Type I Type II, PRCs and Coupling

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Through what mechanism do oscillations appear?
Type 1 Integrator
With such a mechanism

- Oscillations abruptly start or stop
- The period changes drastically when parameters are changed
- The system does not resonate, instead it needs to get kicked
Type 2 Resonator
With such a mechanism

- Oscillations switch from decaying very slowly to growing very slowly
- The period of the oscillations barely changes when going through the bifurcation
- The system “resonates”
Chaotic Entrainment
Design I

Design II

Design III

Design IV
Type I vs. Type II
PloS Computational Biology 2:e30
Design I
Design II

![Diagram showing a graph with x and Δ axes, depicting SNIC bifurcation, subcritical Hopf bifurcation, stable and unstable LC, and stable and unstable x*.](image)

- **SNIC bifurcation**
- **Subcritical Hopf bifurcation**
- **Stable x**
- **Unstable x**
- **Stable LC**
- **Unstable LC**
Coupling by sharing a protein
Coupling by sharing a protein
Coupling by extracellular signaling
Garcia-Ojalvo et al. PNAS 101:10955

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.
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Order Parameter

\[ R = \frac{\langle M^2 \rangle - \langle M \rangle^2}{\langle b_i^2 \rangle - \langle b_i \rangle^2} \]
Coupling can reduce noise

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Phase Shifting

Glass and Winfree AJP 246:R251
PRC Atlas
Formula for the PRC

- Point D is on a limit Cycle
- We perturb in the positive horizontal direction
\[ \frac{|EG|}{|GF|} = \tan \phi \]

\[ \frac{|\Delta z| \sin \theta}{(r - |\Delta z| \cos \theta)} = \tan \phi \]

\[ \phi = \arctan \left( \frac{|\Delta z|}{\sqrt{2 - |\Delta z|}} \right) \]
0-D phaseless region
1-D phaseless region
2-D Phaseless Region

\[ f(C) = \frac{m_{11}}{K_1^m + C^m} + \frac{m_{12}}{K_2^m + C^m} \]
Winfree, The Geometry of Biological Time
Ukai, Nature Cell Biology 9:1327
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