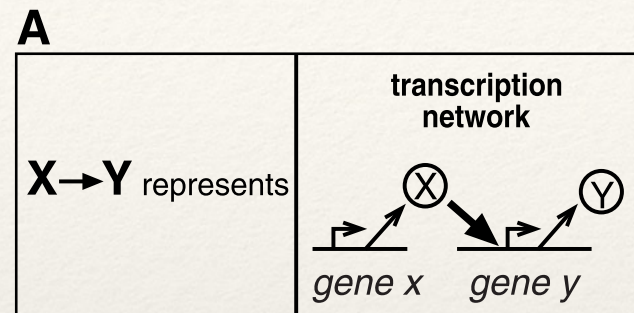
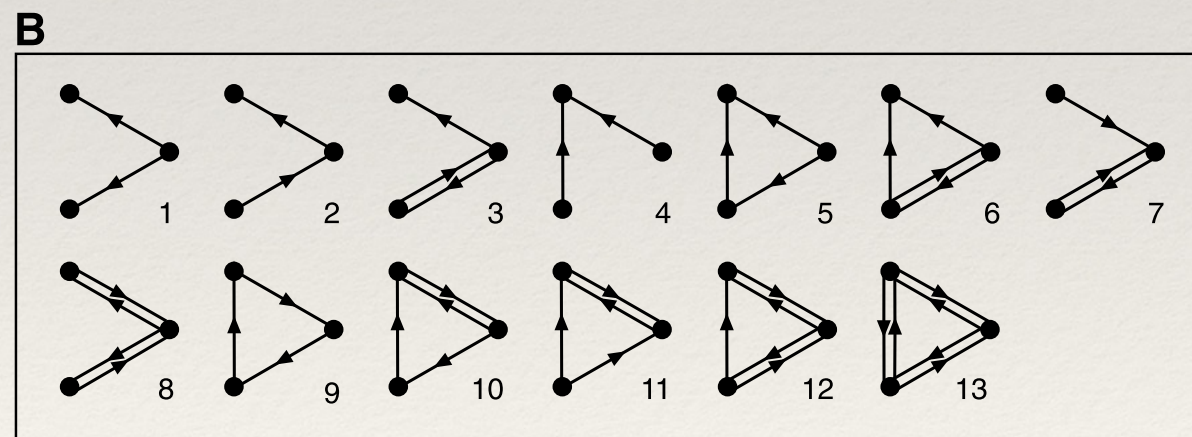


# Network Motifs


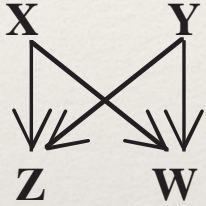


All possible three-node connected networks





# Certain Network Motifs are “Over-represented” in Gene Regulatory Networks

| Network                                    | Nodes | Edges | $N_{\text{real}}$   | $N_{\text{rand}} \pm \text{SD}$ | Z score | $N_{\text{real}}$  | $N_{\text{rand}} \pm \text{SD}$ | Z score |
|--|-------|-------|---|---------------------------------|---------|--|---------------------------------|---------|
| <b>Gene regulation<br/>(transcription)</b> |       |       |  <b>Feed-forward loop</b> |                                 |         |  <b>Bi-fan</b> |                                 |         |
|  |       |       |   |                                 |         |  |                                 |         |
|  |       |       |   |                                 |         |  |                                 |         |
| <i>E. coli</i>                             | 424   | 519   | 40  | $7 \pm 3$                       | 10      | 203  | $47 \pm 12$                     | 13      |
| <i>S. cerevisiae</i> *                     | 685   | 1,052 | 70  | $11 \pm 4$                      | 14      | 1812   | $300 \pm 40$                    | 41      |



# Feed-Forward Loop (FFL) Network Motifs

**a**

## Coherent FFL

Coherent  
type 1



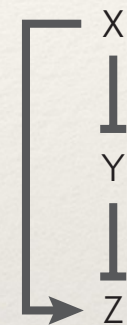
Coherent  
type 2



Coherent  
type 3



Coherent  
type 4



## Incoherent FFL

Incoherent  
type 1



Incoherent  
type 2



Incoherent  
type 3

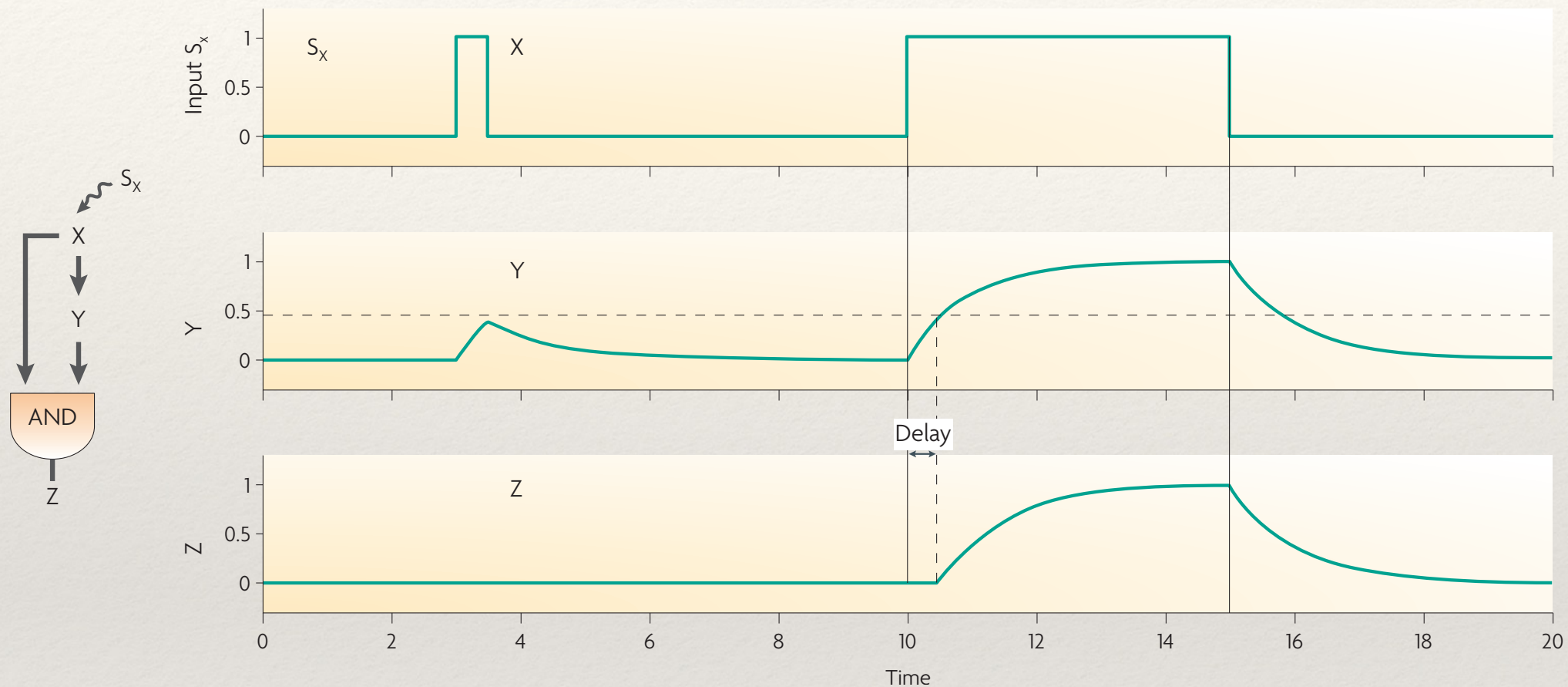


Incoherent  
type 4

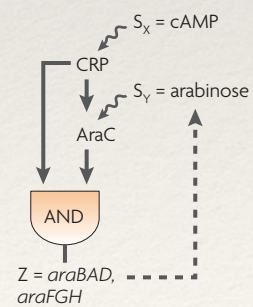




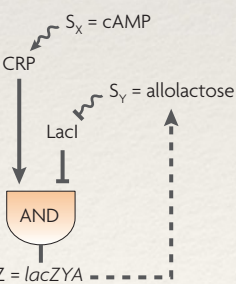
# A Coherent FFL can act as a “sign-sensitive delay” element



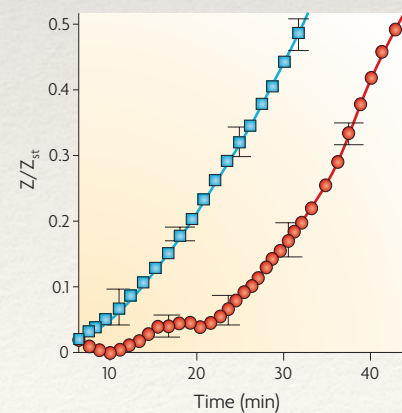
**b** Arabinose system



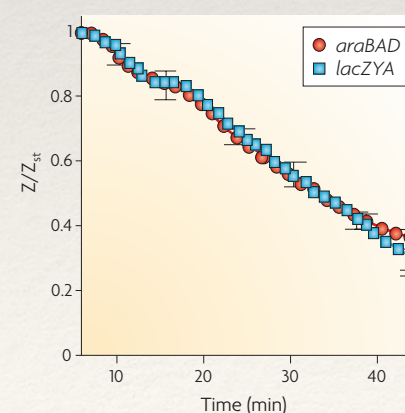
Lac system



ON step of  $S_X$



OFF step of  $S_X$



from Alon 2007, Nature Reviews Genetics