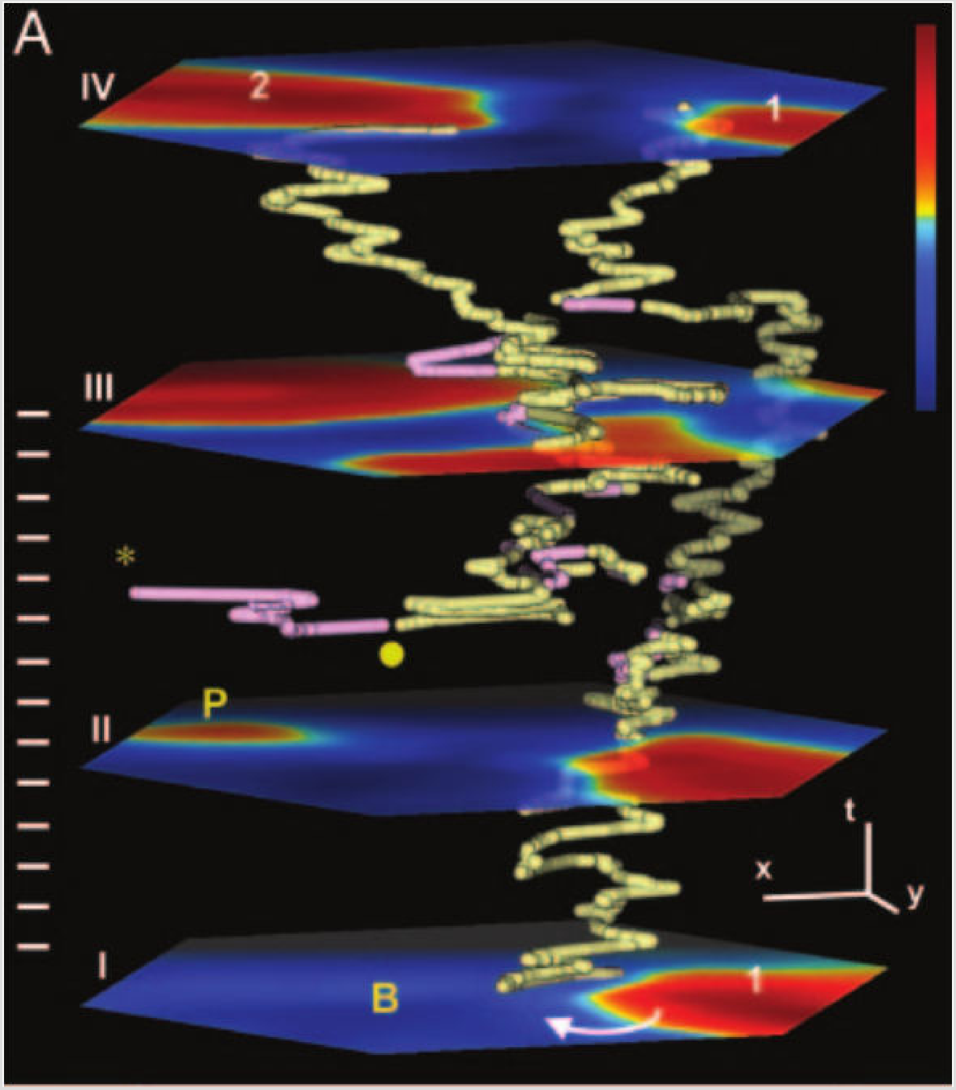
Spirals in Excitable Media



Presentation by:
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Talking Points

- Spirals in Excitable Media
- Spiral Breakup
- Multiarmed Spirals
- Occurence of Spirals in Heart Tissue

Excitable Medium

- FitzHugh-Nagumo

$$\frac{\partial e}{\partial t} = \Delta e - f(e) - g,$$

$$\frac{\partial g}{\partial t} = D_g \Delta g + \varepsilon(e, g)(ke - g),$$

- Activator e increases g
- Recovery var. g inhibits e
- Dg diffusion constant
- Diffusion of both e and g

Spiral Breakup

- FitzHugh-Nagumo

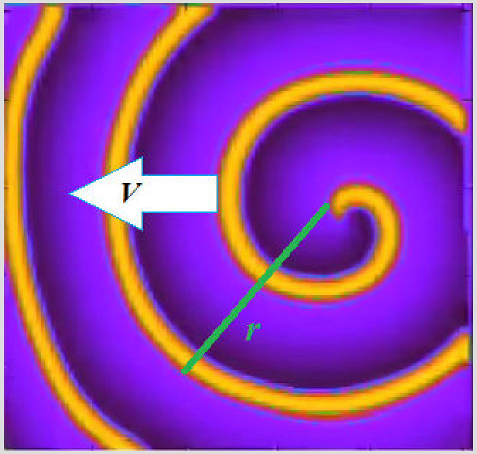
$$\frac{\partial e}{\partial t} = \Delta e - f(e) - g,$$

$$\frac{\partial g}{\partial t} = D_g \Delta g + \varepsilon(e, g)(ke - g),$$

- Existence of spirals
- https://www.youtube.com/watch?v=u0p8d1UI7_0

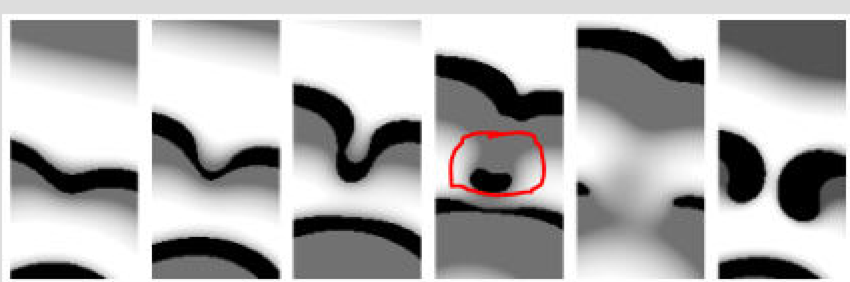
Spiral Breakup

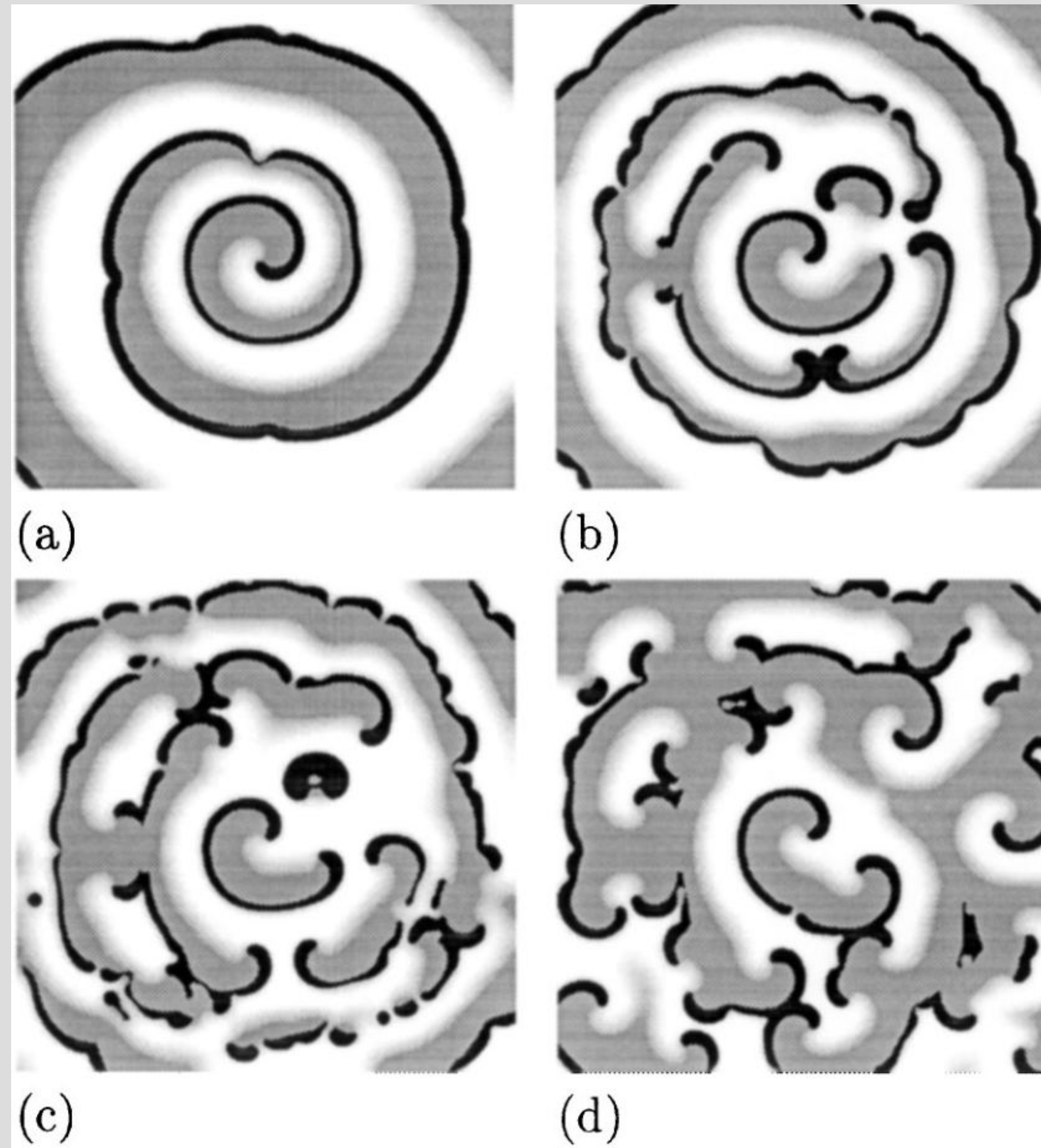
- Speed of spiral wave: $V = V_0 - Dk,$
- V0 = speed of planar wave
- Curvature k = 1/r
- D will influence spiral breakup
- Choose values such that breakup occurs
- https://www.youtube.com/watch?v=JOJ3ryFtMBw



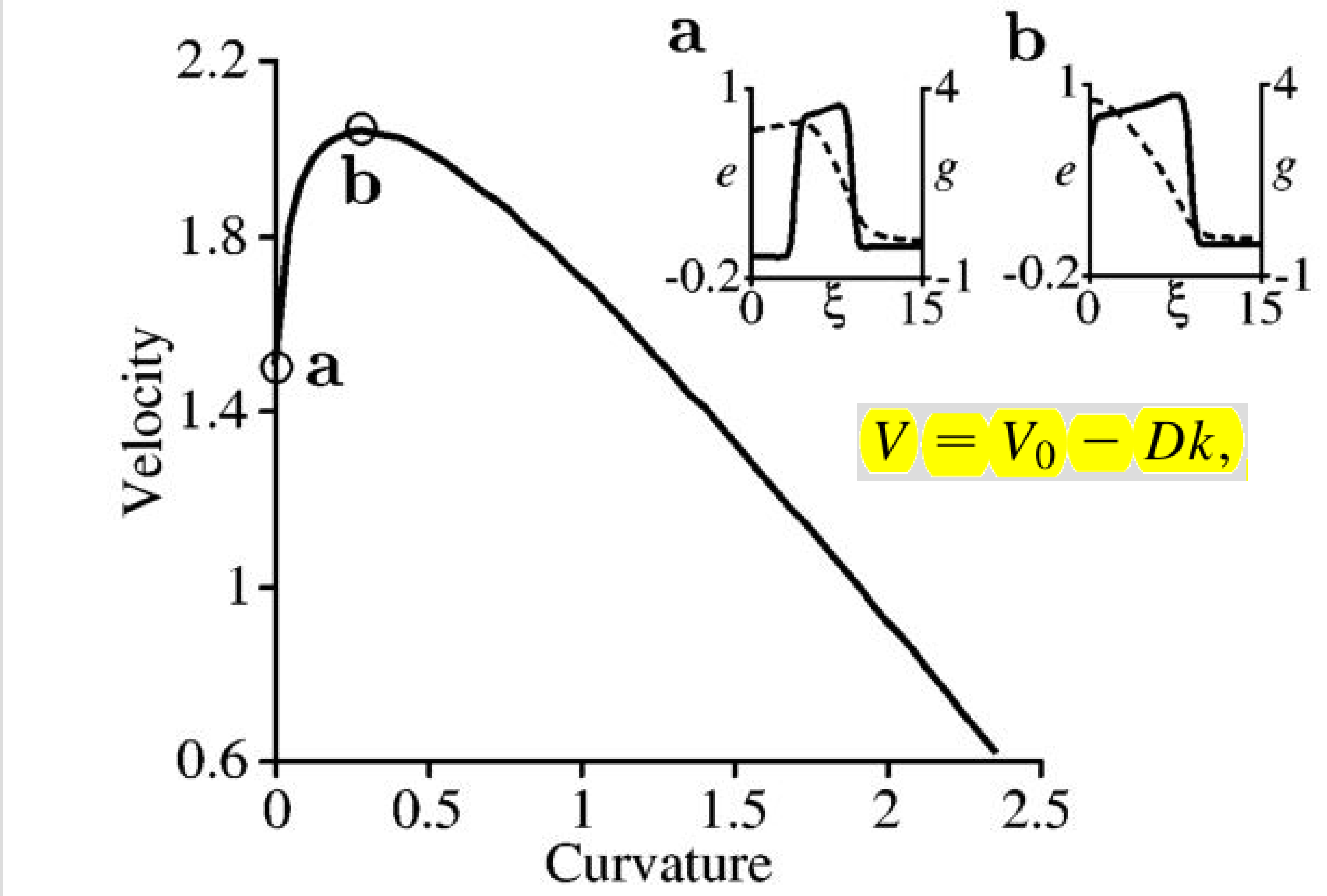
Breakup evolution

- a) Instability
- b) Perforation
- c) Interacting spirals
- d) Stability





Conditions for breakup

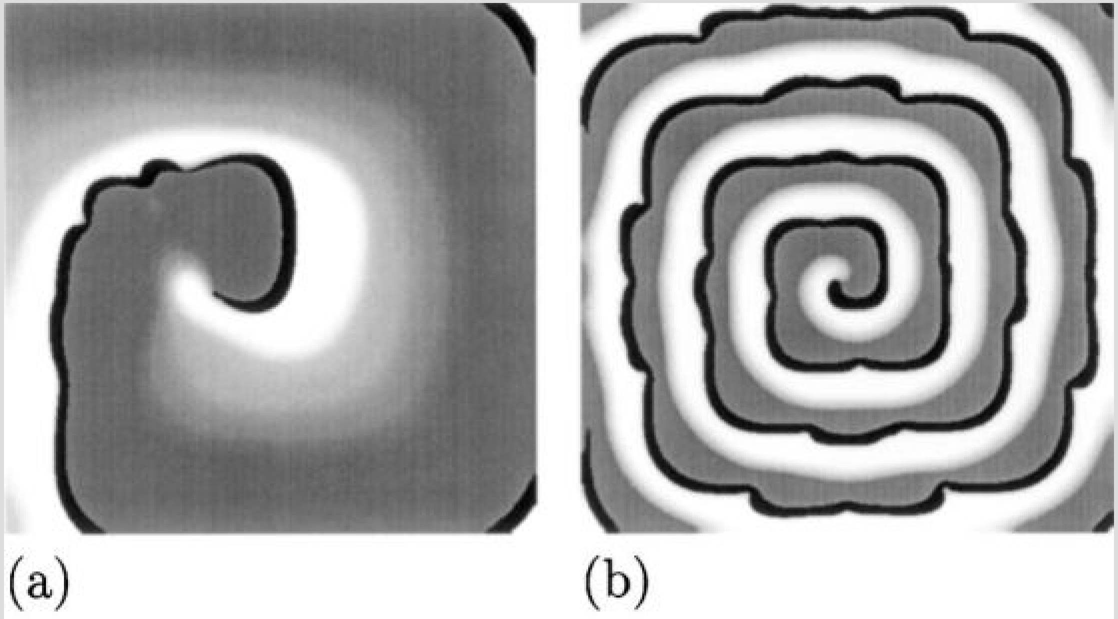


$$V = V_0 - Dk,$$

Stability

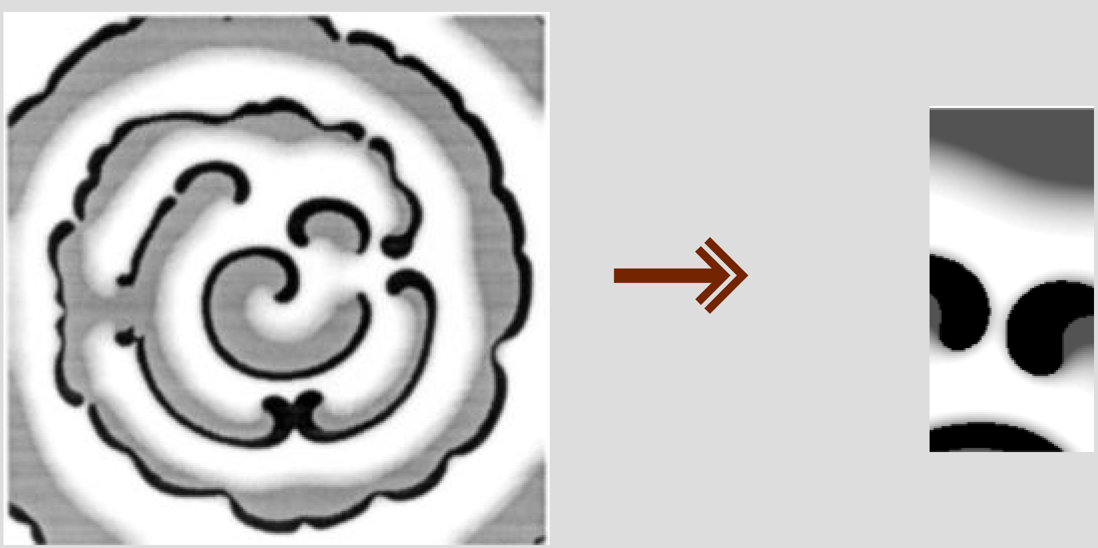
- a) Large refractory period

- b) High excitability

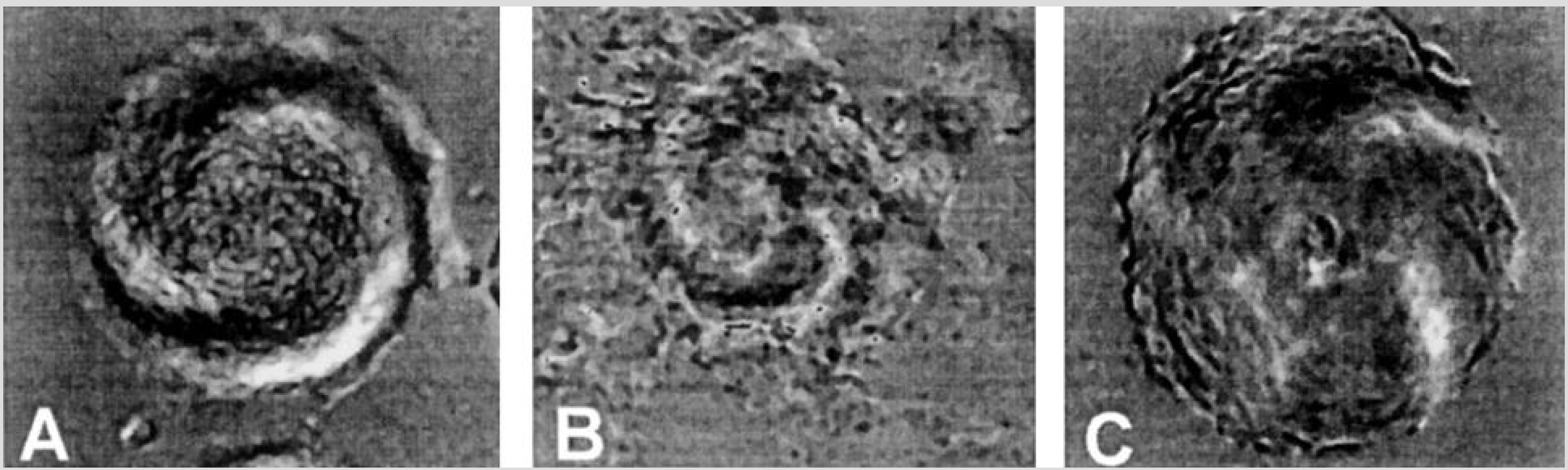


Conclusion

- Spirals are a natural occurrence in Excitable Media
- Spiral breakup occurs in certain places of the parameter space
- Spiral breakup results in 2 new spiral cores



Multiarmed Spirals



Excitable Medium

- FitzHugh-Nagumo:

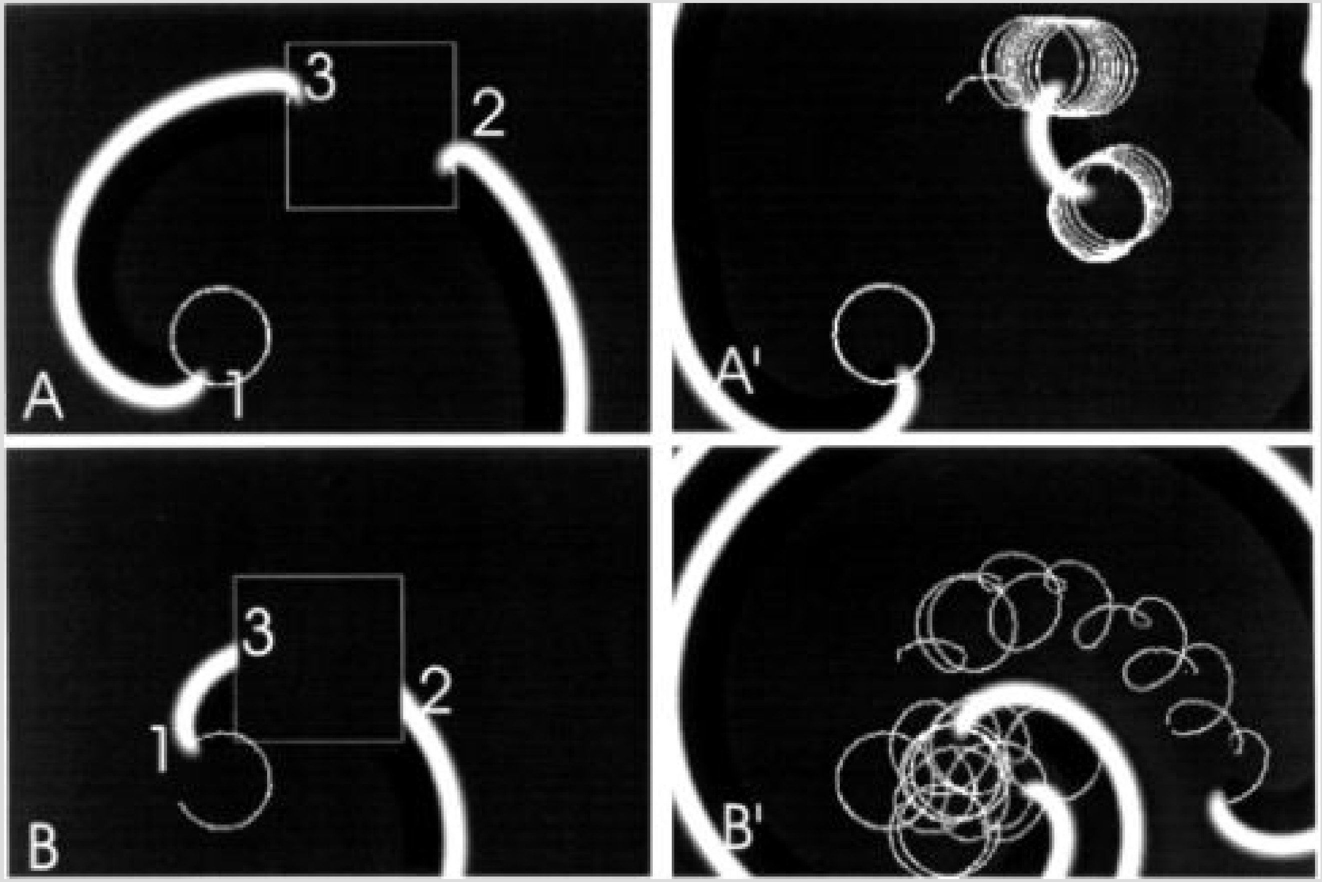
$$\partial g/\partial t = D\Delta g - k_g g(g-a)(g-1) - k_r r\,,$$

$$\partial r/\partial t = (g-r)/\tau\,.$$

- Similar, but no diffusion of recovery variable
- Important variables: k_g, tau

Breakup into Multiarm

- Breakup yields 2 new cores
- Distance between cores is important

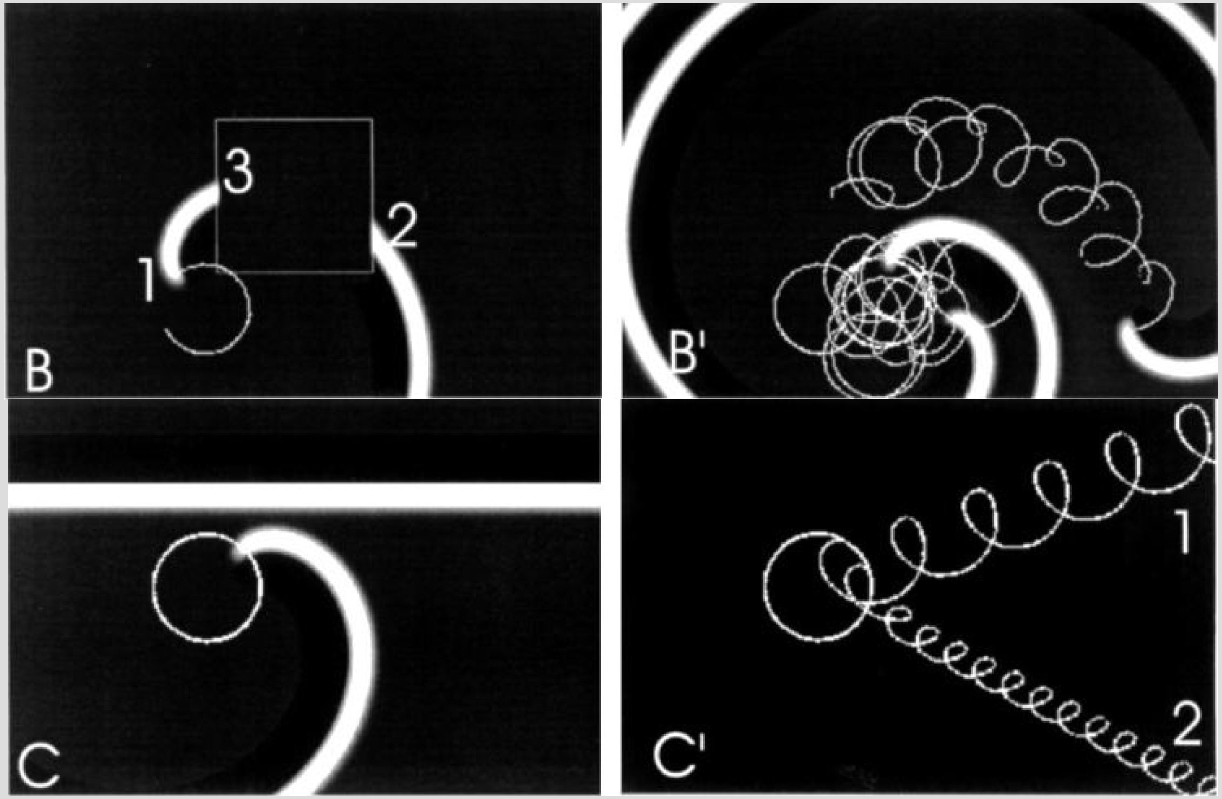


Attraction Spiral Cores

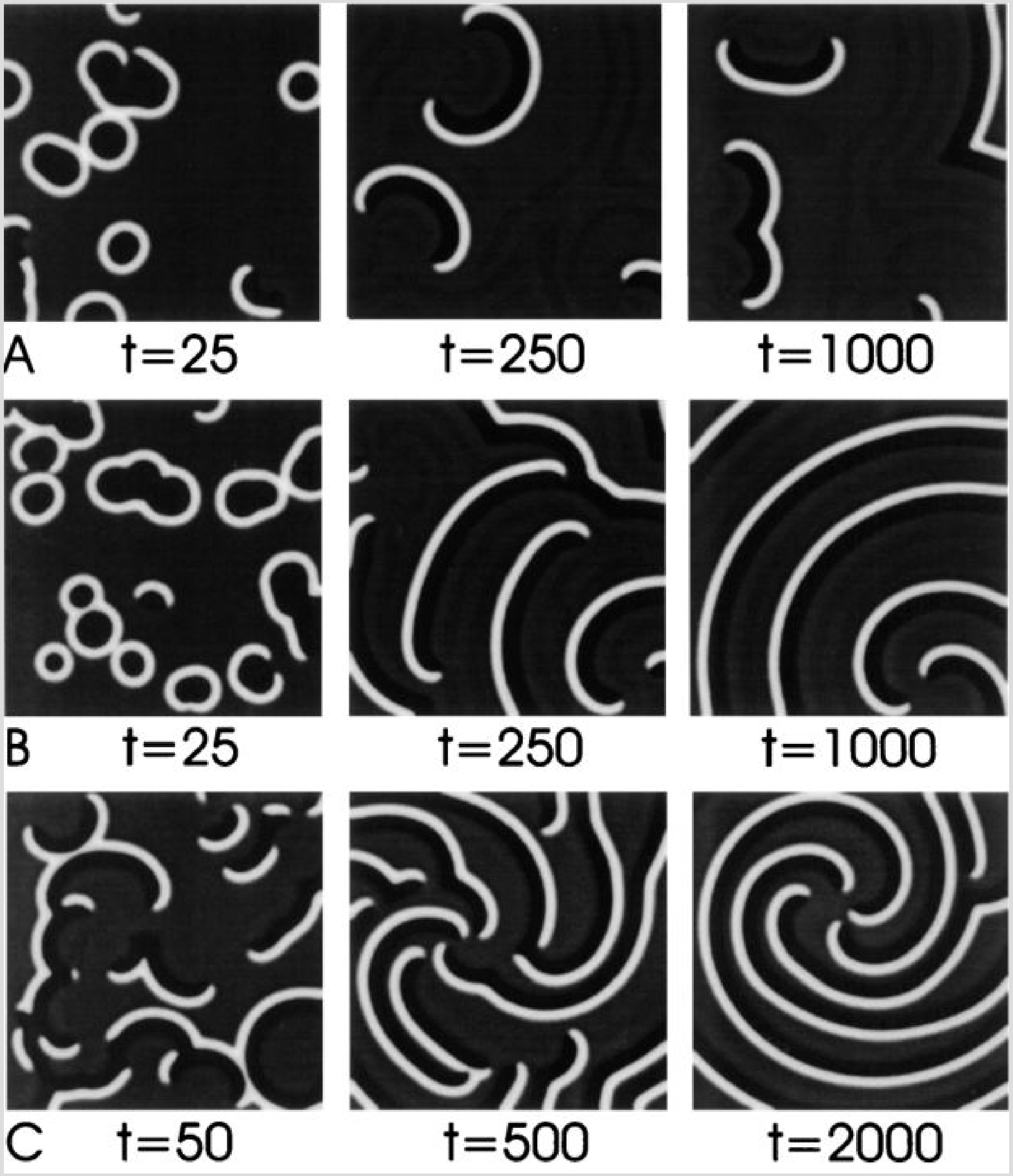
- Higher frequency cores attract lower frequency

TABLE I. Periods of spirals 1 and 2 during the first nine loops of their rotation [Figs. 5(B) and 5(B′)].

LOOP	1	2	3	4	5	6	7	8	9
SPIRAL 1	64.5	82.3	74.2	62.3	87.5	98.5	87.7	96.2	104.3
SPIRAL 2	98.6	60.5	81.1	95.1	96.5	93.7	95.5	96.2	96.4

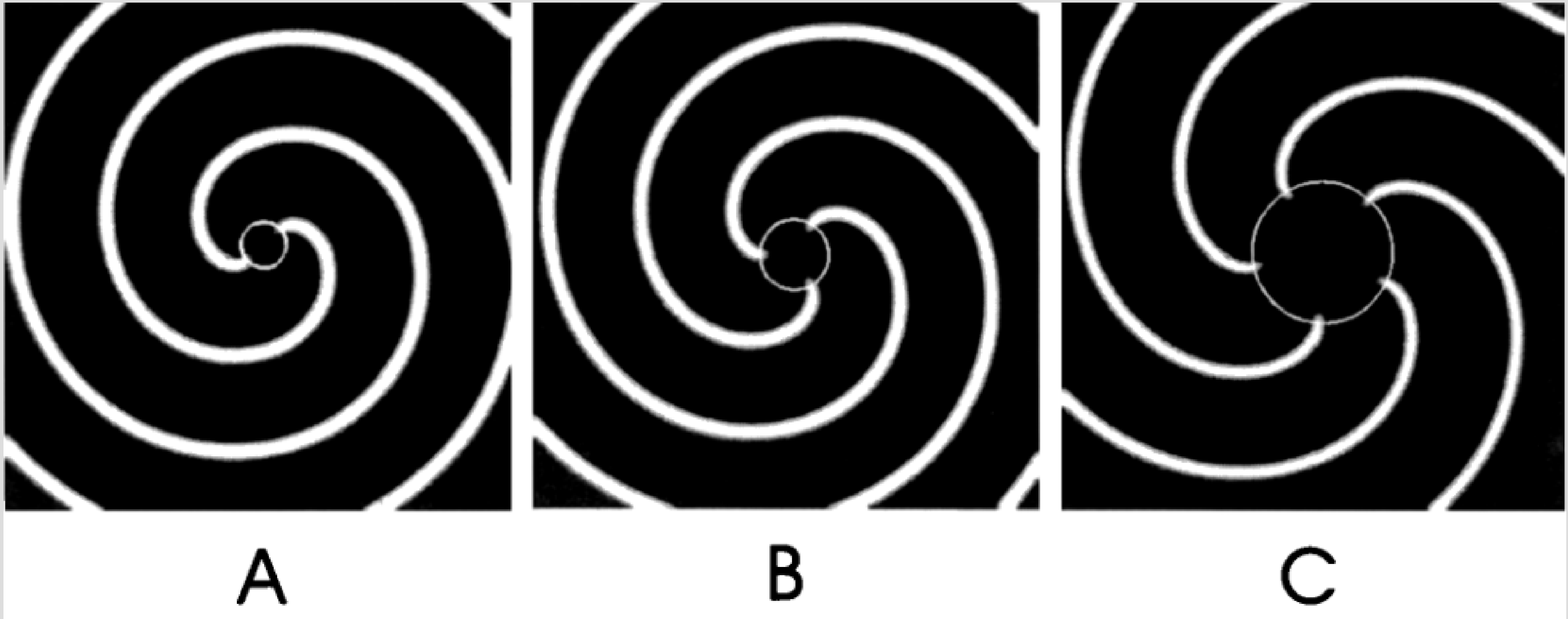


Formation Multiarms



Amount of Arms

- More arms when excitability is lower



$$\partial g/\partial t = D\Delta g - k_g g(g-a)(g-1) - k_r r,$$

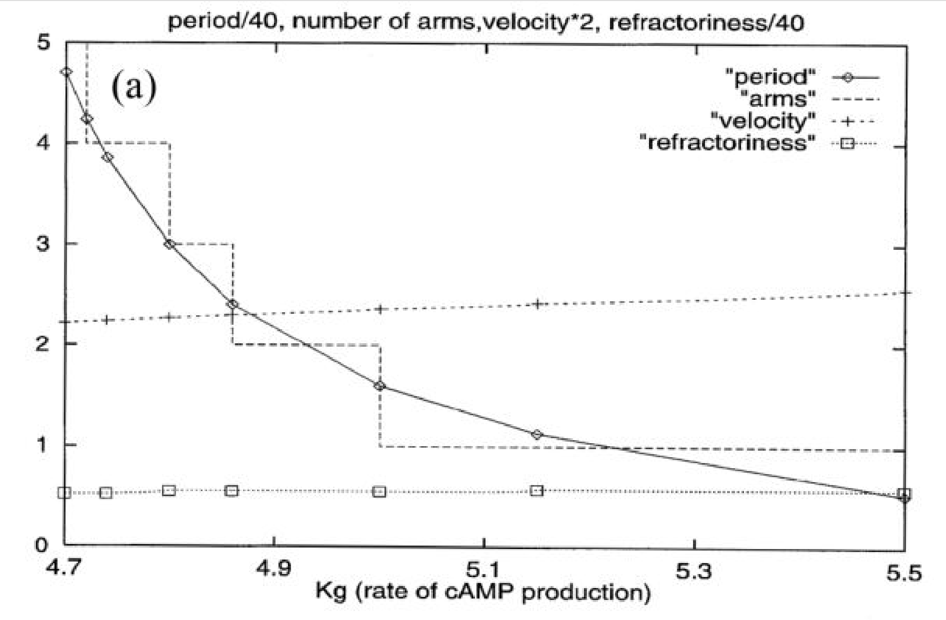
$$\partial r/\partial t = (g-r)/\tau.$$

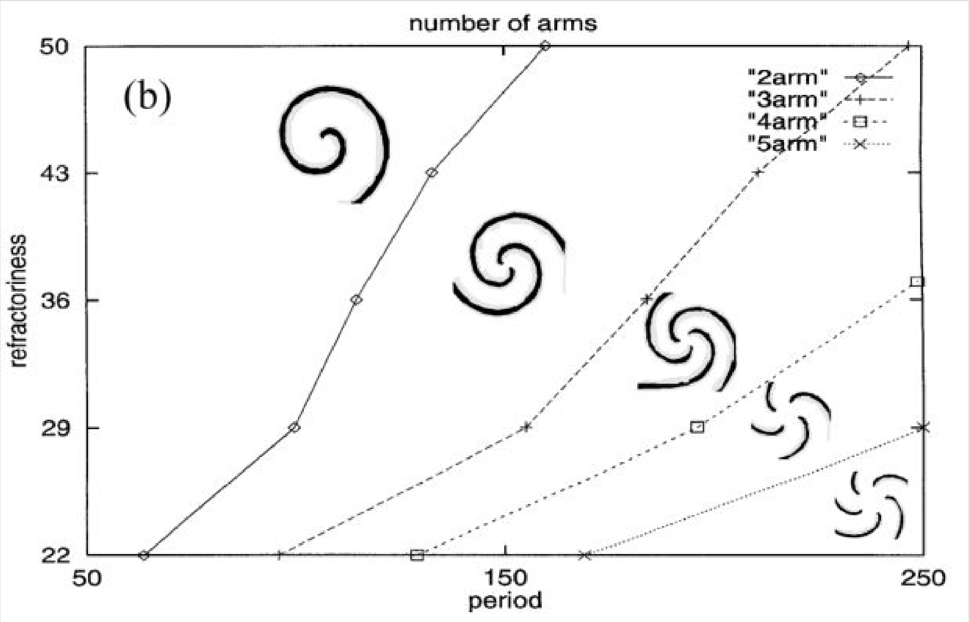
Amount of Arms

- Estimate for spiral arms:

$$N_{\max} = \mathrm{int}(A(T_{\mathrm{sp}})T_{\mathrm{sp}}/\mathrm{Refr}).$$

- Tsp = Single spiral period
- Refr ~ tau





Conclusion

- Spontaneous formation of multiarms
- Low excitability of medium gives more stability
- Enough spiral cores needed so multiarms can form
- Stability of multiarms

Heart Tissue