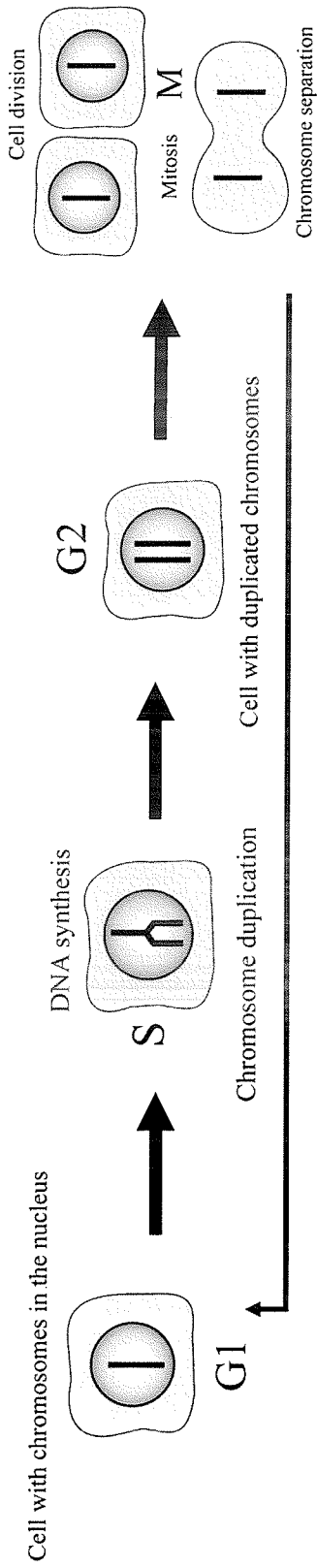
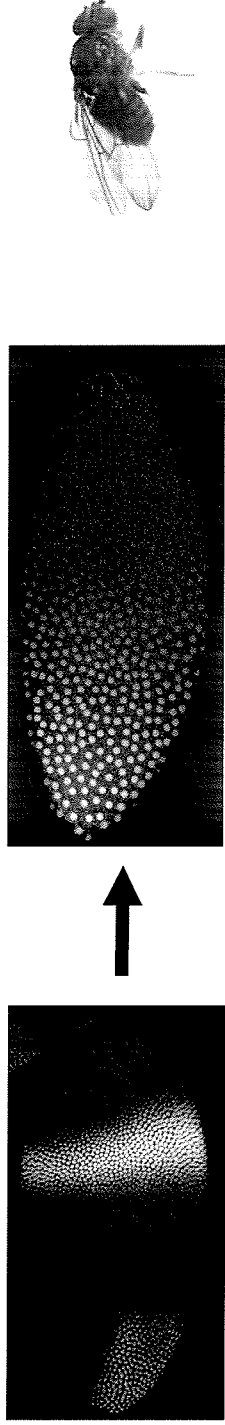


# Switching Between Cell States

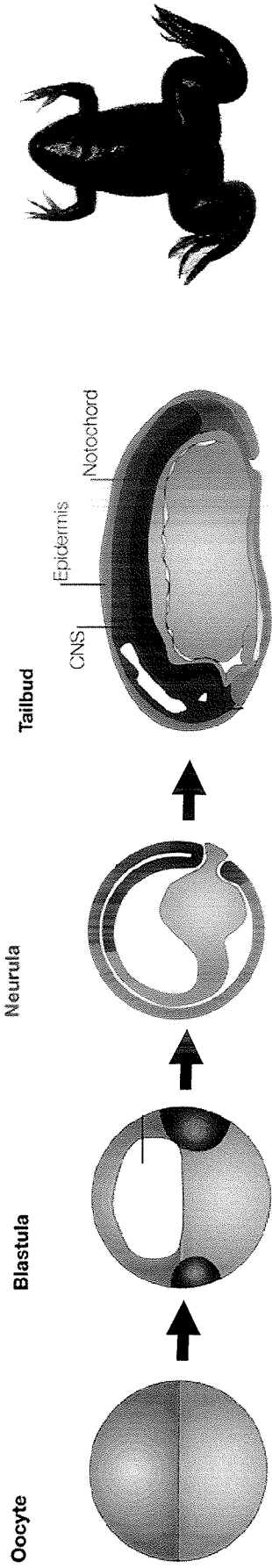
## Cell Cycle



## Drosophila Patterns

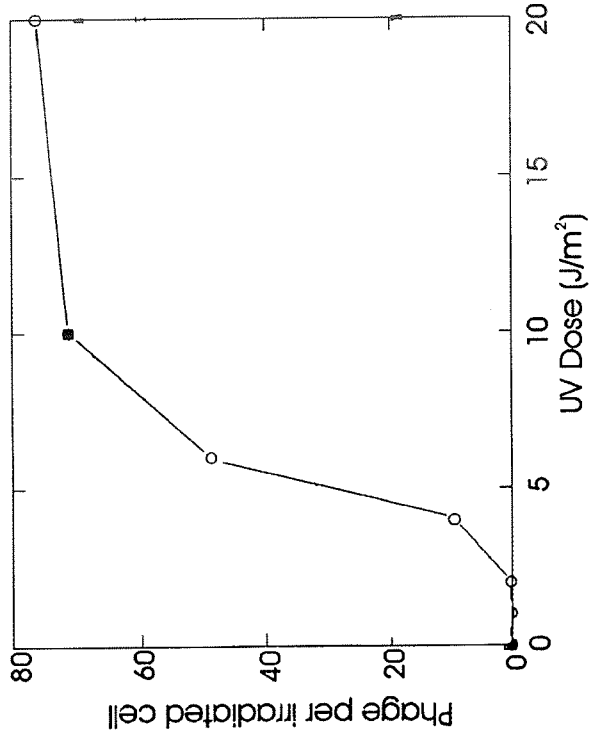
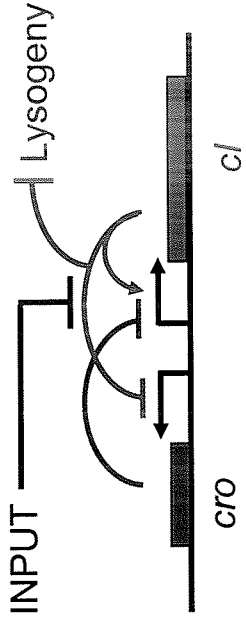


## Xenopus Development



# Phage Lambda

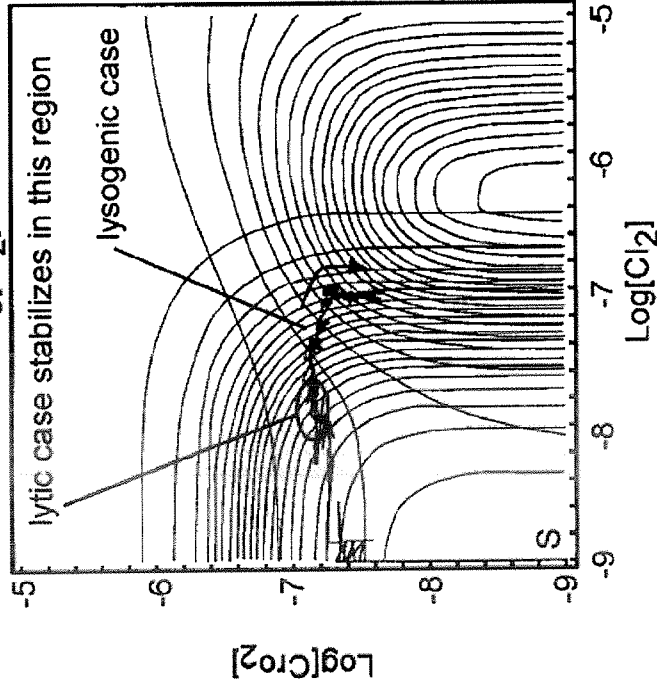
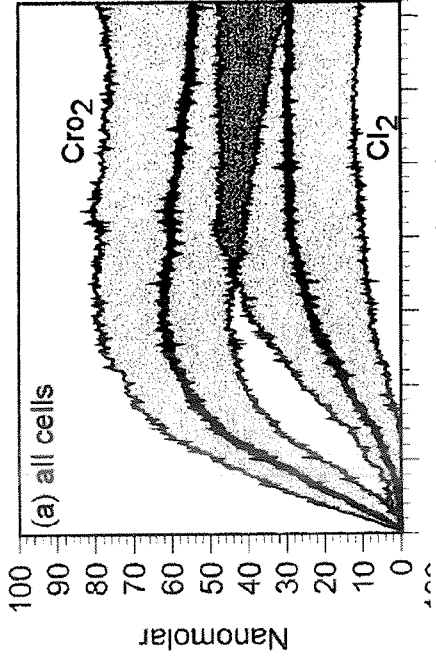
- Both positive feedback and cross repression



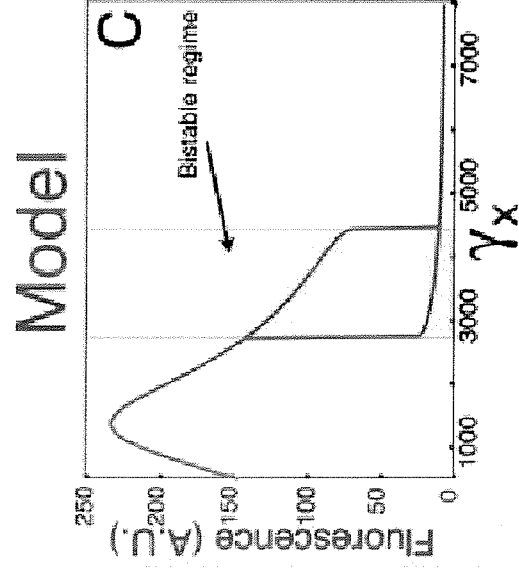
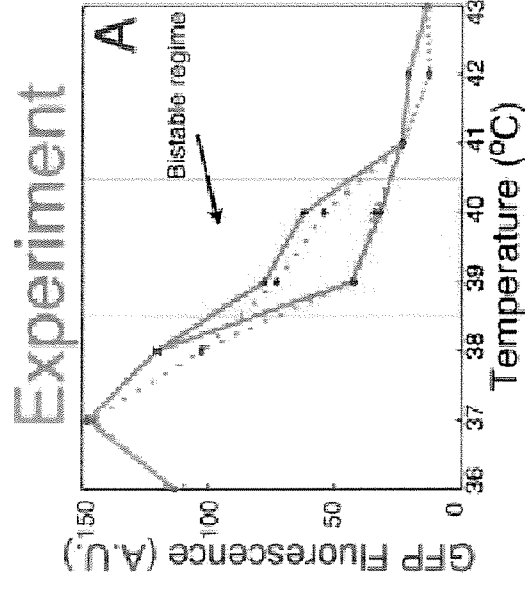
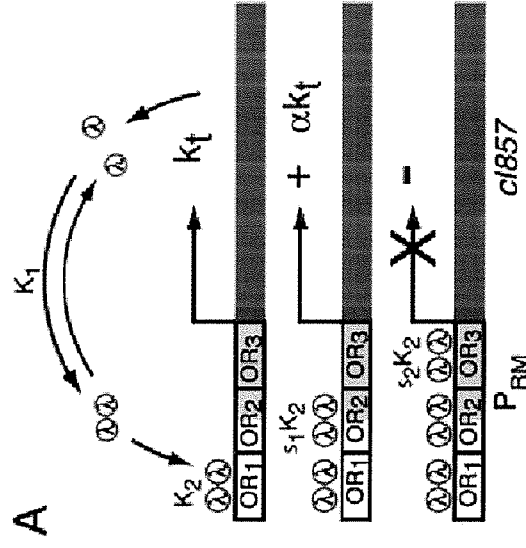
(Arkin, Genetics, 1998; Little, EMBO J, 1999)

- Stochastics can dominate with small numbers of molecules

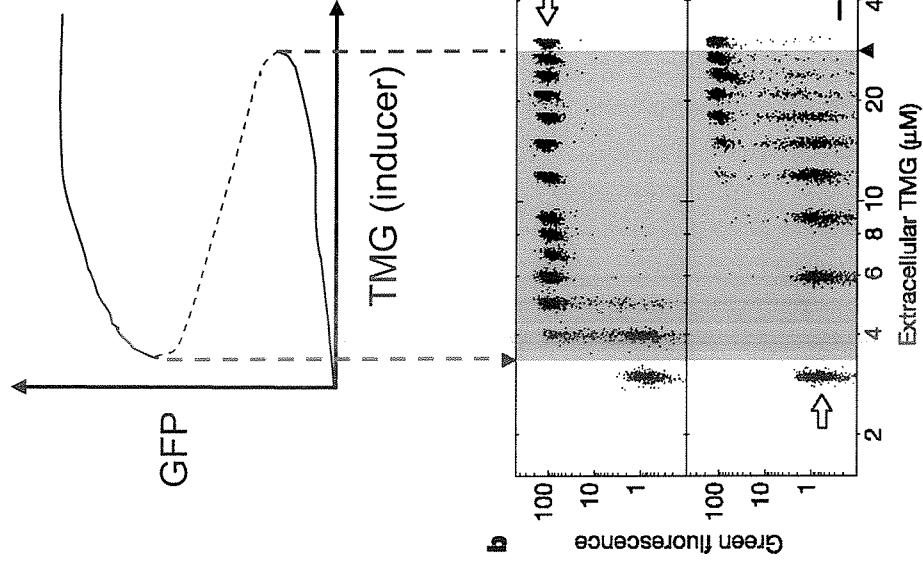
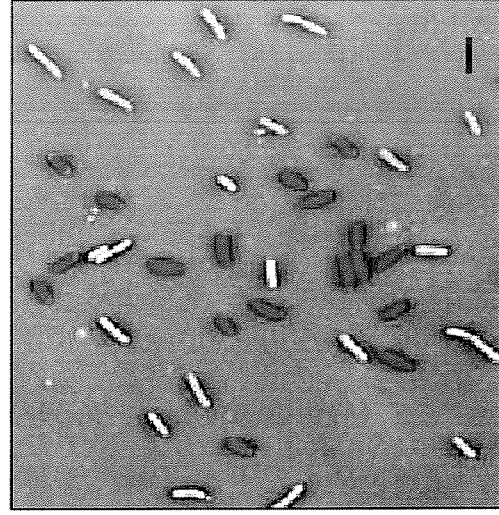
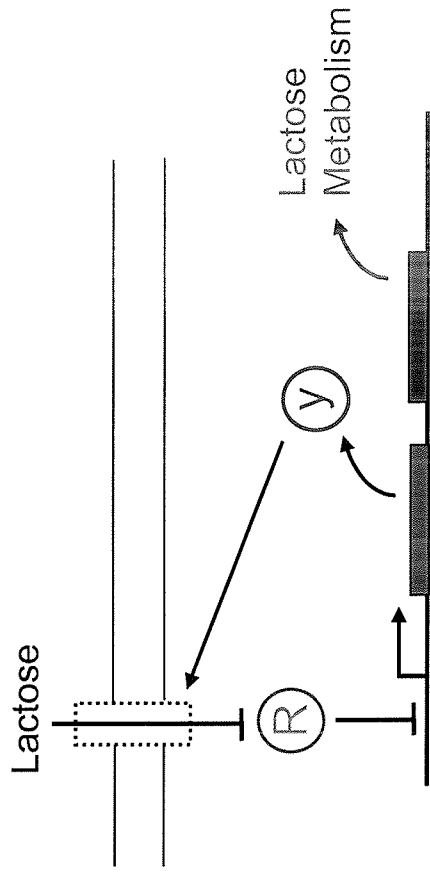
- At moment of infection:



# Bistability in Phage lambda



# Lac Operon and Positive Feedback



(van Oudenaarden, Nature, 2004)

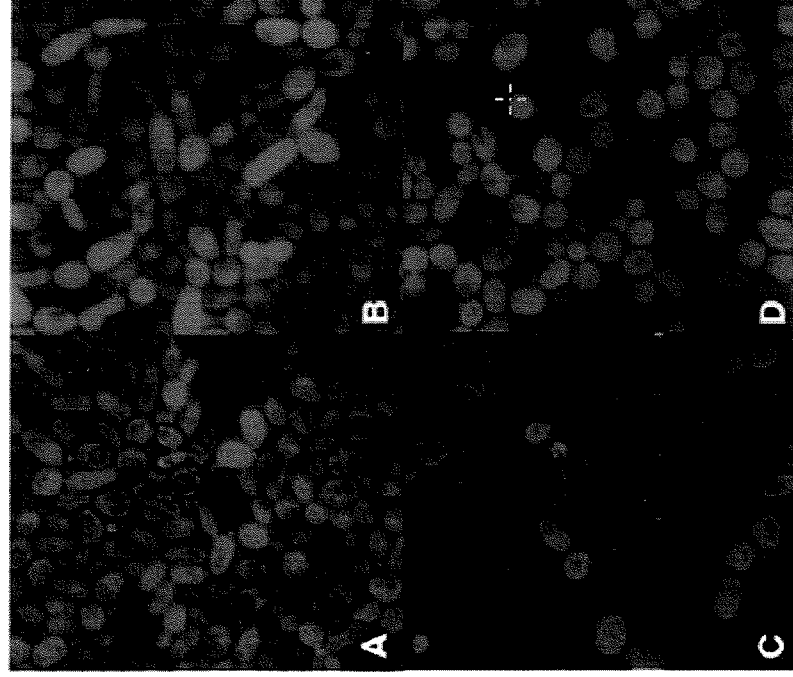
# Graded versus Binary Switching

## Synthetic Positive Feedback Loop in Yeast

Inducer Concentration

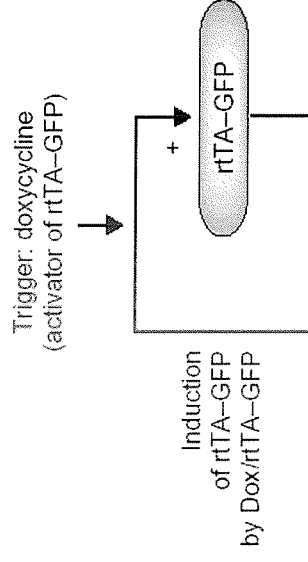
low

high

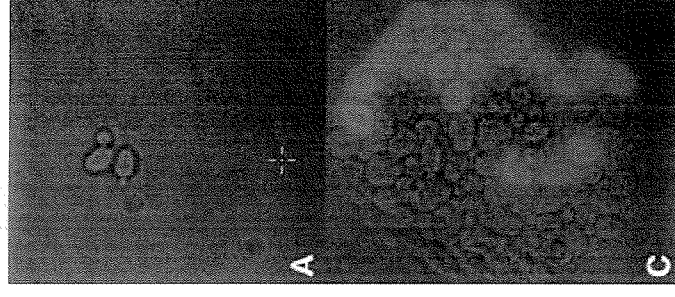


Control  
(graded)

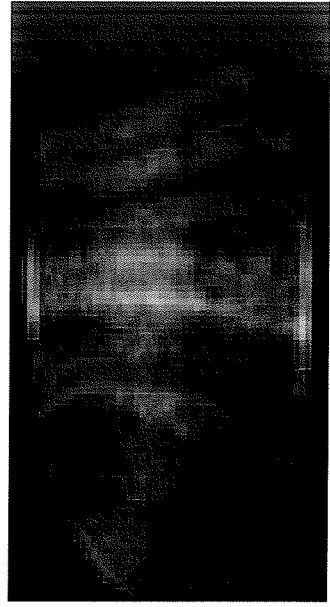
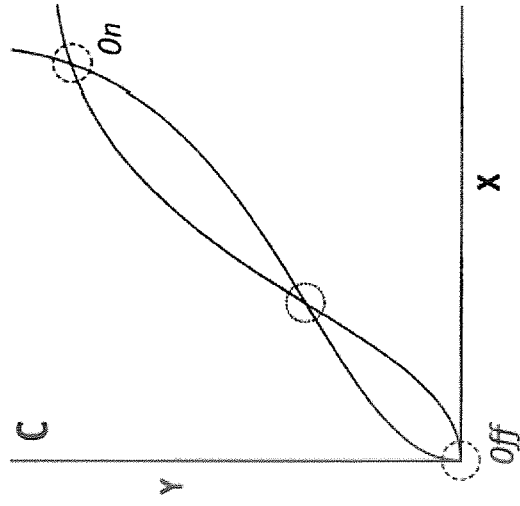
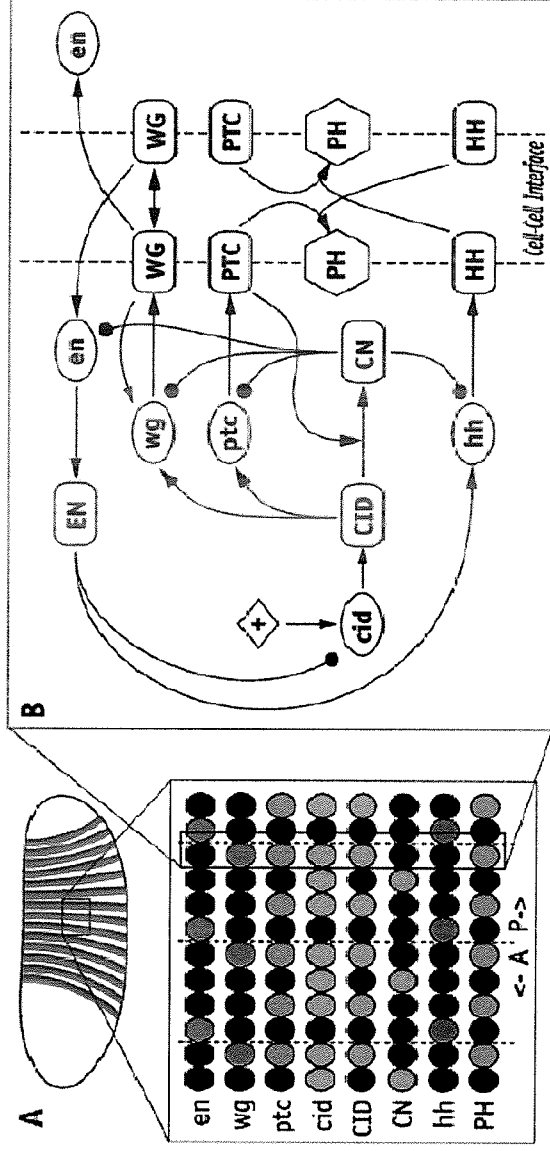
Positive  
Feedback



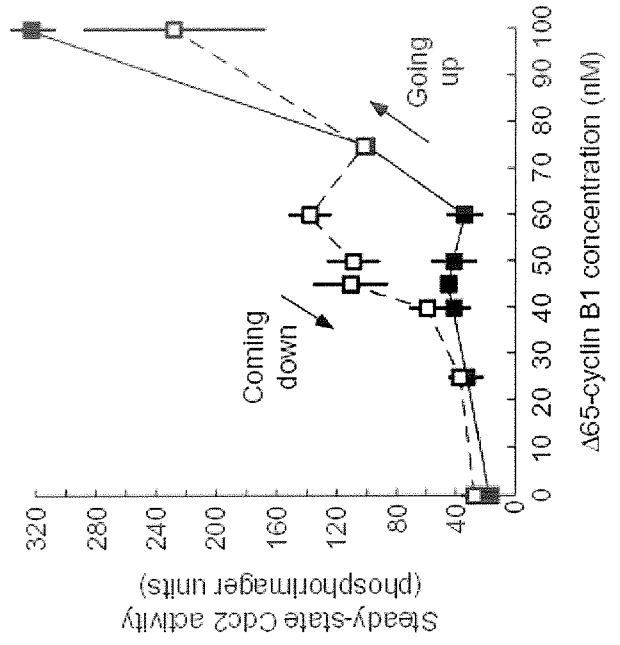
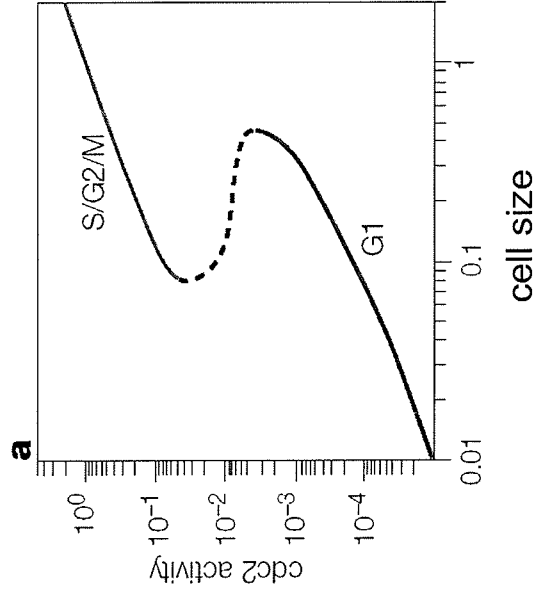
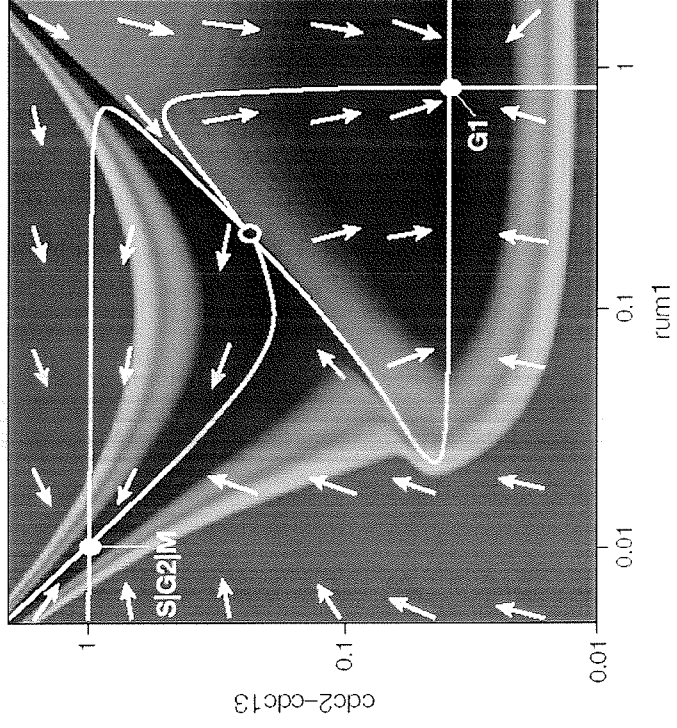
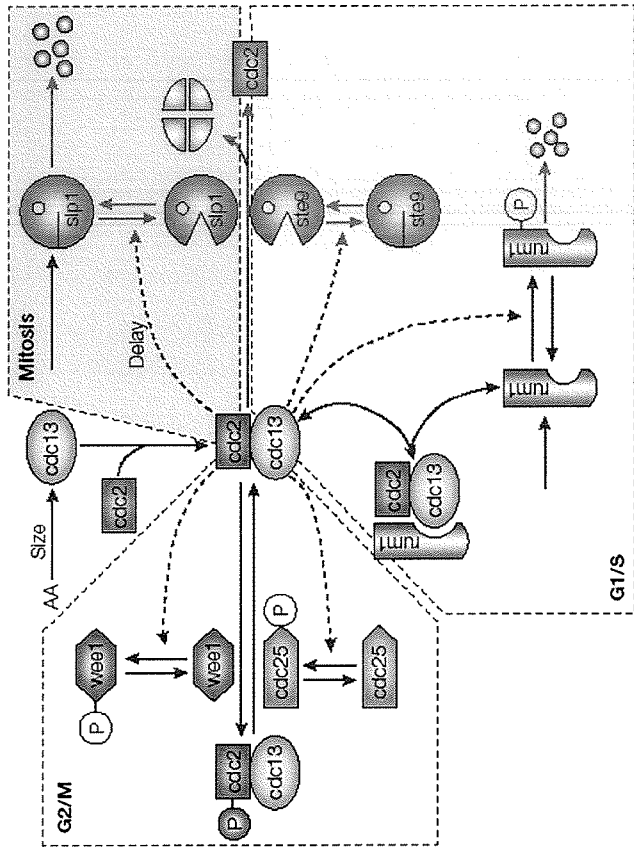
Colony switching



# Drosophila Development



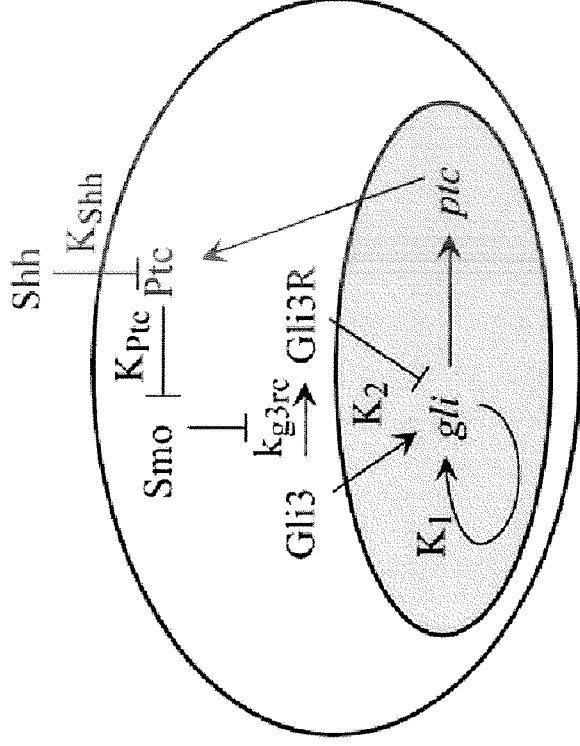
# Yeast Cell Cycle



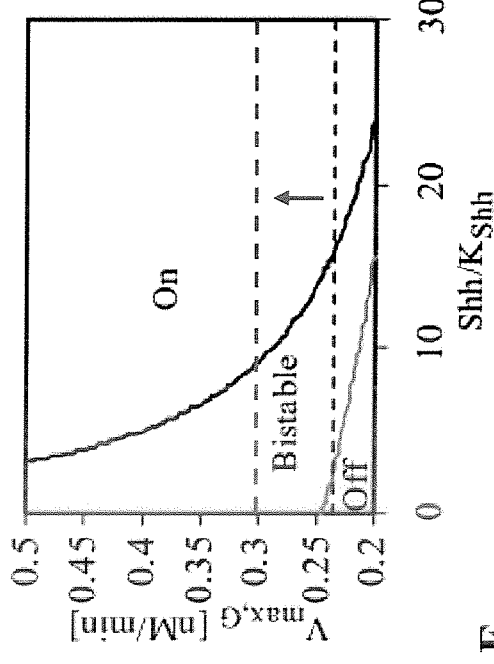
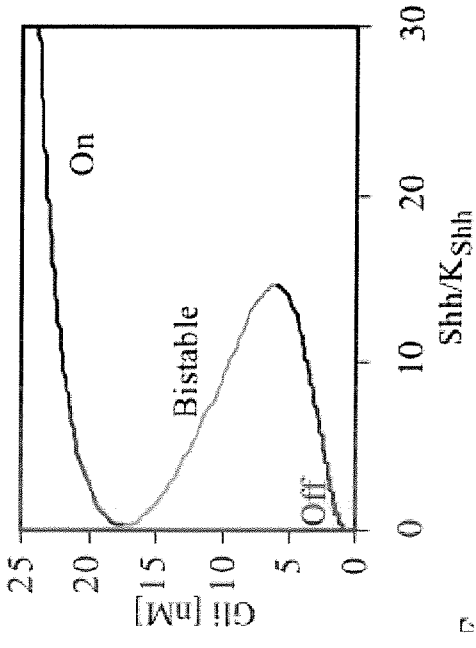
(Tyson, Nature Reviews, 2001;  
Ferrell, Nature, 2003)

# Irreversibility and Cancer

- Sonic hedgehog protein (*Shh*) stem cell fate switch (spinal cord, hippocampus, etc)



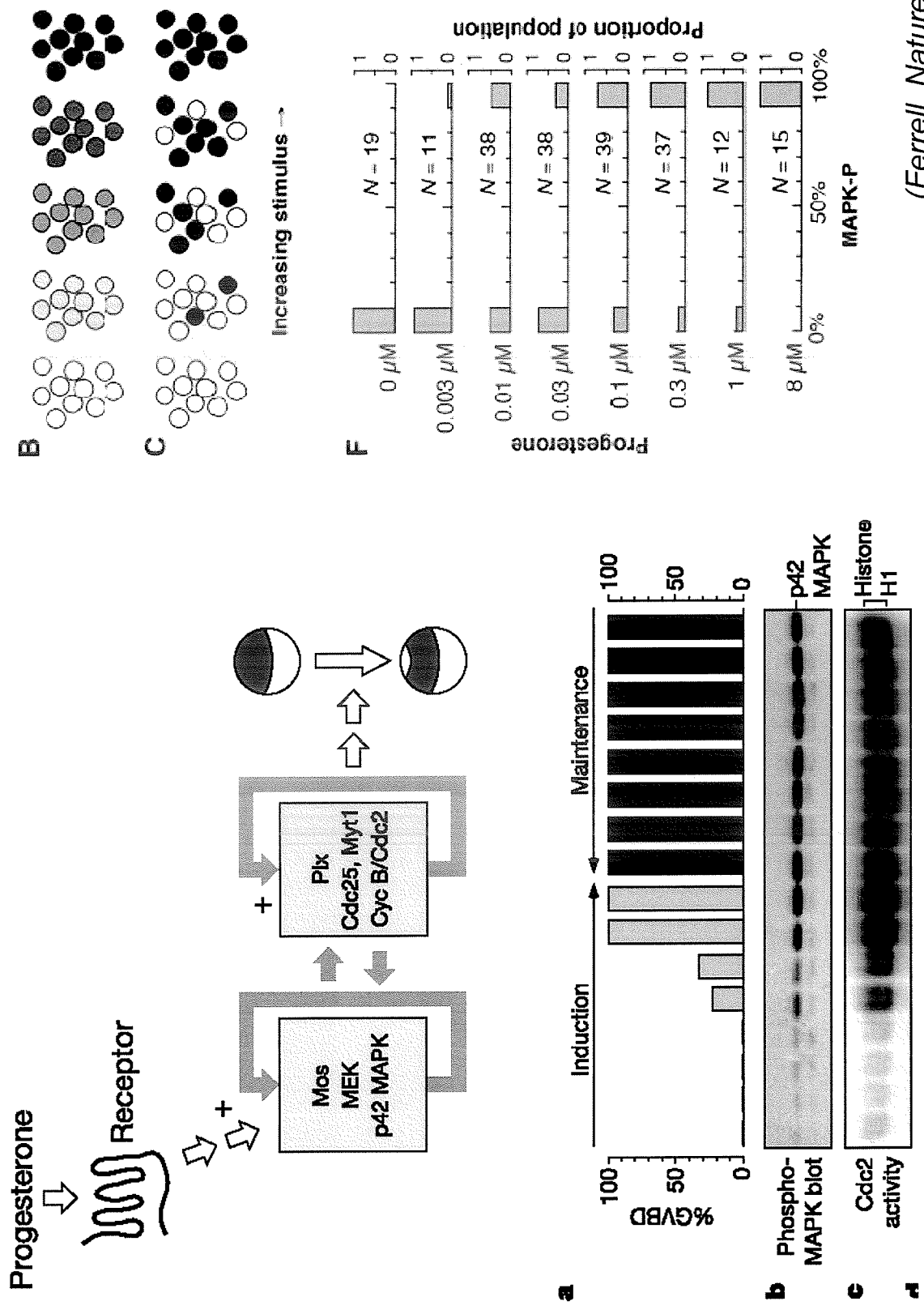
- *gli* expression rate causes change to irreversible switch
- mutations up regulating *gli* have been implemented in cancer (irreversible state of cellular proliferation)



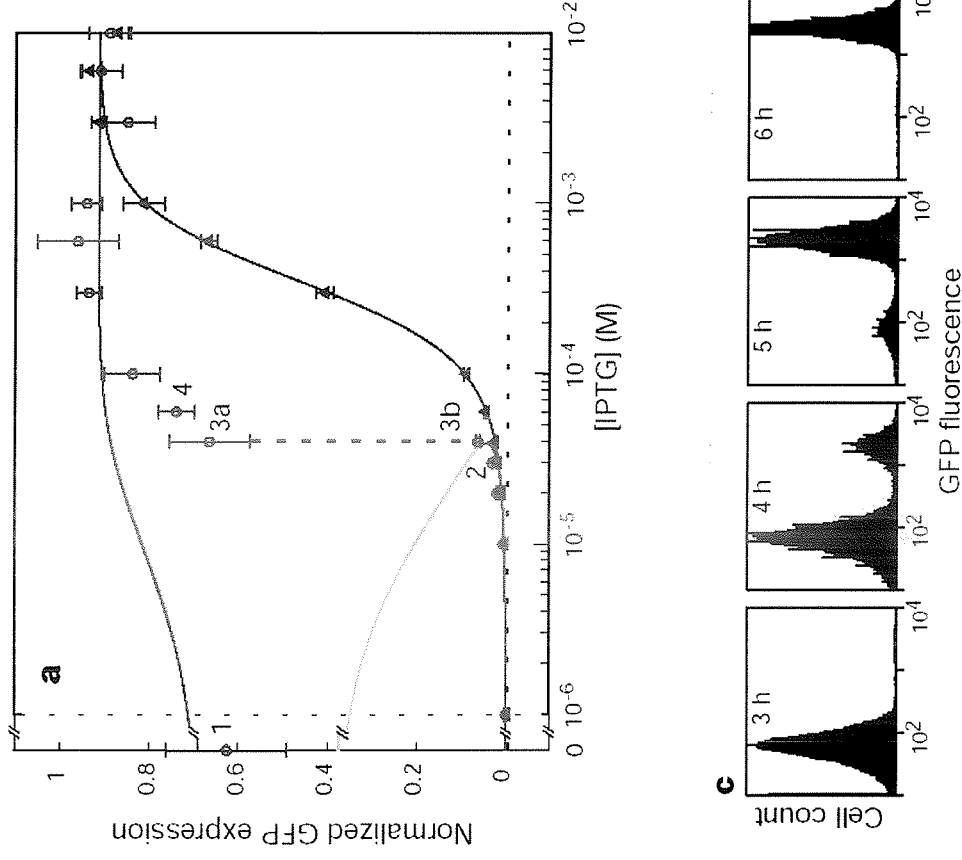
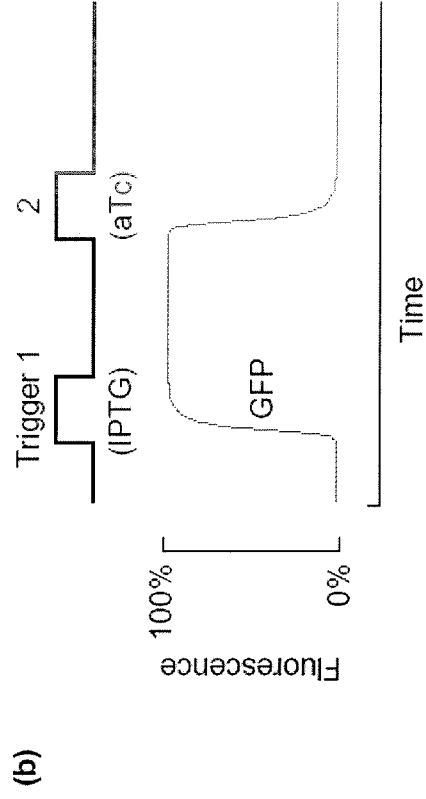
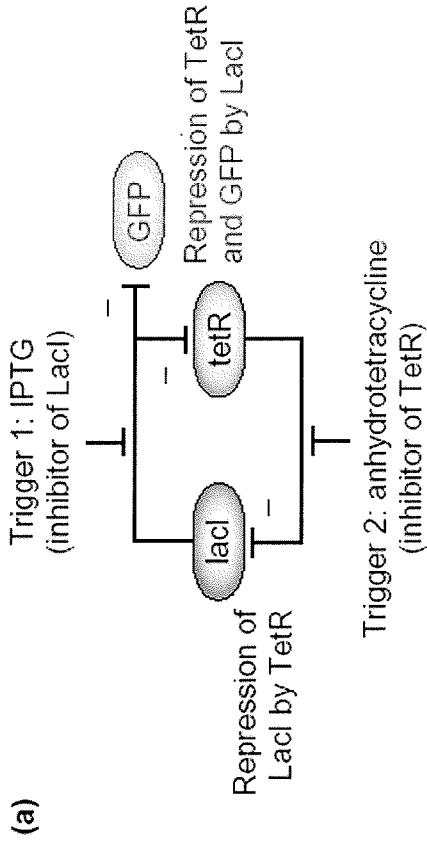


# Xenopus Development

- Phermone-induced germinal vesicle breakdown (GVD) in frog eggs (oocytes)

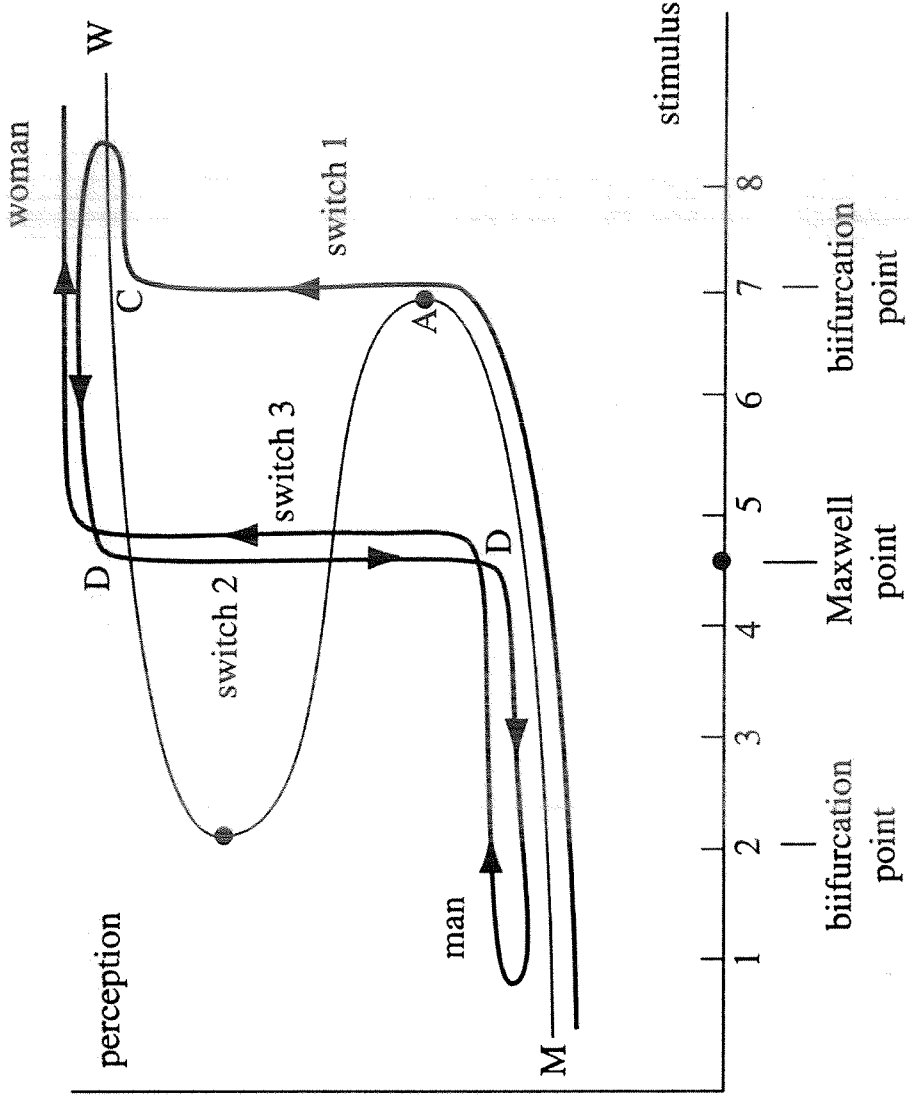


# Toggle Switch (Cross Repression)



(Collins, Nature, 2000)

# Hysteresis and Perception



(Fisher, 1967; Zeeman, 1983)