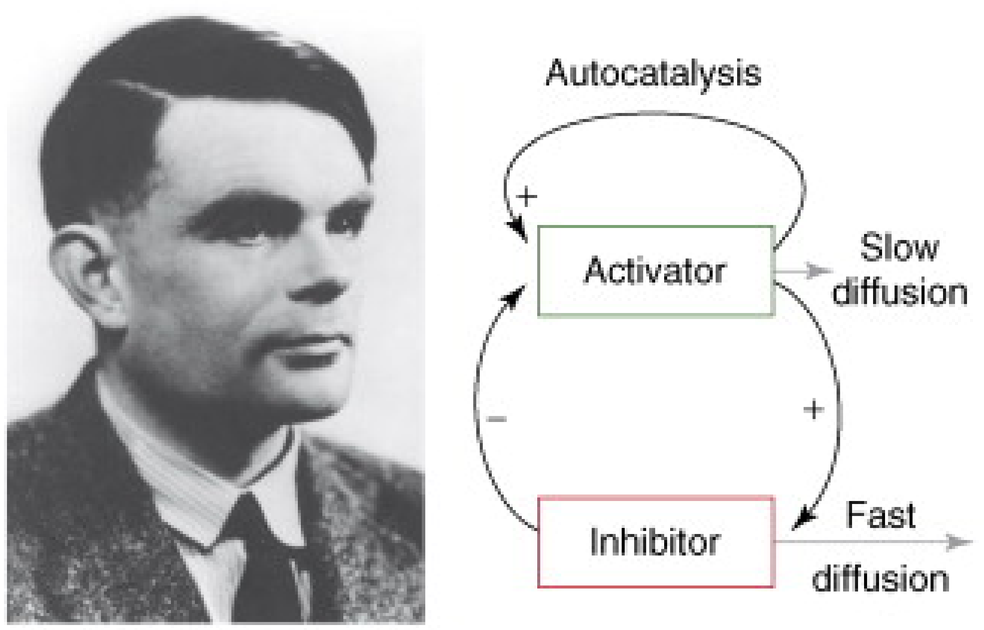
Patterns in Nature 5
Spatial patterns

Stephan Matthiesen

Activator-Inhibitor Model (Turing 1953)

Alan Turing (1912-1954)

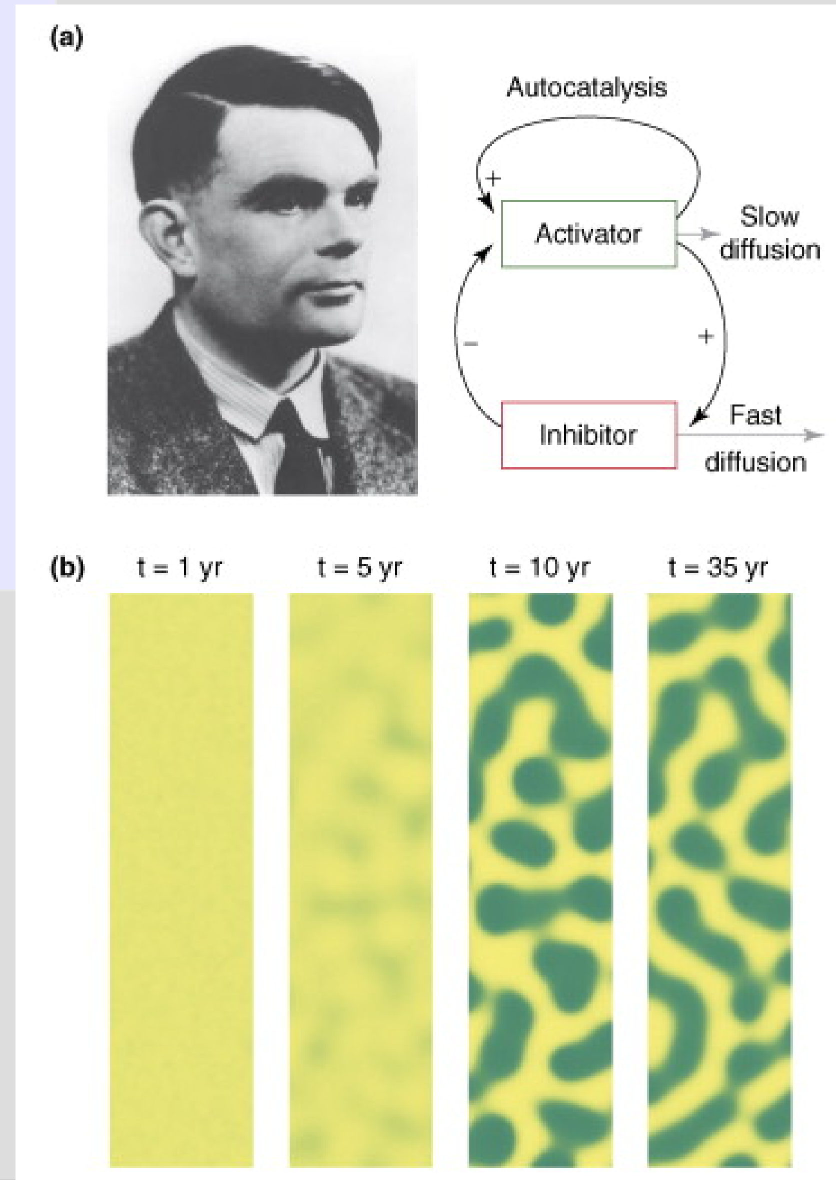
(a)

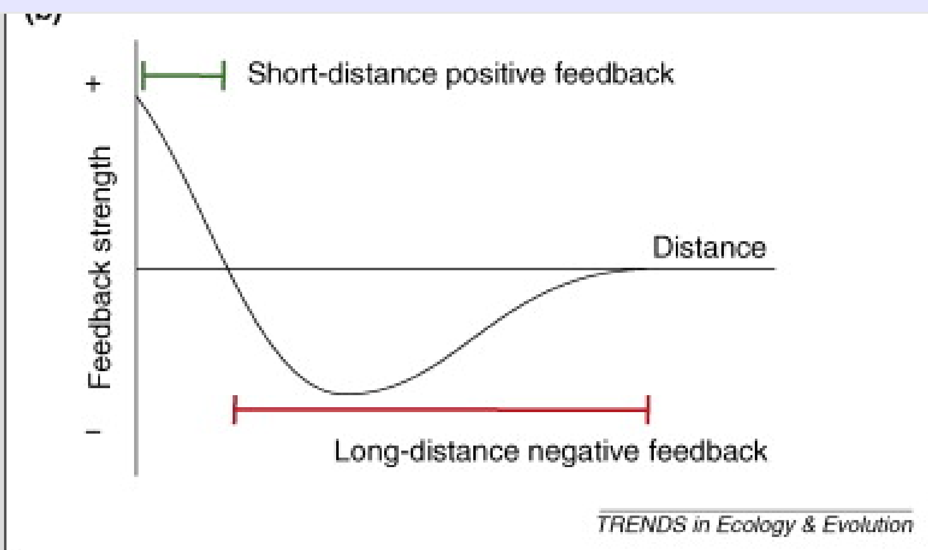


Activator-Inhibitor Model

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

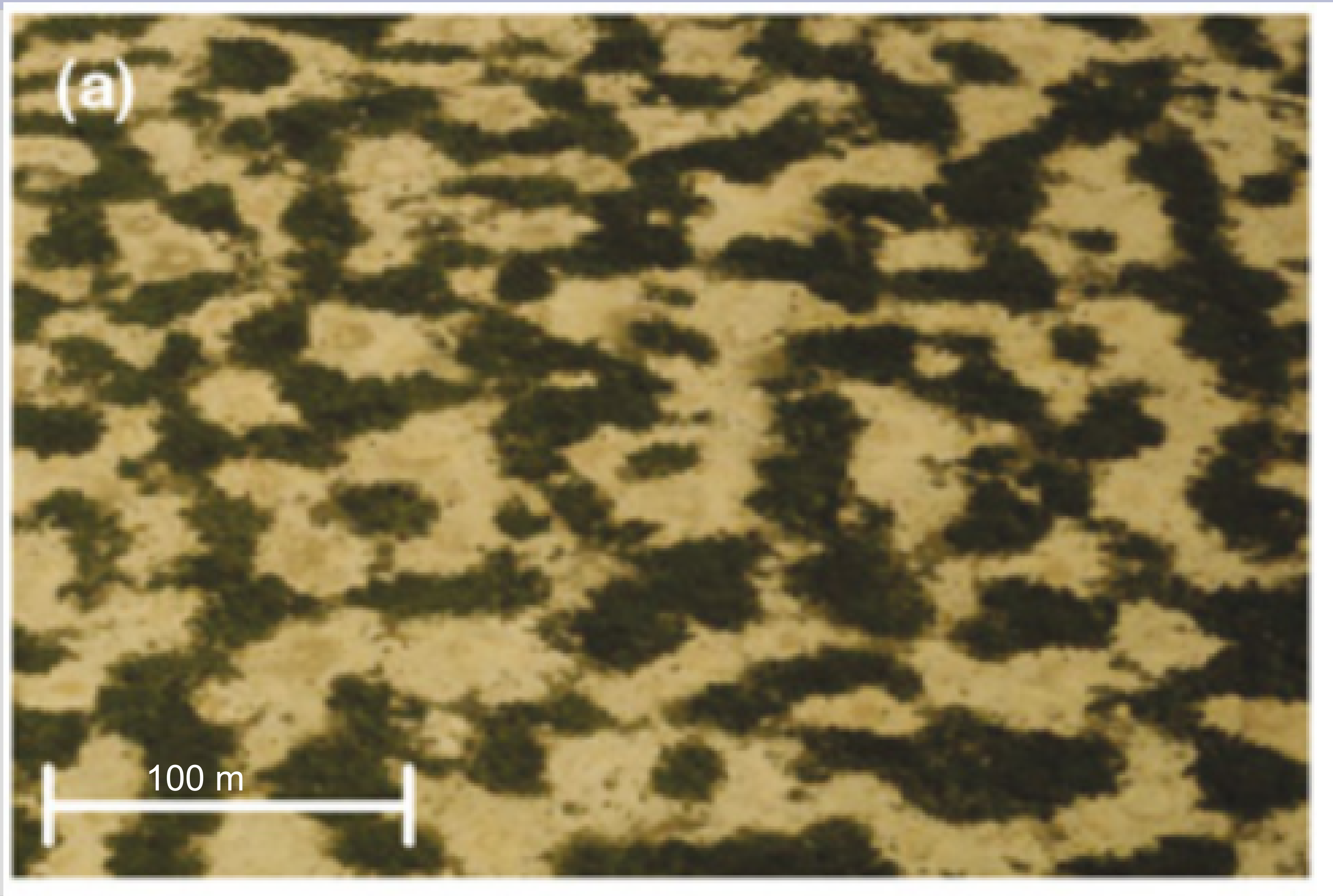
- positive feedback: the system responds to perturbations in the same direction as the perturbation
- negative feedback: it responds in opposite direction



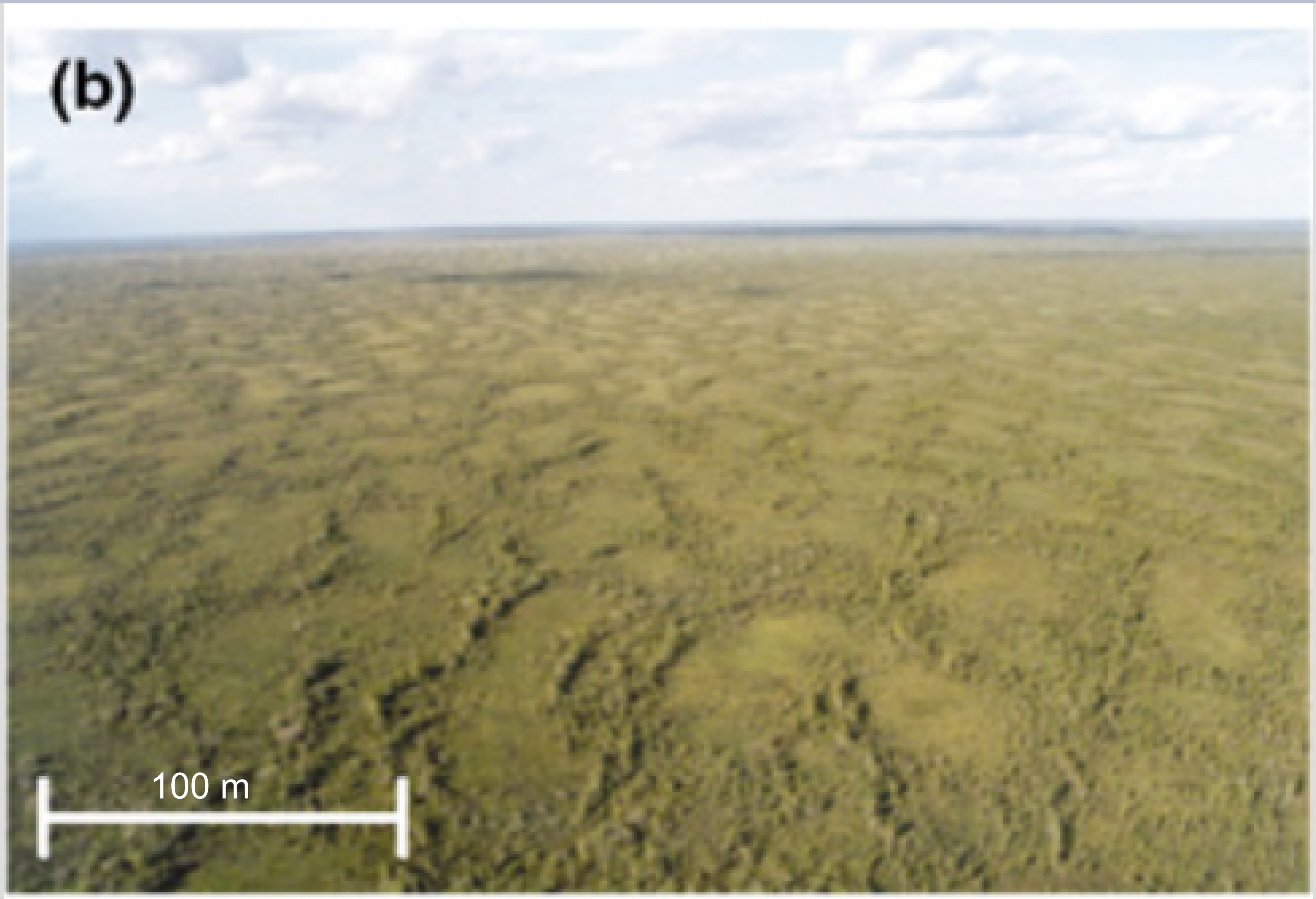


“Tiger bush”

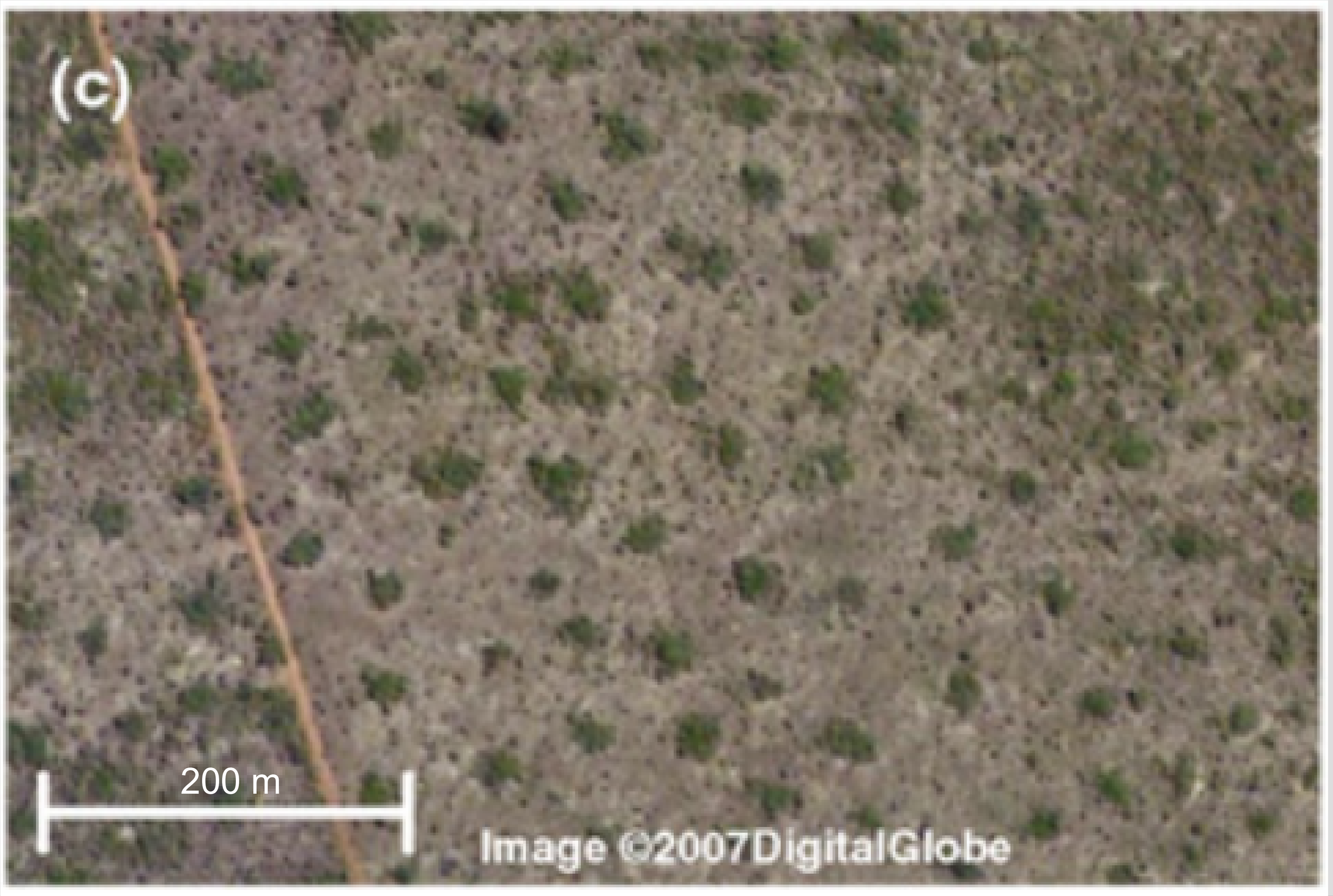
Rietkerk; v.d. Koppel 2008



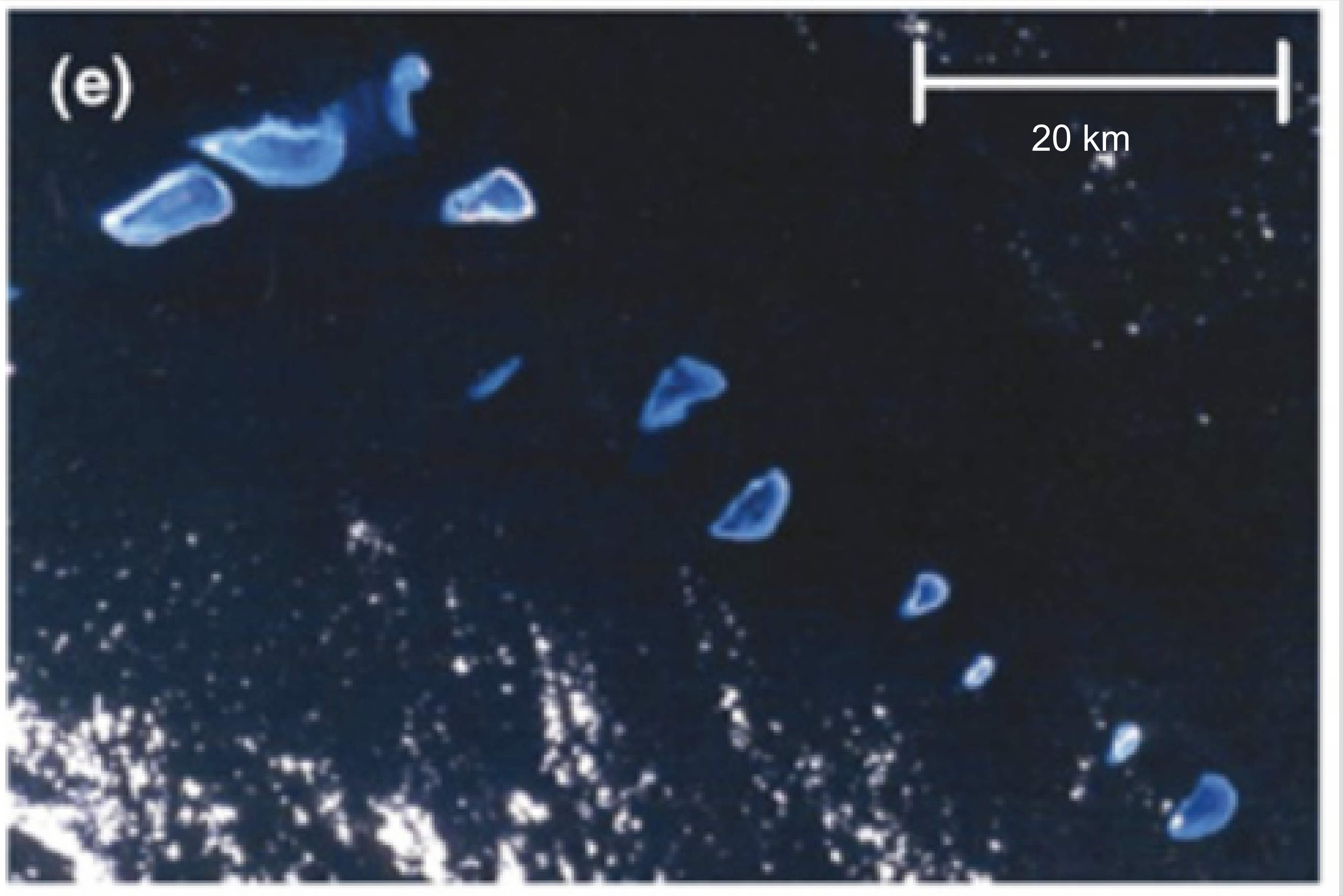
Wetland ecosystems



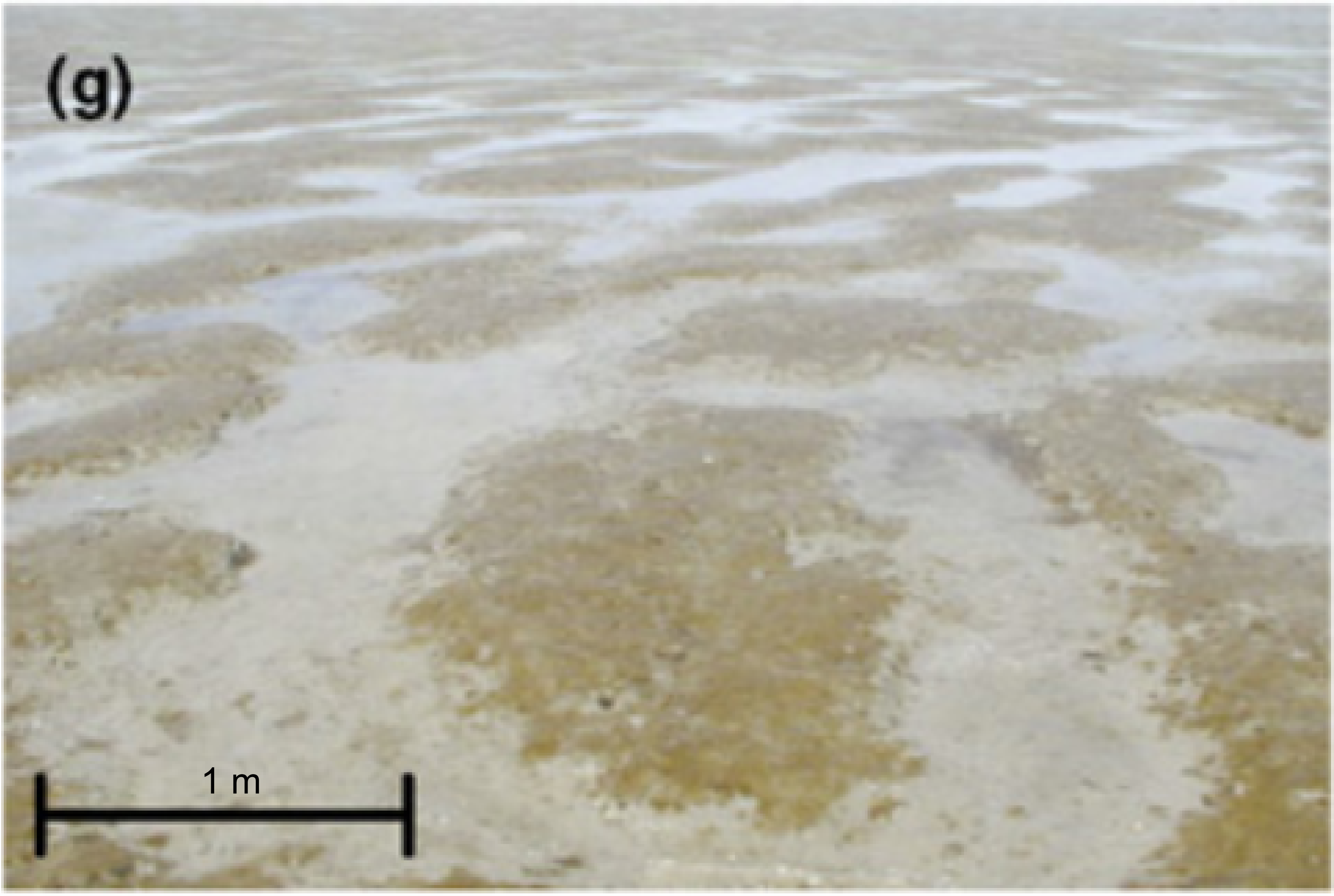
Savannah



Coral reefs

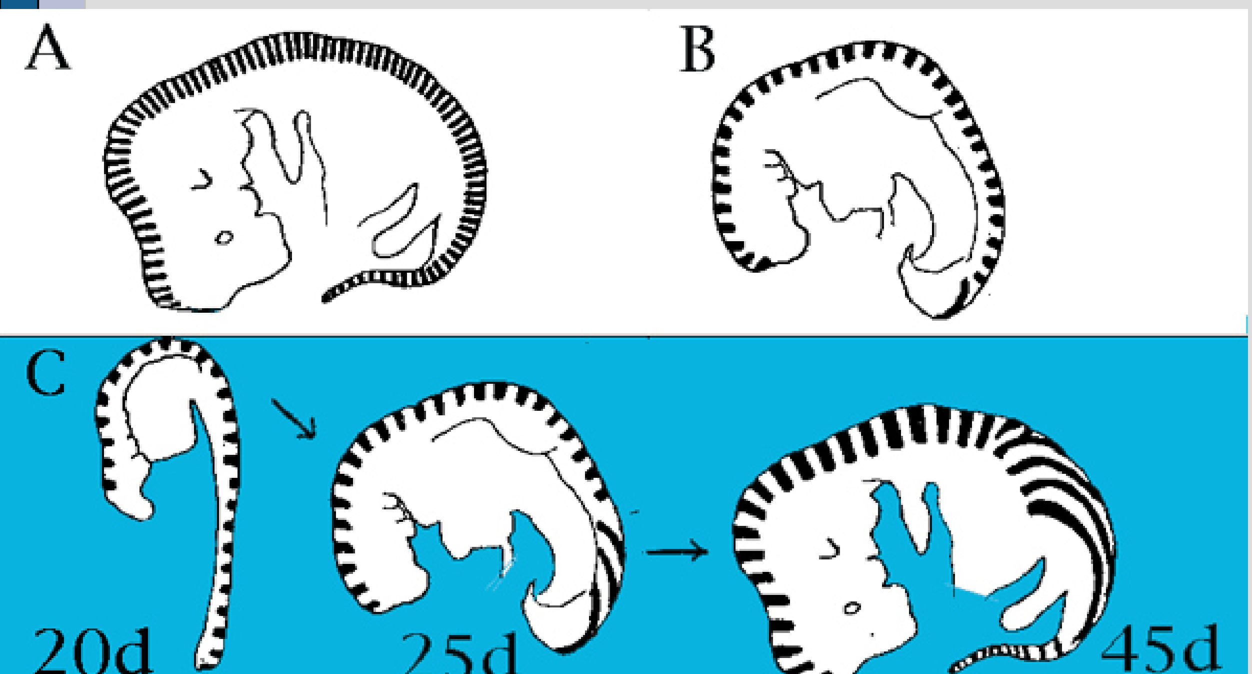


Intertidal mudflats



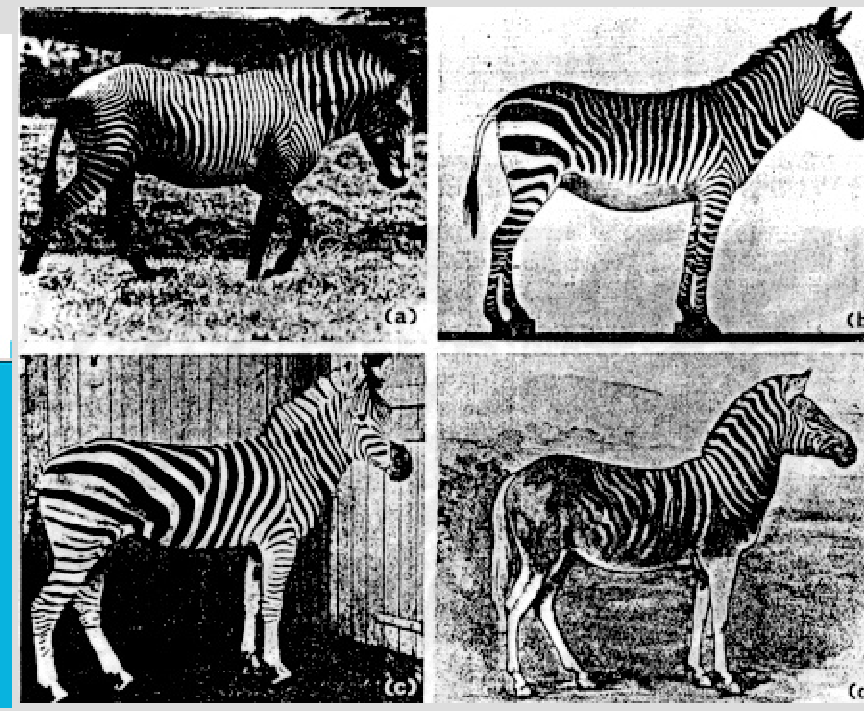
Zebras

Imperial Zebra: week 5 Mountain Zebra: week 4



Common Zebra: week 3

A B



C D

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

Bard 1977

Leopard

2 days: spots

8 weeks: rings

Adult: rosettes

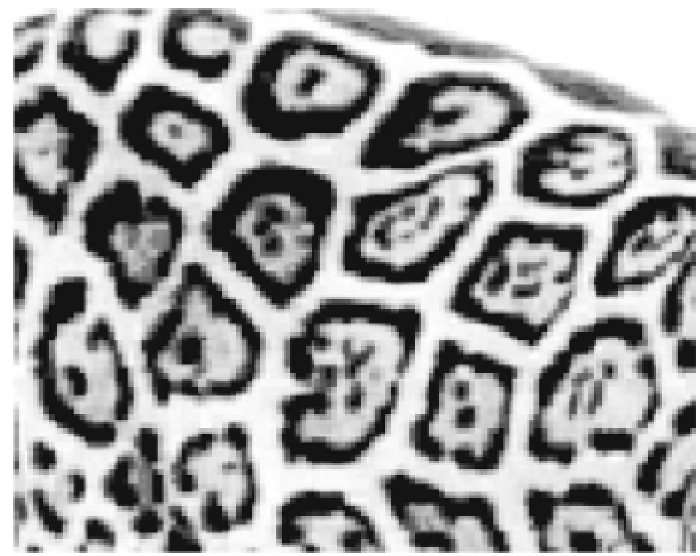
FIG. 1. Coat patterns of a leopard at different stages of growth:) spots (2 days), (b) rings (8 weeks), (c) rosettes (adult).

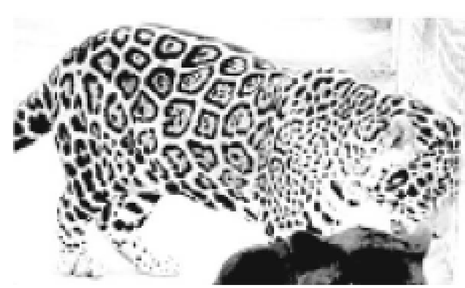
Liu, Liaw, Maini 2006

Jaguar

(a)

5 weeks: spots





3 months:
irregular
rings

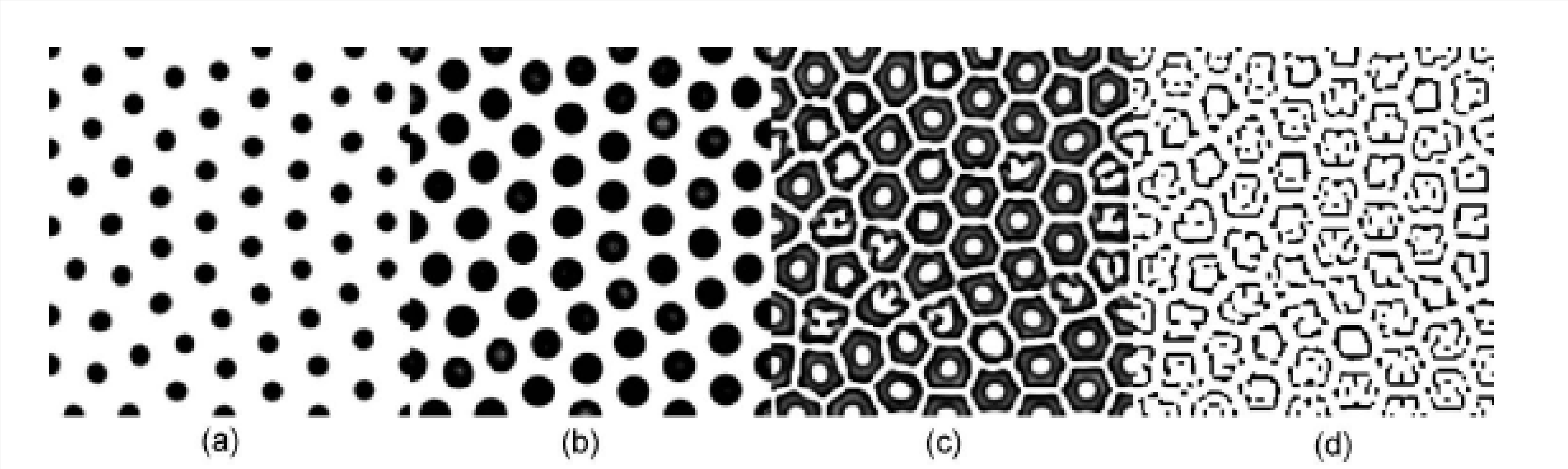
Adult:
small spots
enclosed by
irregular
polygons

(b)

(c)

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

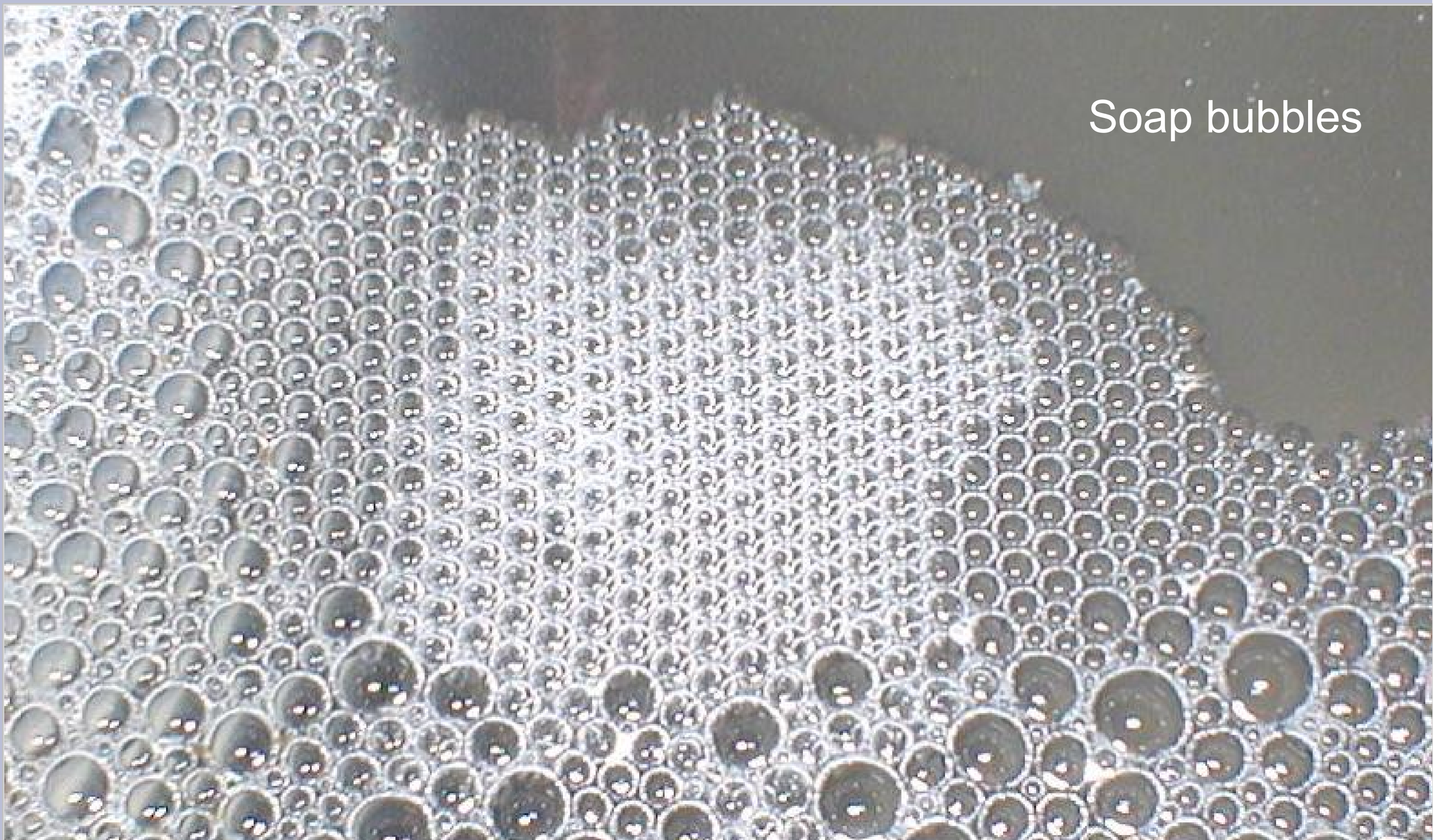


First Stage

Second stage
(with different parameters)

Liu, Liaw, Maini 2006

Hexagonal patterns



Rayleigh-Benard convection

Lane; Christensen 2000

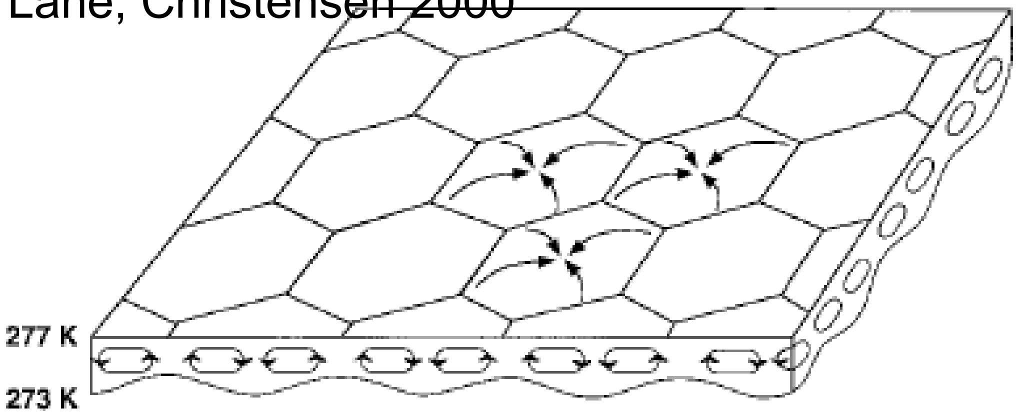
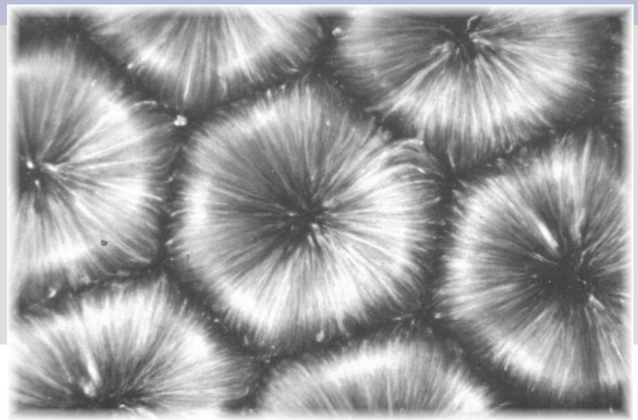
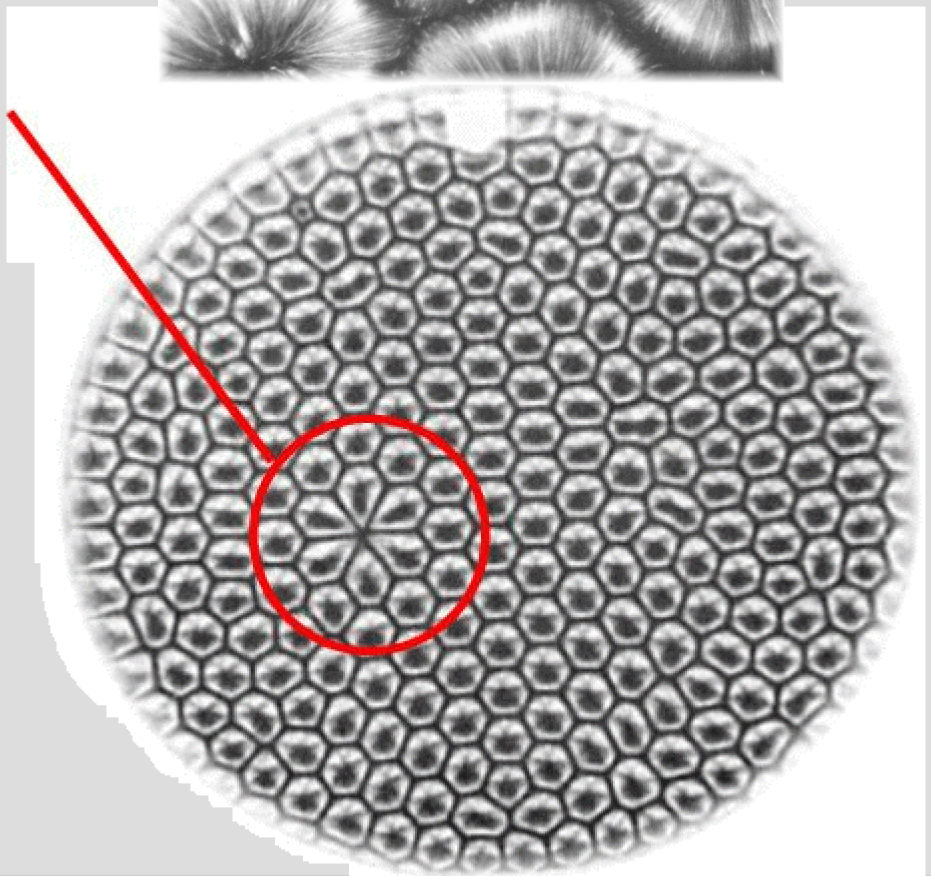
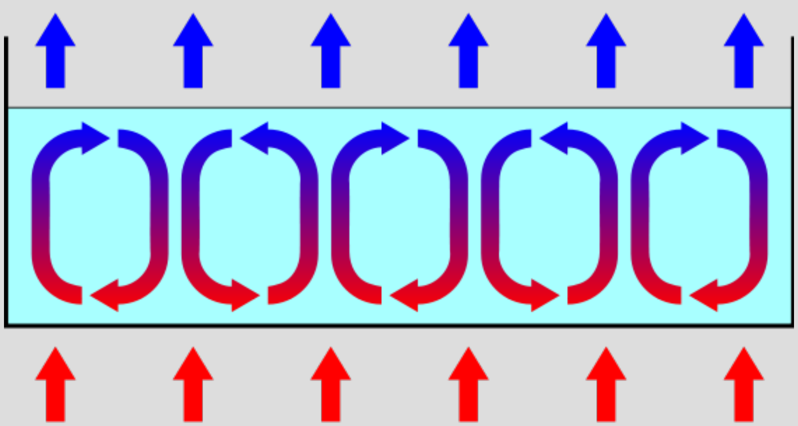


Figure 4. A schematic three-dimensional section of hexagonal Rayleigh convection cells in an active layer.







Polygons on Mars

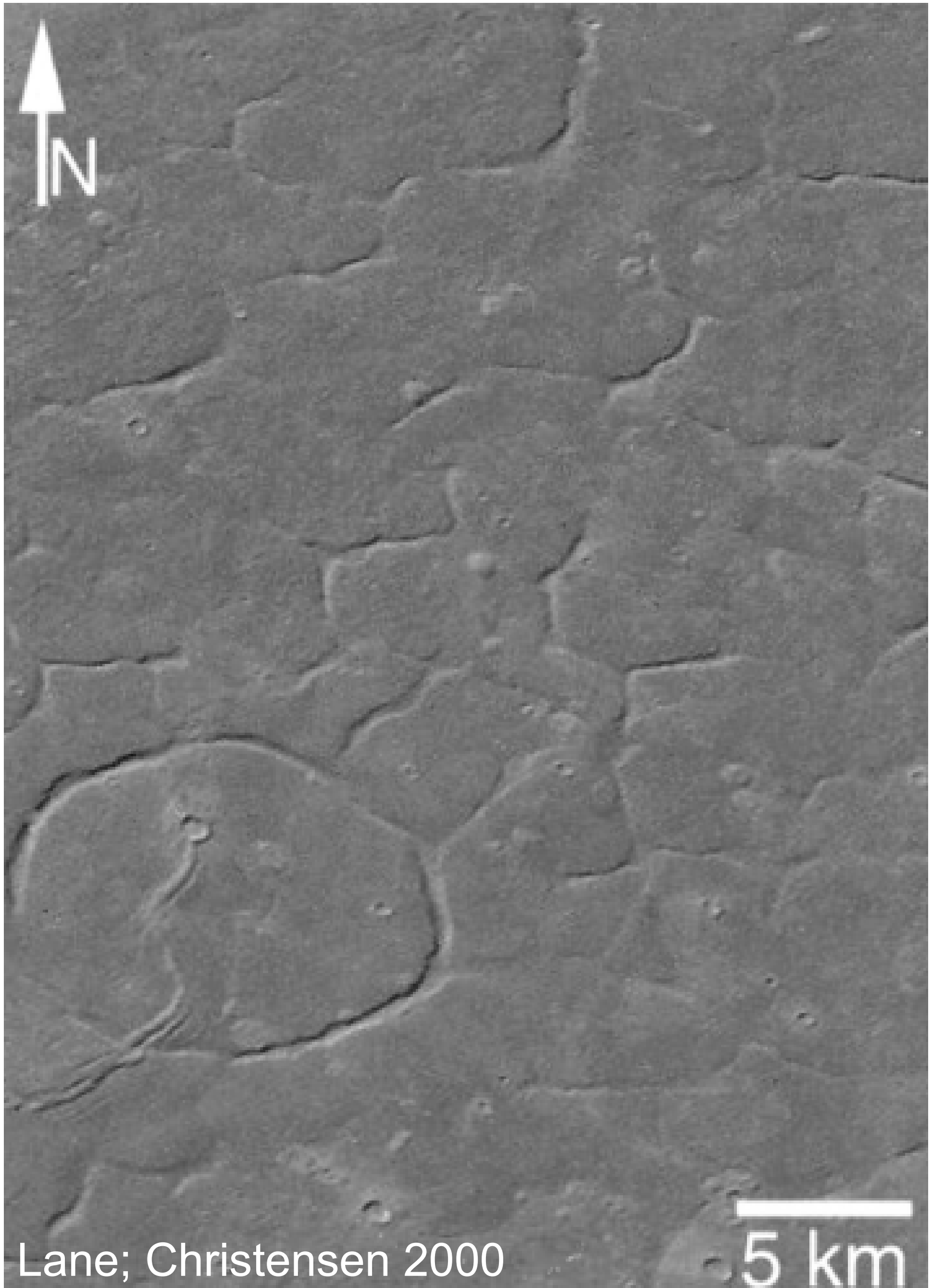


Figure 1. An example of the polygonal terrain on Mars (the large circular feature toward the bottom left of the image may be associated with a buried crater). This is a subframe of a Viking 1 Orbiter image (032A18) of polygonal terrain in Acidalia Planitia, centered near 44.1°N, 18.6°W. Illumination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

http://www.coasttocoastam.com/ /gen/page207.html

Martian Polygons

LANE AND CHRISTENSEN: CONVECTION ORIGIN FOR MARTIAN POLYGONS

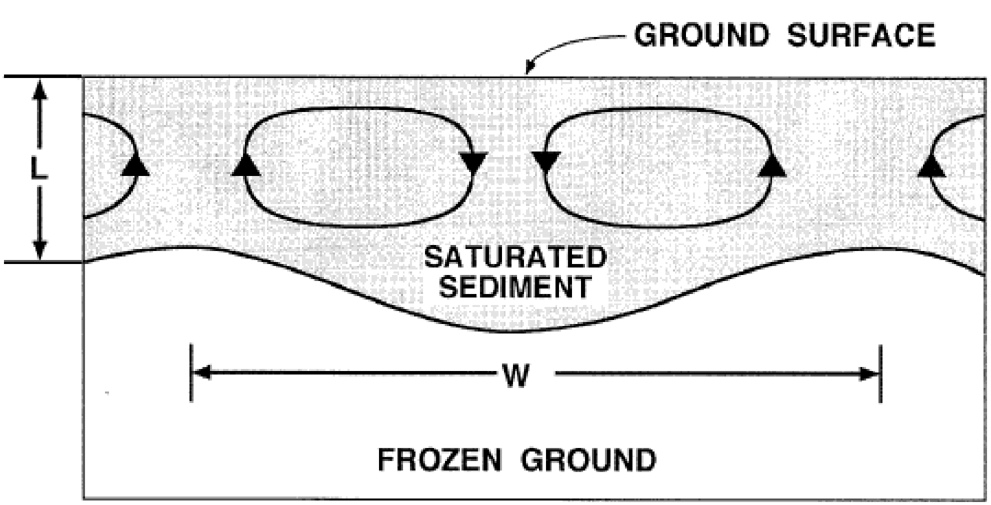
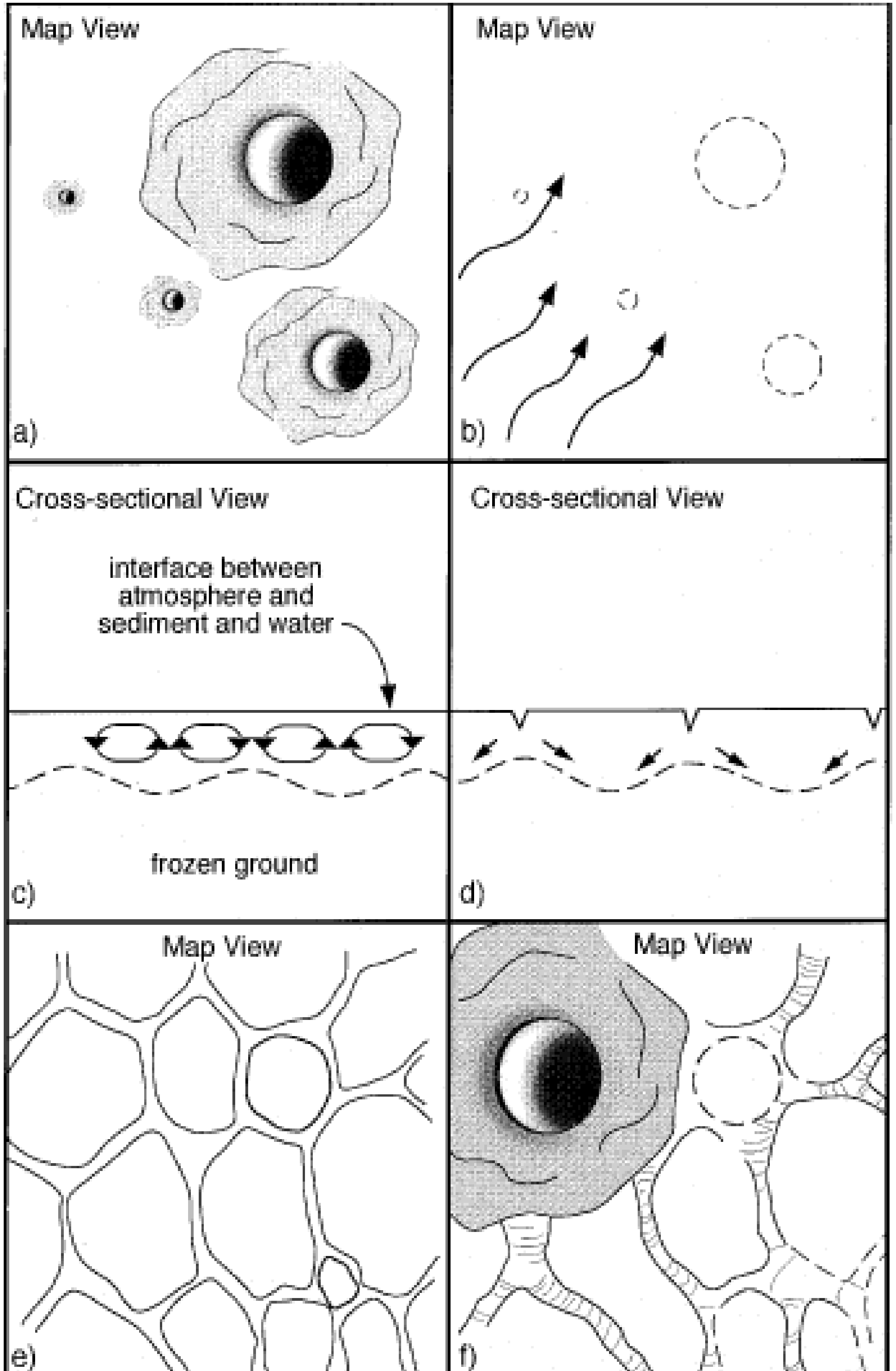
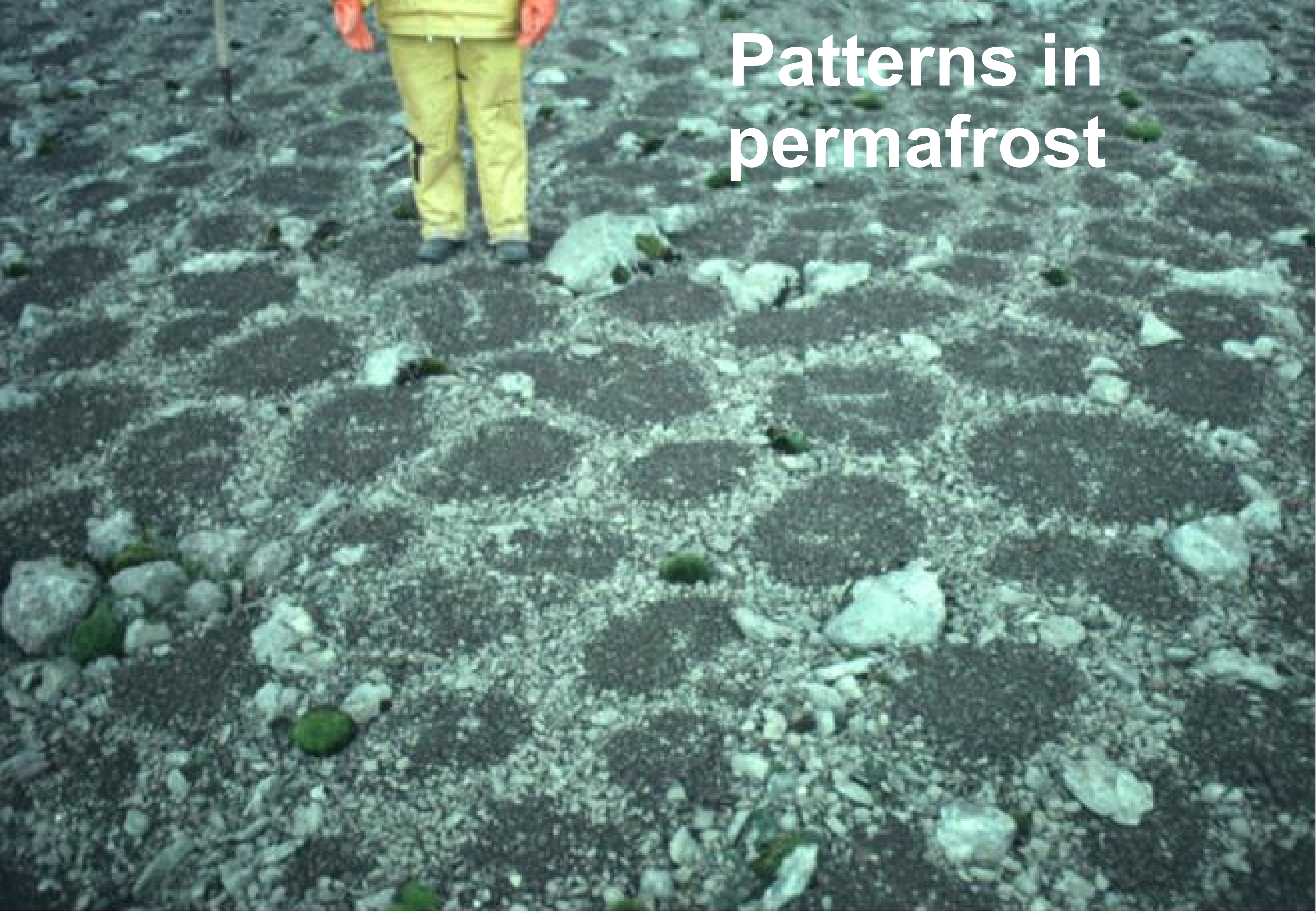


Figure 2. A schematic two-dimensional section of Rayleigh convection cells in an active layer [after *Ray* 1981]. For the case of circulation within a body of standing water, the saturated sediment layer would b thinner and the "ground surface" label would represent the water/atmosphere interface.

LANE AND CHRISTENSEN: CONVECTION ORIGIN FOR MARTIAN POLYGONS



Lane, Christensen 2000


Patterns in permafrost

Columnar jointing

de.wikipedia.org

Giant's causeway

Jagla; Rojo (2002)

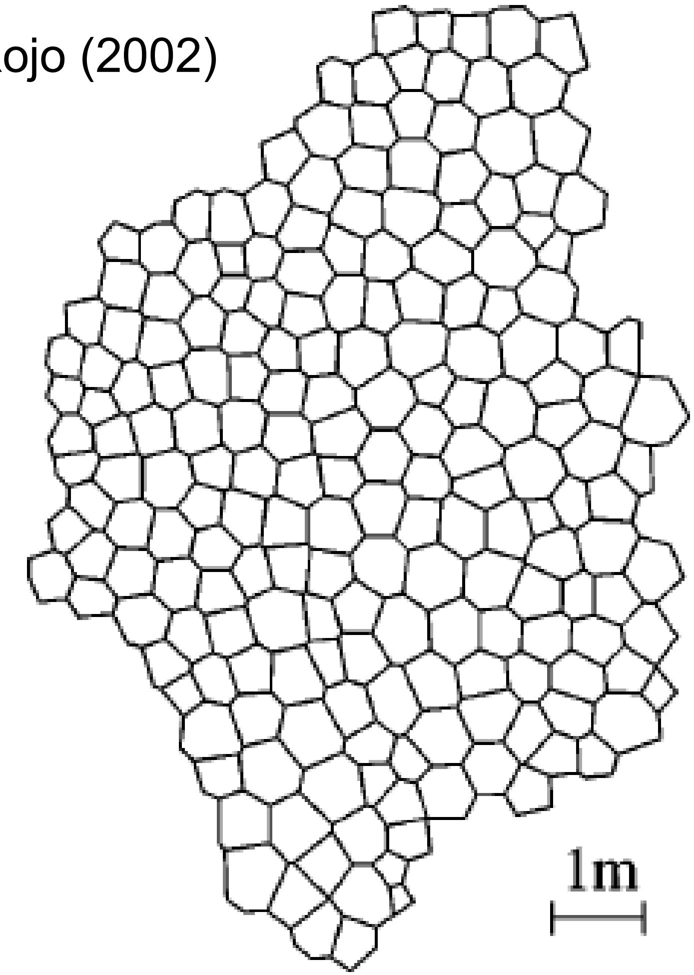


FIG. 1. Polygonal pattern seen perpendicular to some of the columns of the Giant's Causeway, a tertiary lava flow in Antrim, Northern Ireland, from Ref. [20] (originally from a map by O'Reilly [21]).

Kirkjugólf („Church floor“)
Kirkjubæjarklaustur, Iceland


Kirkjugólf („Church floor“)
Kirkjubæjarklaustur, Iceland

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Kirkjubæjarklaustur, Iceland


Dverghamrar („Dwarf cliffs“), Iceland

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Dverghamrar („Dwarf cliffs“), Iceland


Svartifoss, Iceland

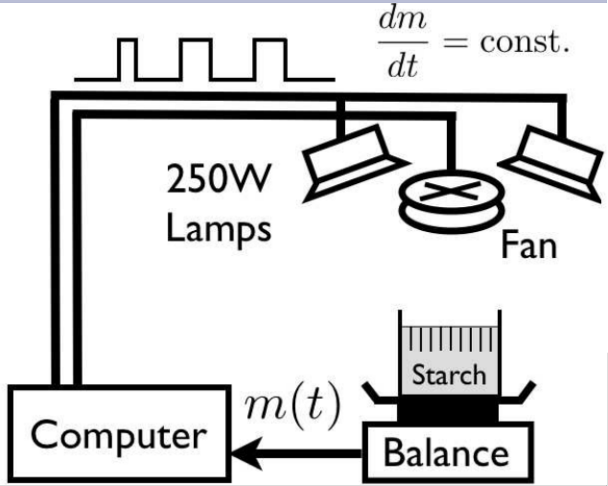
Experiment
Your own Giant's causeway

- 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

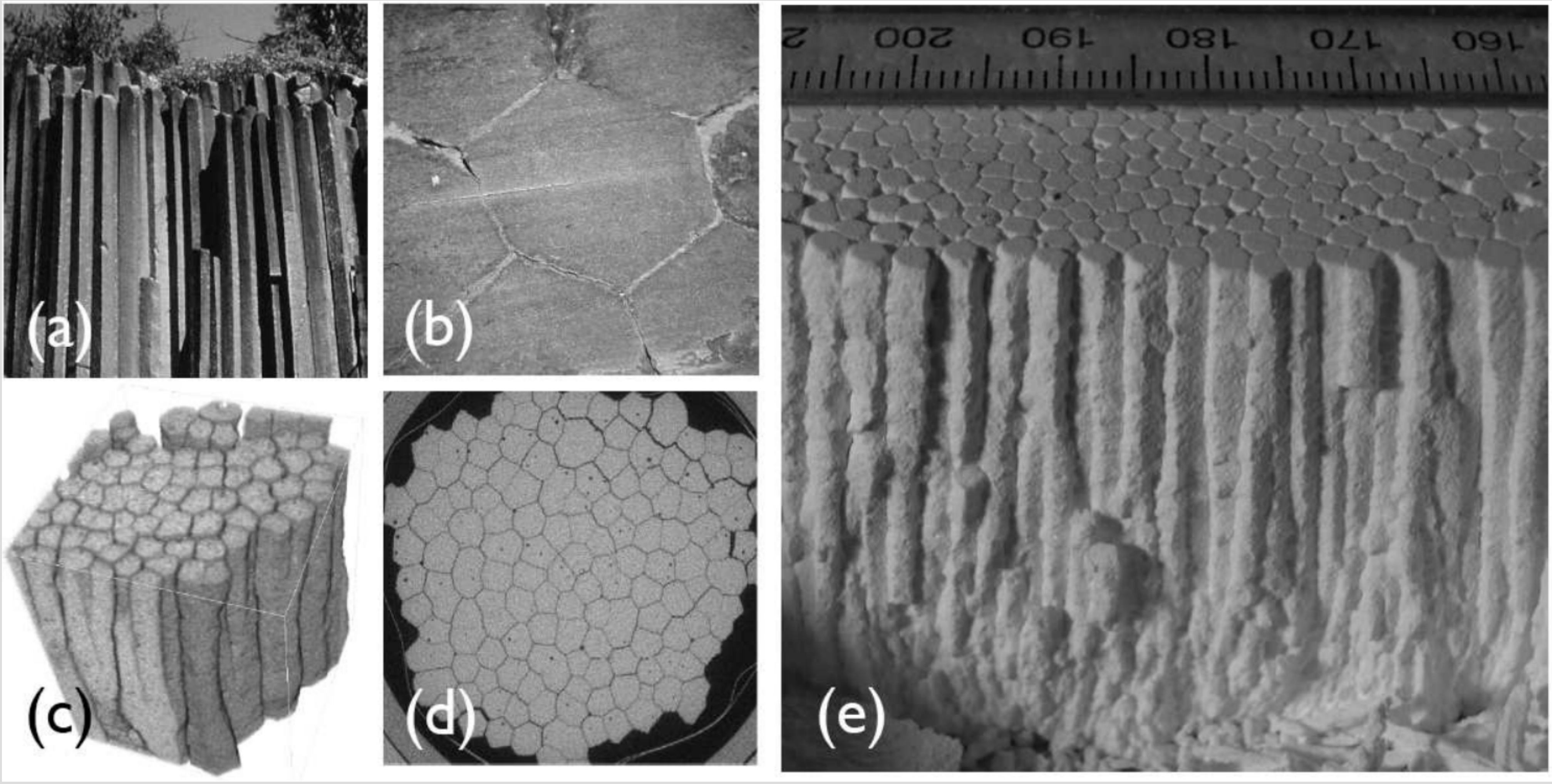
One we prepared earlier (in week 3)

Columns

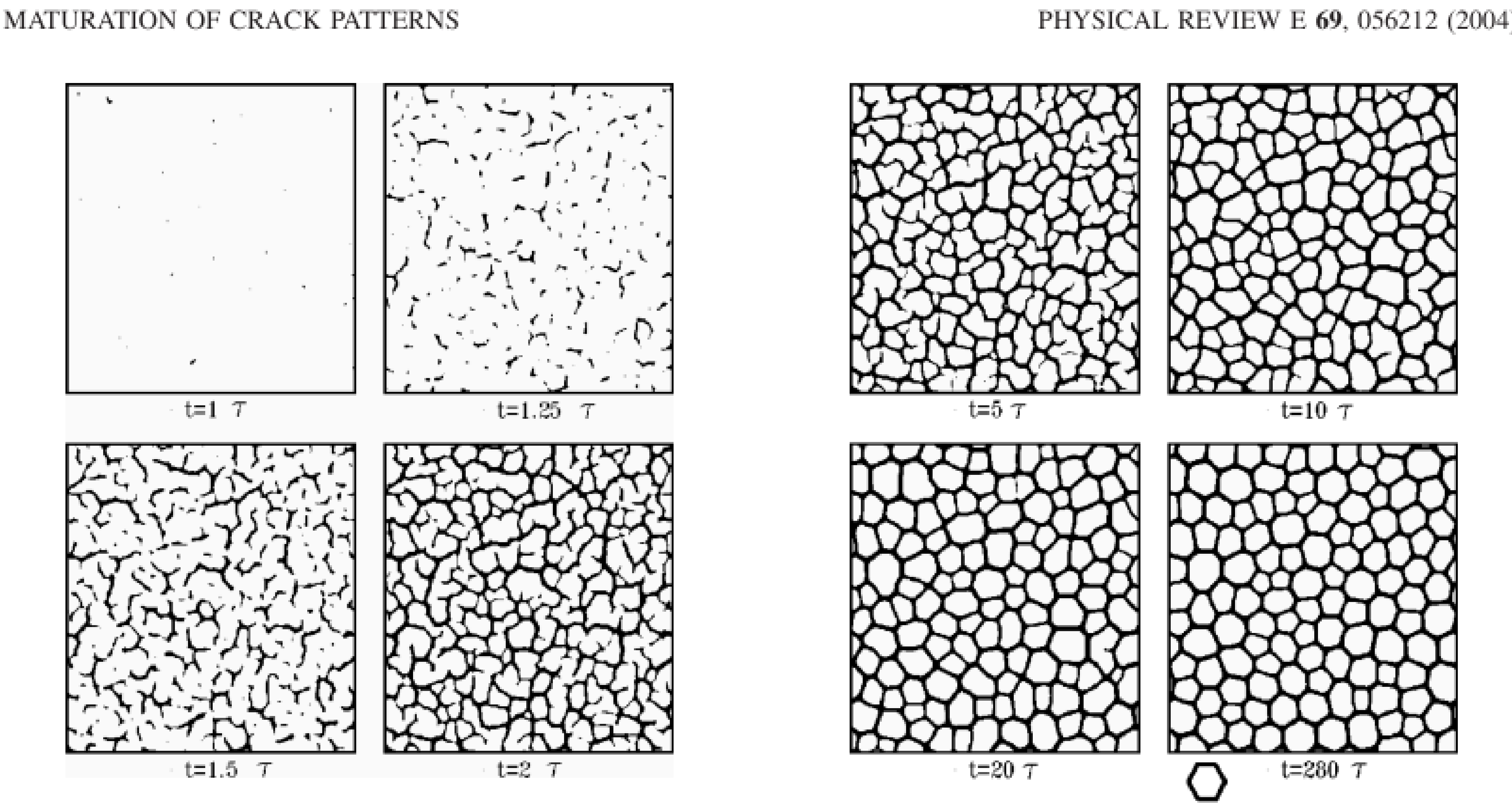
An experiment with cornstarch



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

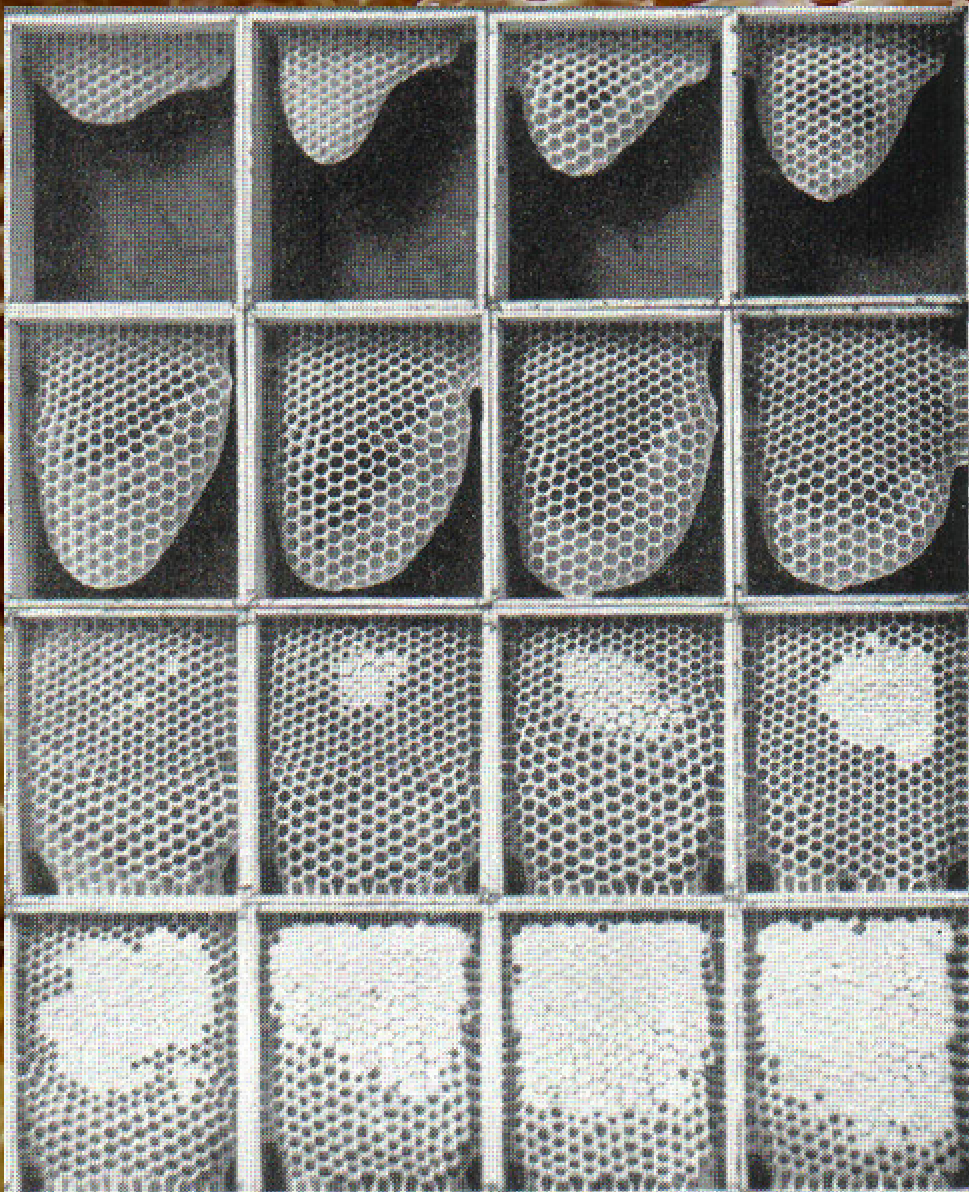


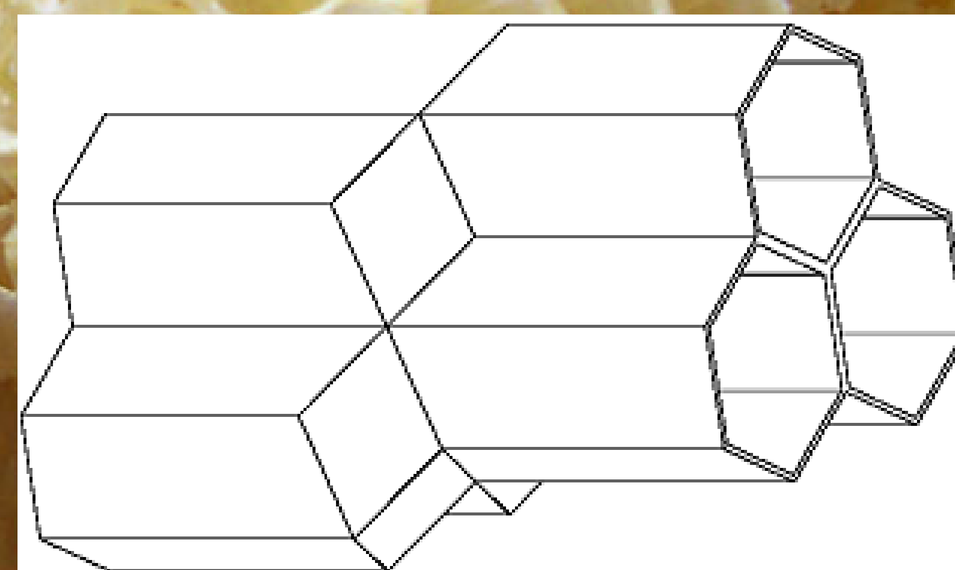
Maturation of crack patterns



Jagla 2004

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

- Ball, P. (1999): *The self-made tapestry.*
- Rietkerk, van de Koppel (2008). *Trends in Ecology&Evolution*
- Jagla, Rojo (2002). *Phys. Rev. E.* 65, 026203
- Jagla (2004). *Phys. Rev. E.* 69, 056212
- Goehring (2003), MSc thesis; available at: http://www.msm.cam.ac.uk/wjc/Lucas/Papers.html
- Goehring, Morris, Lin (2006): *Phys. Rev. E.* 74, 036115
- Lane, Christensen (2000). *JGR* 105 (E7), 17617
- Bard, J. B. L. 1977. *J. Zool. (London)* 183: 527-539