

Patterns in Nature 5

Spatial patterns



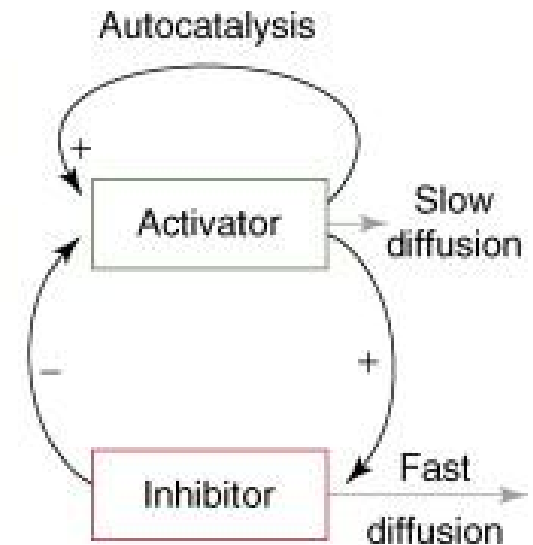
Stephan Matthiesen

Activator-Inhibitor Model (Turing 1953)



Alan Turing (1912-1954)

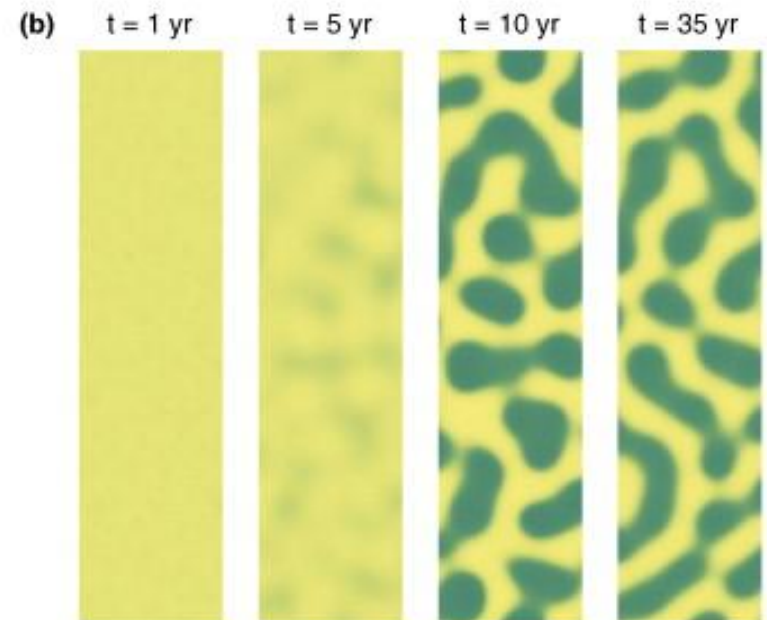
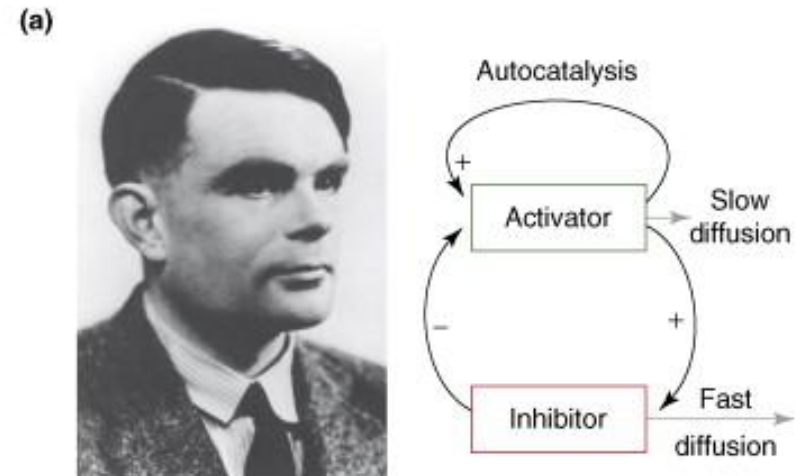
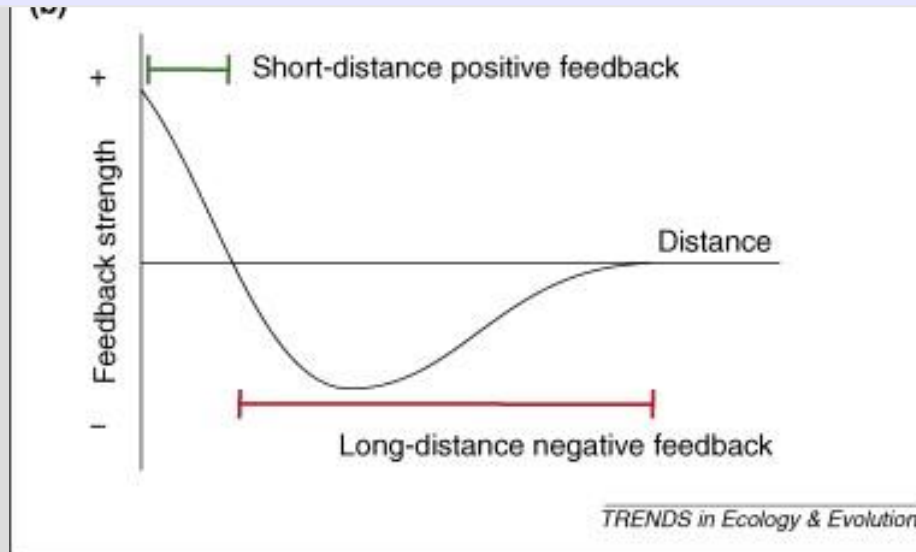
(a)



Activator-Inhibitor Model

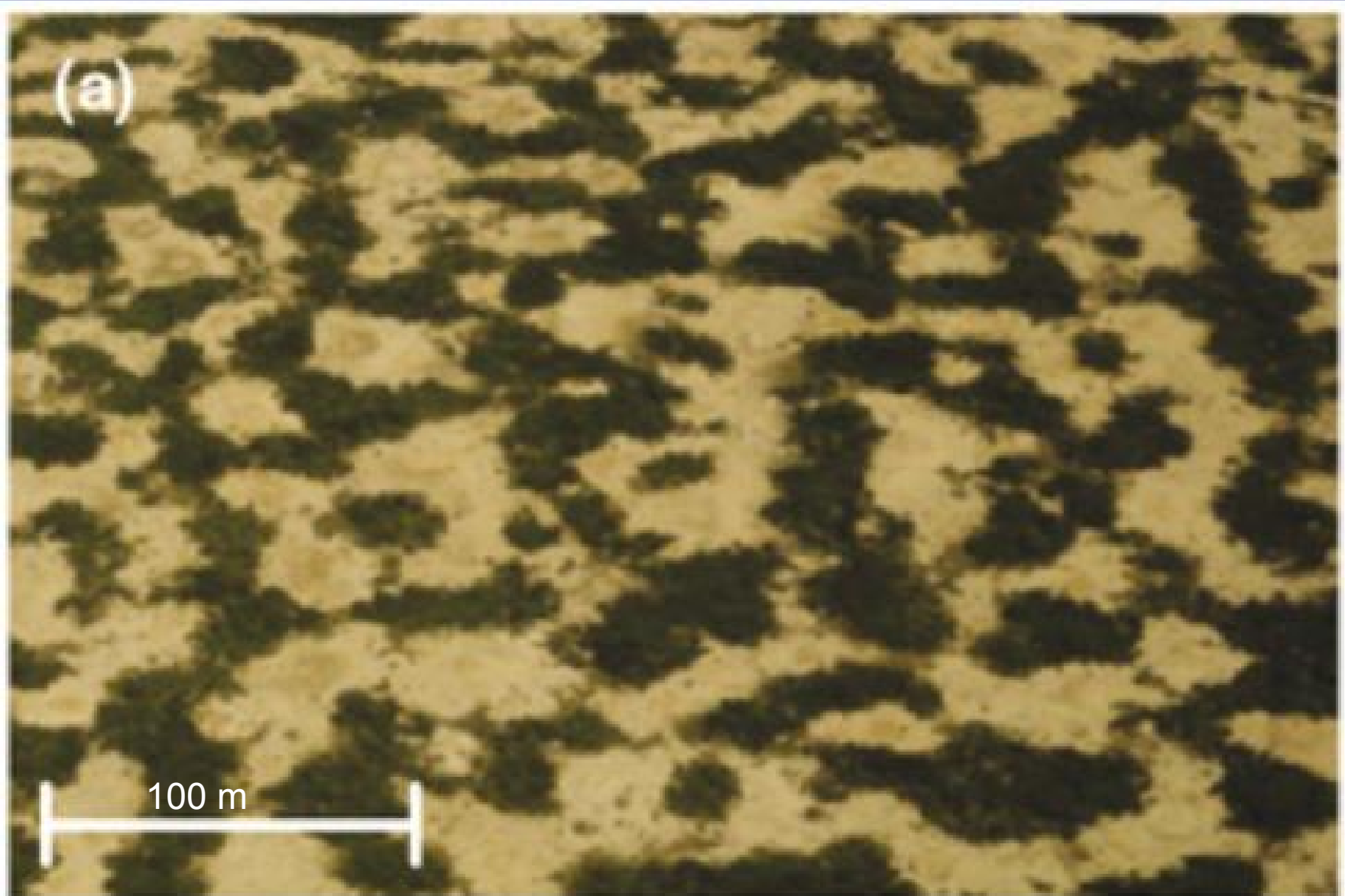
feedback: part of a system's output influences the input

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

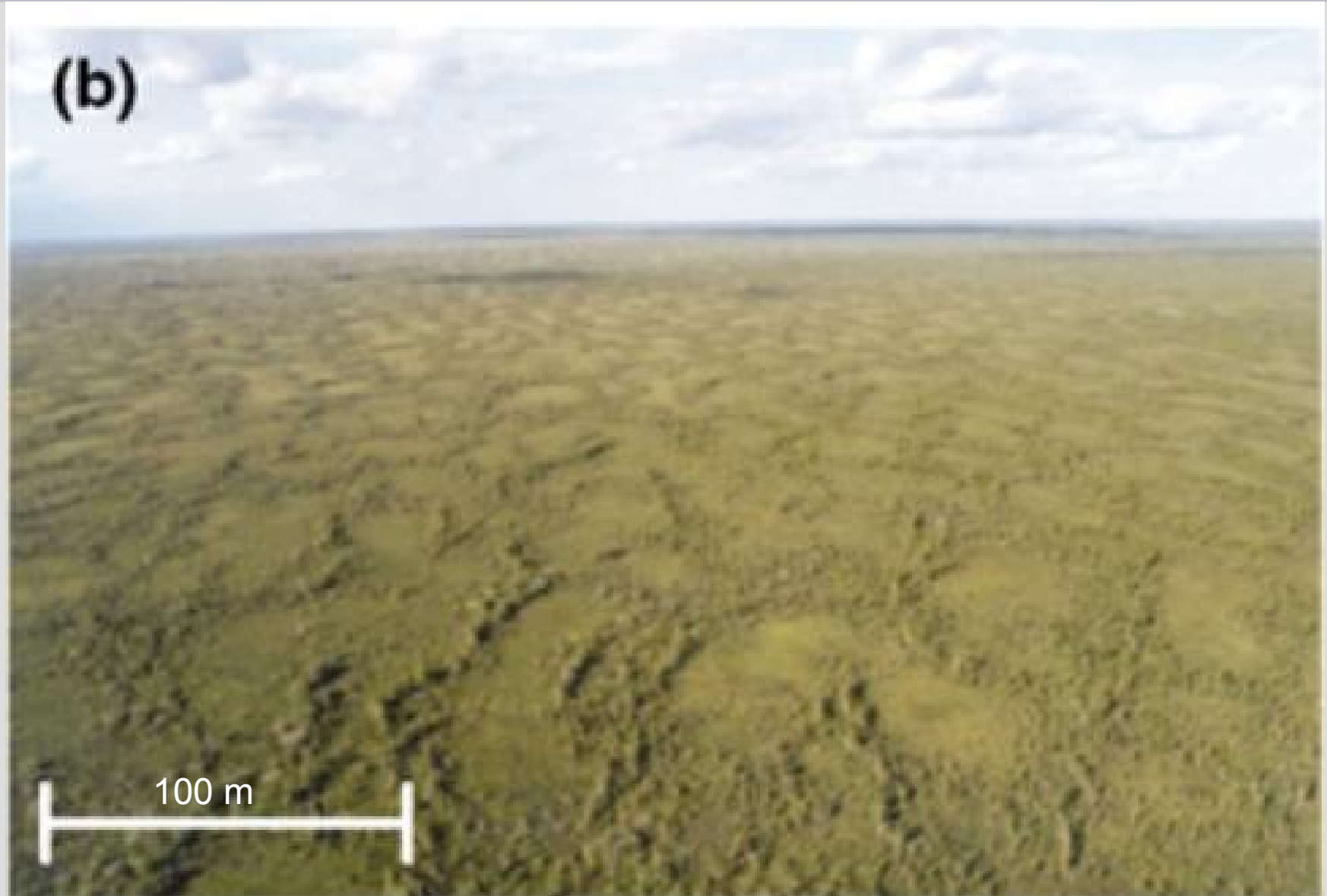


“Tiger bush”

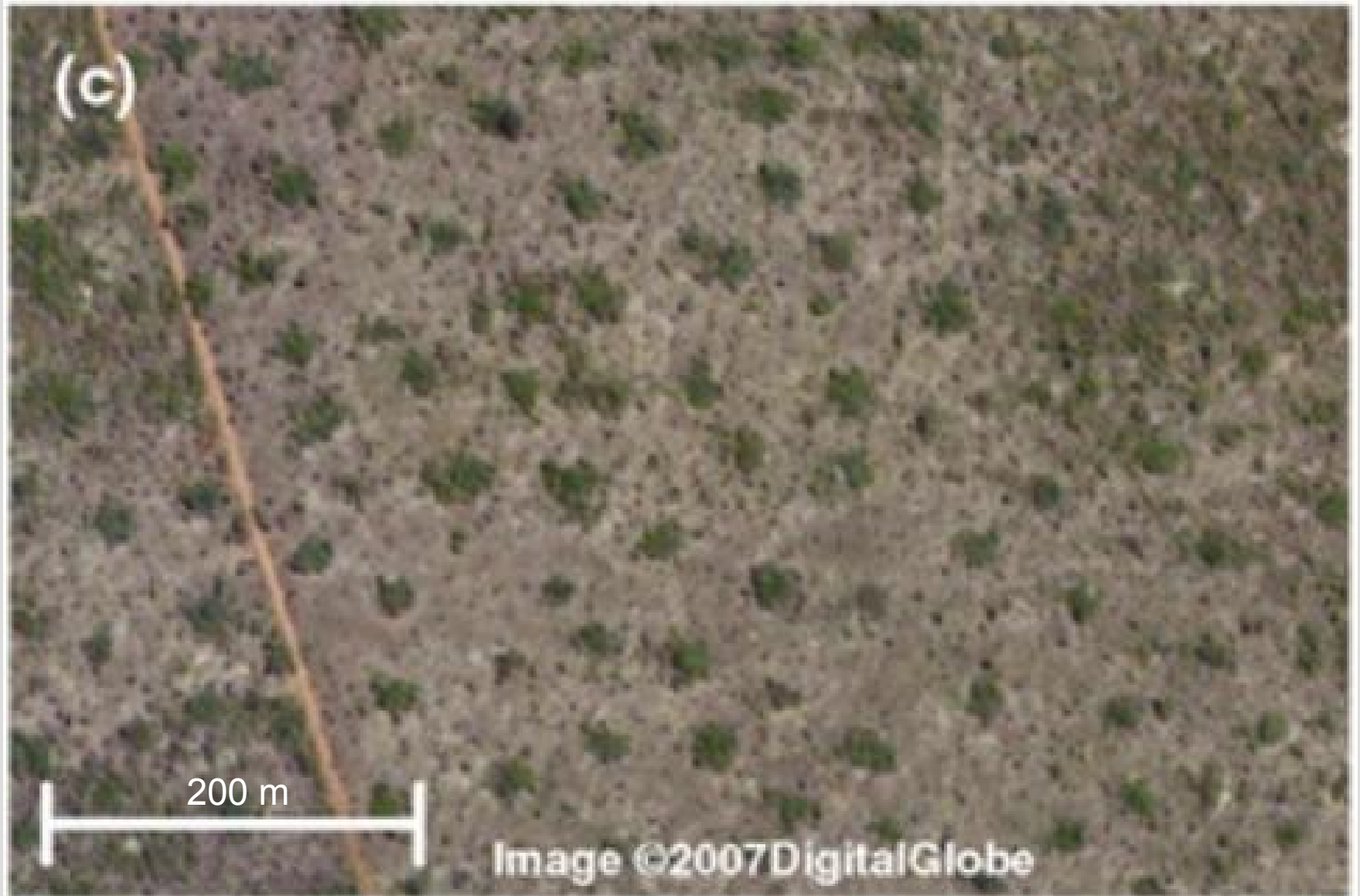
Rietkerk; v.d. Koppel 2008



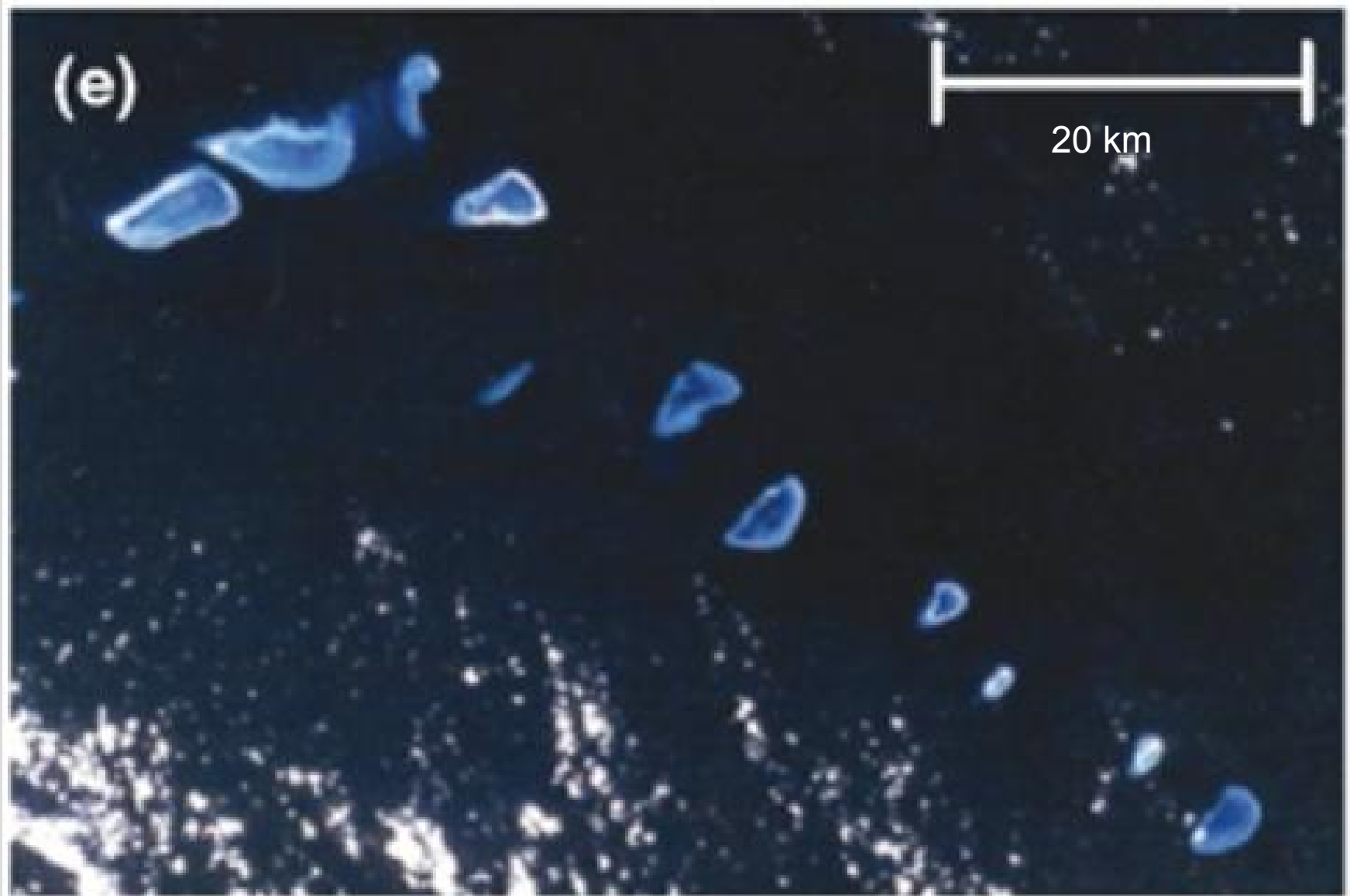
Wetland ecosystems



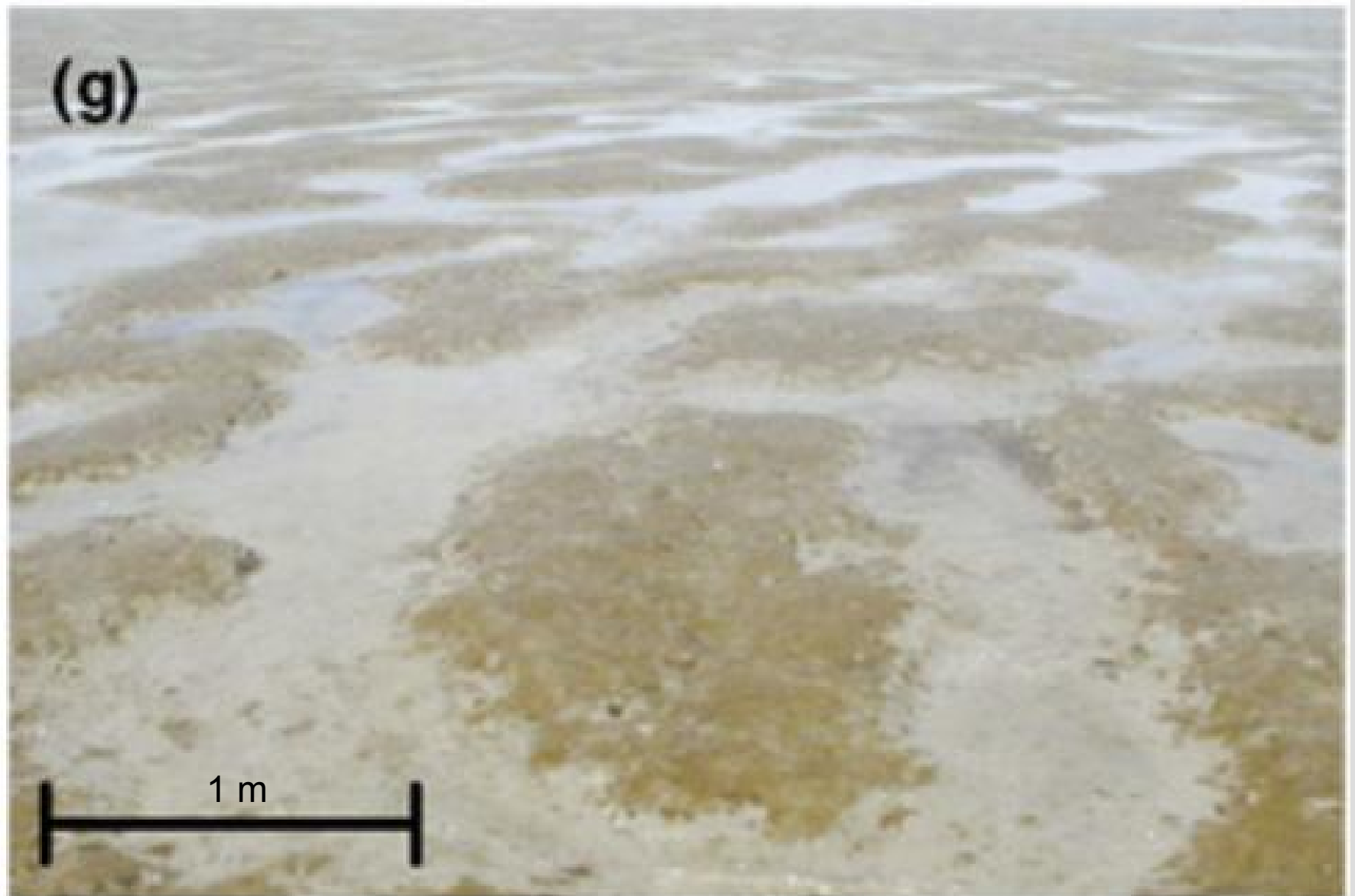
Savannah



Coral reefs



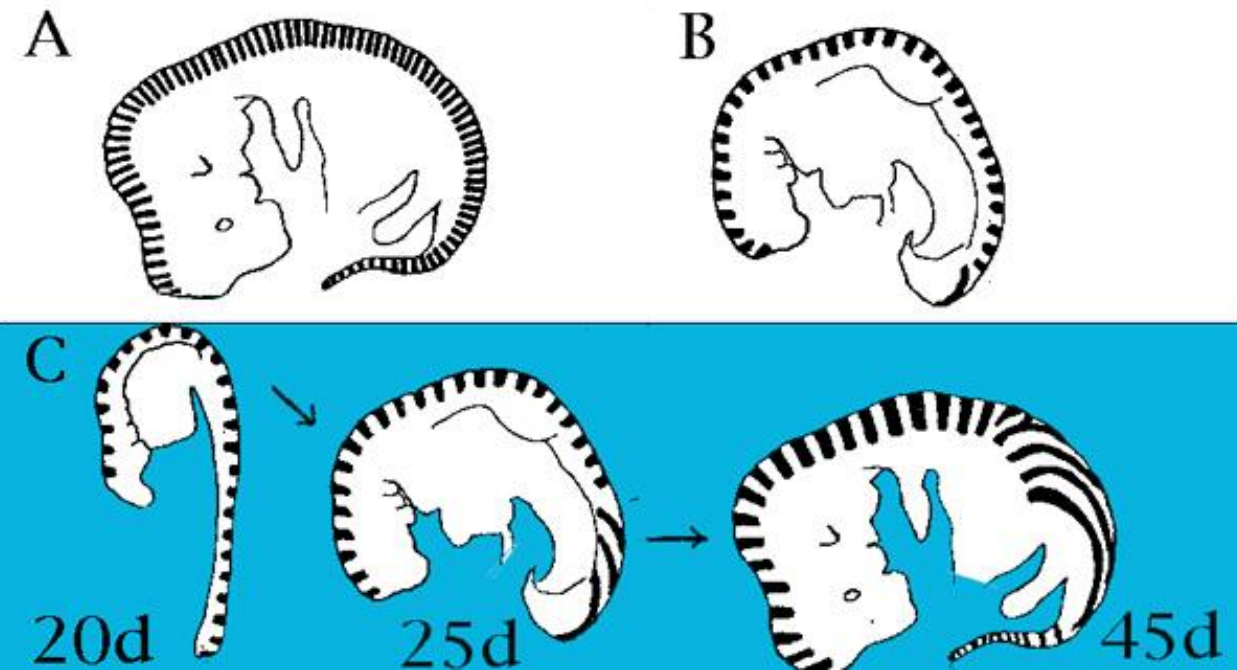
Intertidal mudflats



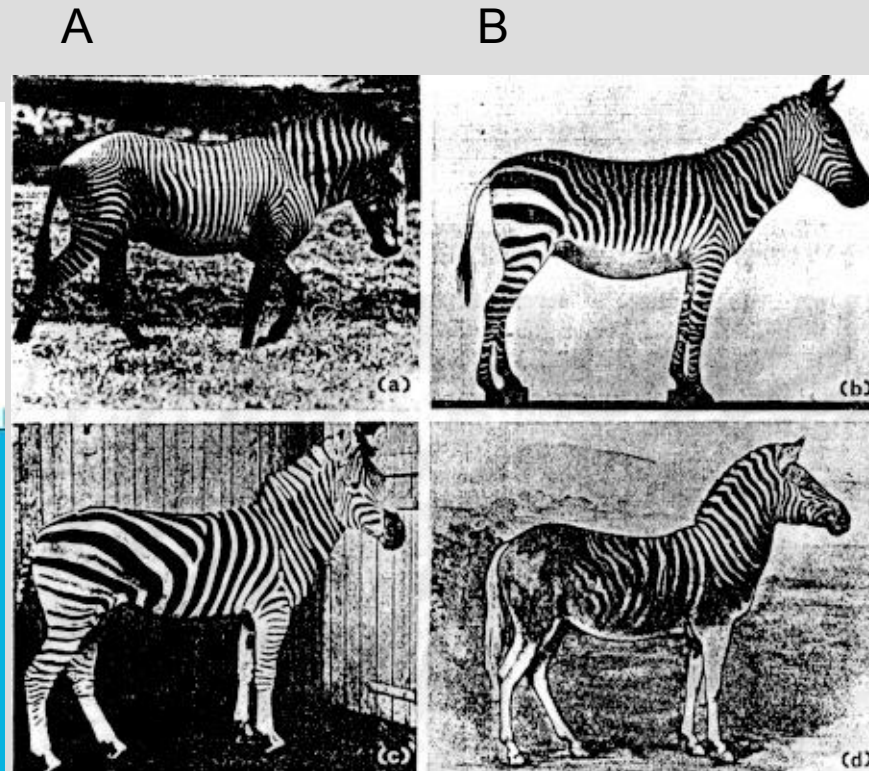
Zebras

Imperial Zebra: week 5

Mountain Zebra: week 4



Common Zebra: week 3



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

Leopard



2 days: spots



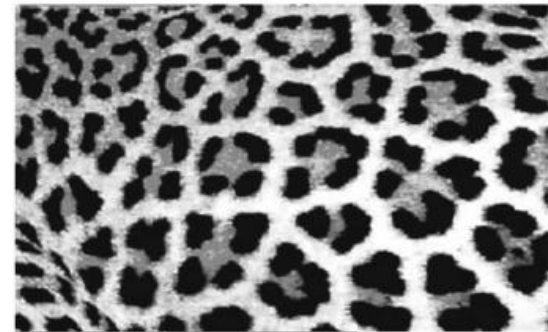
(a)

8 weeks: rings



(b)

Adult: rosettes



(c)

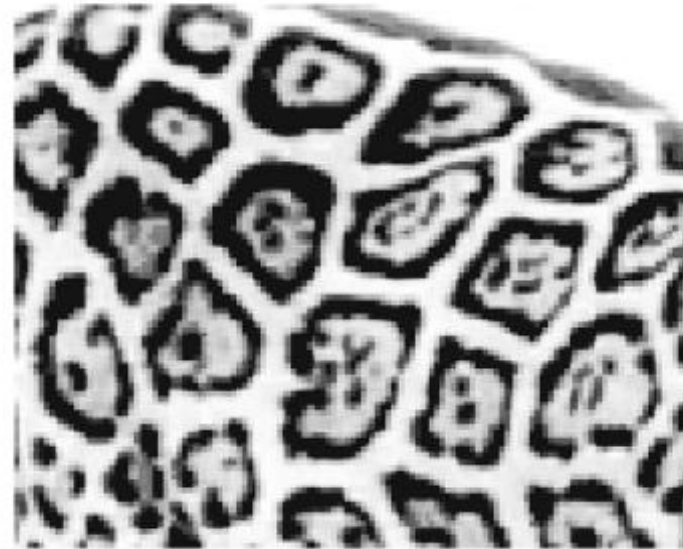
FIG. 1. Coat patterns of a leopard at different stages of growth: a) spots (2 days), (b) rings (8 weeks), (c) rosettes (adult).

Liu, Liaw, Maini 2006

Jaguar



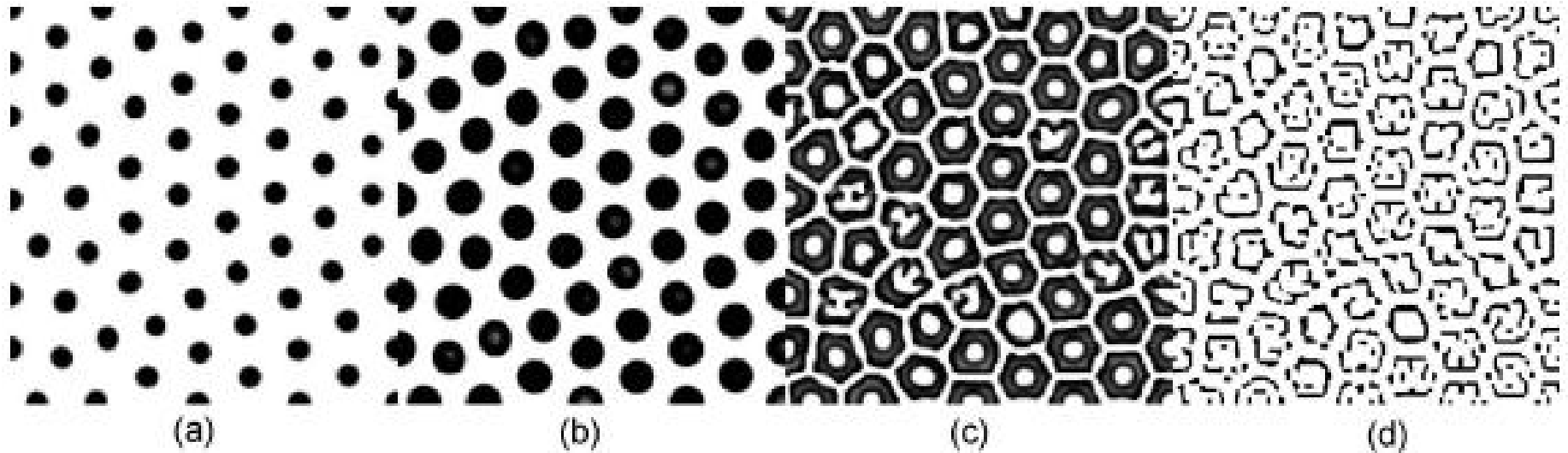
5 weeks: spots

Adult:
small spots
enclosed by
irregular
polygons3 months:
irregular
rings

(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).

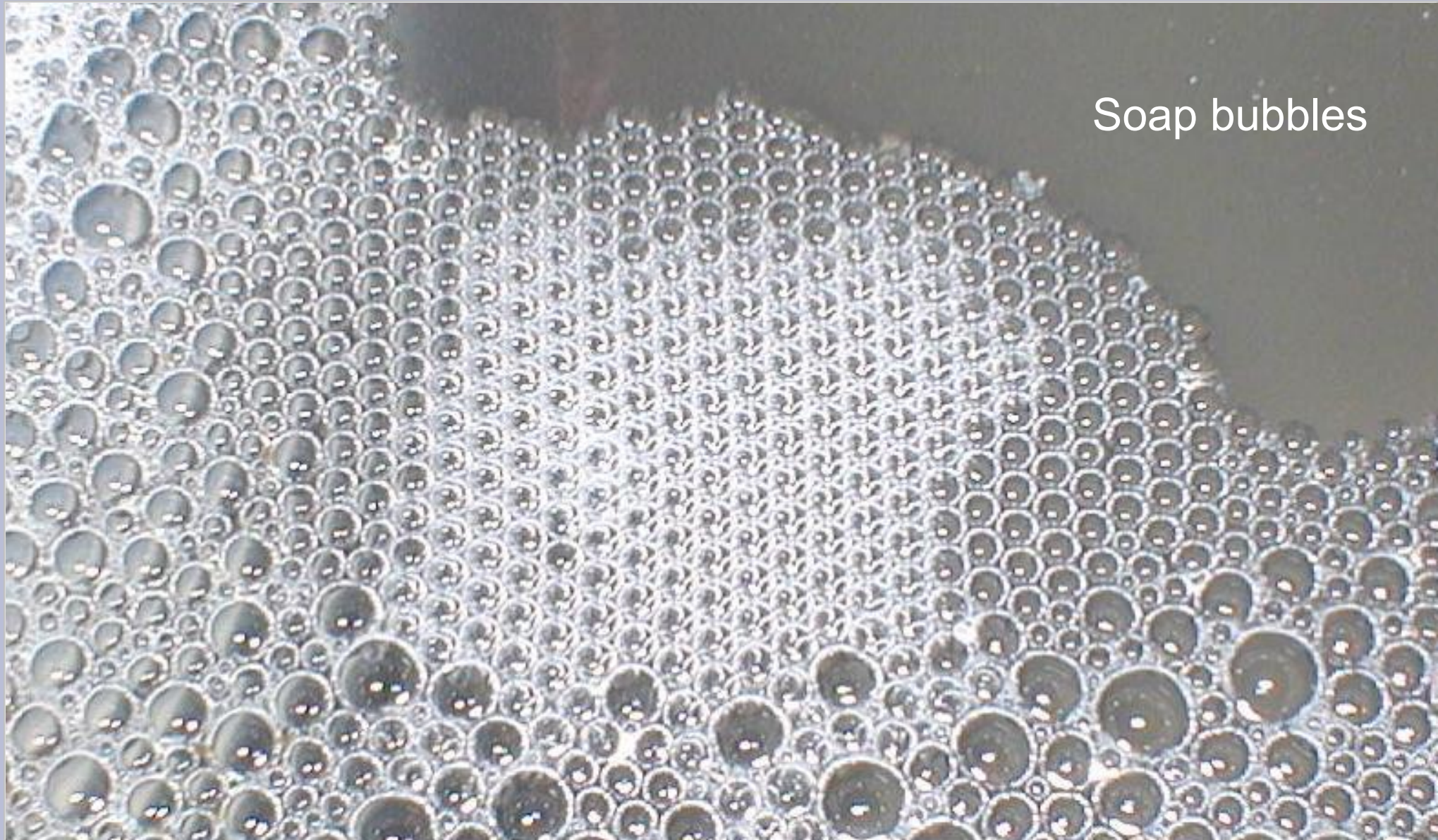
Two-stage model for the Jaguar



First Stage

Second stage
(with different parameters)

Hexagonal patterns



Soap bubbles

Rayleigh-Benard convection

Lane; Christensen 2000

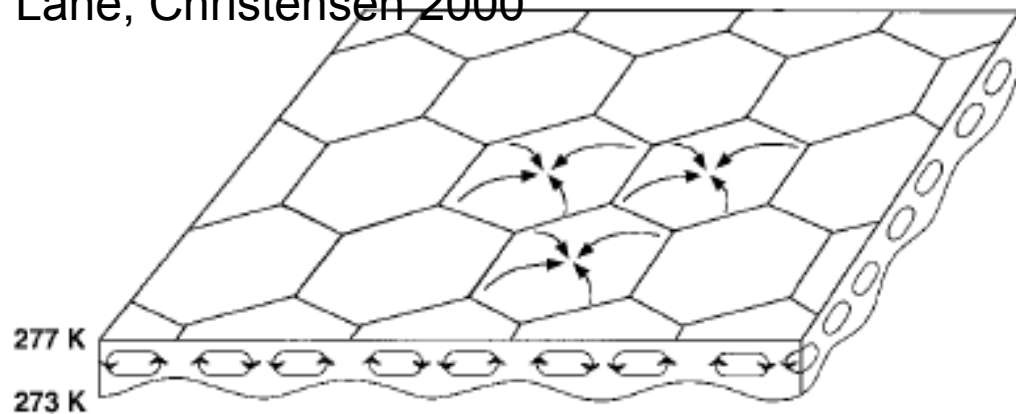
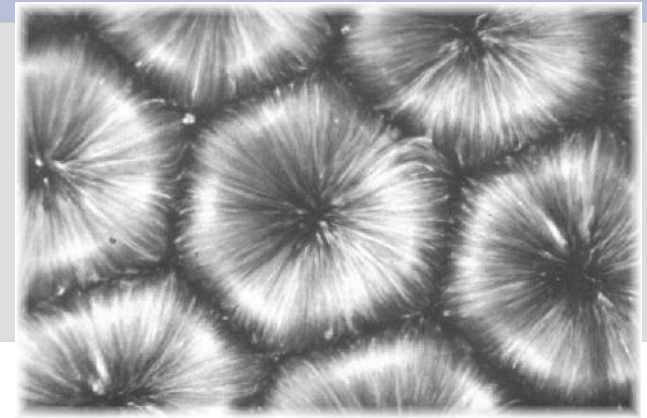
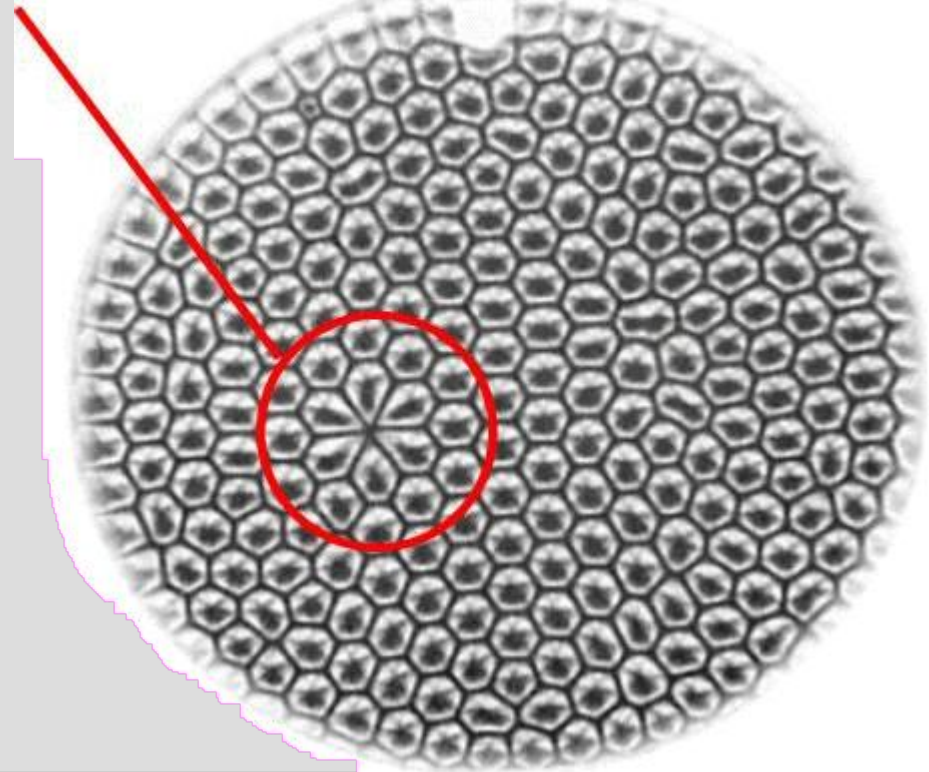
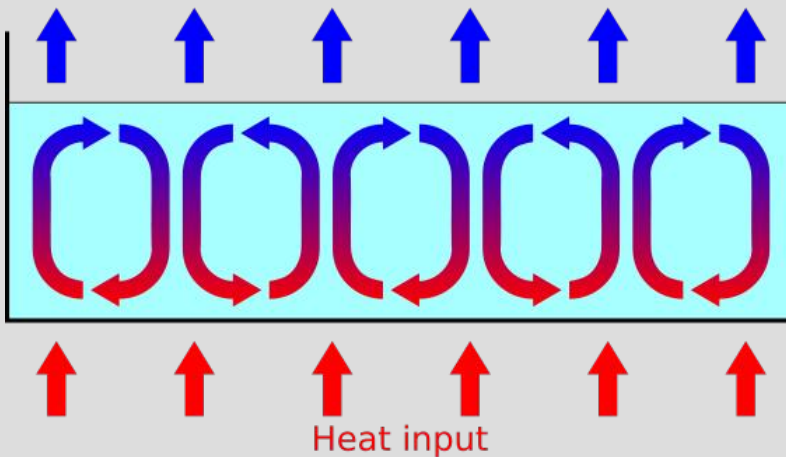
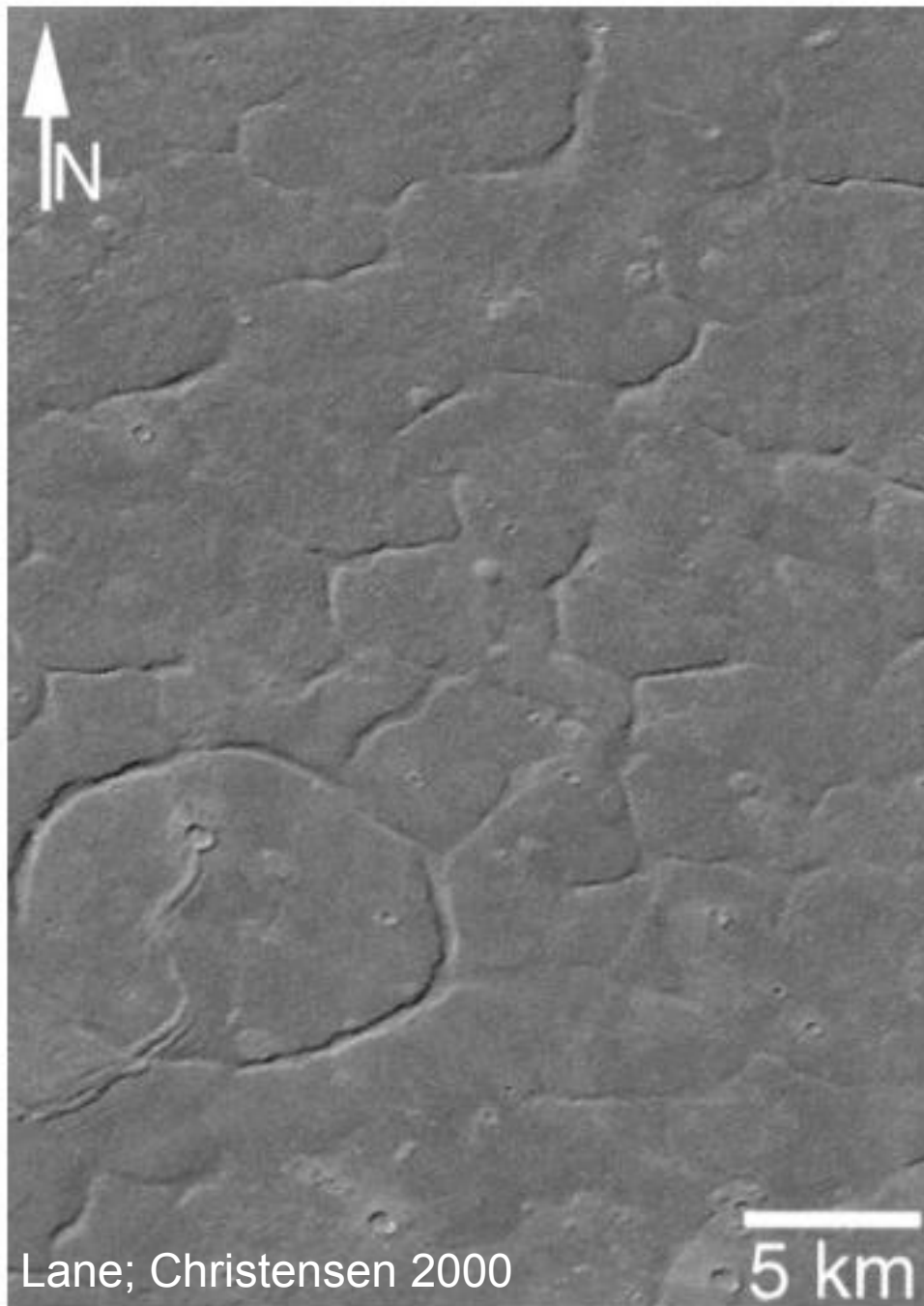


Figure 4. A schematic three-dimensional section of hexagonal Rayleigh convection cells in an active layer.



Fluid cools by losing heat through the surface





Lane; Christensen 2000

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.

Polygons on Mars



UFO CARTOON

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

Martian Polygons

LANE AND CHRISTENSEN: CONVECTION ORIGIN FOR MARTIAN POLYGONS

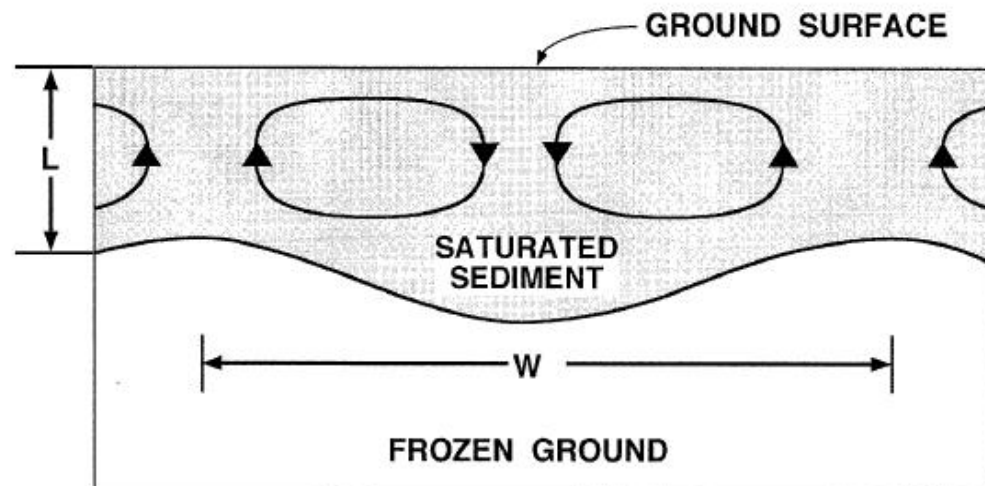
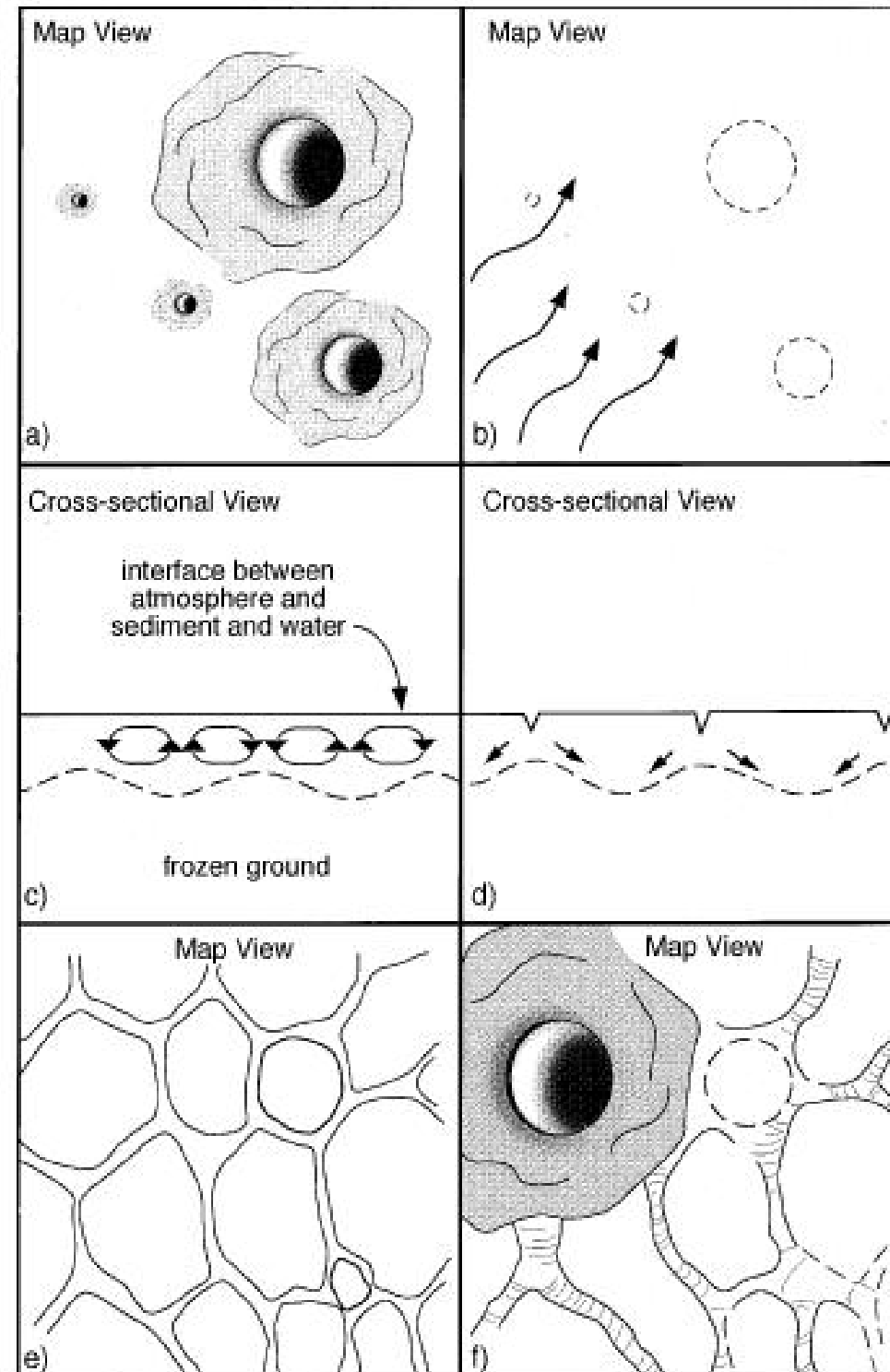


Figure 2. A schematic two-dimensional section of Rayleigh convection cells in an active layer [after Ray 1981]. For the case of circulation within a body of standing water, the saturated sediment layer would be thinner and the "ground surface" label would represent the water/atmosphere interface.



Patterns in permafrost

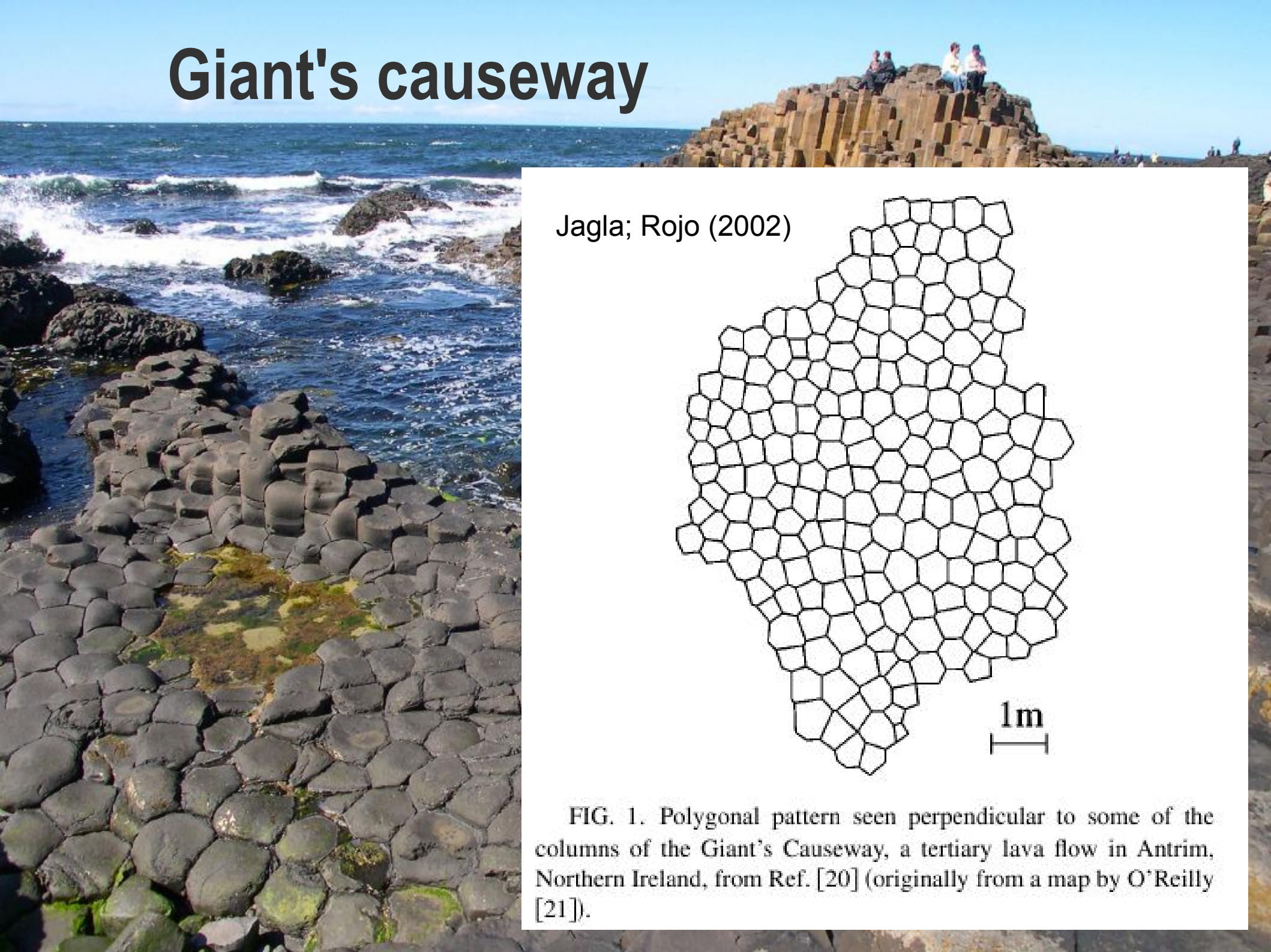




Columnar jointing



Giant's causeway



Jagla; Rojo (2002)

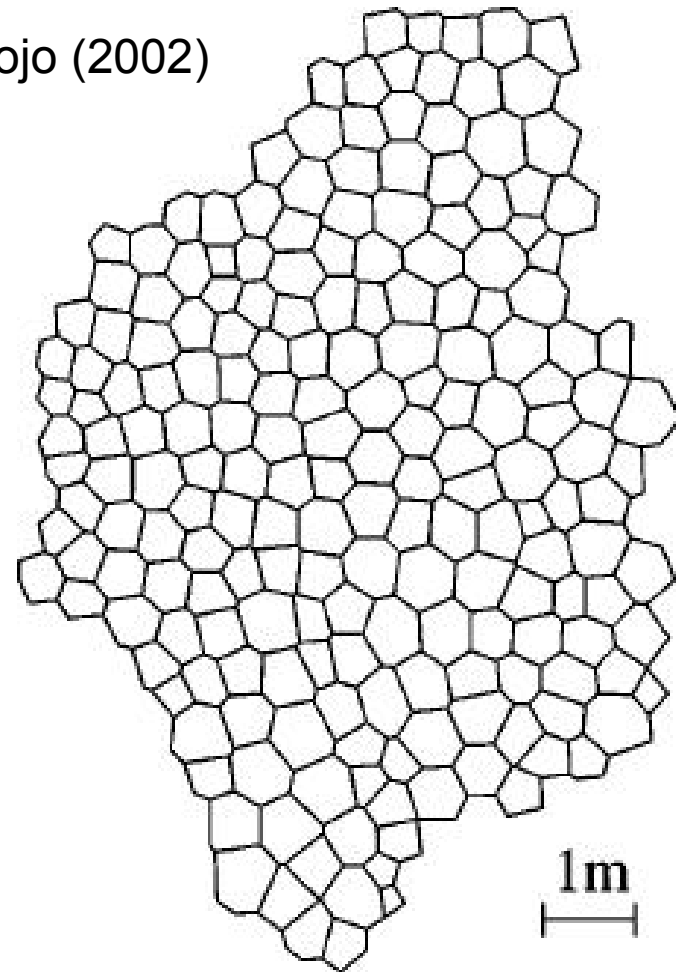
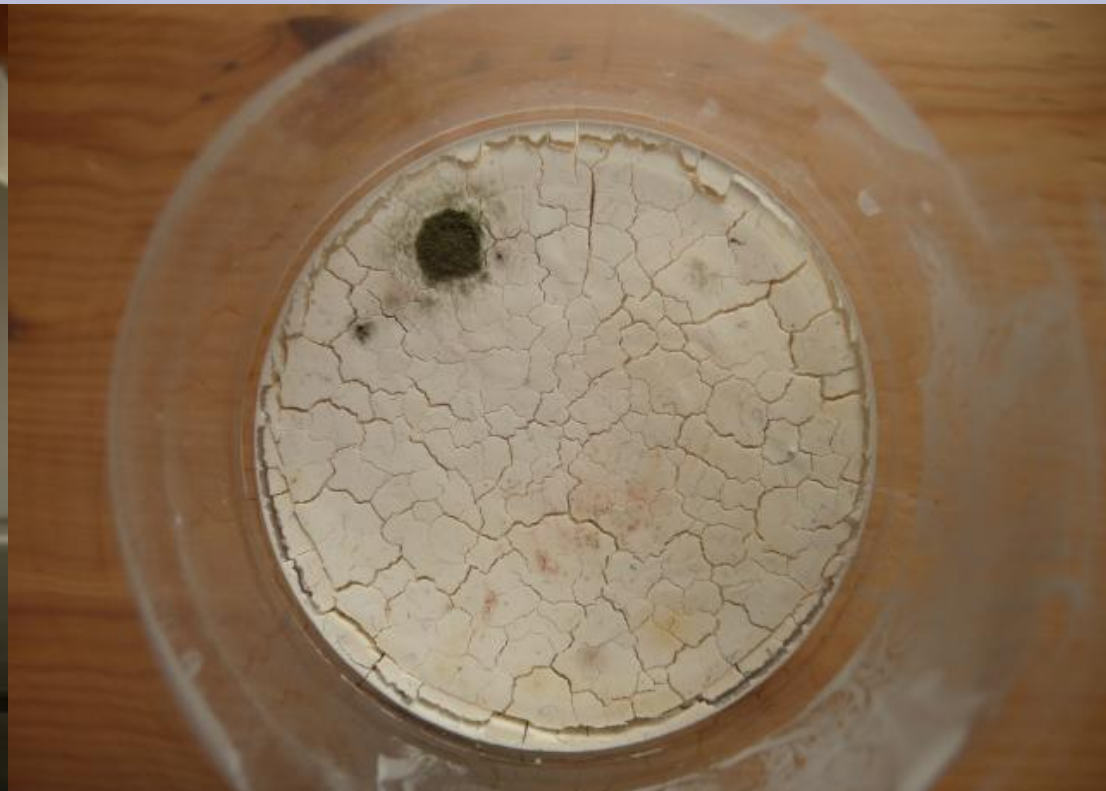


FIG. 1. Polygonal pattern seen perpendicular to some of the columns of the Giant's Causeway, a tertiary lava flow in Antrim, Northern Ireland, from Ref. [20] (originally from a map by O'Reilly [21]).

Create your own Giant's Causeway

- Mix cornflour with equal volume of water; add some bleach (to stop the mould)
- Not part of the experiment, but great fun: Mess around with it, try to stir it quickly and slowly, drop objects in it.
- Fill into a plastic cup, at least 3-4 cm deep
- Leave open in a warm, dry place until the stuff is completely dry (1-2 weeks)
- Look at the cracks on the surface
- Cut off the plastic cup, break the starch and see the columnar jointing

When we did the experiment...

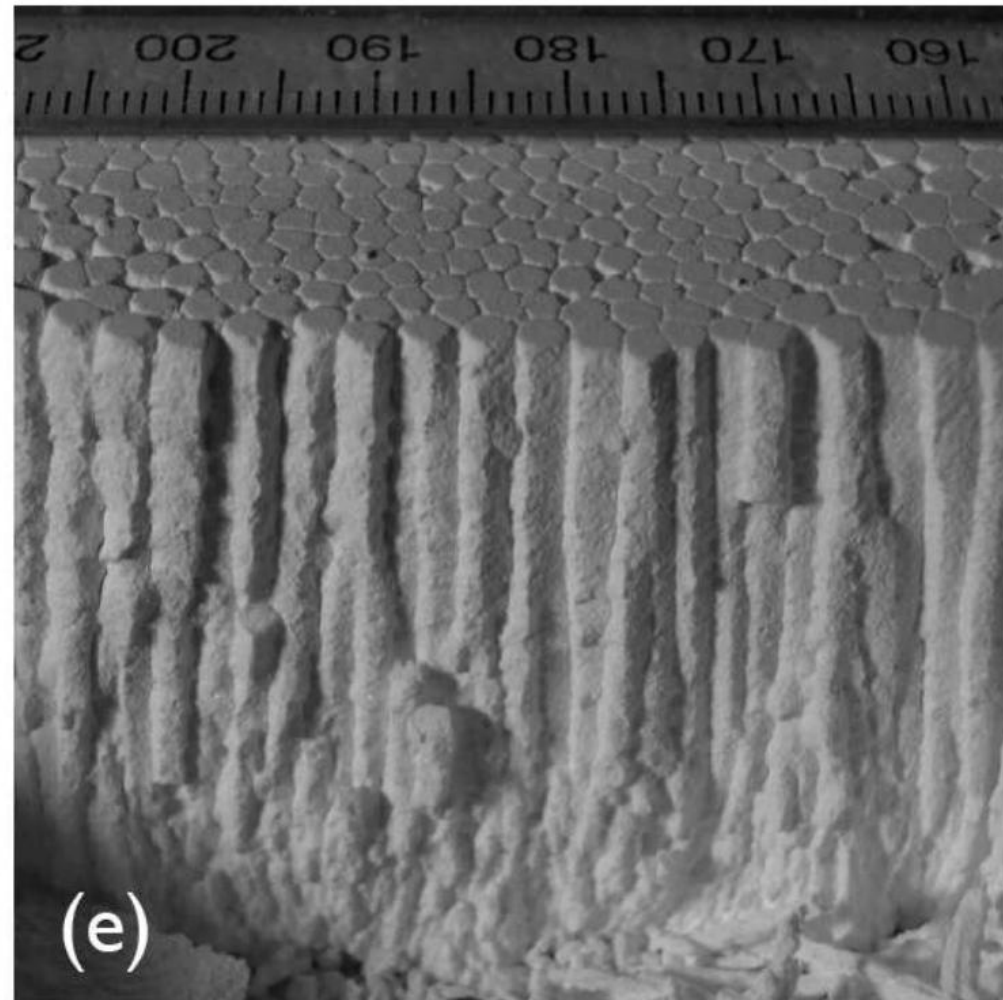
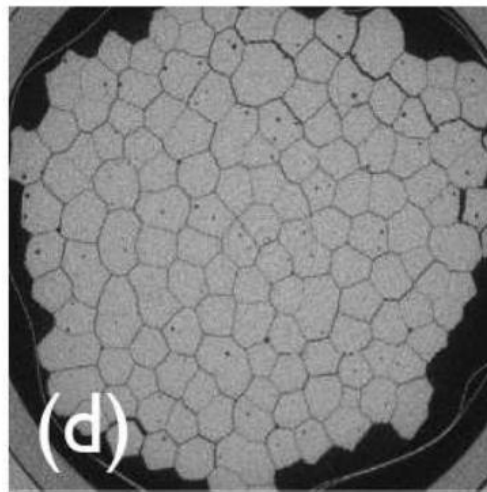
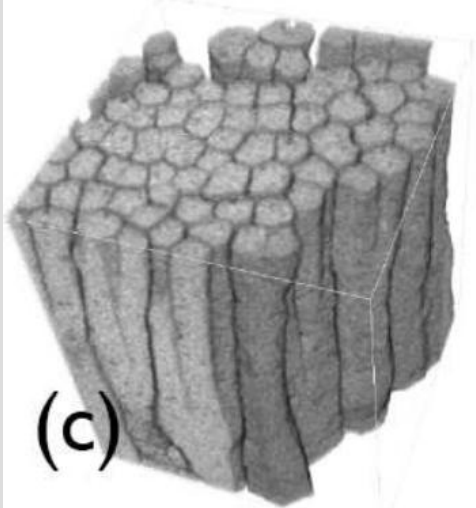
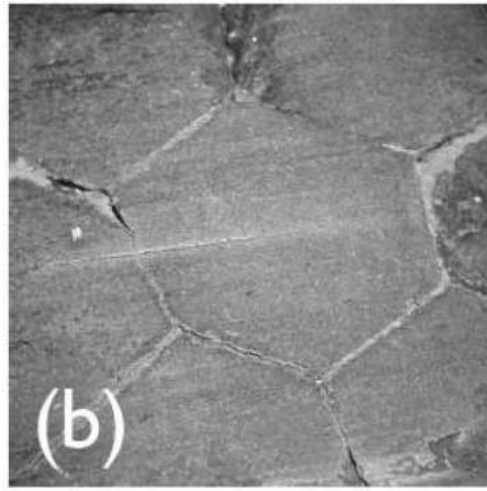
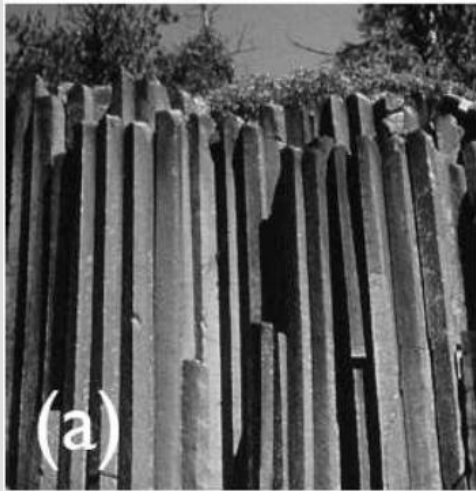
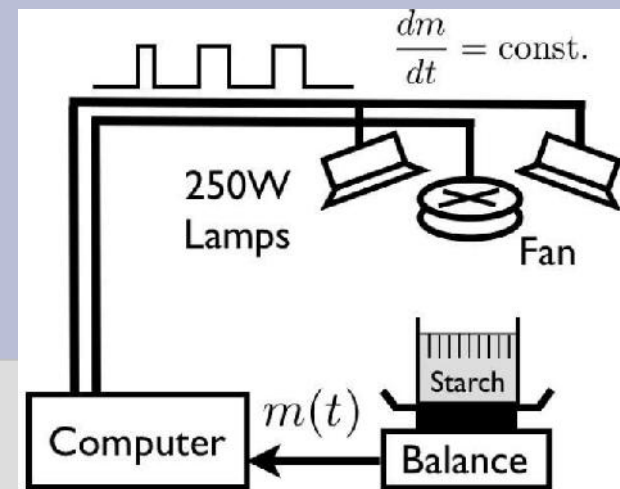


When we did the experiment...



An experiment with cornstarch

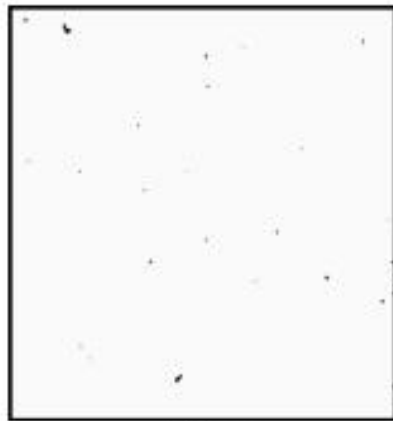
Goehring (2003); Goehring, Morris, Lin (2006)



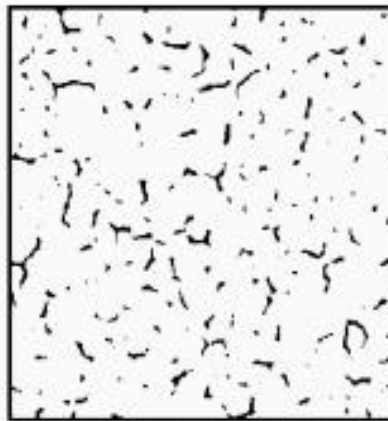
Maturation of crack patterns

MATURATION OF CRACK PATTERNS

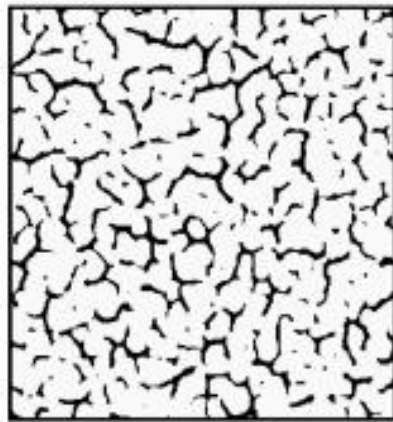
PHYSICAL REVIEW E **69**, 056212 (2004)



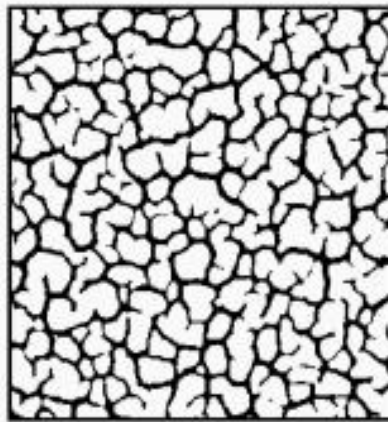
$t=1 \tau$



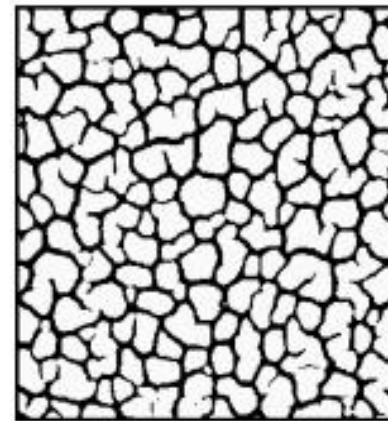
$t=1.25 \tau$



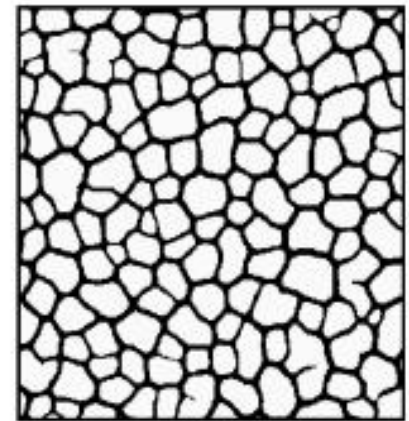
$t=1.5 \tau$



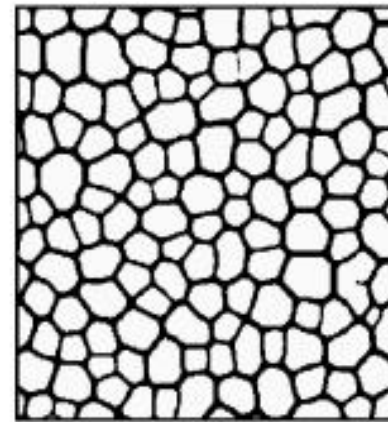
$t=2 \tau$



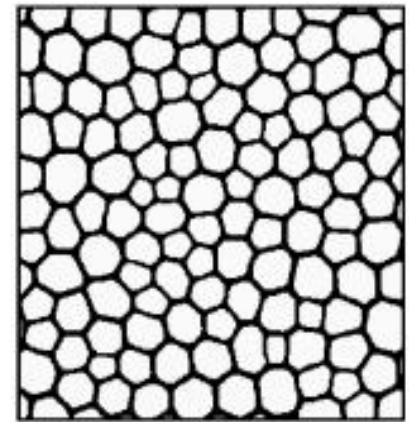
$t=5 \tau$



$t=10 \tau$



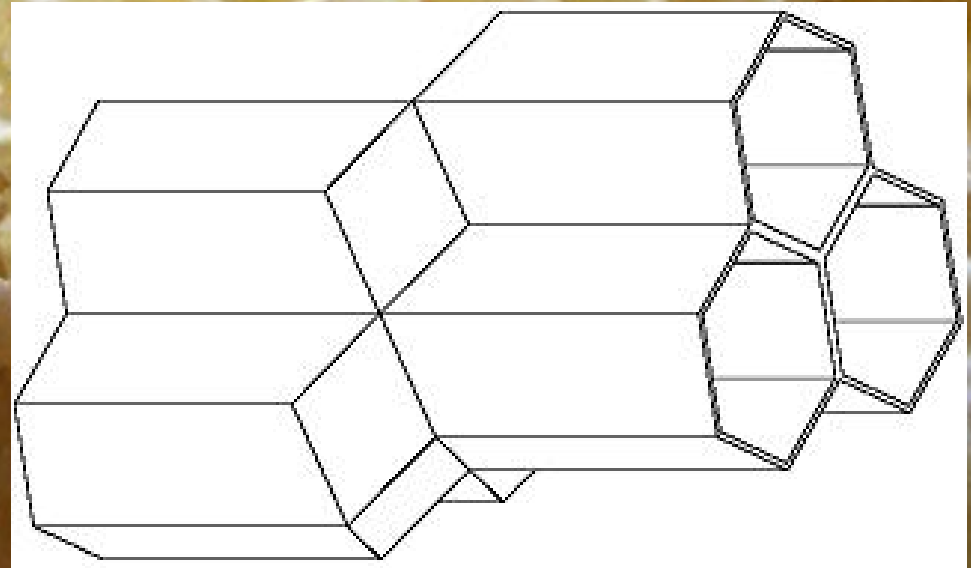
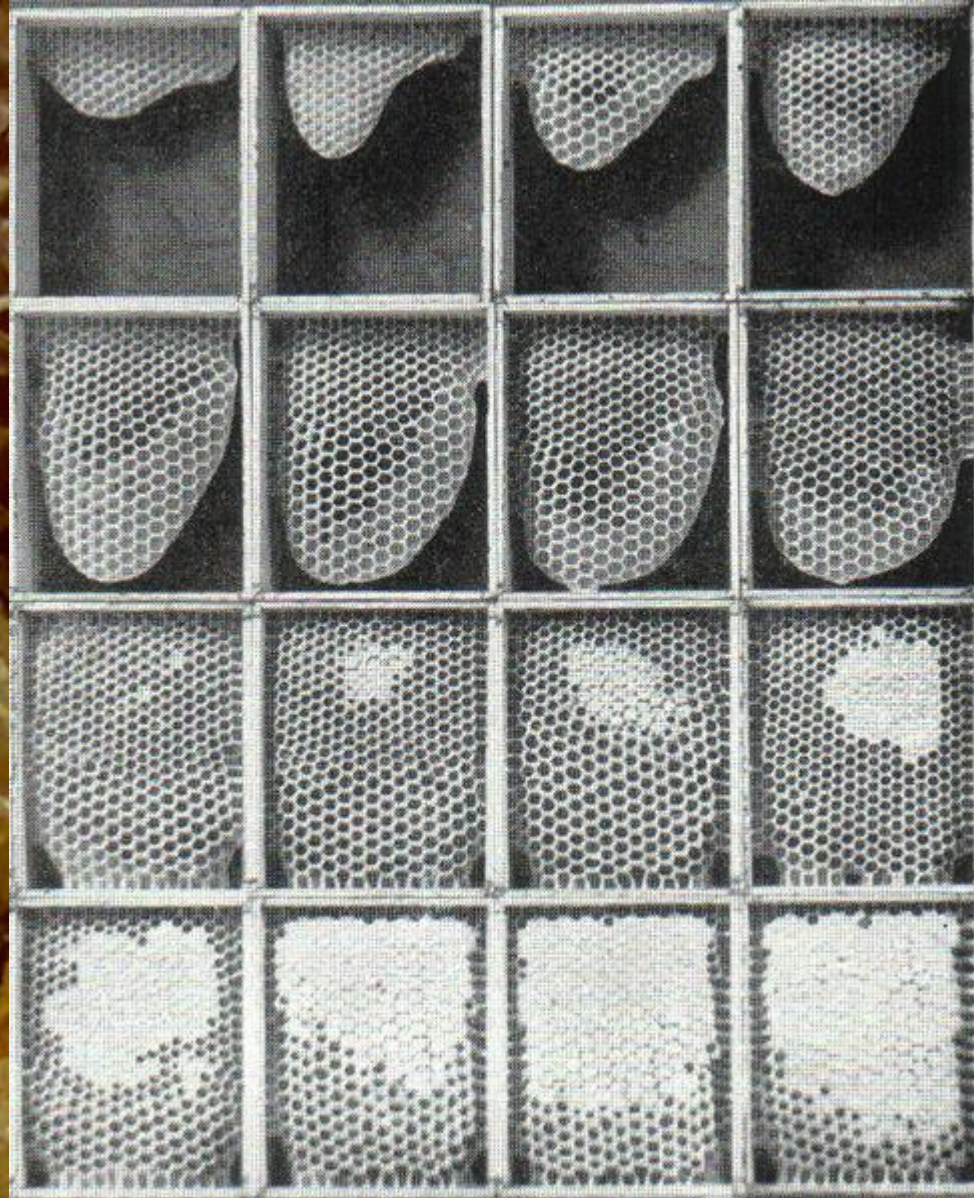
$t=20 \tau$



$t=280 \tau$



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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