Complex Systems

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Complex systems:

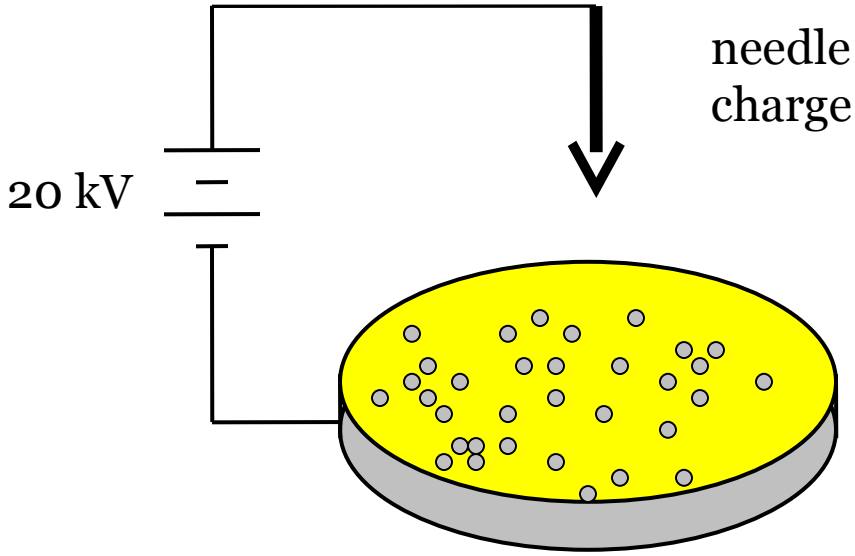
A system with a large throughput of

- a fluid = turbulence, river networks
- chemicals = flames & explosion
- tension = fracture
- electrical current = lightning, dielectric breakthrough
- information = internet, social networks

The throughput is large means “sudden appearance of a pattern or dynamics (self-organization)”

This self-organization causes emergent properties.

Example of Emergence: Experimental Study of Structural Changes in Materials due to High-voltage Currents



needle electrode sprays charge over oil surface

air gap between needle electrode and oil surface approx. 5 cm

ring electrode forms boundary of dish

has a radius of 12 cm

particles are non-magnetic stainless steel, diameter D=1.6 mm

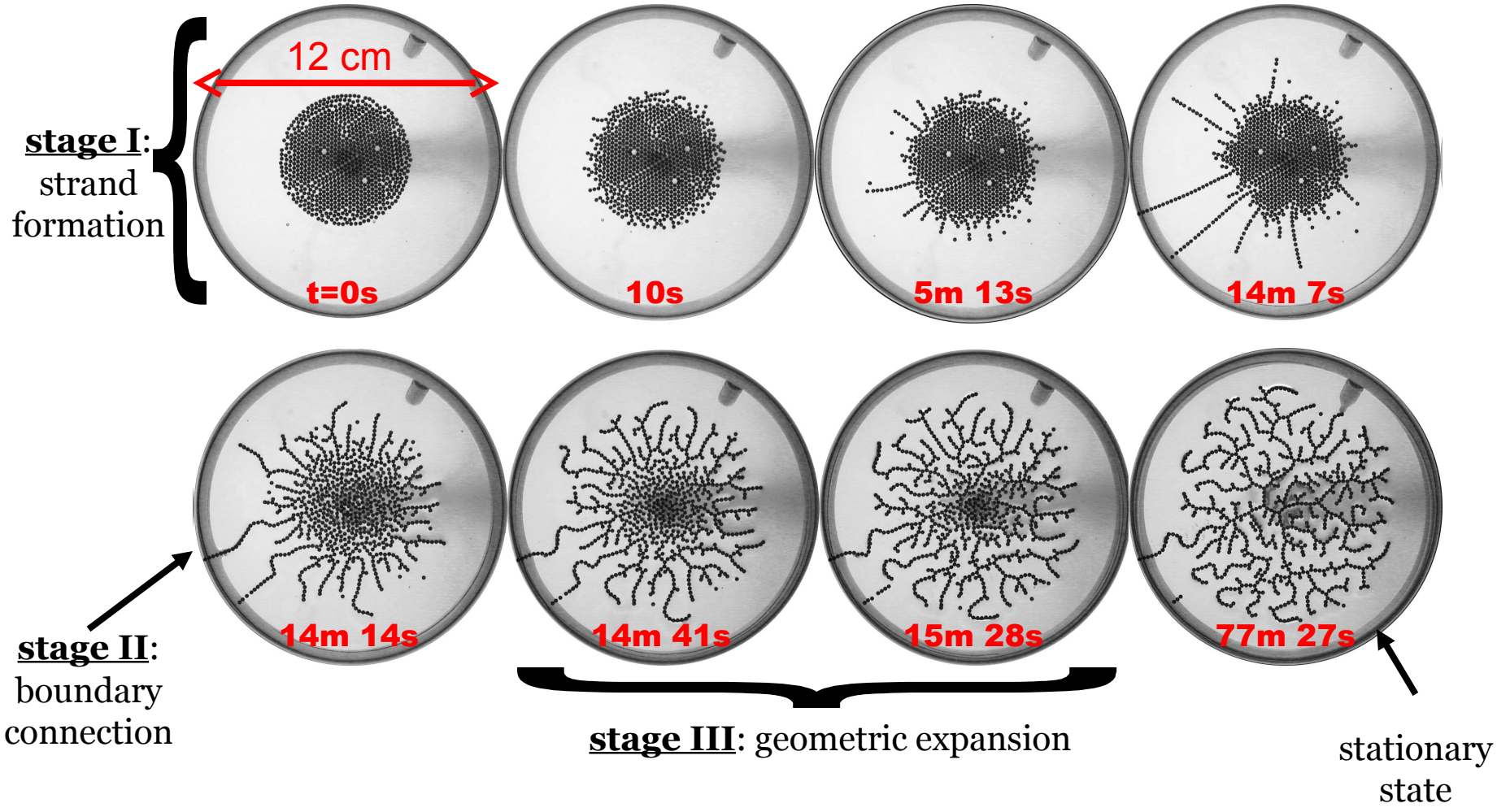
particles sit on the bottom of the dish

oil height is approximately 3 mm, enough to cover the particles

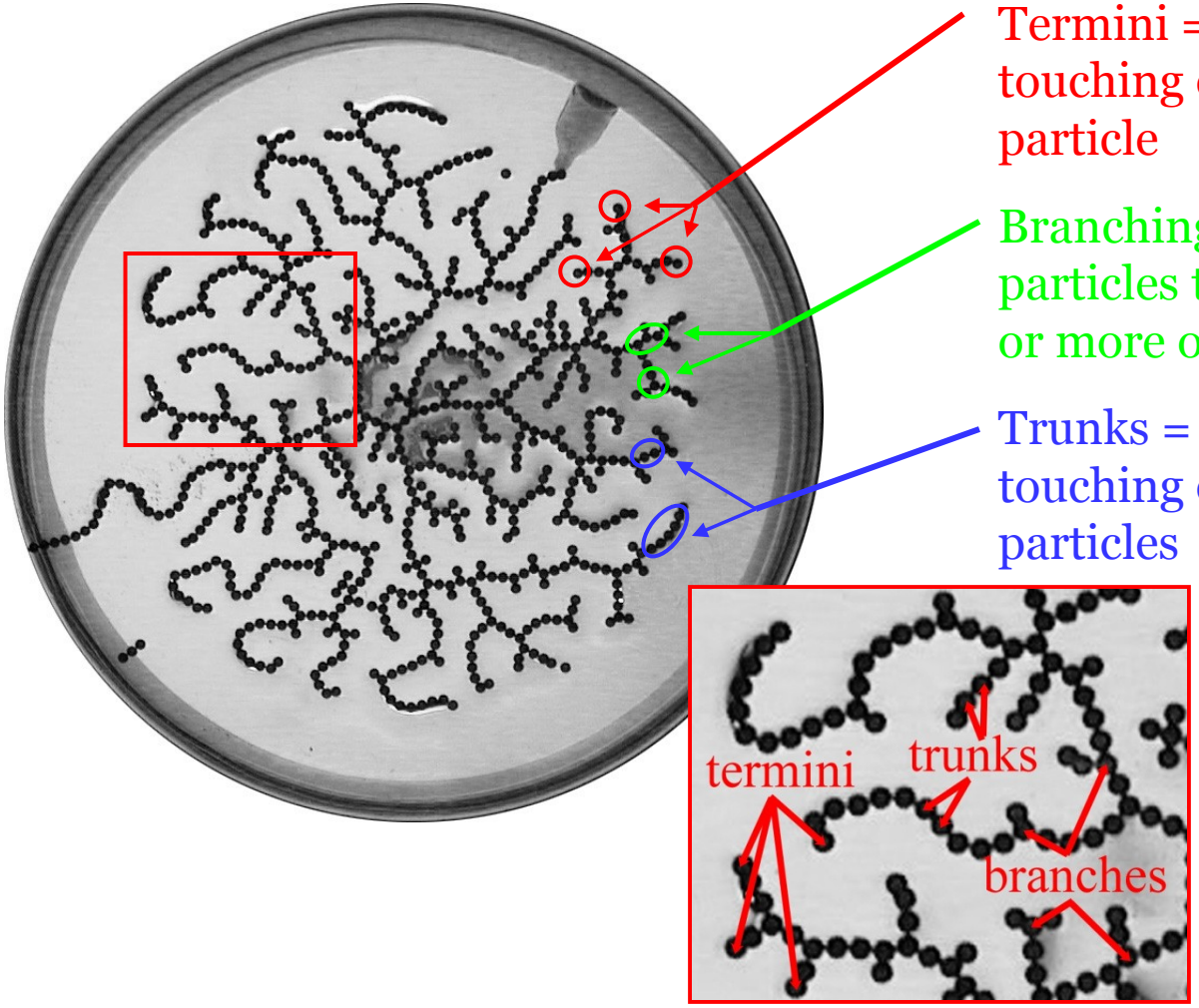
castor oil is used: high viscosity, low ohmic heating, biodegradable

J. Jun, A. Hubler, PNAS **102**, 536 (2005)

Self-organization

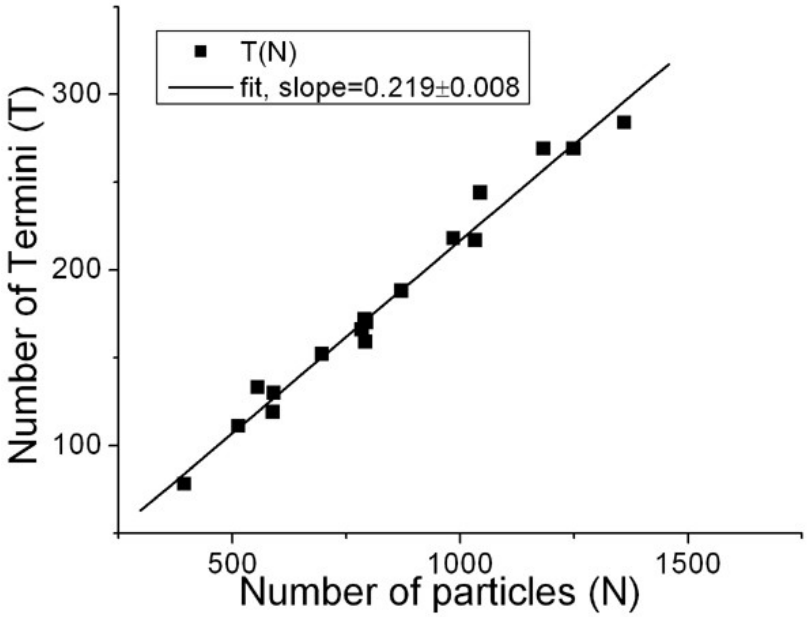


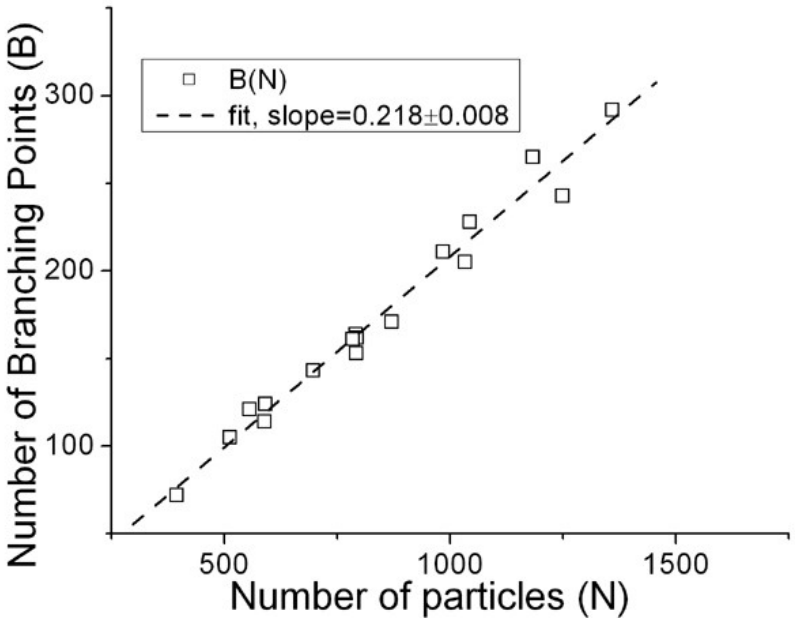
Emergent properties: Adjacency defines topological species



Particles become termini or three-fold branch points in stage III. In addition there are a few loners (less than 1%). Loners are not connected to any other particle. There are no closed loops in stage III.

Emergent property: Relative number of each species is robust





Graphs show how the number of termini, T, and branching points, B, scale with the total number of particles in the tree.

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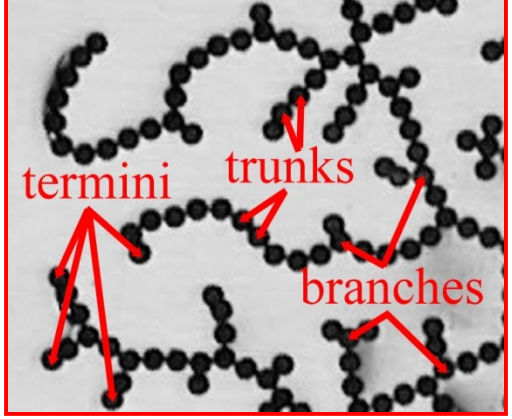
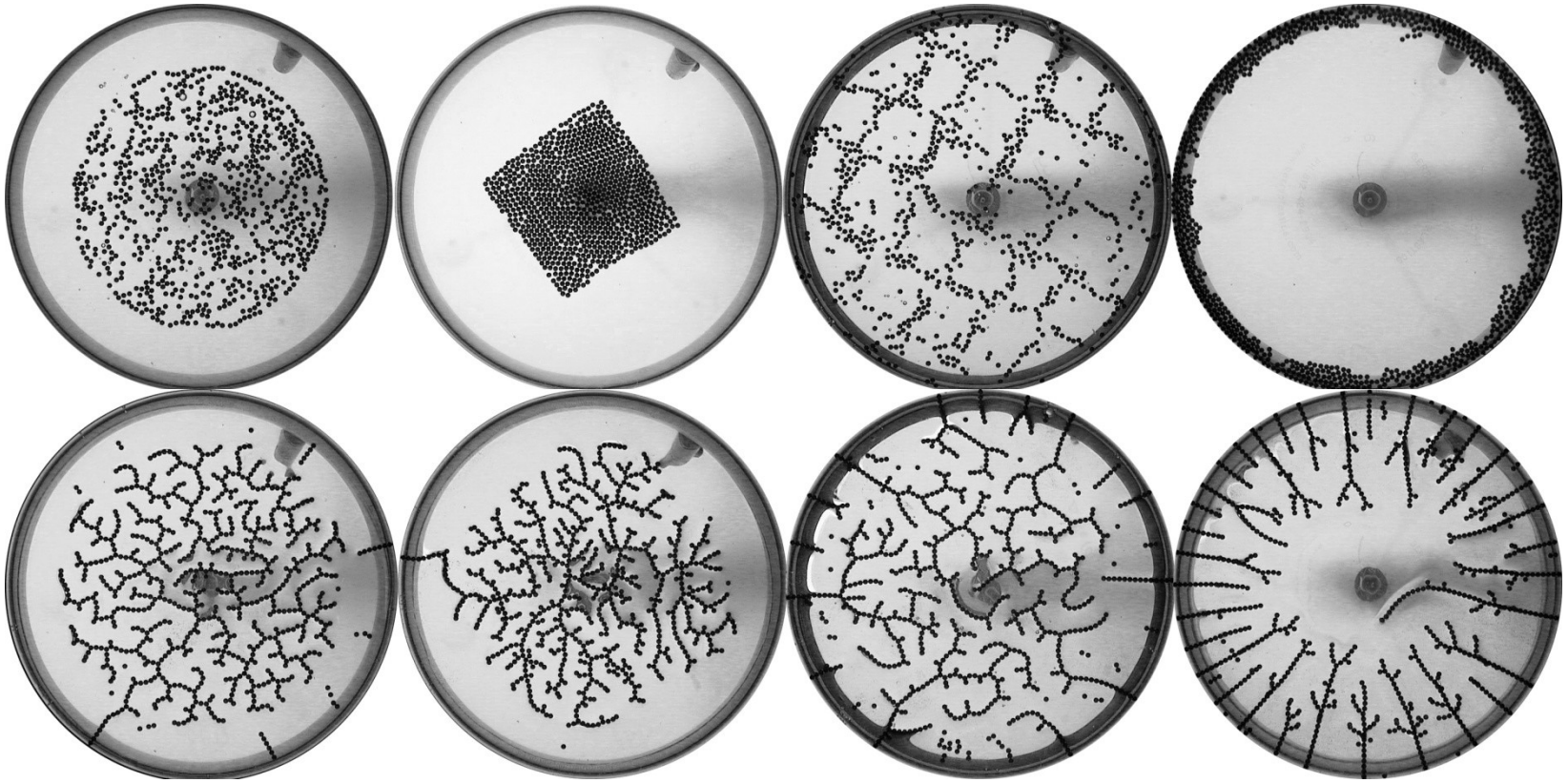


Emergence (Y. Bar-Yam):

- substructure (stem, branch, sub-branch, …)
- the relationship of component to collective behavior (termini, branching points, trunks)
- the relationship of internal behavior to external influence (minimum resistance, open loop, dimension, minimum spanning tree predictor)
- multiscale structure and dynamics (fractal dimension = 1.67)

The number of trees is not an emergent property



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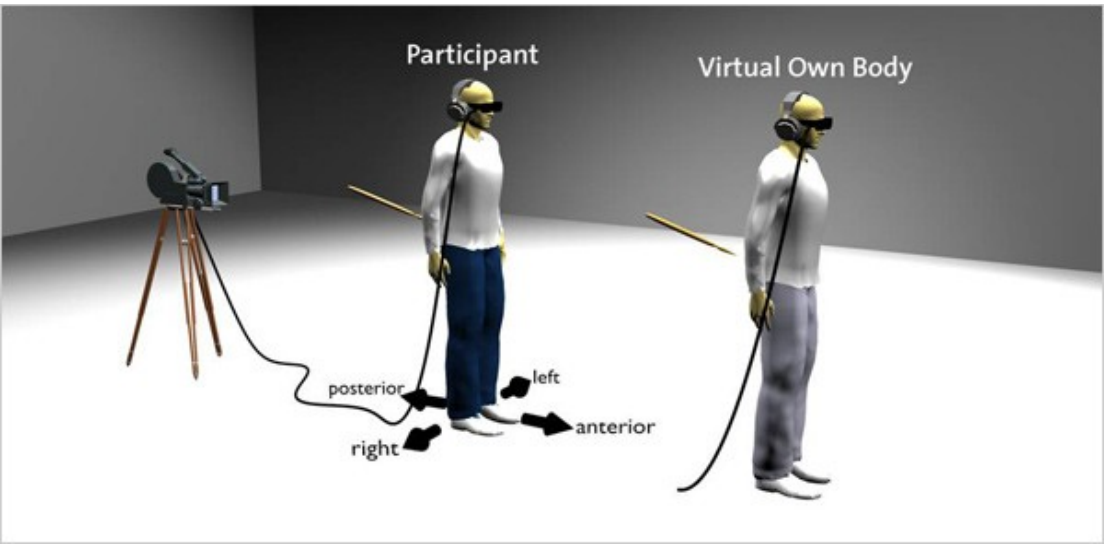
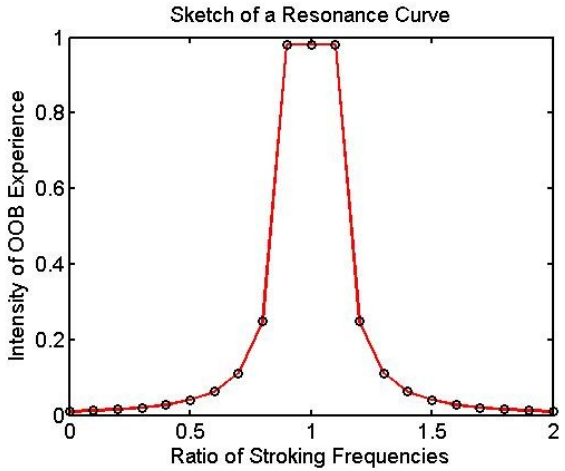
Emergence: Out-of-body experiences with video feedback



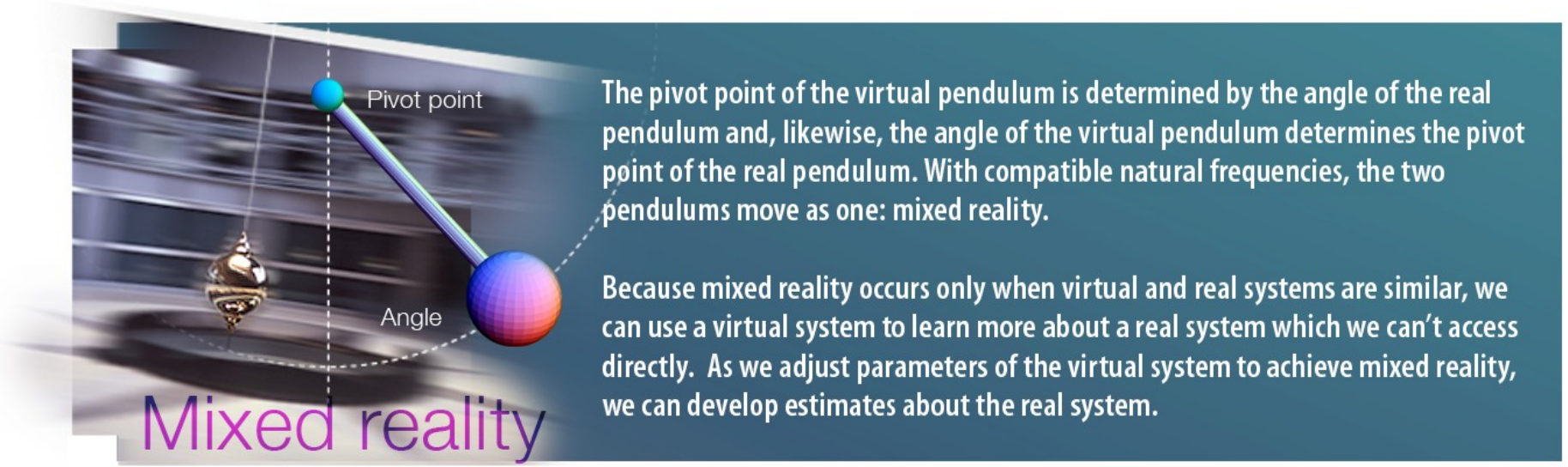


- Subject sees video image of itself with 3D goggles
- Two sticks, one strokes person's chest for two minutes, second stick moves just under the camera lenses, as if it were touching the virtual body.
- Synchronous stroking => people reported the sense of being outside their own bodies, looking at themselves from a distance where the camera is located.
- While people were experiencing the illusion, the experimenter pretended to smash the virtual body by waving a hammer just below the cameras. Immediately, the subjects registered a threat response as measured by sensors on their skin. They sweated and their pulses raced.

Real system & similar virtual system & bi-directional instant. coupling = mixed reality

Blanke O et al.Linking OBEs and self processing to mental own body imagery at the temporo-parietal junction. J Neurosci 25:550-55 (2006).

Emergence: Experimental evidence for mixed reality states in physical systems



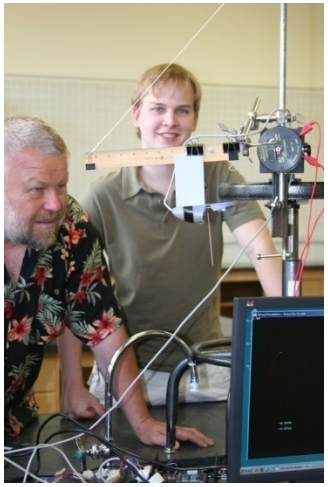
Objective: Understand synchronization between virtual and real systems.

Approach:

- Couple a real dynamical system to its virtual counterpart with an instantaneous bi-direction coupling (so far: non-linear pendulum, future: network).

- Measure an order parameter of the real and the virtual systems and then detect synchronization.

Emergence:Mixed reality states in physical systems, why are they important?



- Virtual systems match their real counter parts with ever-increasing accuracy, such as graph theoretical network predictors.

- New hardware for instantaneous bi-directional coupling, such as video feedback.

- In mixed reality states there is no clear boundary between the real and the virtual system. Mixed reality states can be used to analyze and control real systems with high precision. And then there is the possibility for time travel ... by the virtual system.

Publication: The paper "Experimental evidence for mixed reality states in an inter-reality system" by Vadas Gintautas and Alfred Hubler, in Phys. Rev. E 75, 057201 (2007),

was selected for the APS tip sheet:
http://www.aps.org/about/tipsheets/tip68.cfm

Photo: A. Hubler and V. Gintautas at the inter-reality system