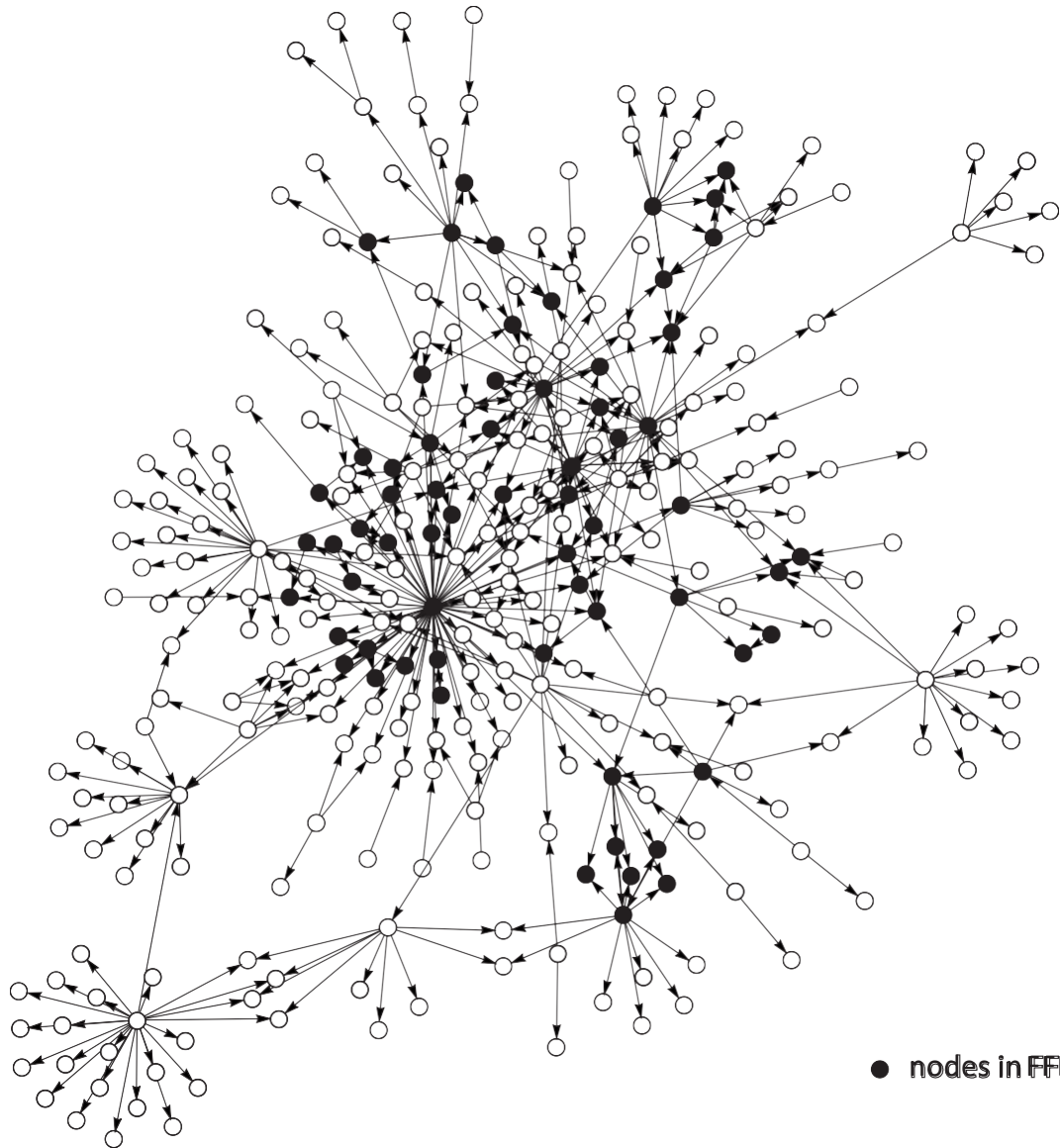


semi
clique



clique

Probability in random network
to find FFL or FBL very low.
Why?



FFL:

Prob in random: $1.2^3 = 1.7$

In real: 42

For FBL:

Prob in random: $1.2^3/3 \sim 0.6$

In real: 0

-> FFL is a strong network motif...but why?

Structure of feed forward loop in gene networks

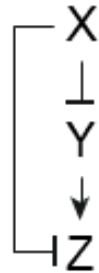
$2^3 = 8$ types

Coherent FFL

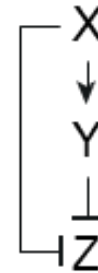
Coherent type 1



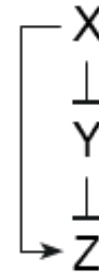
Coherent type 2



Coherent type 3



Coherent type 4

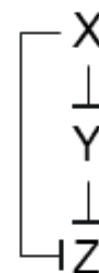


Incoherent FFL

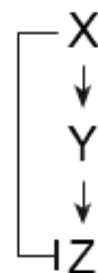
Incoherent type 1



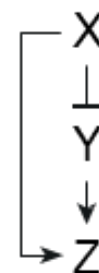
Incoherent type 2

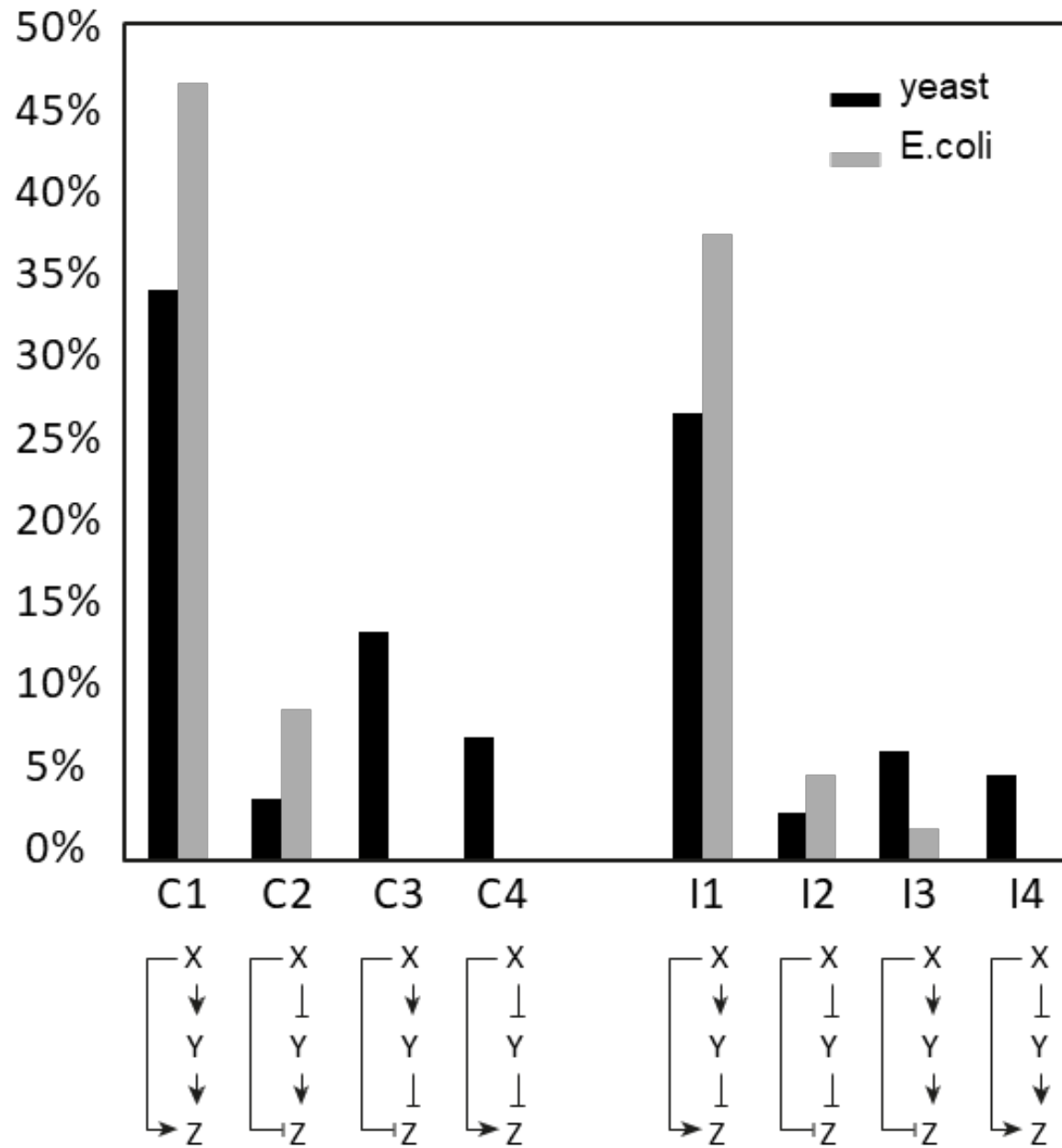


Incoherent type 3



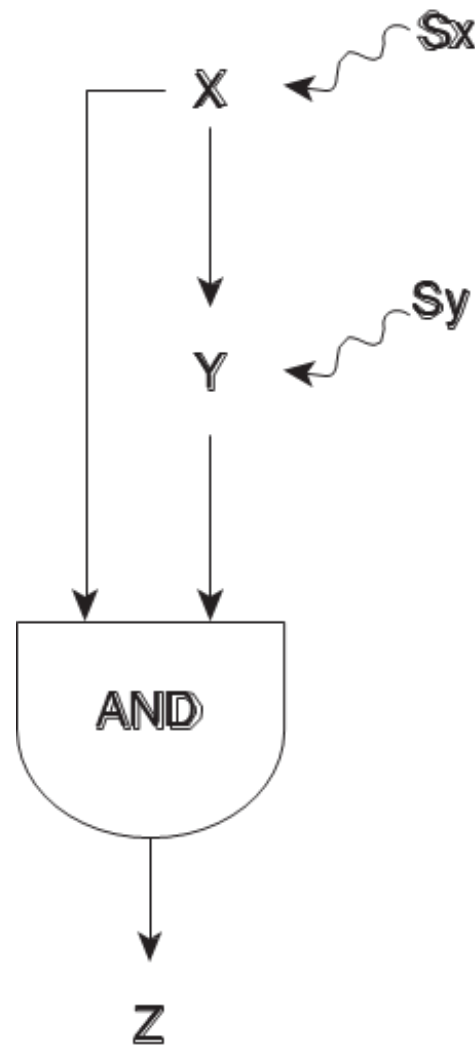
Incoherent type 4

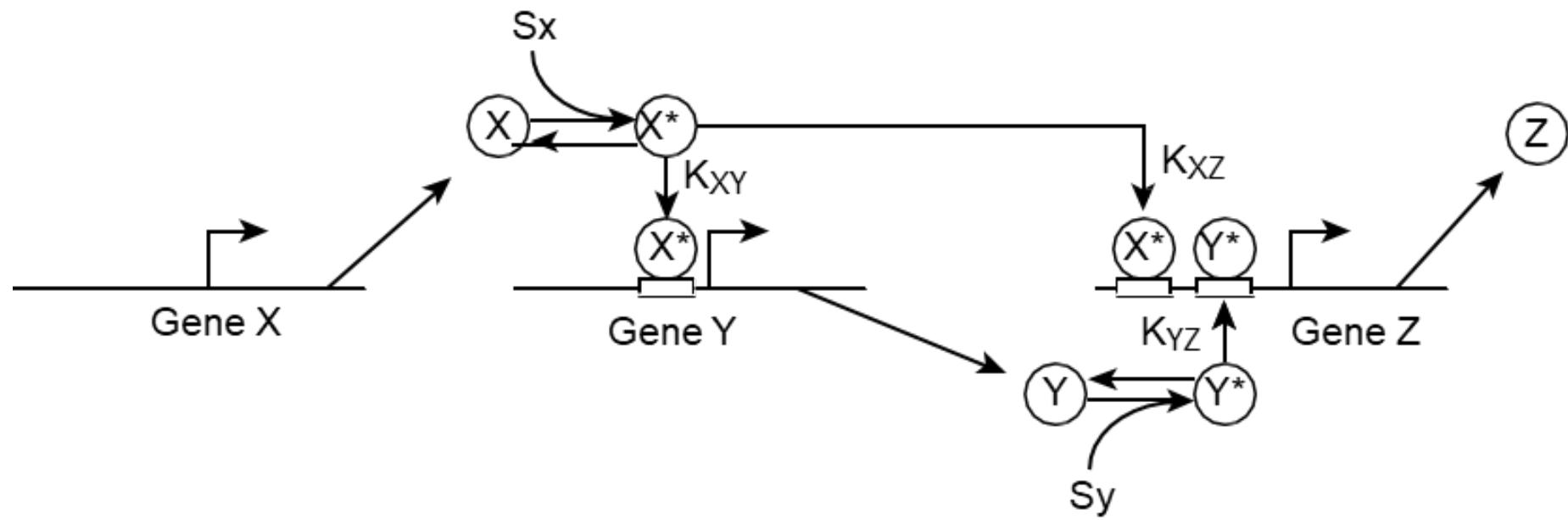




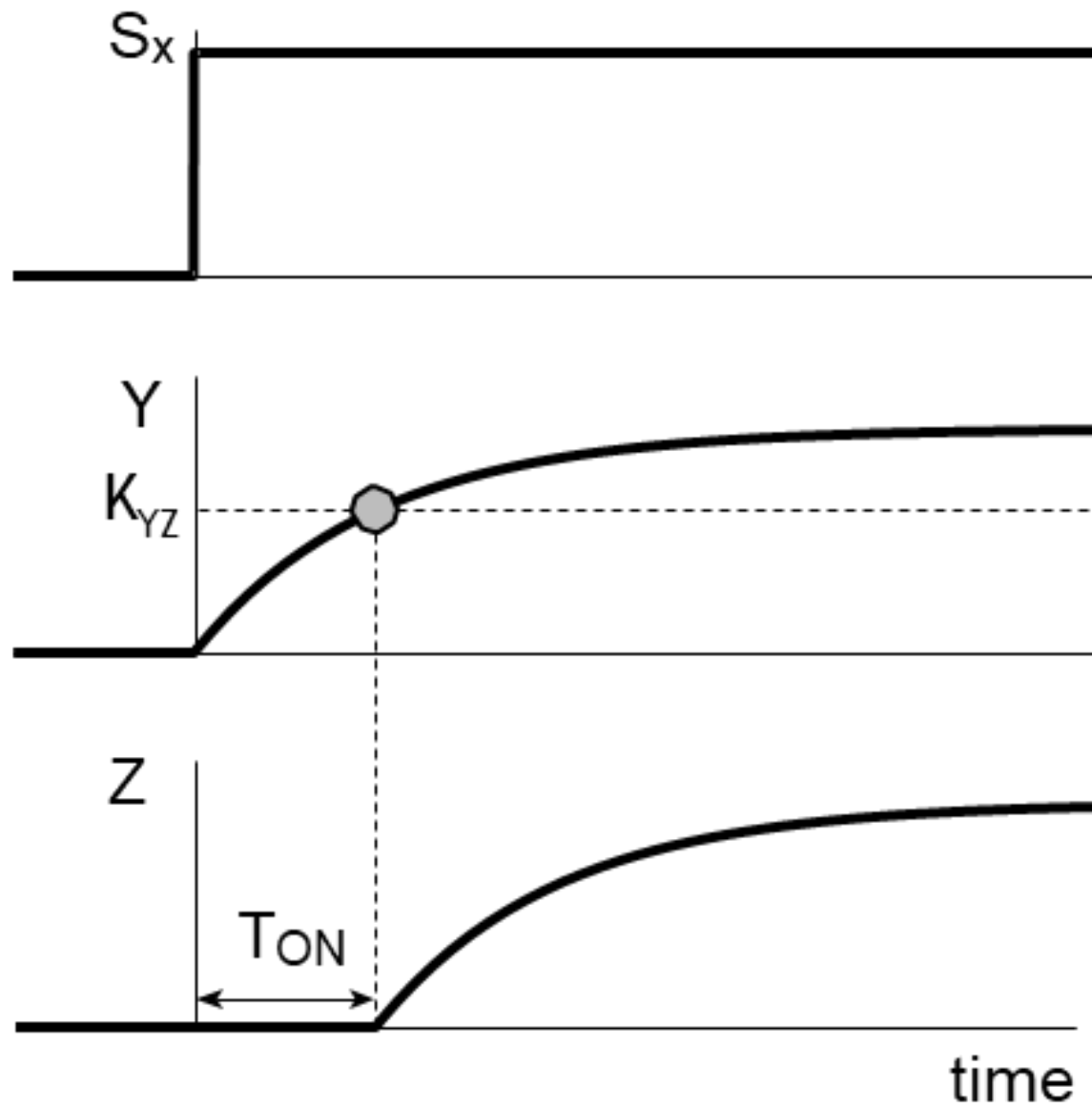
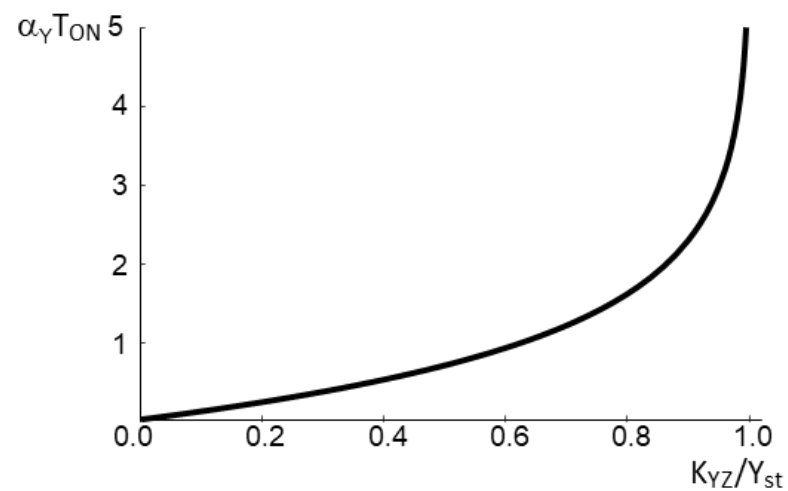
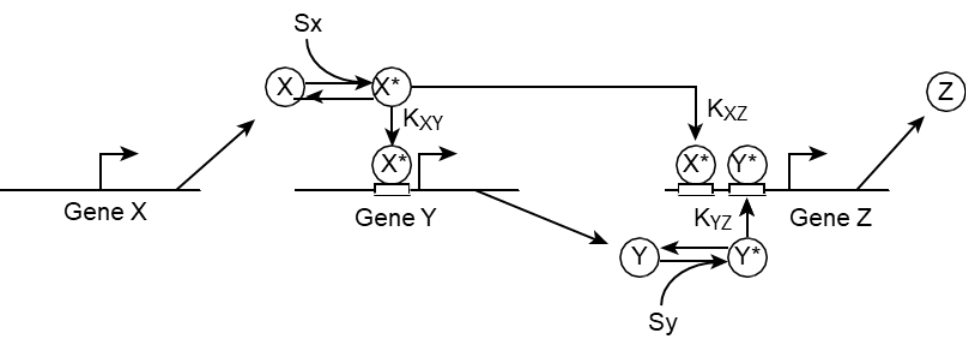
Input can be logical AND, and OR.

Let's look at the AND logic:

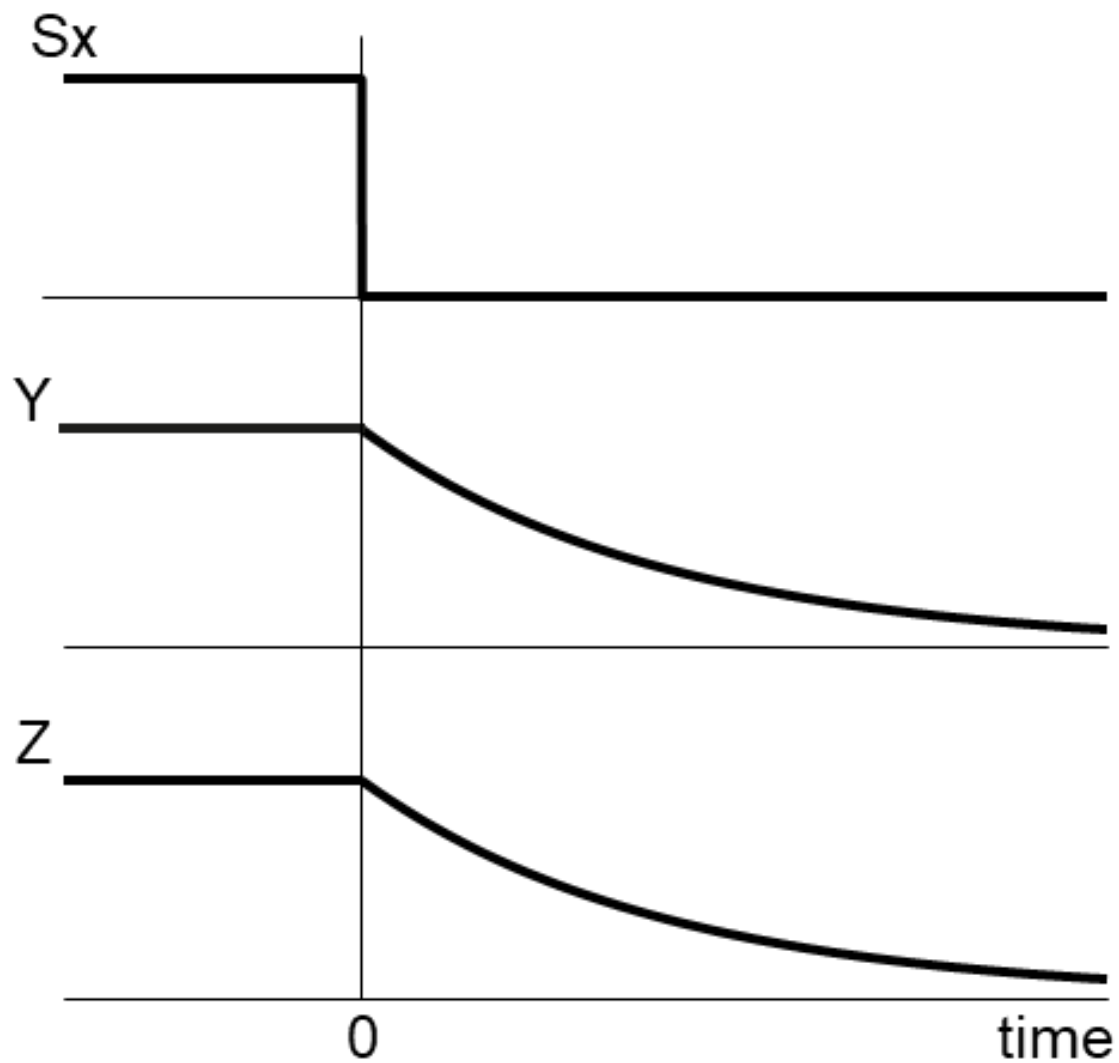




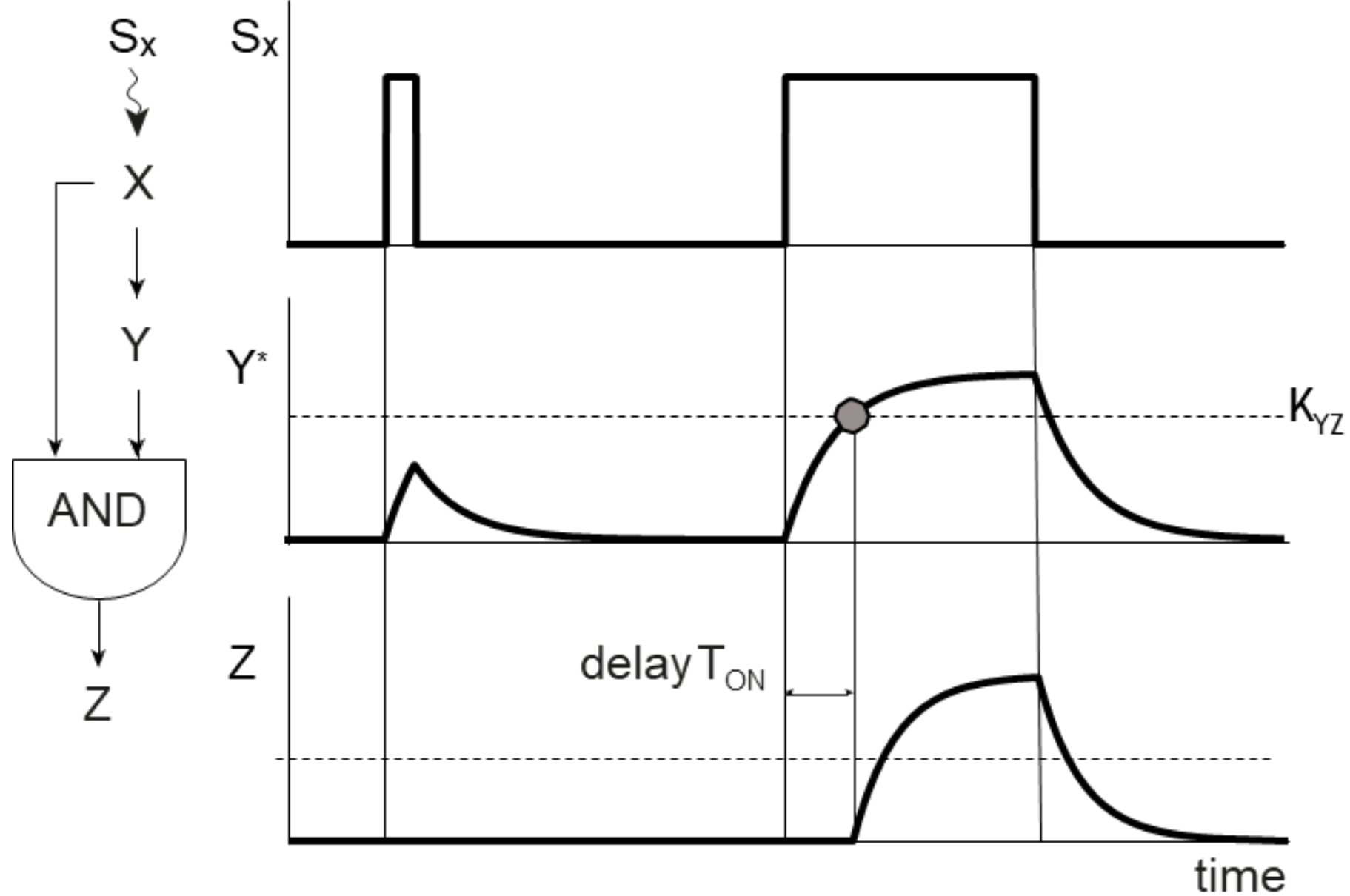
Signal ON:

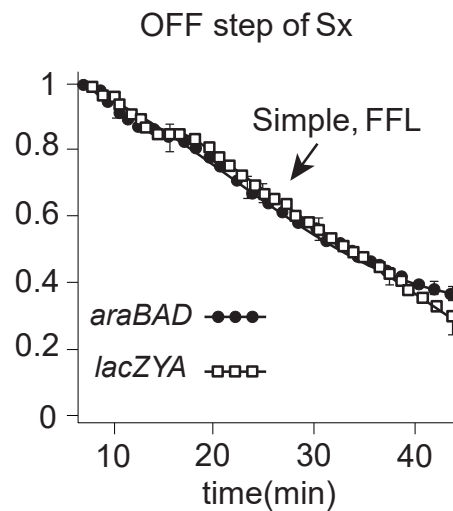
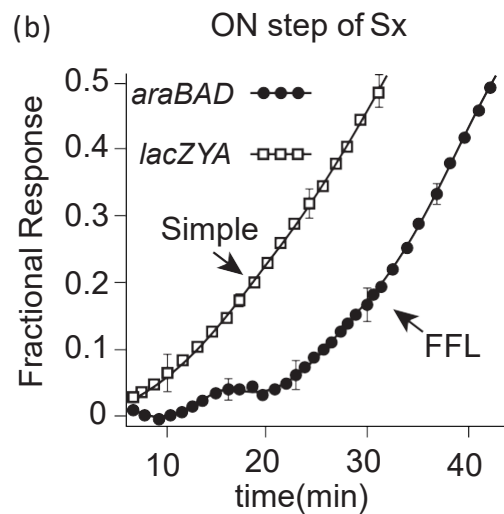
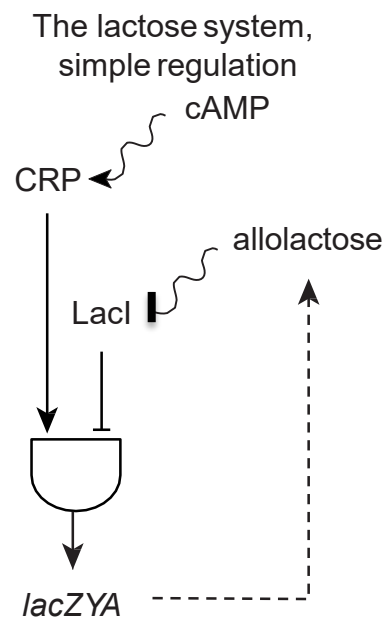
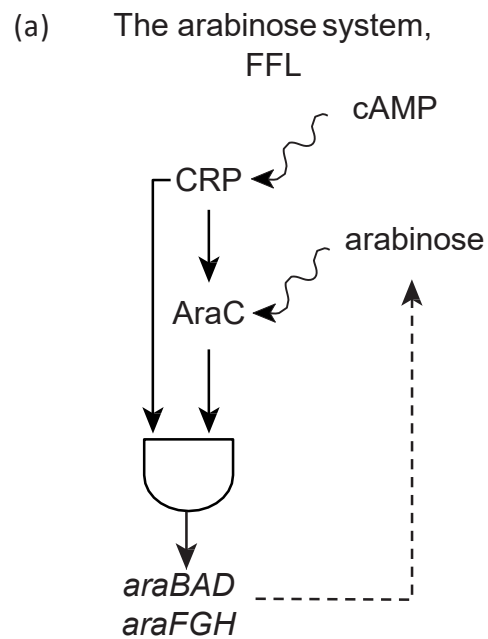


Signal OFF:

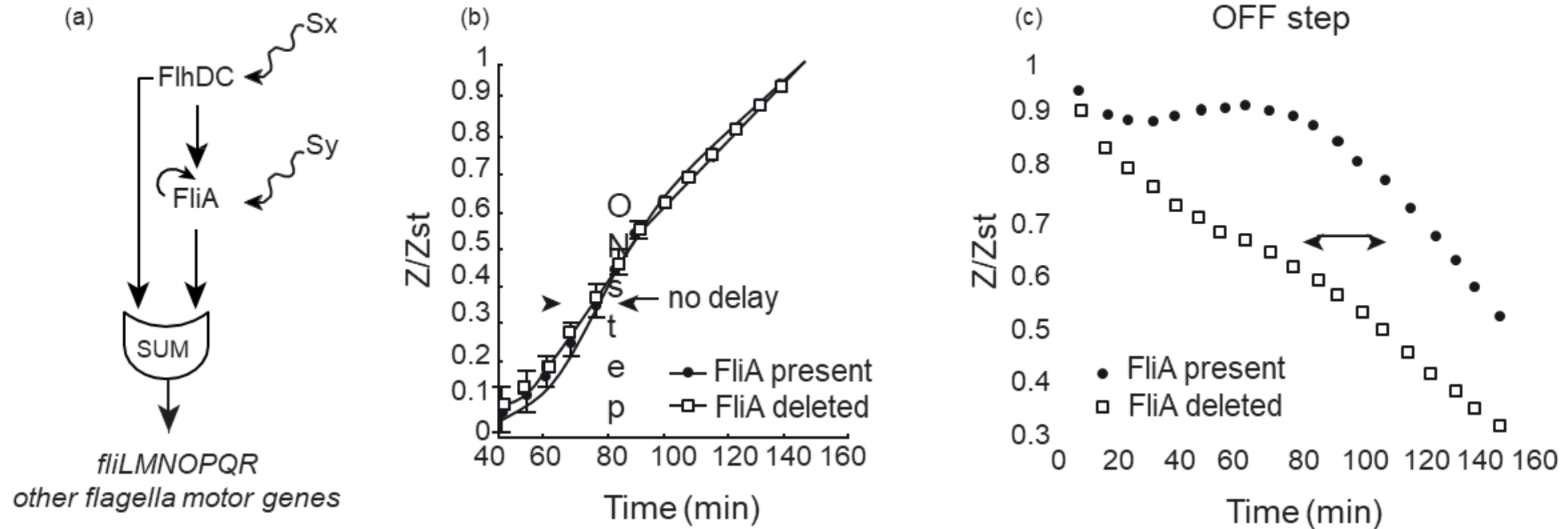


This is a sign sensitive delay:
Time filter, short pulses
filtered
Persistence detector



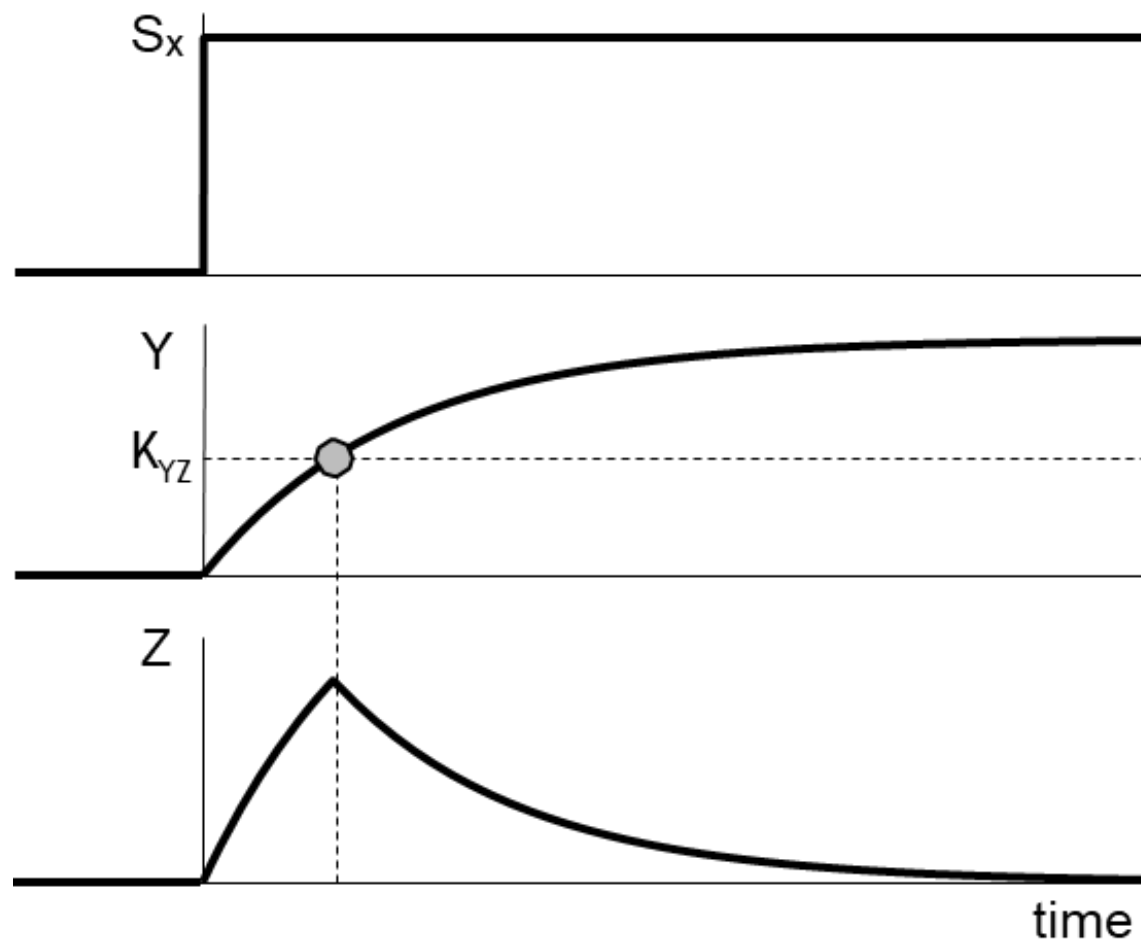
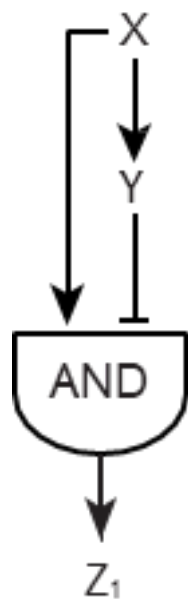


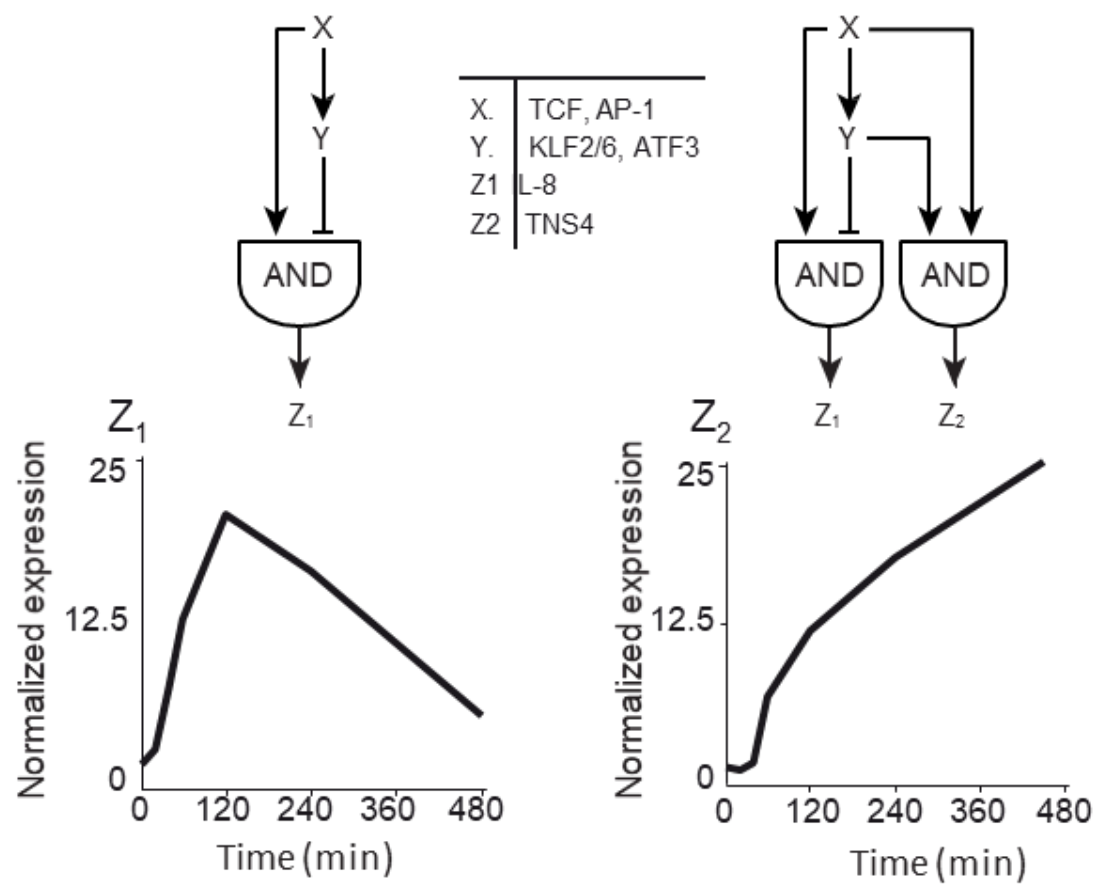
C1-FFL: OR case



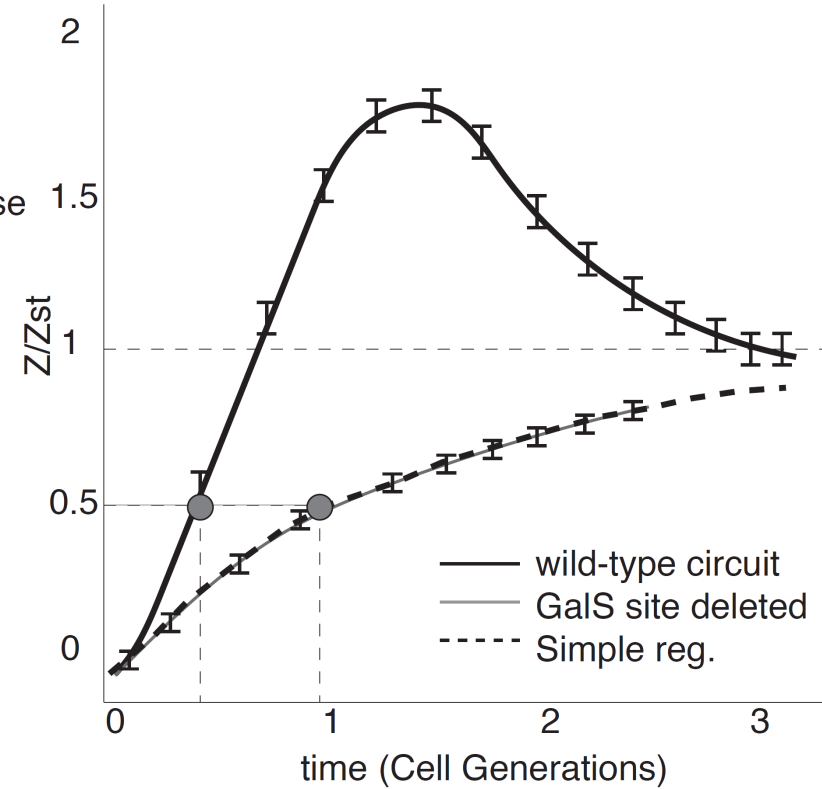
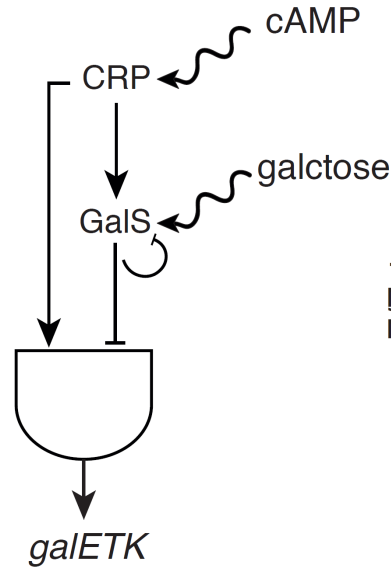
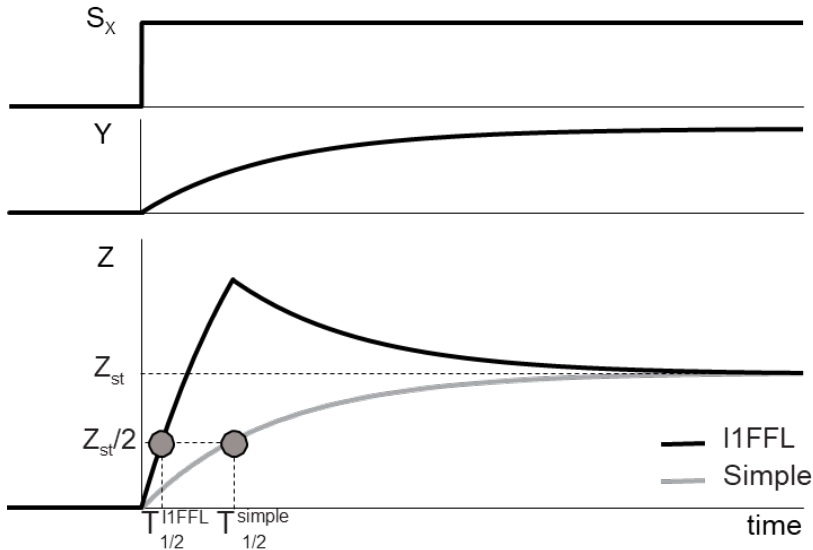
(No delay when turned on, but delay when turned off.
Protection against transient loss of input signal)

I1-FFL: AND case





I1-FFL Increases response time!



Sign sensitive response accelerator (only for on steps, not for off steps)

Three ways to increase response:

a) Increase degradation: Response time is inverse to degradation (Recall $X_{ST} = \frac{\beta}{\alpha}$)

b) Negative autoregulation (because now we can use strong promoter, but the system self regulates to maximal value)

c) Incoherent FFL: As we have just seen