

Patterns in Nature 5

Spatial patterns



c

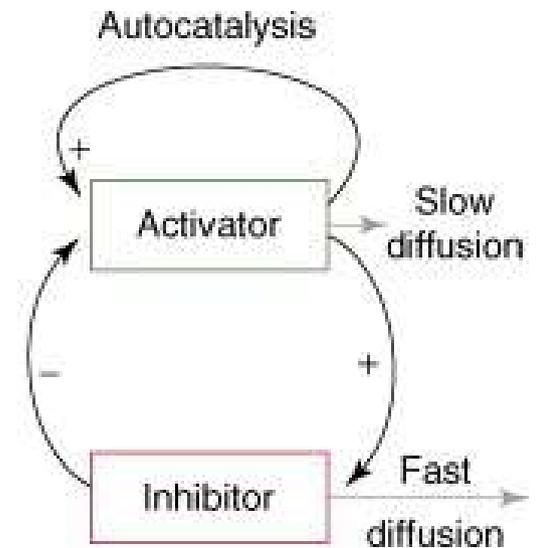
Stephan Matthiesen

Activator-Inhibitor Model (Turing 1953)



Alan Turing (1912-1954)

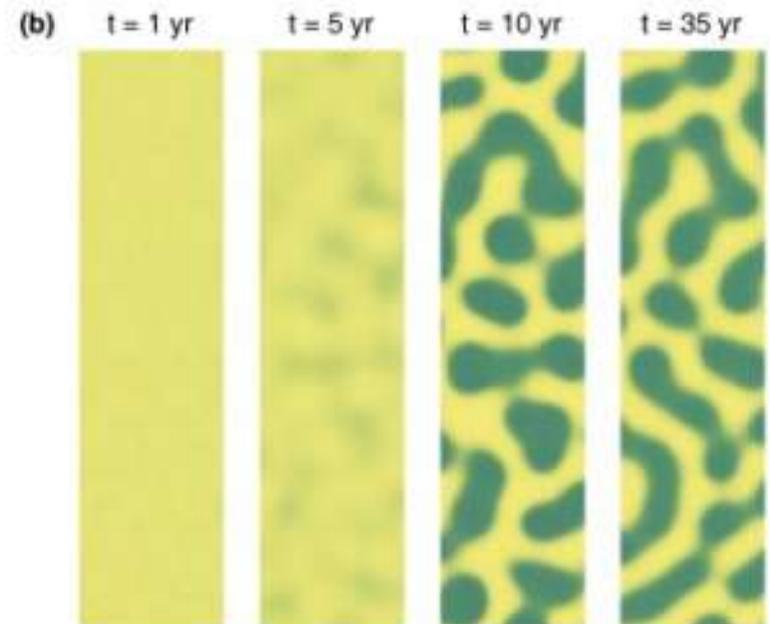
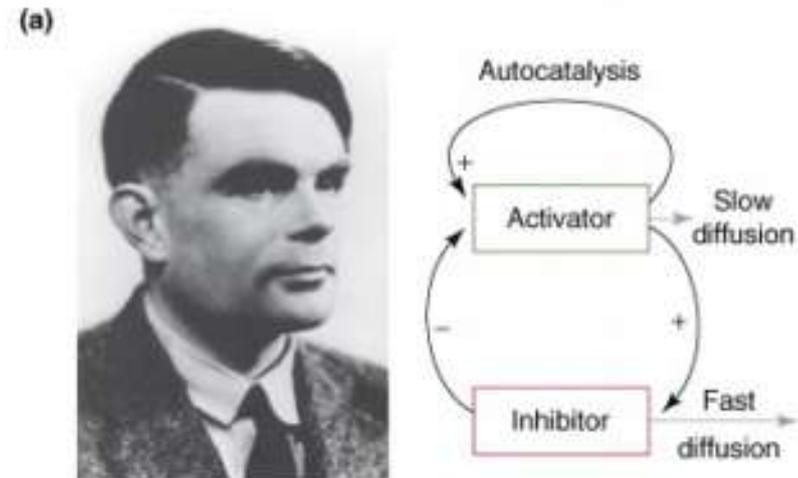
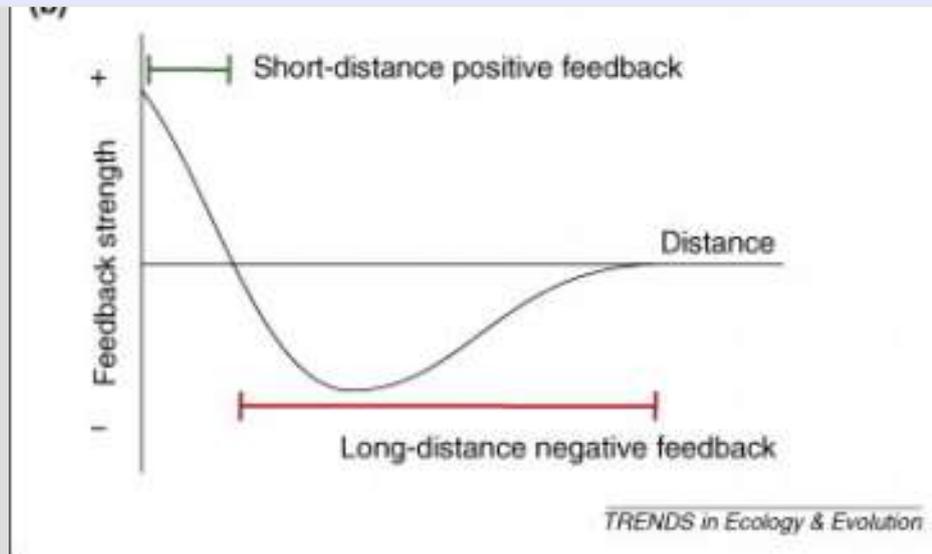
(a)



Activator-Inhibitor Model

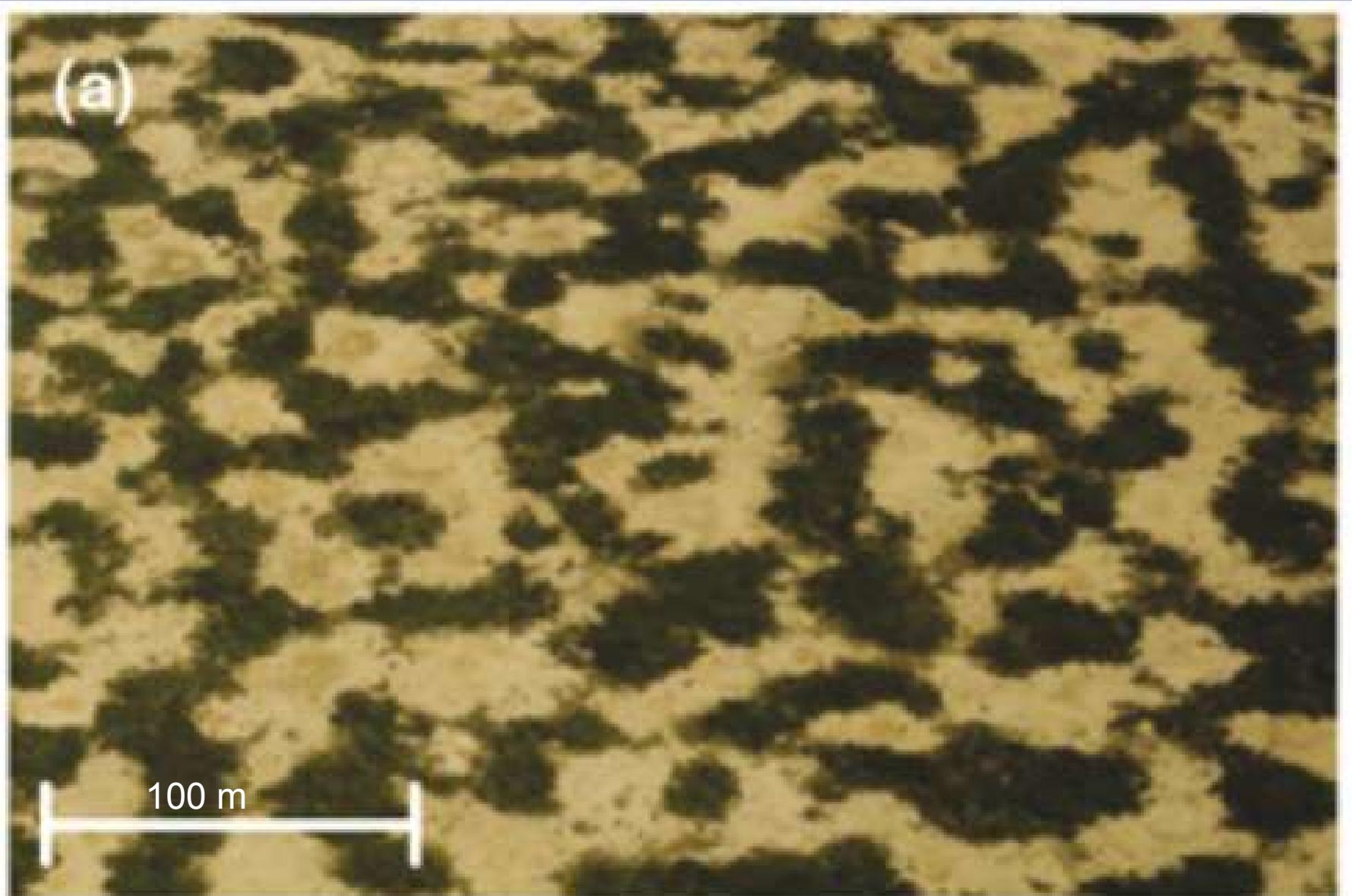
feedback: part of a system's output influences the input

- positive feedback: the system responds to perturbations in the same direction as the perturbation
- negative feedback: it responds in opposite direction



“Tiger bush”

Rietkerk; v.d. Koppel 2008



Wetland ecosystems

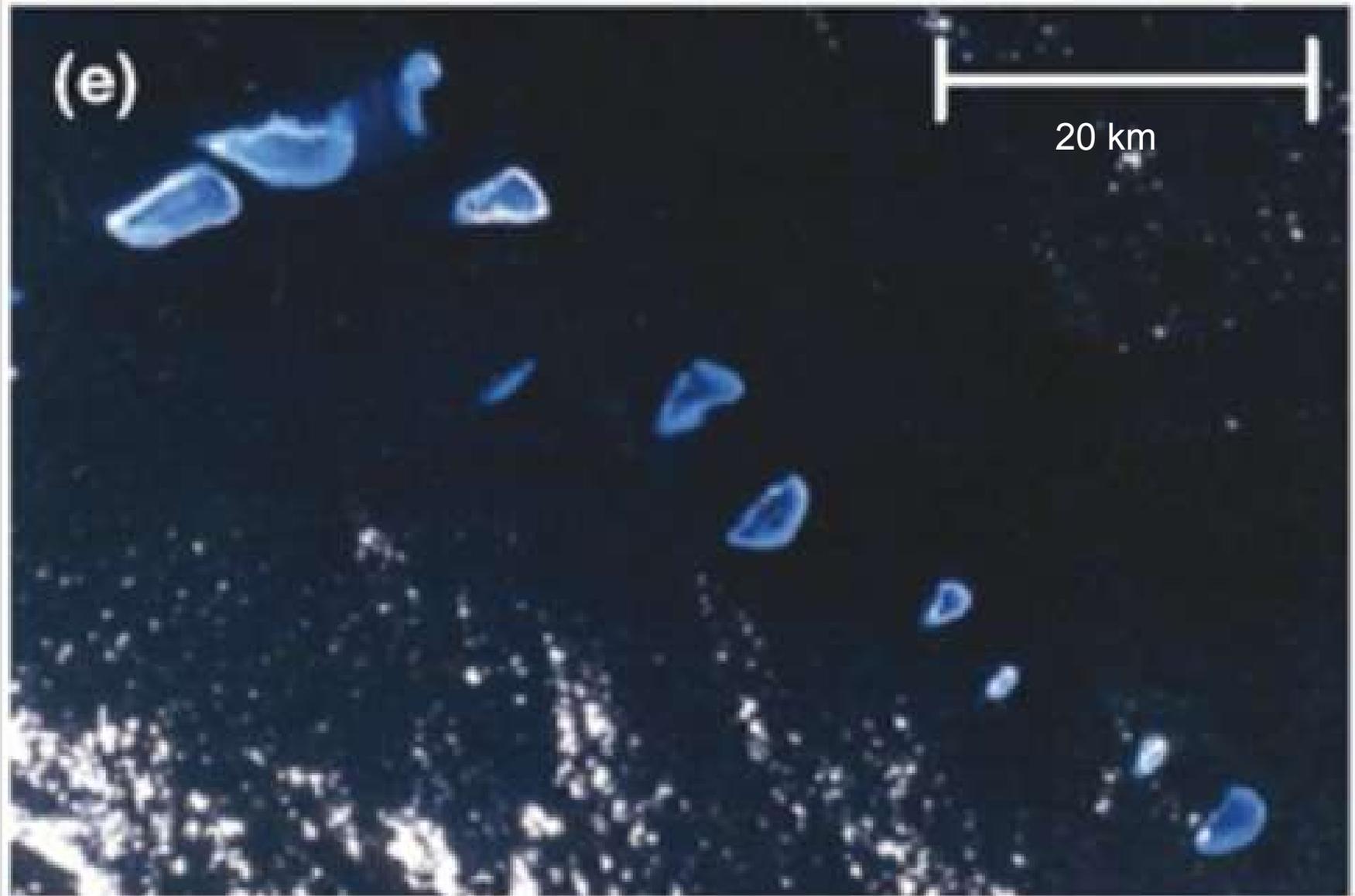
(b)



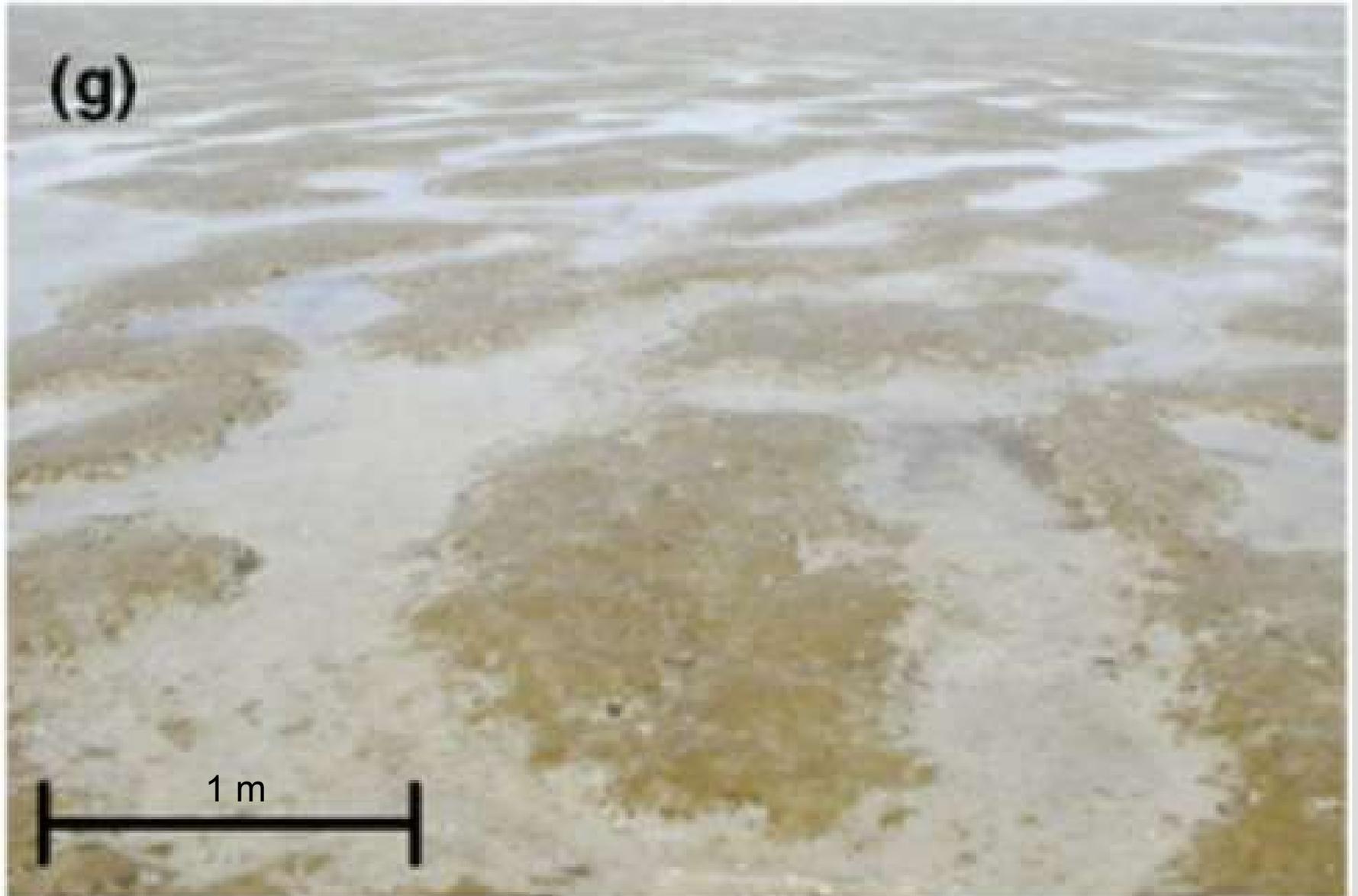
Savannah



Coral reefs



Intertidal mudflats



Zebras

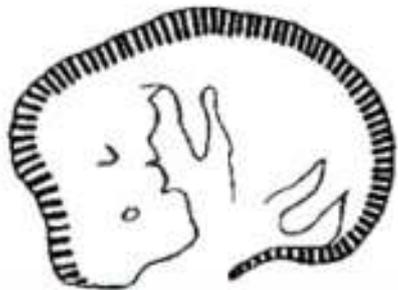
Imperial Zebra: week 5

Mountain Zebra: week 4

A

B

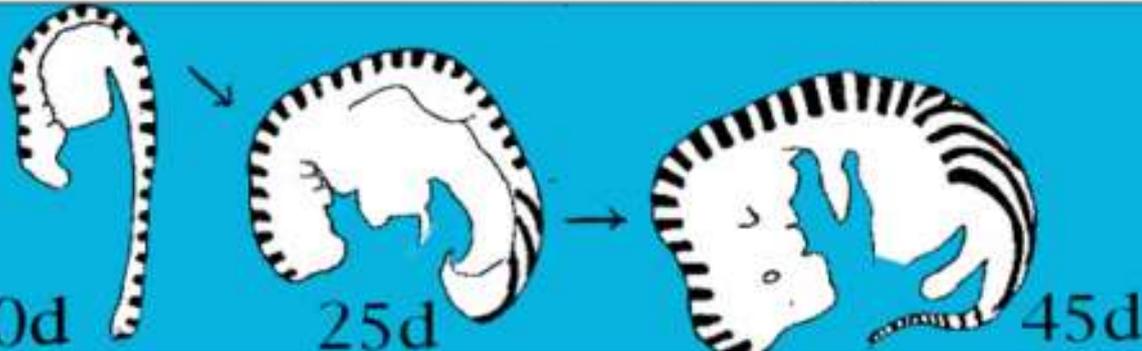
A



B



C



Common Zebra: week 3

C

D

- (a) Imperial zebra (*Equus grevyi*)
- (b) Mountain zebra (*Equus zebra*)
- (c) Common zebra (*Equus burchelli*)
- (d) Quagga (*Equus quagga*).

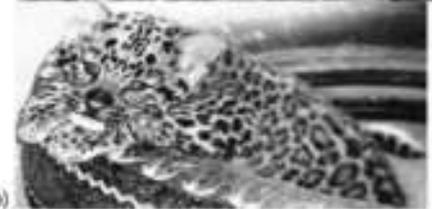
Leopard



2 days: spots



8 weeks: rings



Adult: rosettes



FIG. 1. Coat patterns of a leopard at different stages of growth: (a) spots (2 days), (b) rings (8 weeks), (c) rosettes (adult).

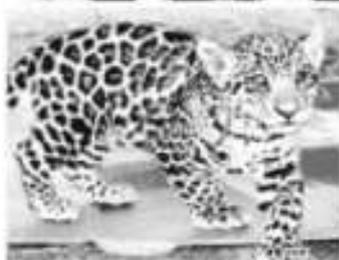
Liu, Liaw, Maini 2006

Jaguar



5 weeks: spots

(a)

3 months:
irregular
rings

(b)

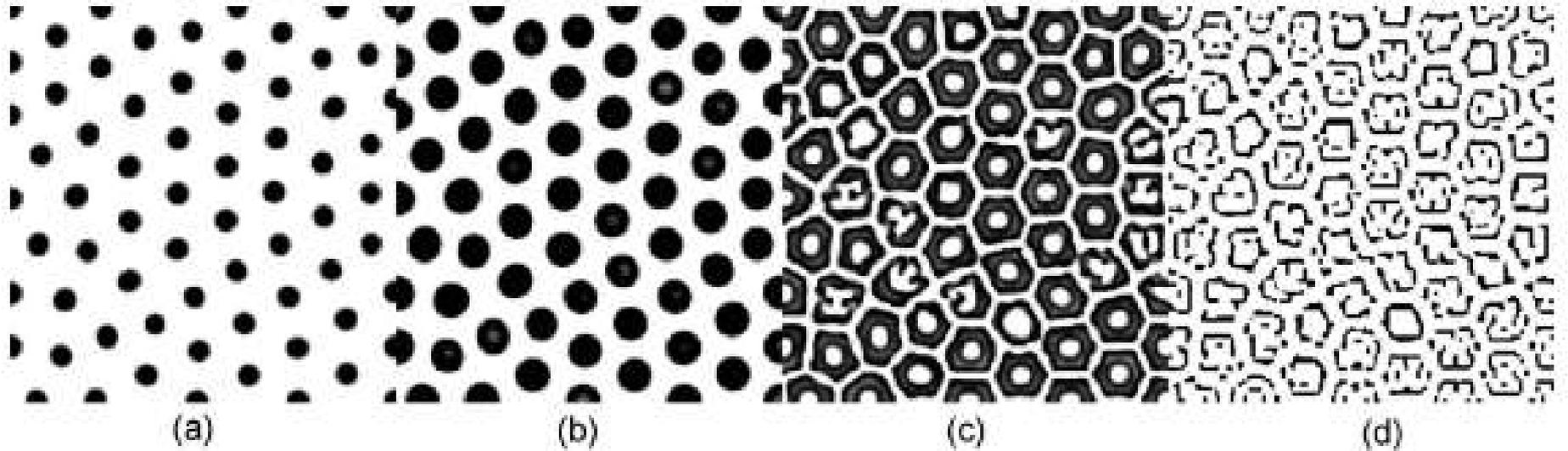


(c)

Adult:
small spots
enclosed by
irregular
polygons

FIG. 2. (Color online) Coat patterns of a jaguar at different stages of growth: (a) spots (5 weeks), (b) irregular rings (3 months), (c) small spots enclosed by irregular broken polygons (adult).

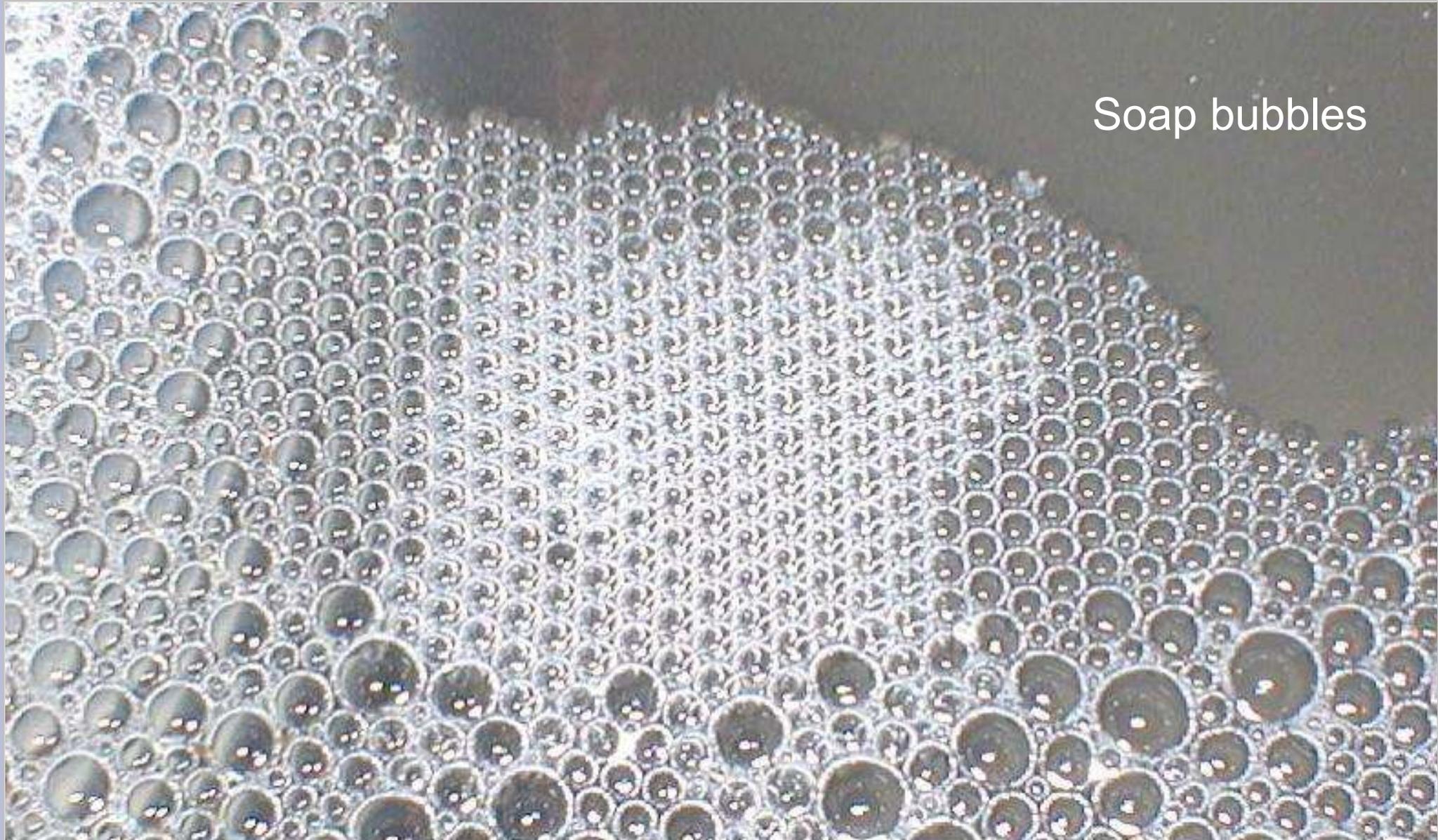
Two-stage model for the Jaguar



First Stage

Second stage
(with different parameters)

Hexagonal patterns



Soap bubbles

Rayleigh-Benard convection

Lane; Christensen 2000

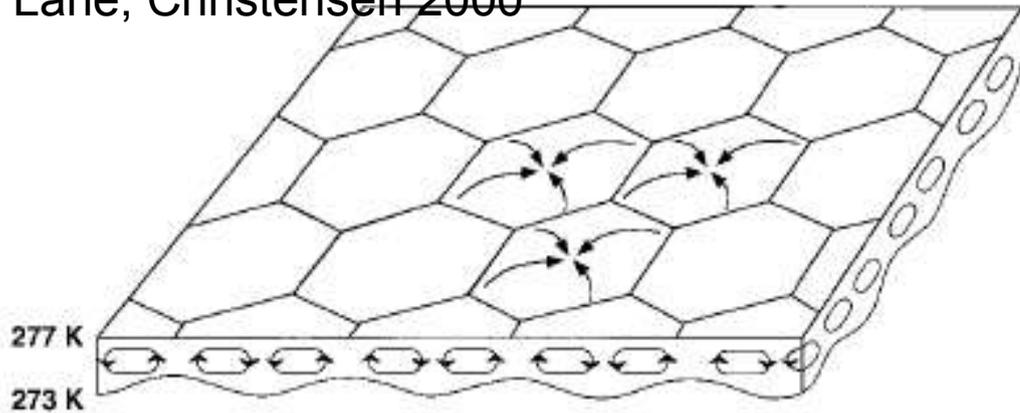
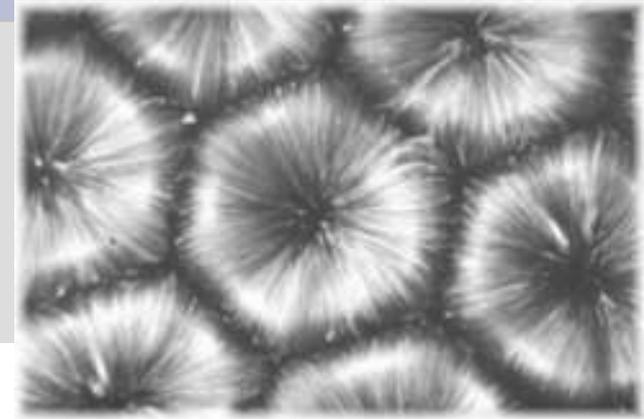
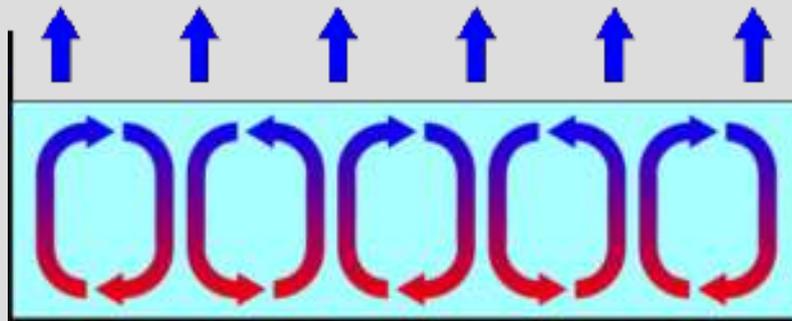


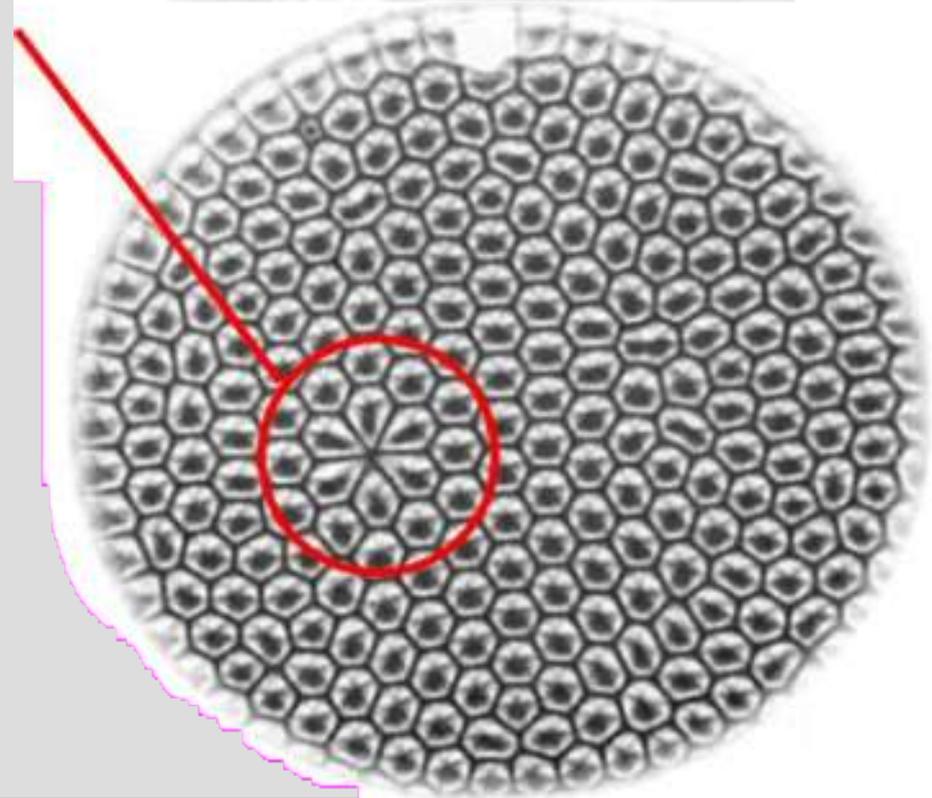
Figure 4. A schematic three-dimensional section of hexagonal Rayleigh convection cells in an active layer.

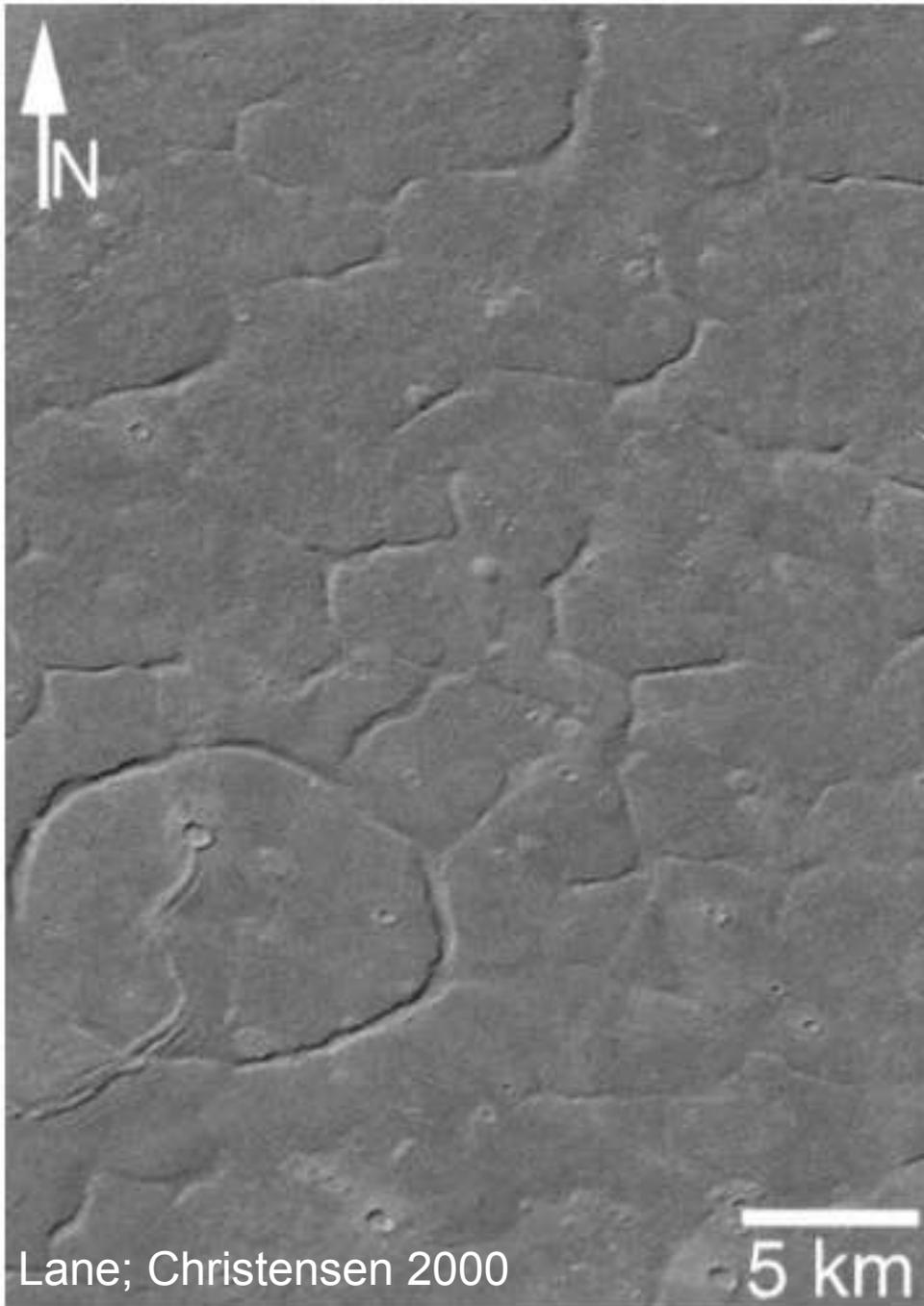


Fluid cools by losing heat through the surface



Heat input





Lane; Christensen 2000

5 km

Polygons on Mars



UFO CARTOON

Figure 1. An example of the polygonal terrain on Mars (the large circular feature toward the bottom left of the image may be associated with a buried crater). This is a subframe of a Viking 1 Orbiter image (032A18) of polygonal terrain in Acidalia Planitia, centered near 44.1°N, 18.6°W. Illumination is from the upper left. Figure 1 was prepared by Ken Edgett at Malin Space Science Systems.

Martian Polygons

LANE AND CHRISTENSEN: CONVECTION ORIGIN FOR MARTIAN POLYGONS

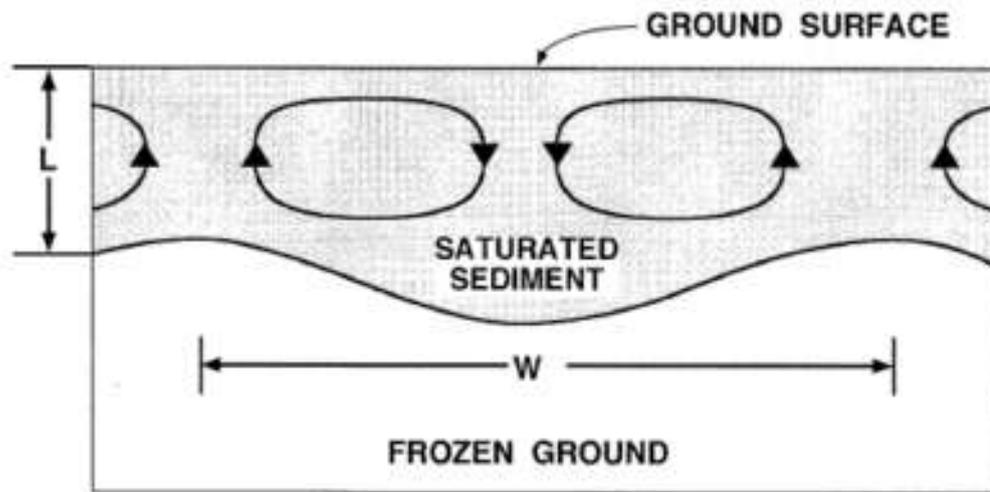
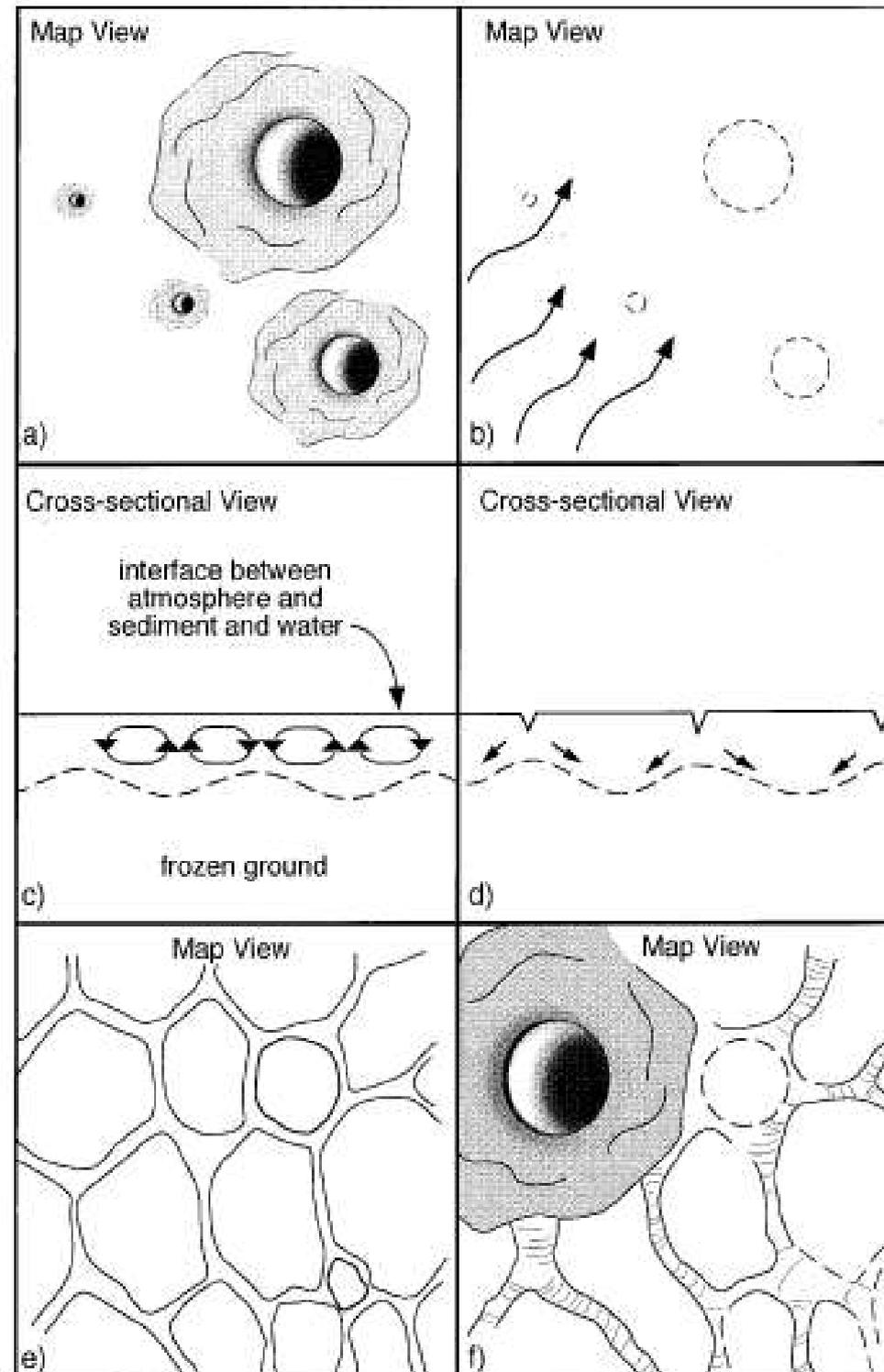


Figure 2. A schematic two-dimensional section of Rayleigh convection cells in an active layer [after Ray 1981]. For the case of circulation within a body of standing water, the saturated sediment layer would be thinner and the "ground surface" label would represent the water/atmosphere interface.



Patterns in permafrost





Columnar jointing



Giant's causeway



Jagla; Rojo (2002)

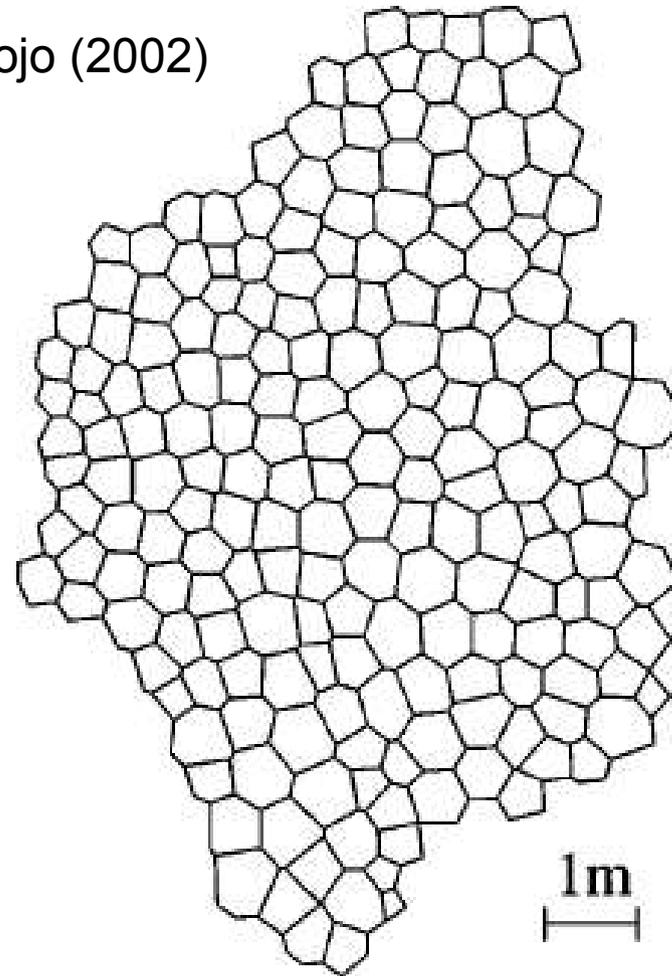


FIG. 1. Polygonal pattern seen perpendicular to some of the columns of the Giant's Causeway, a tertiary lava flow in Antrim, Northern Ireland, from Ref. [20] (originally from a map by O'Reilly [21]).



Kirkjugólf („Church floor“)
Kirkjubæjarklaustur, Iceland



Kirkjugólf („Church floor“)
Kirkjubæjarklaustur, Iceland



Kirkjugólf („Church floor“)
Kirkjubæjarklaustur, Iceland



Dverghamrar („Dwarf cliffs“), Iceland



Dverghamrar („Dwarf cliffs“), Iceland



Dverghamrar („Dwarf cliffs“), Iceland



Svartifoss, Iceland

Experiment

Your own Giant's causeway

- Take a plastic food container, ca 20cm wide and 3-4 cm deep.
- Mix cornflour with equal volume of water to a stiff paste; add some bleach (to stop mould)
- Not part of the experiment, but great fun: Try to stir it quickly and slowly, drop objects in it.
- Leave open in a warm, dry place until the substance is completely dry (1-2 weeks)
If you used too much water, drain the clear water from the top carefully after the first day.
- Look at the cracks on the surface
- Turn it upside down carefully and observe the shape of the individual columns

One we prepared earlier (in week 3)





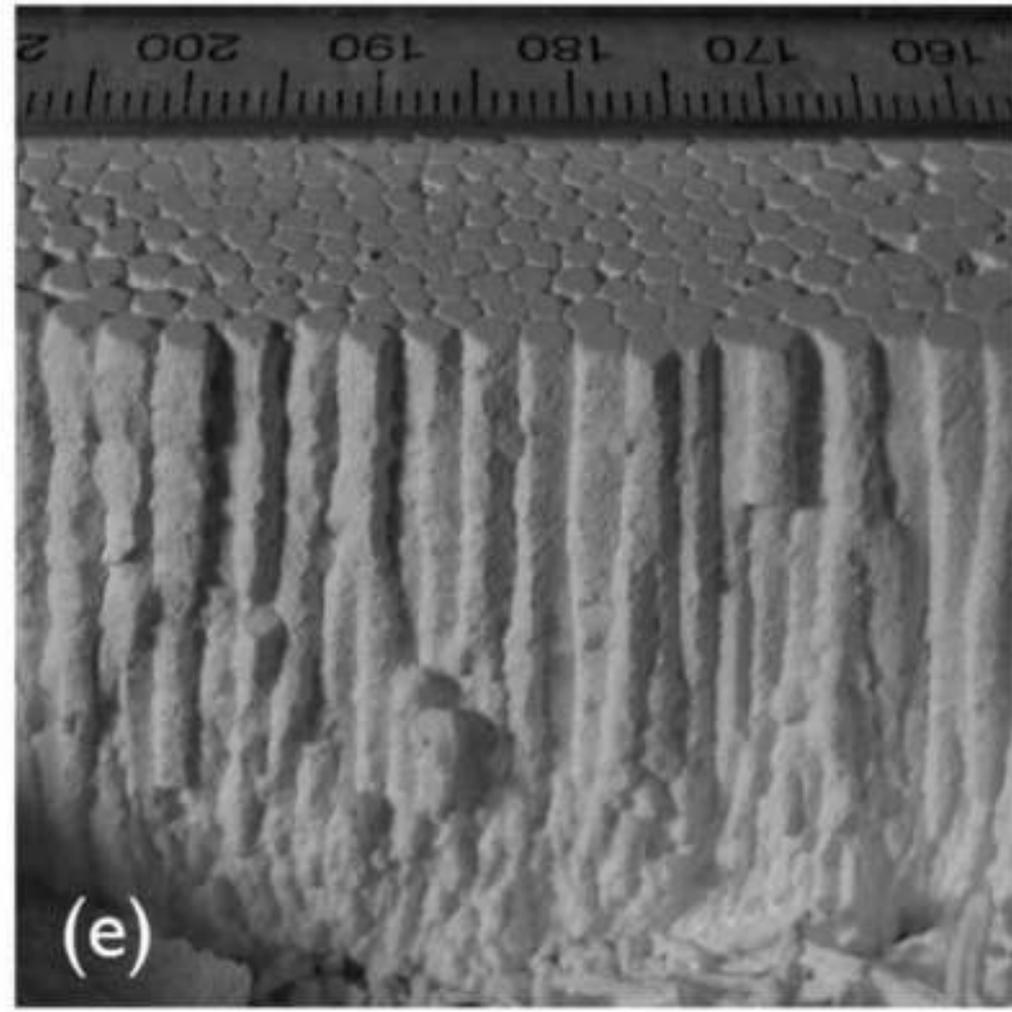
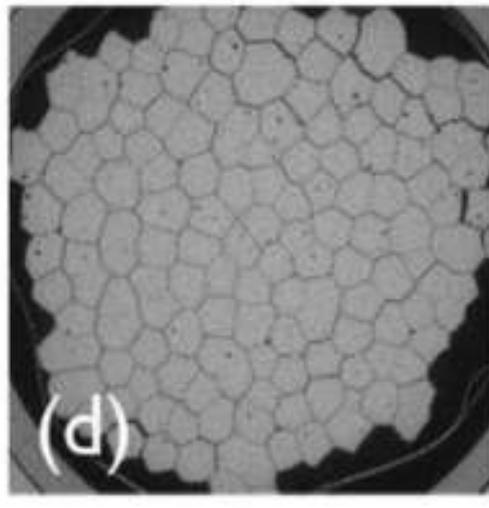
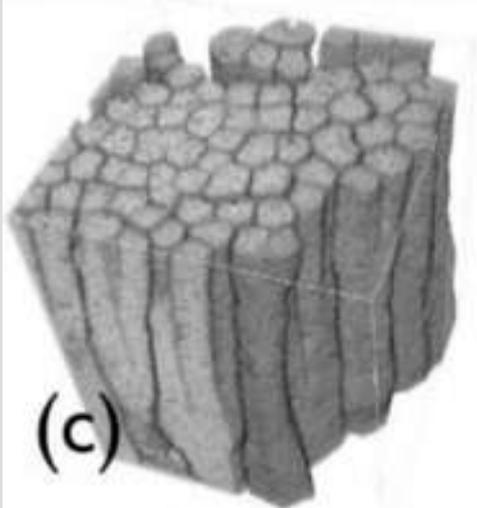
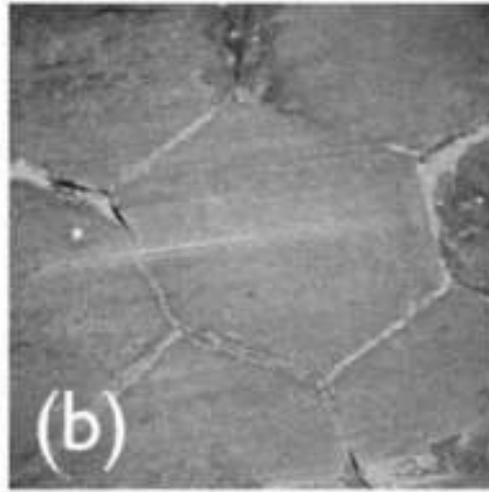
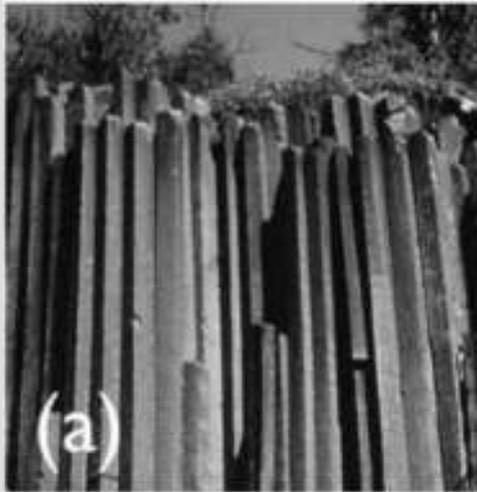
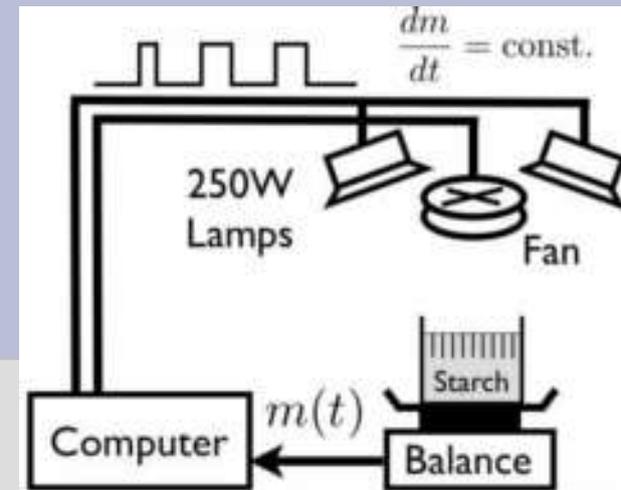
Columns



Original top surface

An experiment with cornstarch

Goehring (2003); Goehring, Morris, Lin (2006)



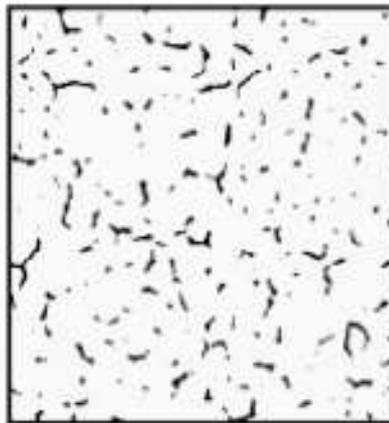
Maturation of crack patterns

MATURATION OF CRACK PATTERNS

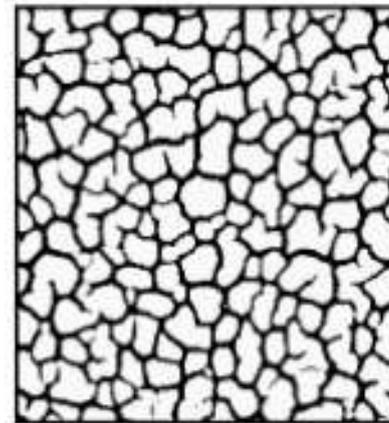
PHYSICAL REVIEW E 69, 056212 (2004)



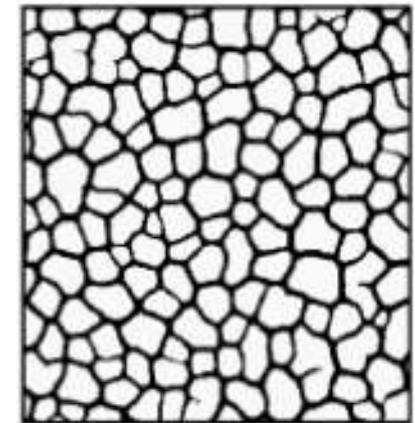
$t=1 \tau$



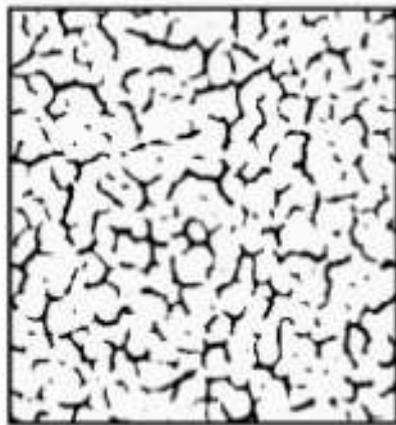
$t=1.25 \tau$



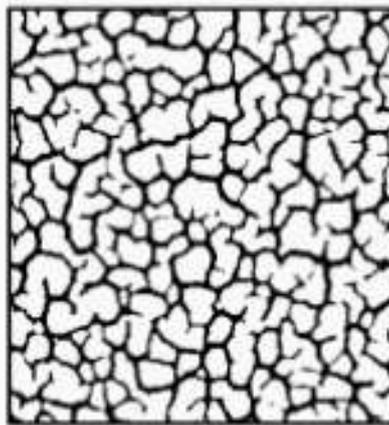
$t=5 \tau$



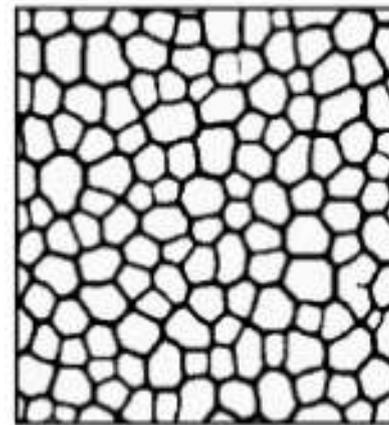
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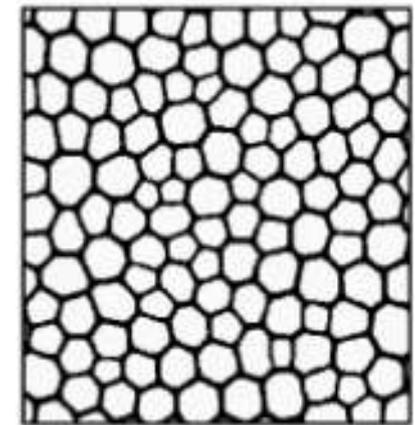
$t=1.5 \tau$



$t=2 \tau$



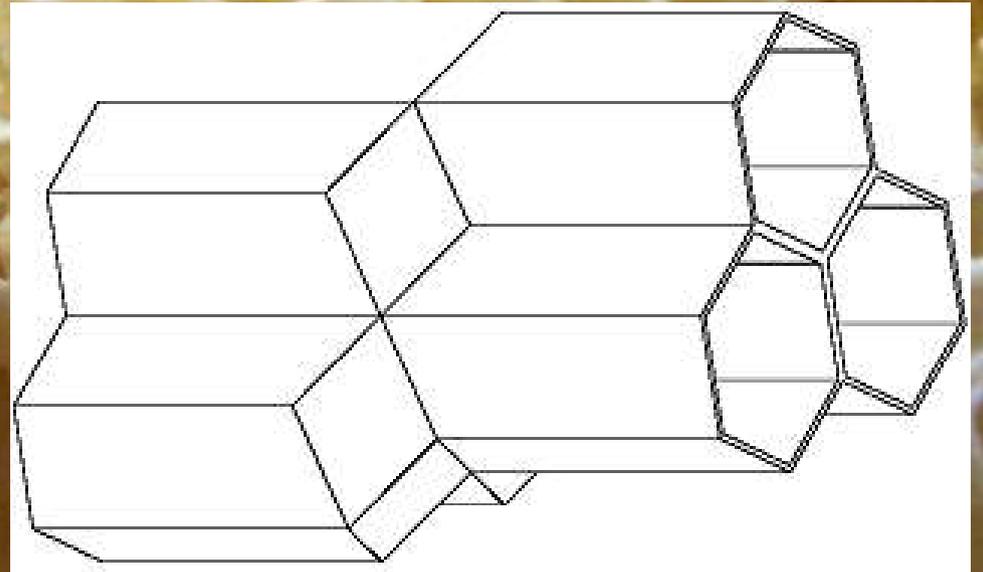
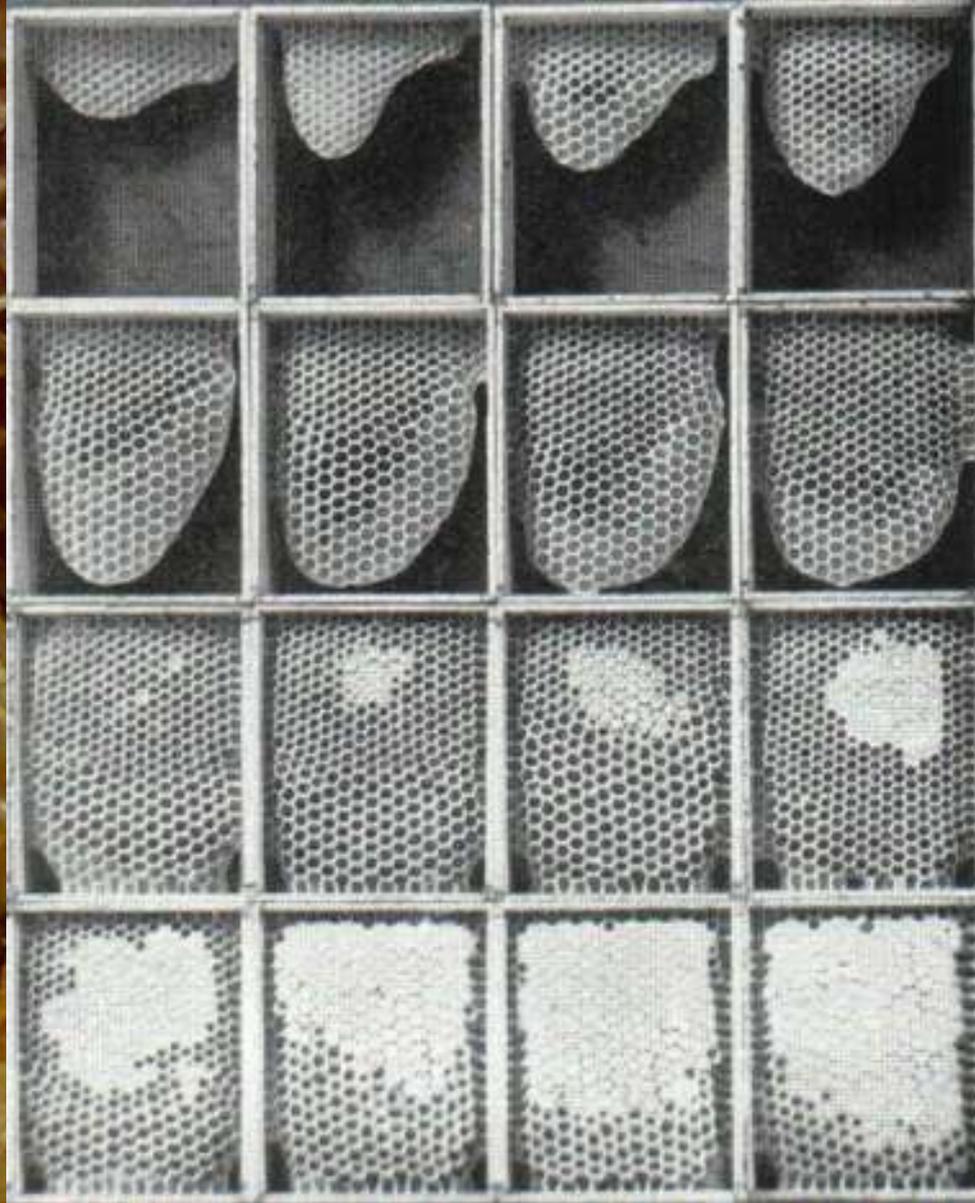
$t=20 \tau$



$t=200 \tau$



And honeycombs?



Patterns in Nature Outline

1. Introduction
2. Waves and oscillations
3. Regularity and chaos
4. Animal cooperation
- 5. Spatial patterns**
6. Aggregation and growth processes
7. Cellular automata
8. Fractals
9. Miscellaneous topics
10. Concluding session



Literature

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