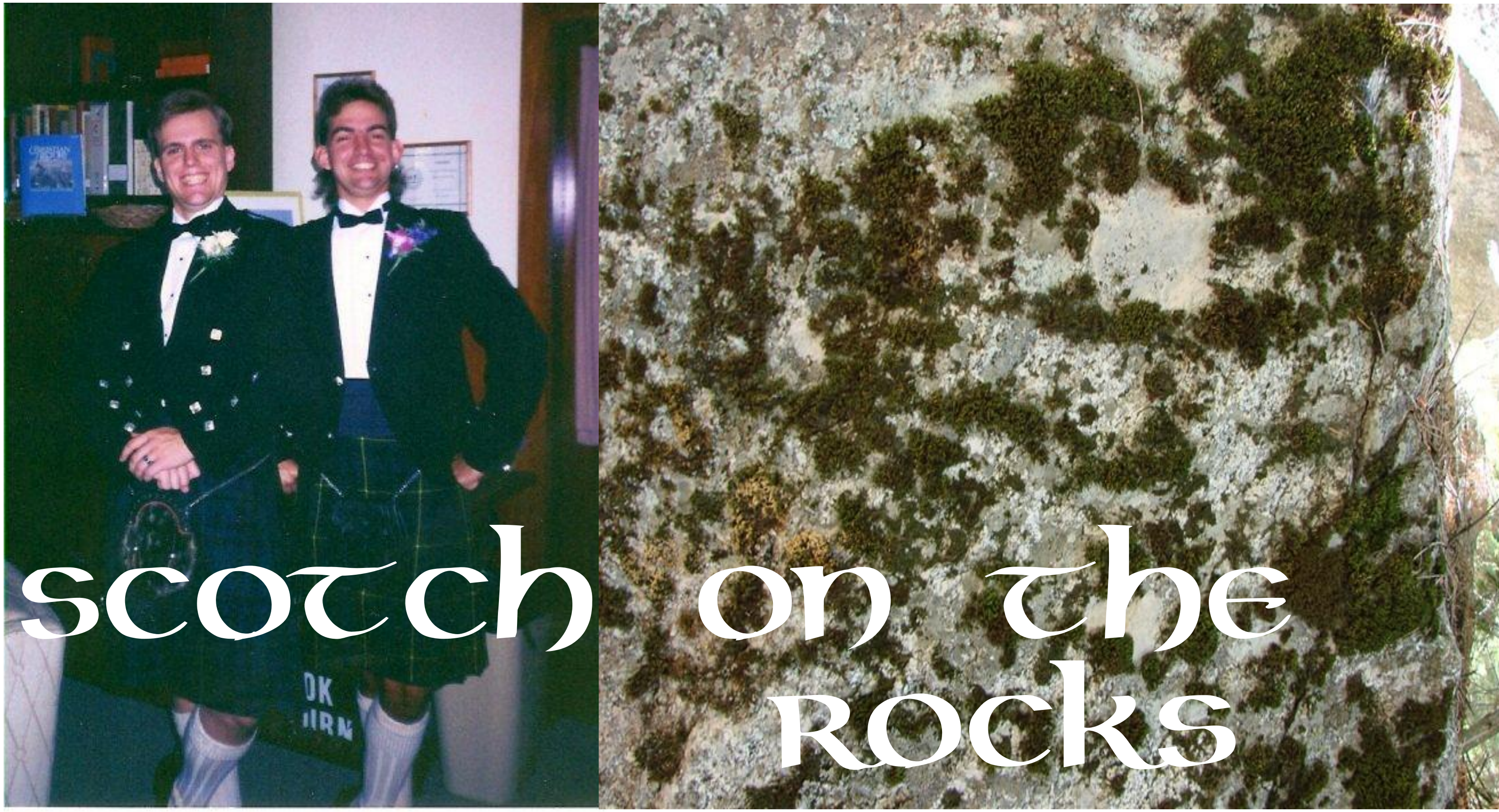


Scotch on the Rocks

Keith Evan Schubert

Penny Boston, Jane Curnutt, Ernesto Gomez

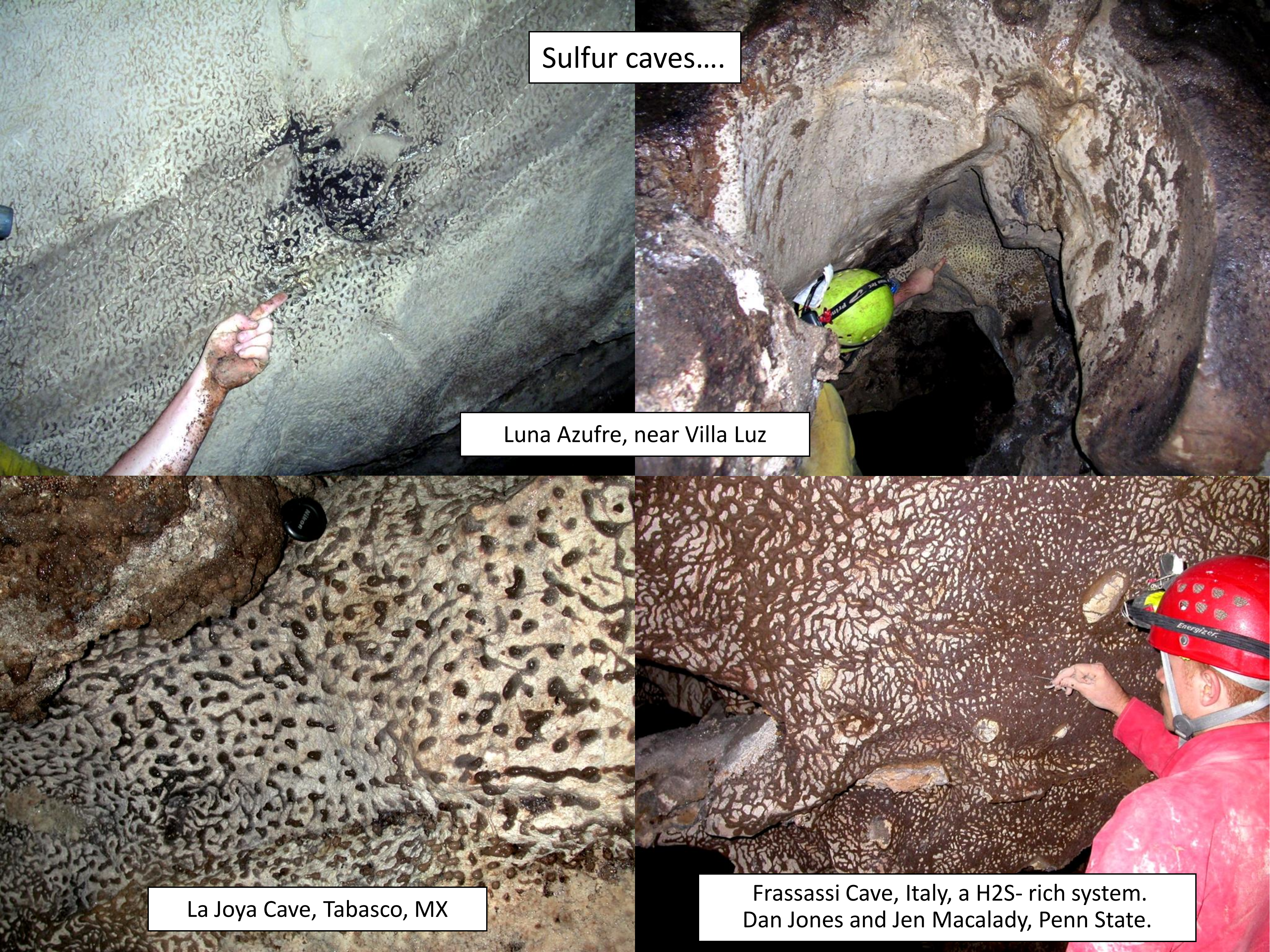
Biological Soil Crusts

Solid lawns of goo grade into biovermiculations and back again

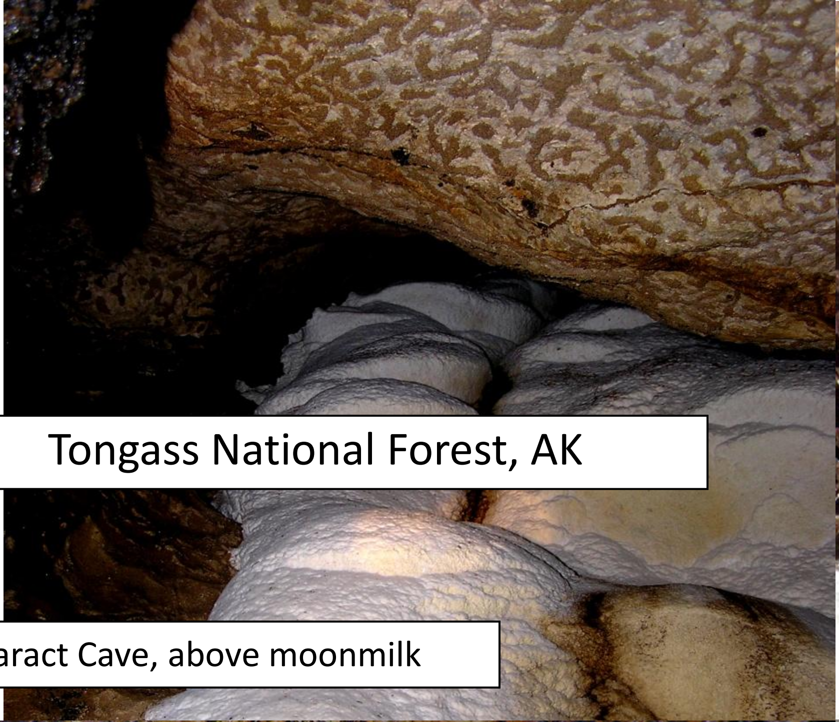
Images by K. Ingham

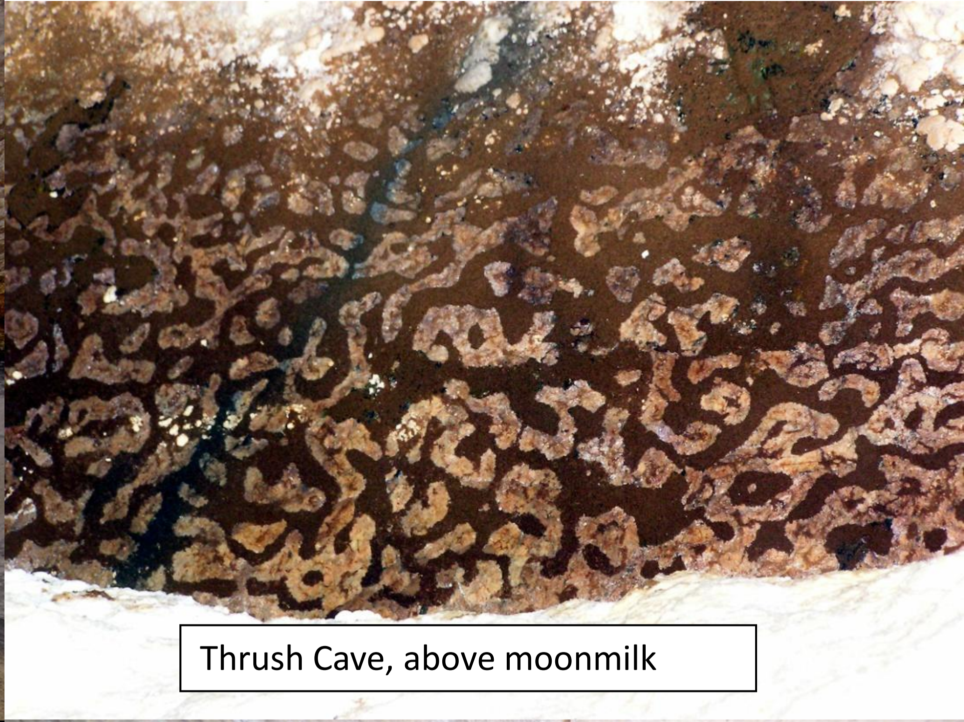
Image by P. Boston

In the twilight zone, organisms are photosynthetic….

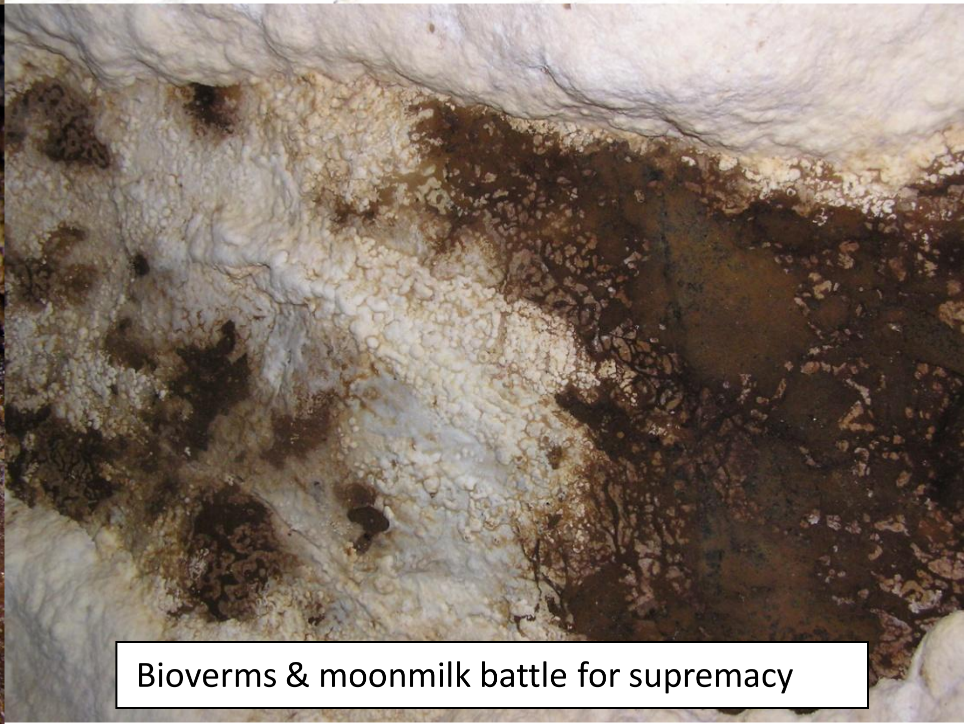

Sulfur caves….
Luna Azufre, near Villa Luz
La Joya Cave, Tabasco, MX
Frassassi Cave, Italy, a H2S- rich system.
Dan Jones and Jen Macalady, Penn State.

Tongass National Forest, AK


Cataract Cave, above moonmilk


Thrush Cave, above moonmilk


Wingate Cave, heavily iron rich.
A frequently "washed" system…


Bioverms & moonmilk battle for supremacy

Lavatube Bioverms

Gruta do Natal, Azores

Image by D. Northup

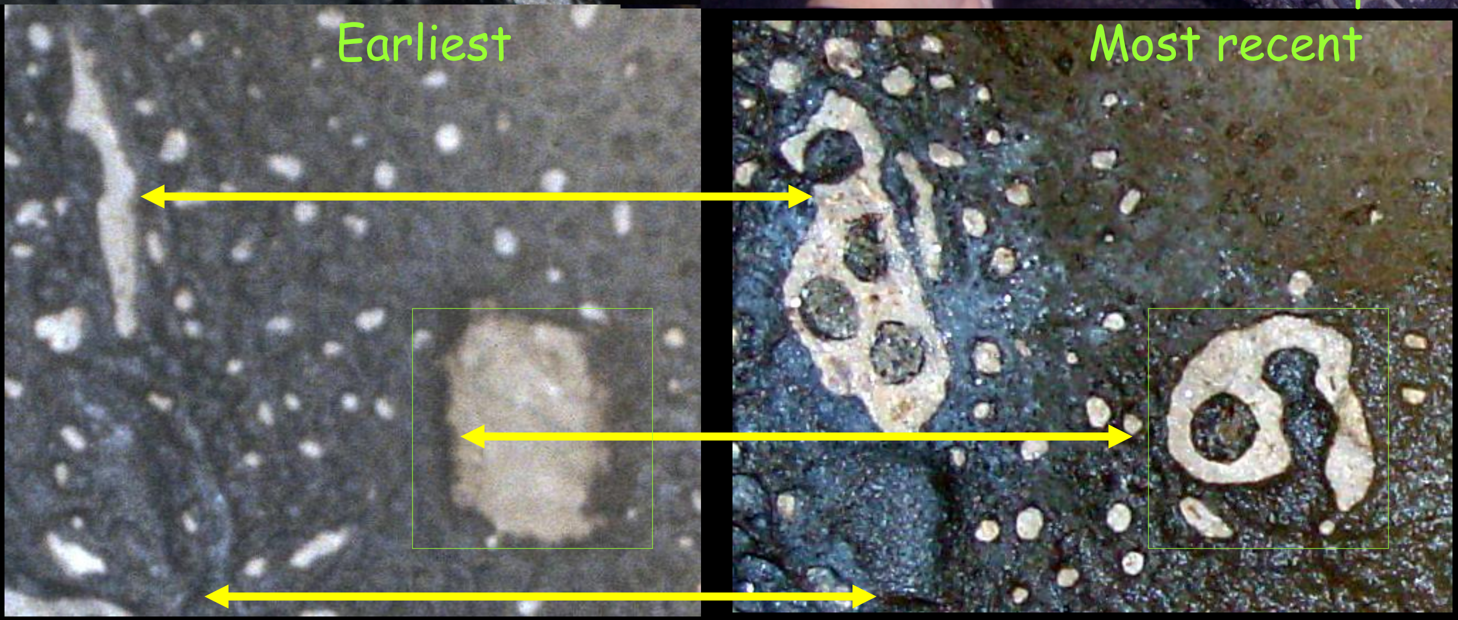
Kula Kai Cave, Hawaii

Images by K. Ingham

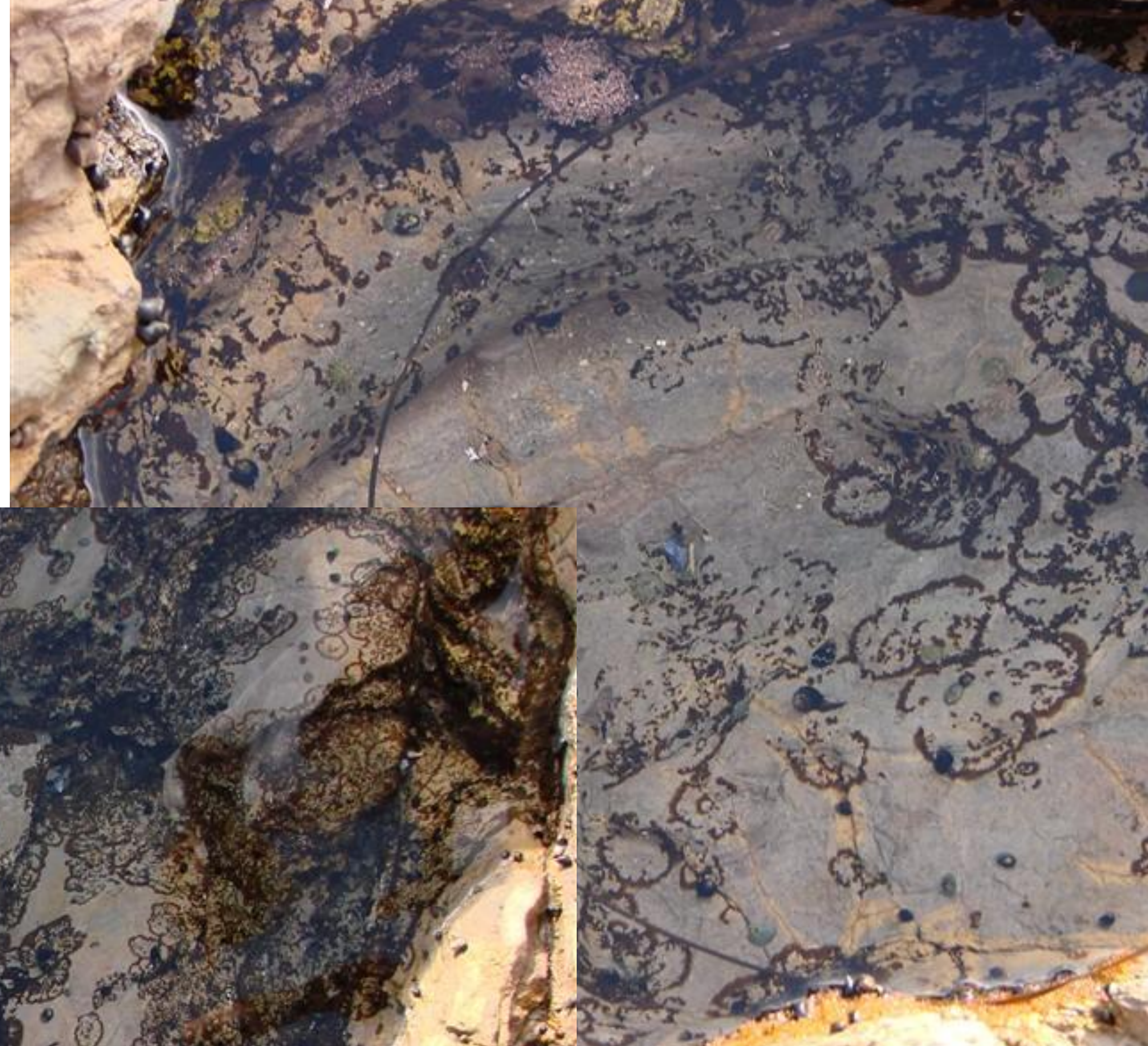
Epperson's Cave, Hawaii

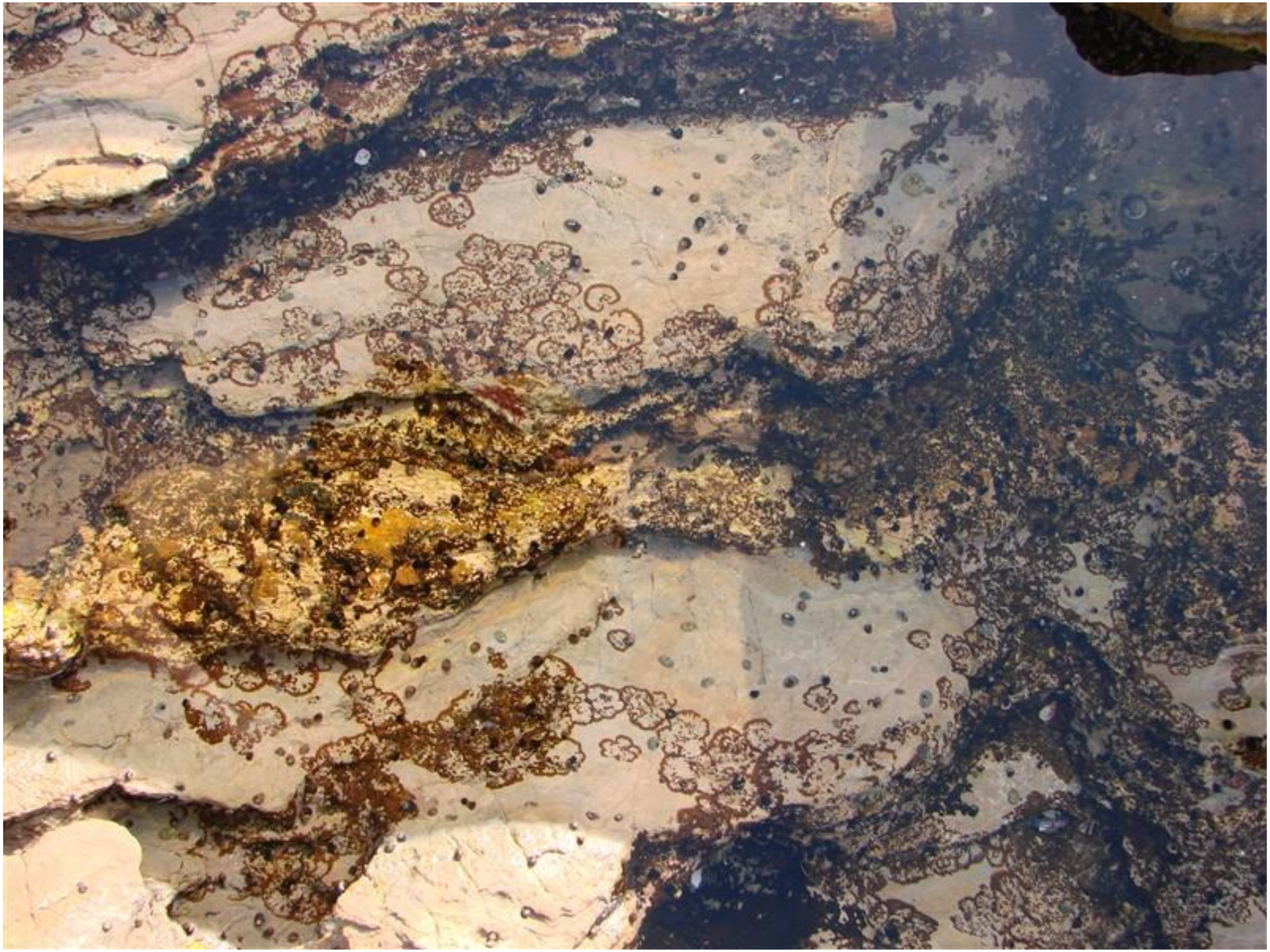
Regrowth experiment by Louise Hose

TEST
SITE 1








Rietkerk, M., Dekker, S.C., de Ruiter, P.C., & van de Koppel, J. 2004.
Self-organized patchiness and catastrophic shifts in ecosystems. *Science* 305:1926-1929.

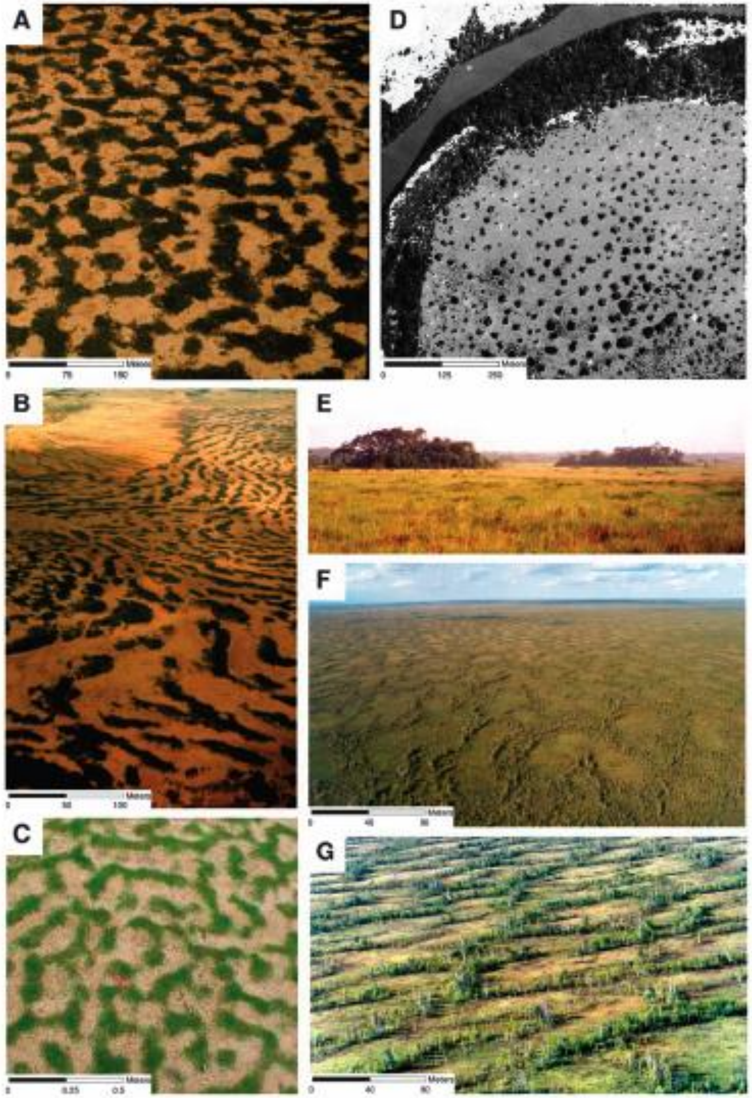


Fig. 1. Field observations. (A to C) Arid ecosystems: (A) Labyrinth of bushy vegetation in Niger [(*12*), © 2002 University of Chicago]; (B) Striped pattern of bushy vegetation in Niger; (C) Labyrinth of perennial grass *Paspalum vaginatum* in Israel [(*11*), © 2001 American Physical Society]. (D and E) Savanna ecosystems: Aerial and ground photographs of spots of tree patches in Ivory Coast and French Guiana, respectively [(*15*), © 2002 American Physical Society]. (F and G) Peatlands: Regular maze patterns of shrubs and trees in western Siberia [(*25*), © 2004 University of Chicago]. Scales of oblique aerial photographs [all panels except (E)] are order-of-magnitude approximations of distance in the *x* direction shown in the scale bars.

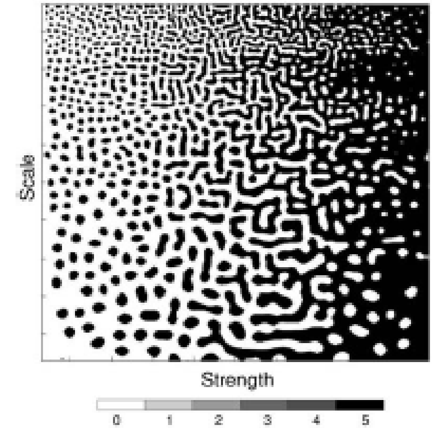


Fig. 2. Model results from a modified version of the Thiery *et al.* (*30*) cellular automaton, showing stable isotropic vegetation patterns after time step $t = 15$ (supporting online text and movie S1). Grid size is 500 × 500 cells. Black areas represent vegetation in maximum state 5; white areas represent bare soil in minimum state 0. Simulations were started by randomly introducing vegetation state 2 on 5% of the cells. Vegetation patterns are the result of fine-scale positive feedback and coarse-scale negative feedback. On the *x* axis, the strength of the positive feedback is increased; on the *y* axis, the scale of influence is decreased. Patterns change from spots to labyrinths and gaps at different spatial scales.

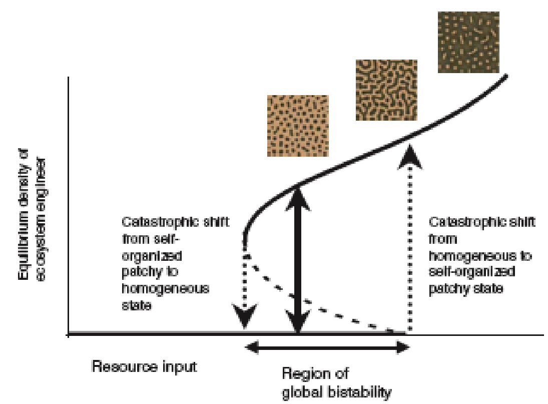


Fig. 3. Model showing how ecosystems may undergo a predictable sequence of emerging self-organized patchiness as resource input decreases or increases (*11*, *12*, *14*, *25*). Thick solid lines represent mean equilibrium densities of consumers functioning as ecosystem engineers. Dotted arrows represent catastrophic shifts between self-organized patchy and homogeneous states, and vice versa. Dark colors in the insets represent high density. The range of resource input for which global bistability and hysteresis exists is between these dotted arrows. Solid arrows represent development of the system toward the coexisting self-organized patchy state or homogeneous state, depending on initial ecosystem engineer densities.

Biological Patterning

- $U_t = DU_{xx} + R(U)$
- Paper:

  The chemical basis of morphogenesis

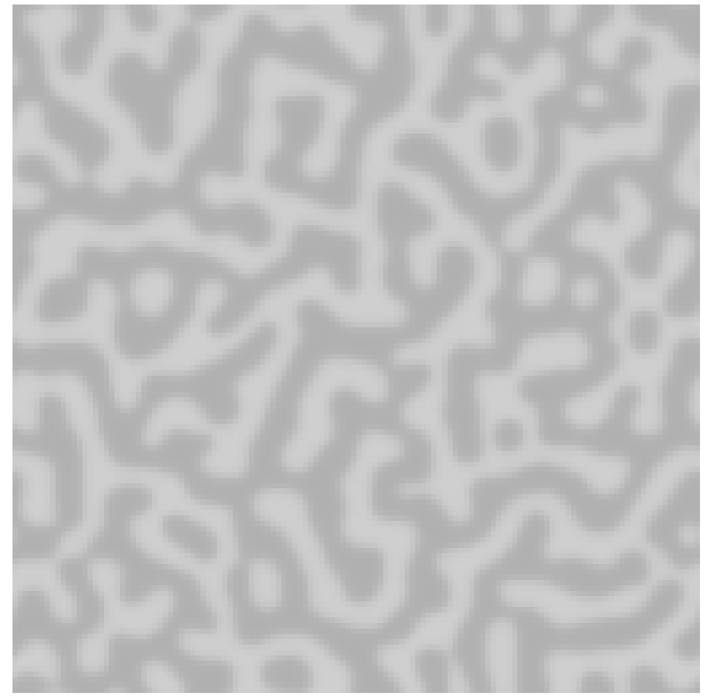
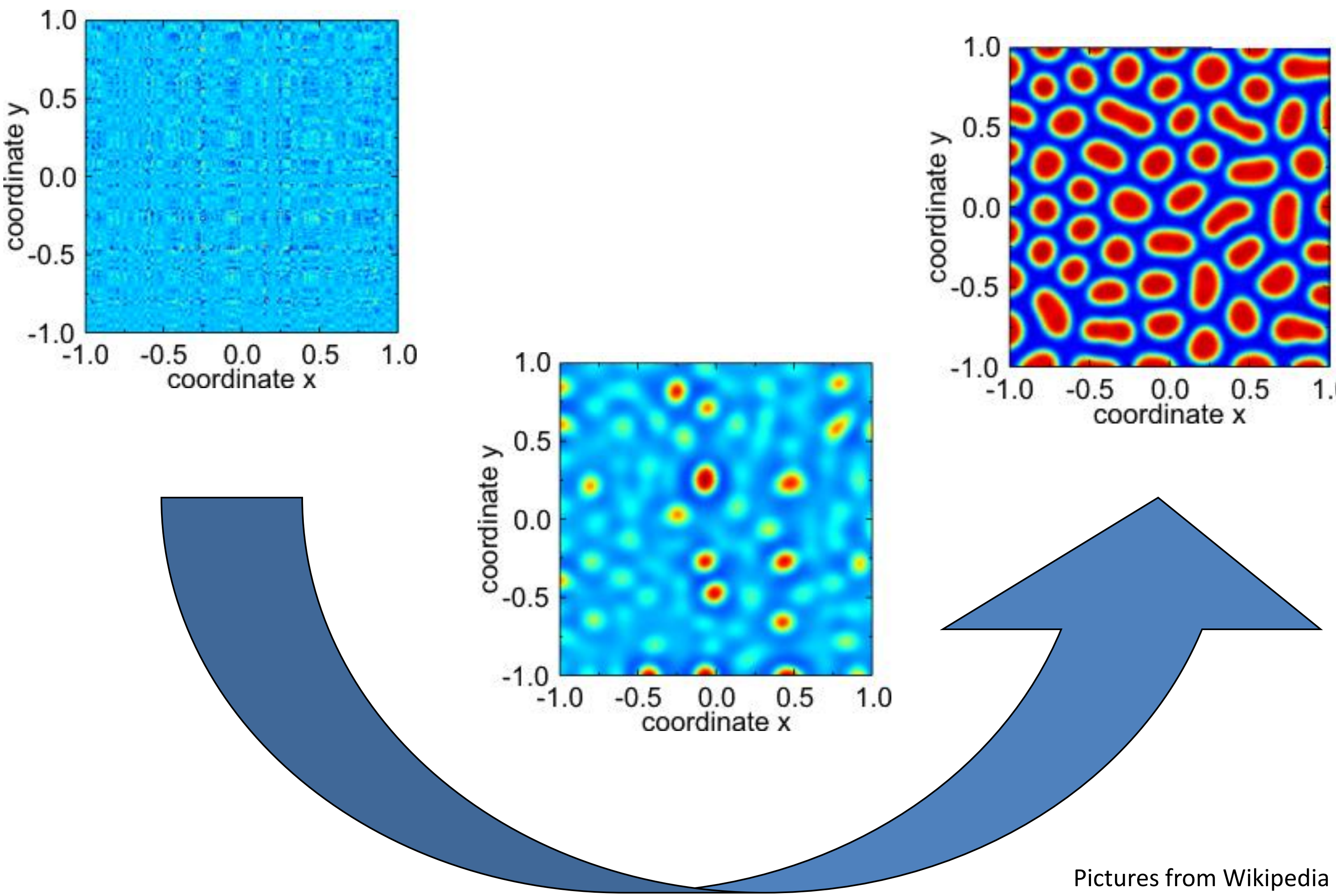


Image from Greg Turk

Example



Pictures from Wikipedia

Baseline Model

Growth dependent on water and nutrients

Oscillation and bias

Diffusion

$$\frac{\partial P}{\partial t} = k\left(\frac{w}{1+\sigma w} - \frac{n}{1+\gamma n}\right)P - cP^2 + \frac{\partial^2 P}{\partial t^2} + \nabla_x p + \nabla_x^2 p$$

nutrient addition and use

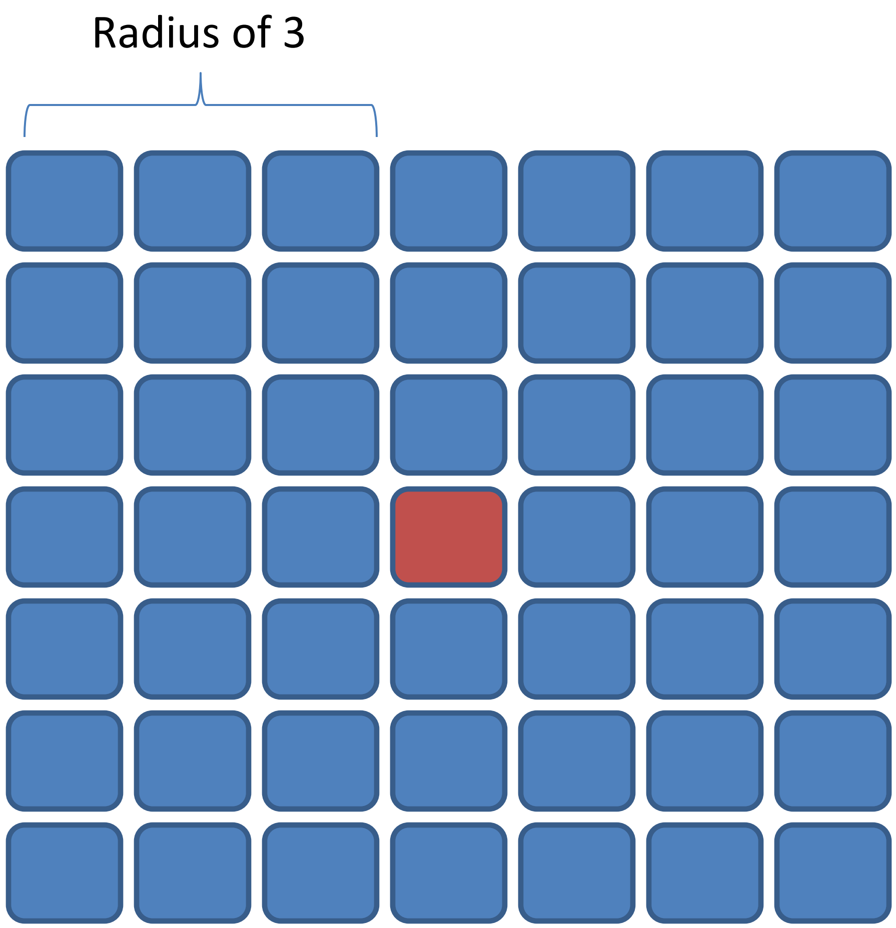
$$\frac{\partial n}{\partial t} = g - \left(\frac{\gamma n}{1+\gamma n}\right)p$$

$$\frac{\partial w}{\partial t} = p - (1-\rho n)w - w^2 n + \delta \nabla_x^2 (w - \beta n) - v\frac{\partial (w - \alpha n)}{\partial x}$$

Runoff, evaporation, absorption, diffusion, etc.

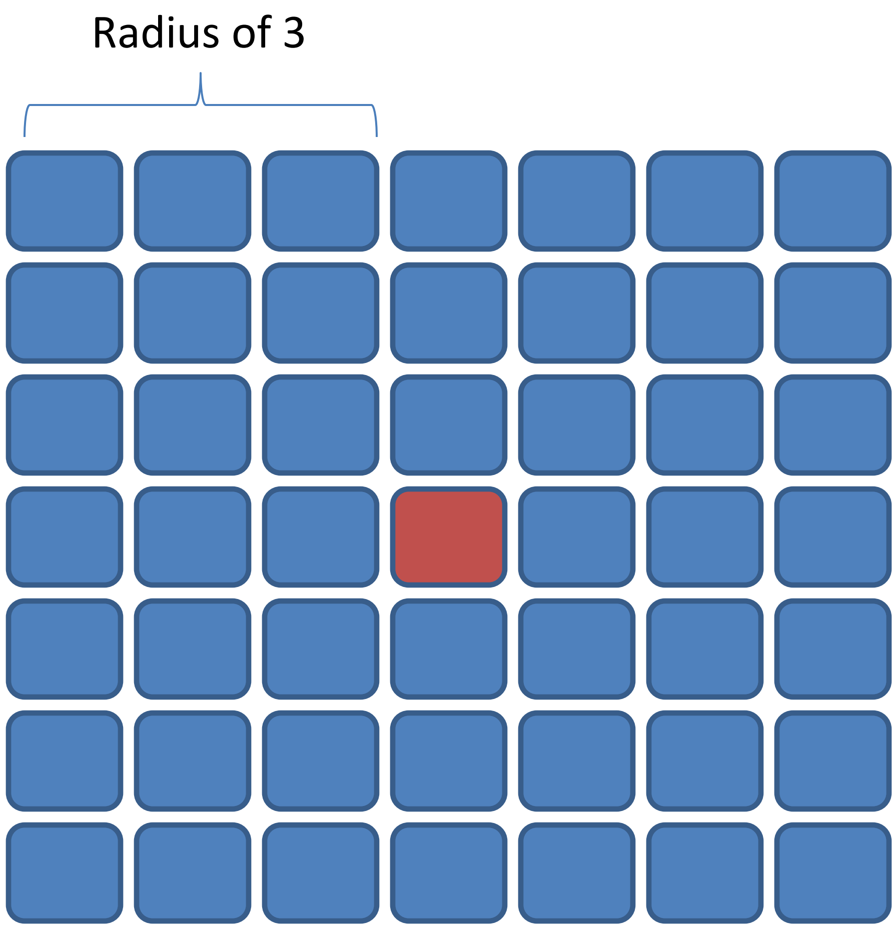
Precipitation

Generalized Cellular Automaton



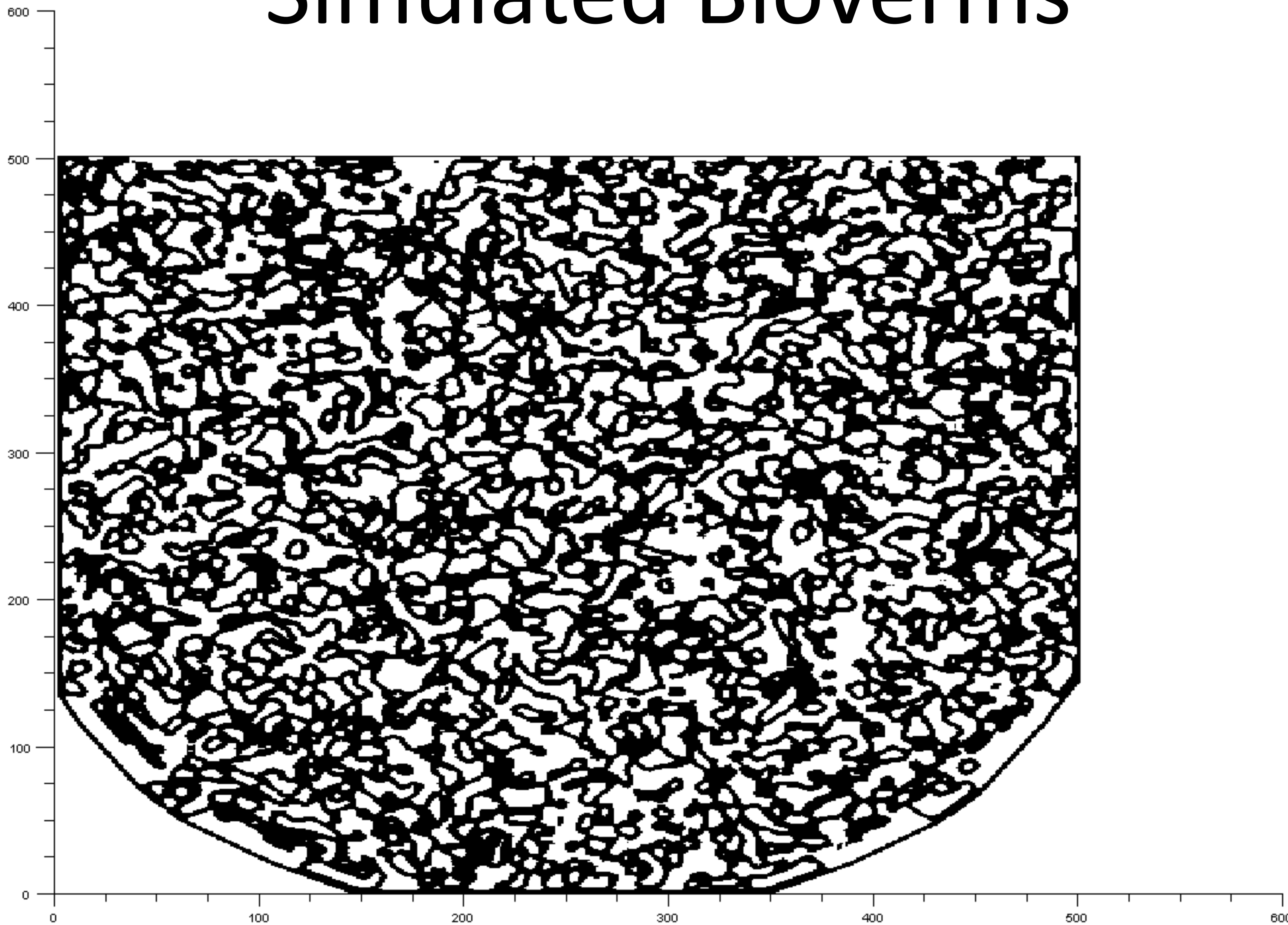
- Each cell has variable for biomass, nutrients, and water
- Next state of a cell is based on its current value, those within the radius, random factors
- Weights set to capture effect of differential equations

Simple Example



- Each cell has variable for biomass ∈ {0,1}
- Water and nutrients in abundance
- Next state of a cell is
  - same if sum of neighbors in range 8-12
  - Grow if sum of neighbors in range 13-34
  - Die else or randomly 5% of time

Simulated Bioverms



So Long And Thanks For All The Coffee