


2016

Patterns Around Us Presentation

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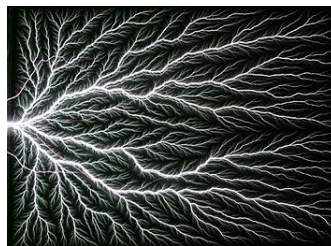
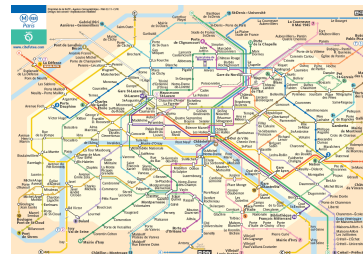
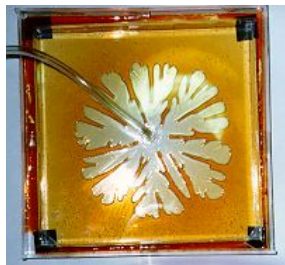
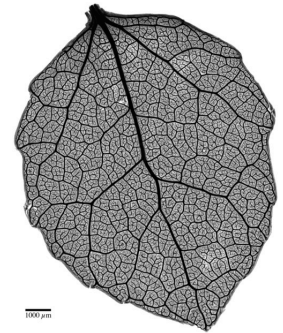
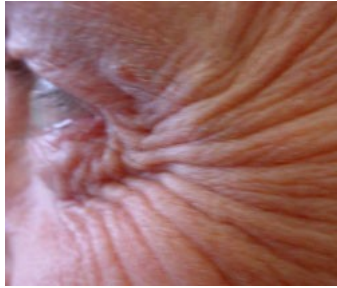
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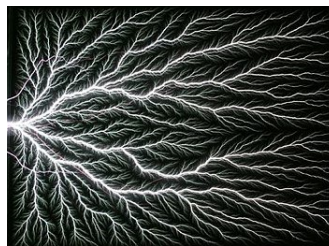
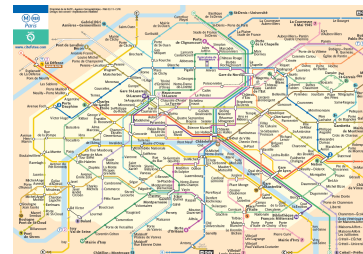
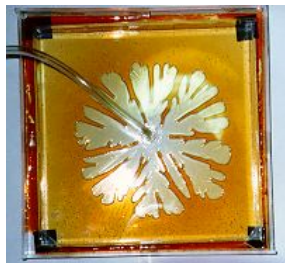
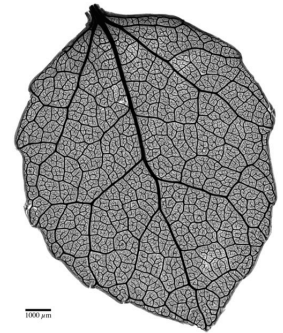
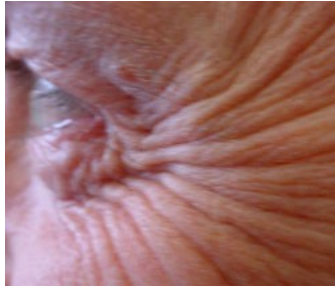
Patterns around us

2-day workshop,
June 2016



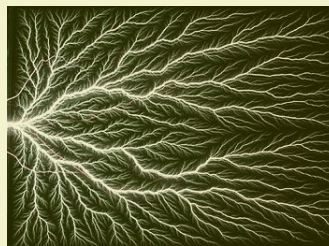
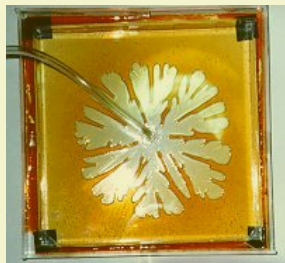
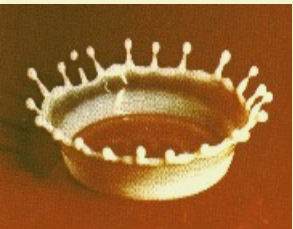
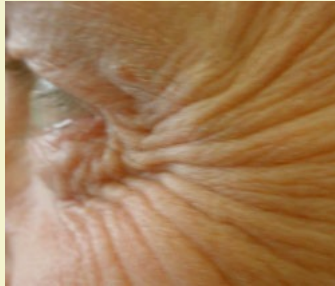
What is a “pattern”?

- Basic structure repeated many times
- One characteristic length (or a few, or many ..)

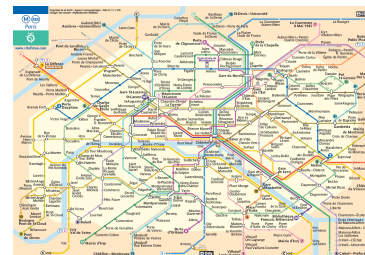


Types of patterns

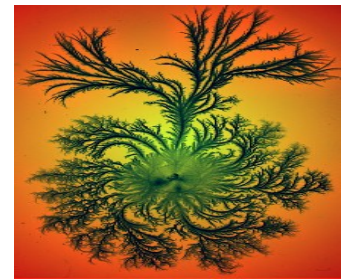
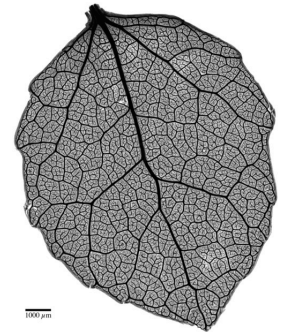
Spontaneous



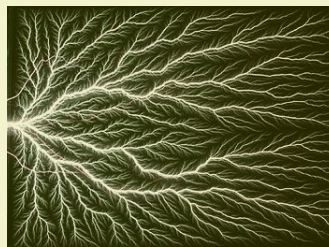
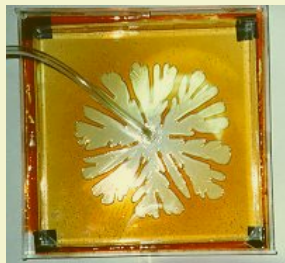
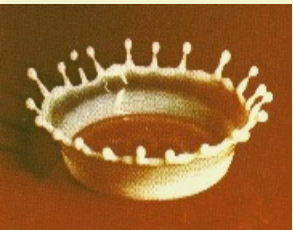
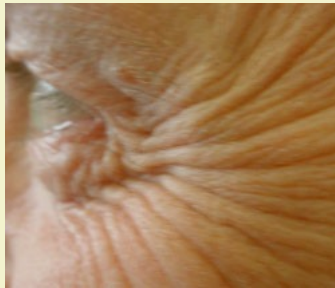
Engineered



Hybrid



Spontaneous



Reflect **competition** of
2-3 elementary forces

Described by simple models

An indirect probe of various
system parameters

Outline

- Why do we study patterns
- Pattern formation theory in a nutshell
- A glimpse at some work at UMass Amherst

Outline

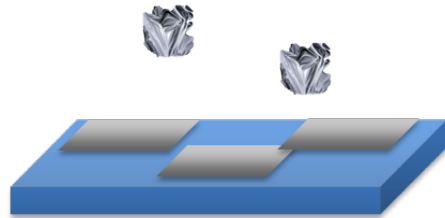
- **Why do we study patterns**
- Pattern formation theory in a nutshell
- A glimpse at some work at UMass Amherst

The taxpayer perspective



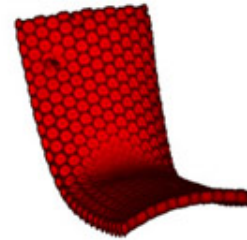
NSF-MRSEC

*Surface instabilities
In polymers*



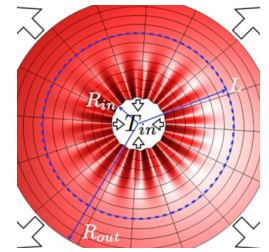
W.M. Keck Foundation

Unfurling of ultrathin sheets



NSF-DMR

*Origami-inspired
material design*



NSF-DMR

*Morphologies of
tensed sheets*

Goal I: Creating “good” patterns

e.g. cheap patterning of surfaces at nano-scale

Goal II: Eliminating “bad” patterns

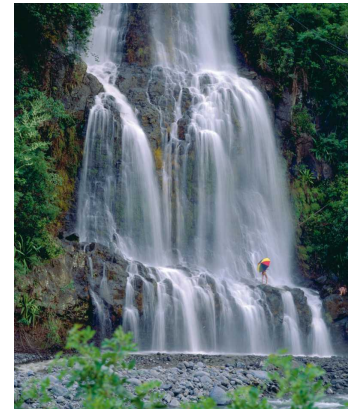
e.g. wrinkles and scars on skin, cracks in materials

The physicist's perspective



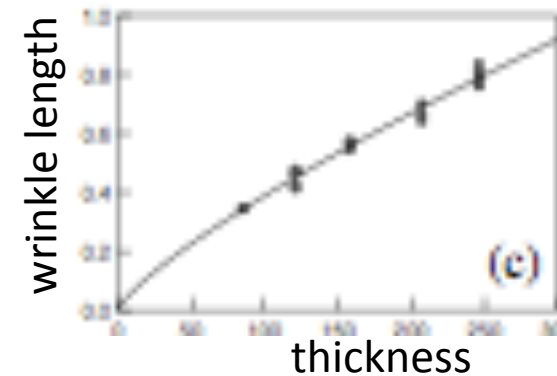
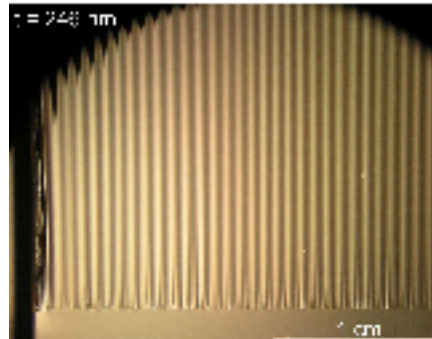
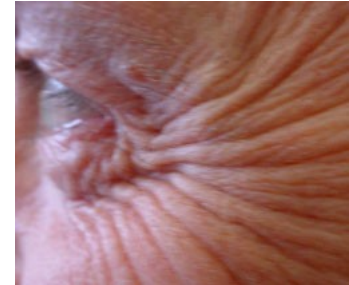
Exploring **universal** mechanisms in nature:

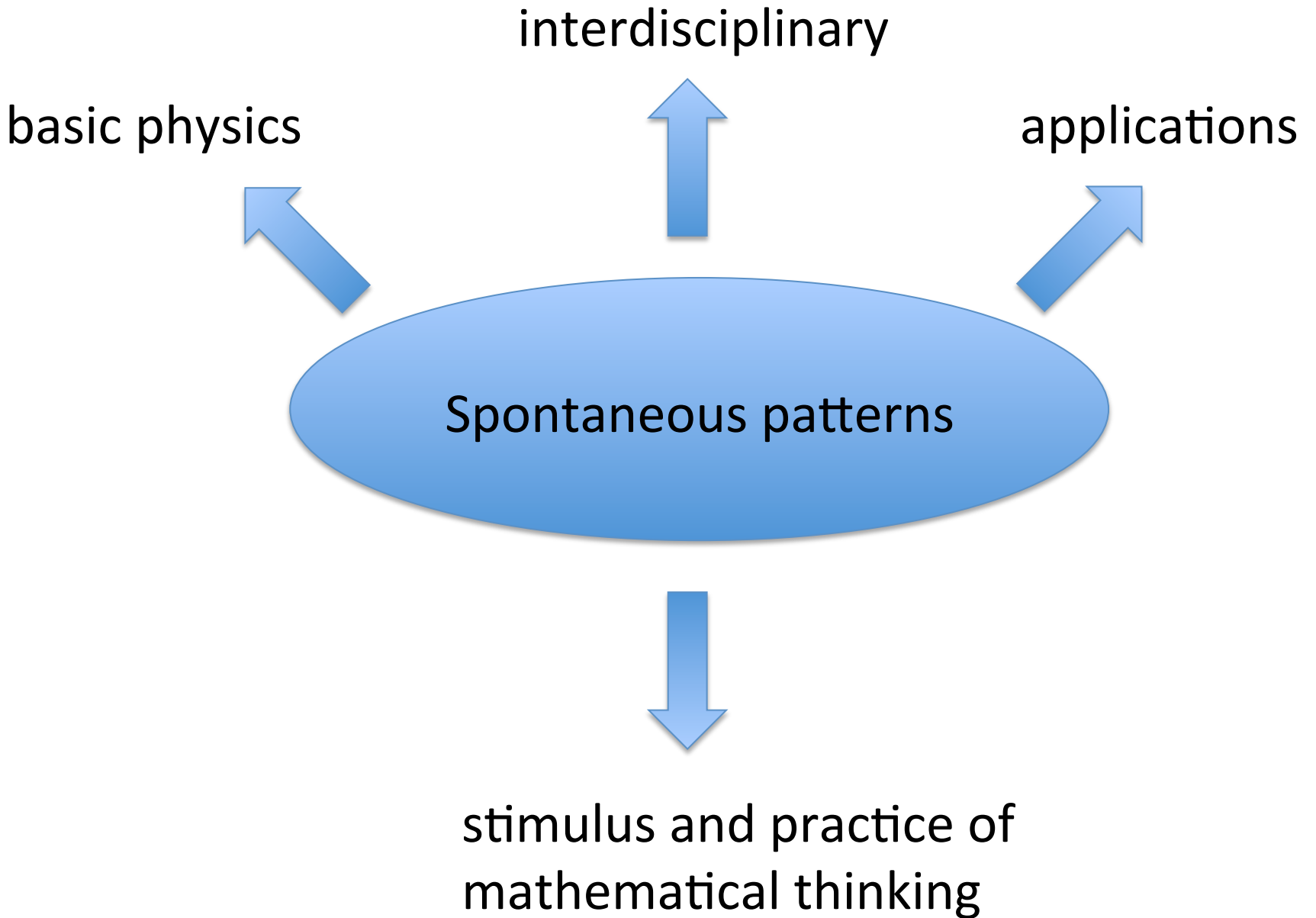
- across different scales
- across distinct physical systems



The student perspective

- Eye opening experience
- Bridging bio-physics-chemistry
- Zest for Math

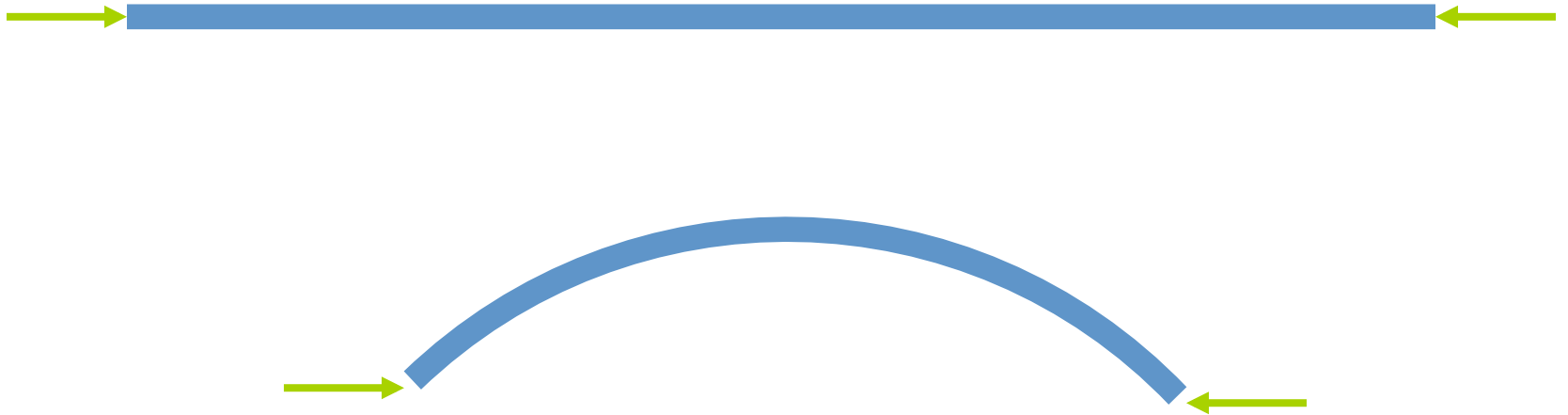




Outline

- Why do we study patterns
- **Pattern formation theory in a nutshell**
- A glimpse at some work at UMass Amherst

Buckling

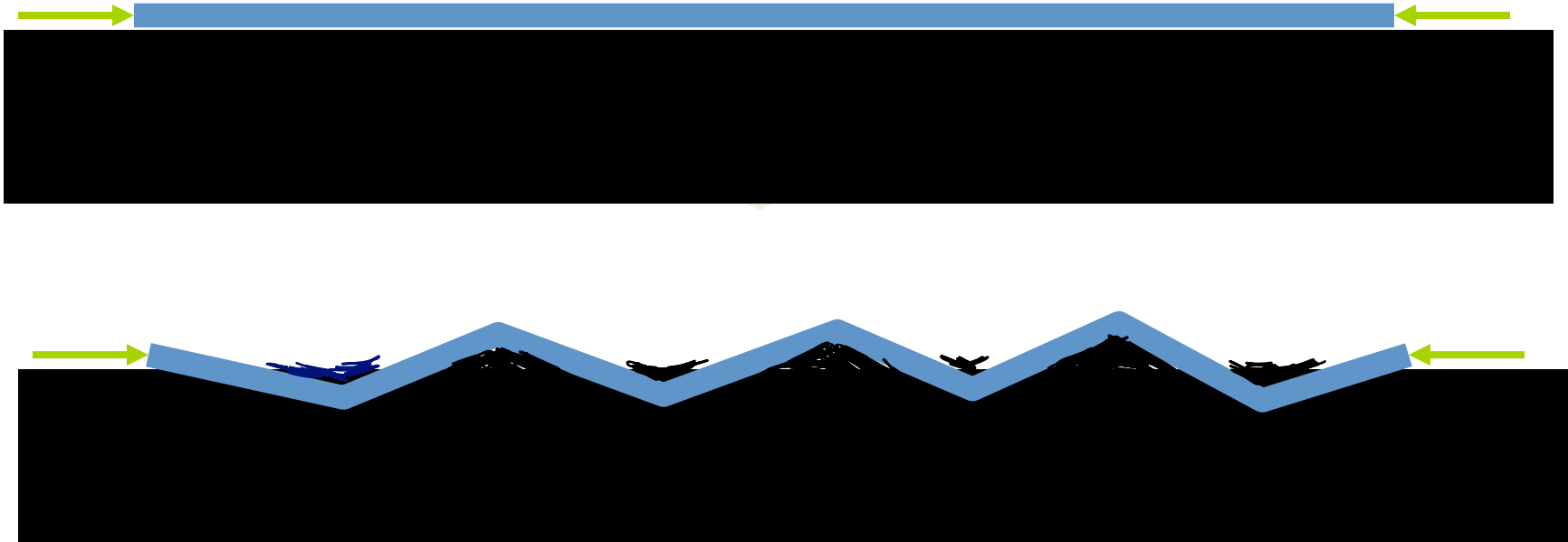


Instability governed by weak bending resistance of thin objects

Wrinkling on a liquid bath

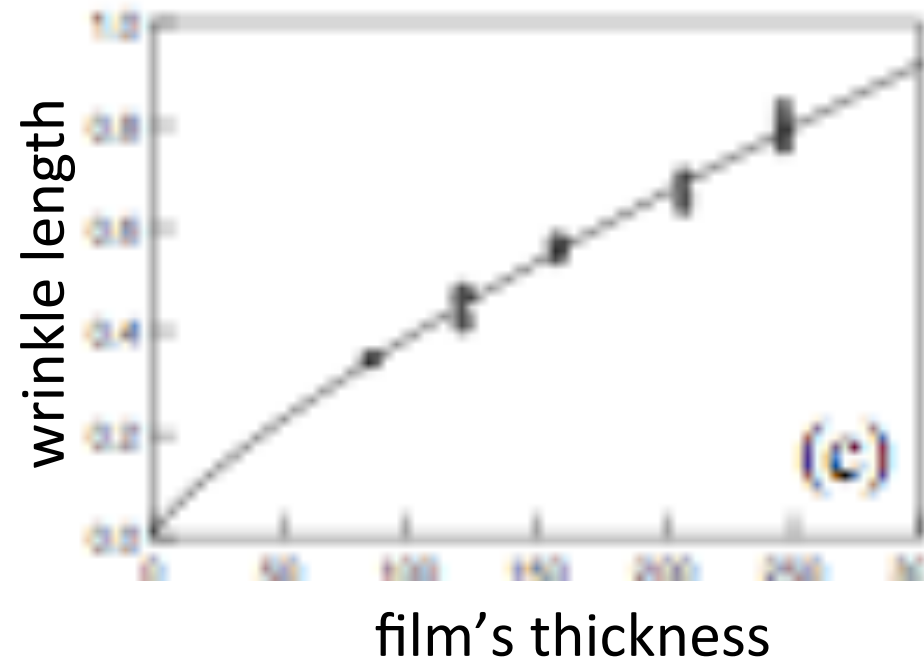
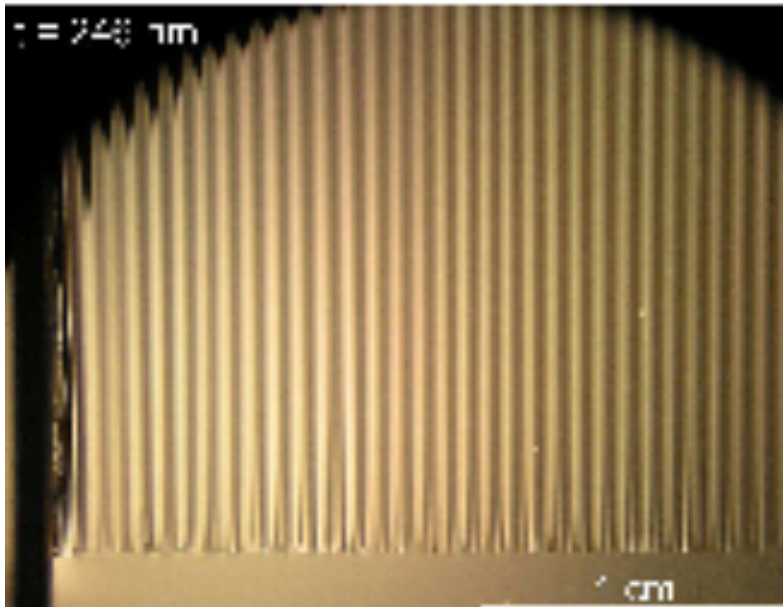


Wrinkling on a liquid bath



Wavelength governed by **competition of forces**:
bending resistance (sheet) *versus* gravity (liquid)

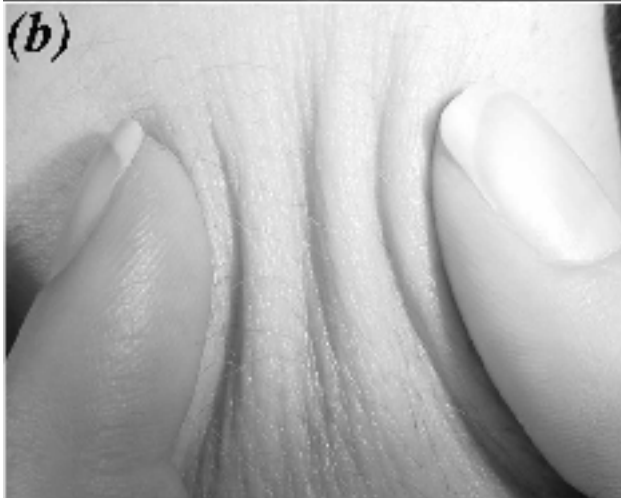
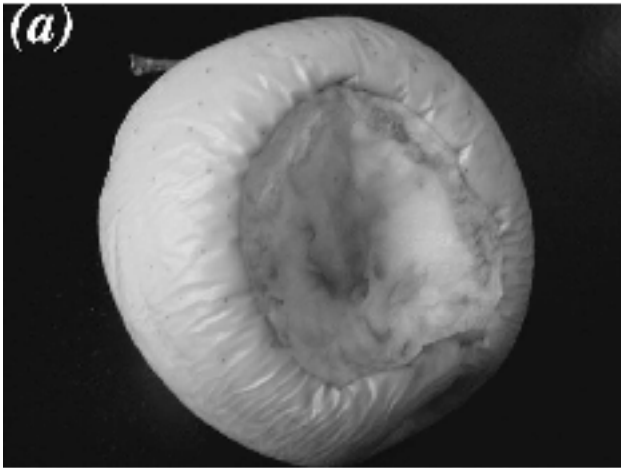
Wrinkling on a liquid bath



Metrology:

Indirect measurement of thickness of ultrathin films

Wrinkling on flesh



Wavelength governed by
competition of forces:

bending resistance of sheet (=skin)
versus
Stiffness of substrate (=flesh)

Chemical reactions



Wavelength governed by
competition of rates:

reaction rate

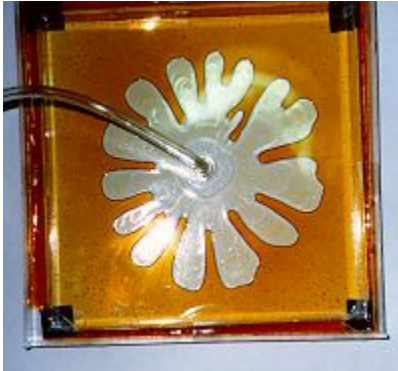
versus

diffusion rate



(??)

Viscous Fingering

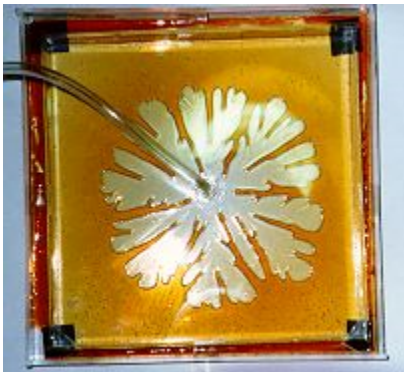


Wavelength governed by
competition of rates:

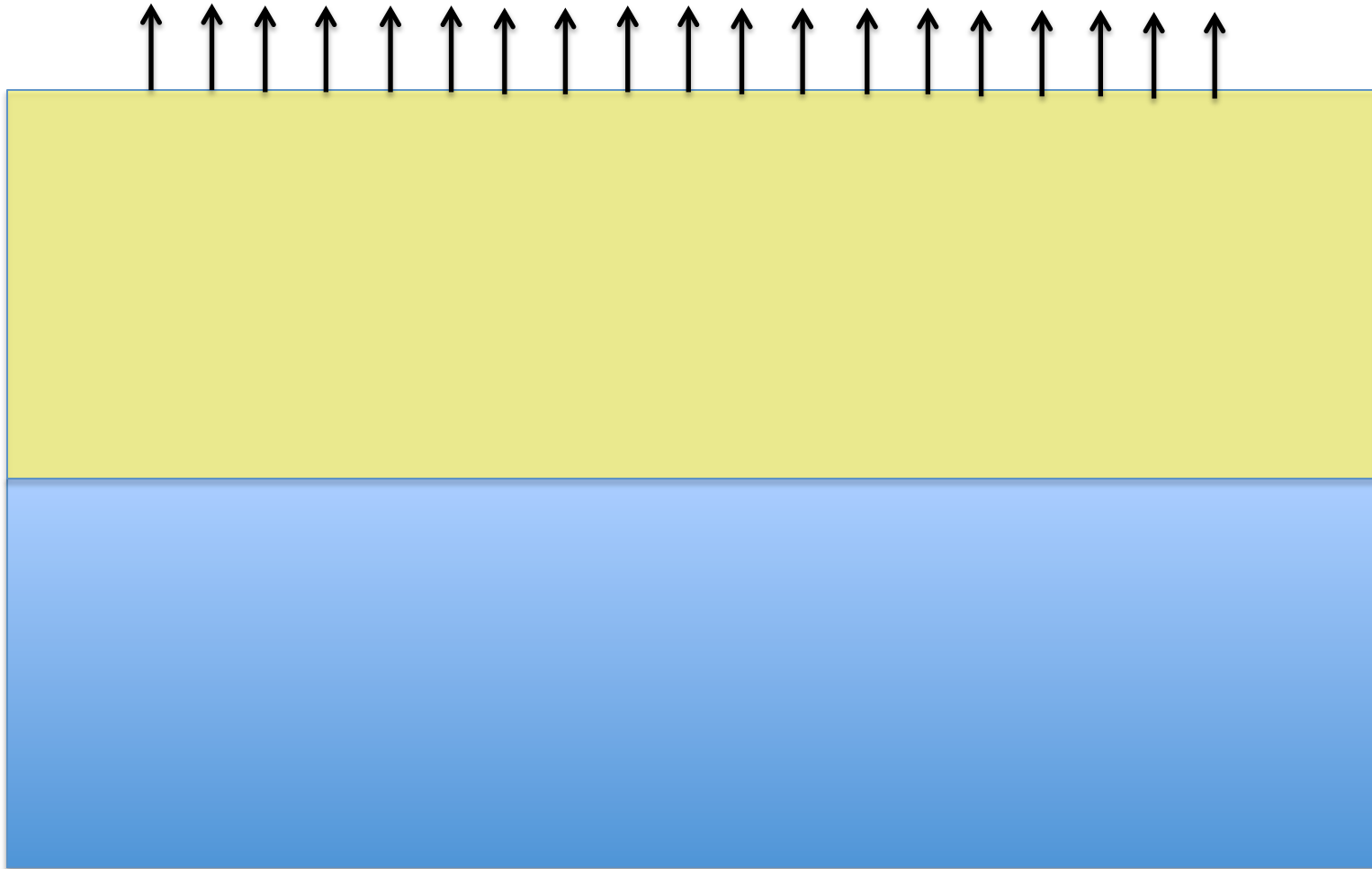
Injection rate

versus

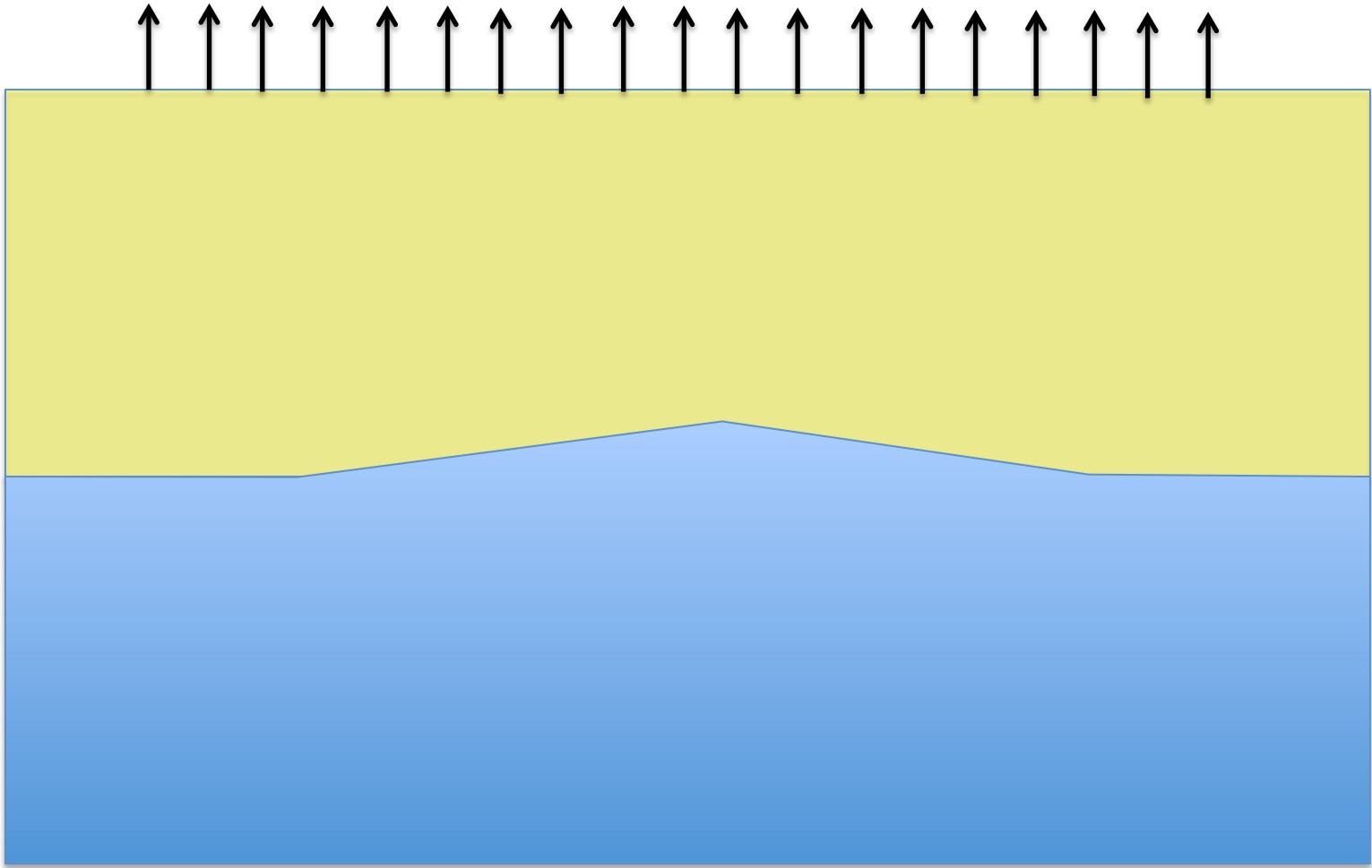
Viscous diffusion of liquid pressure



Why viscous fingers form

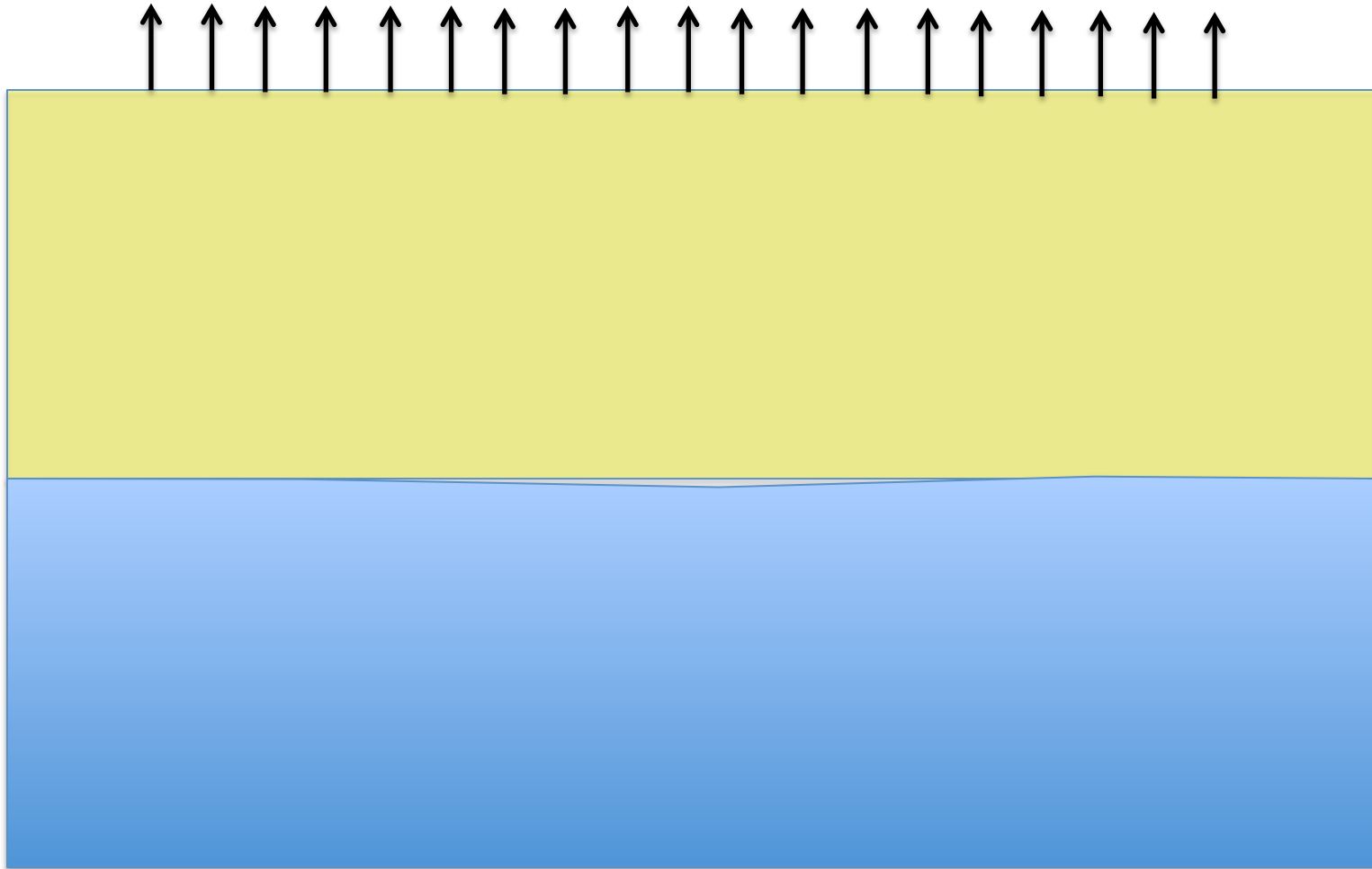


Why Viscous fingers form



Assume a small "perturbation"

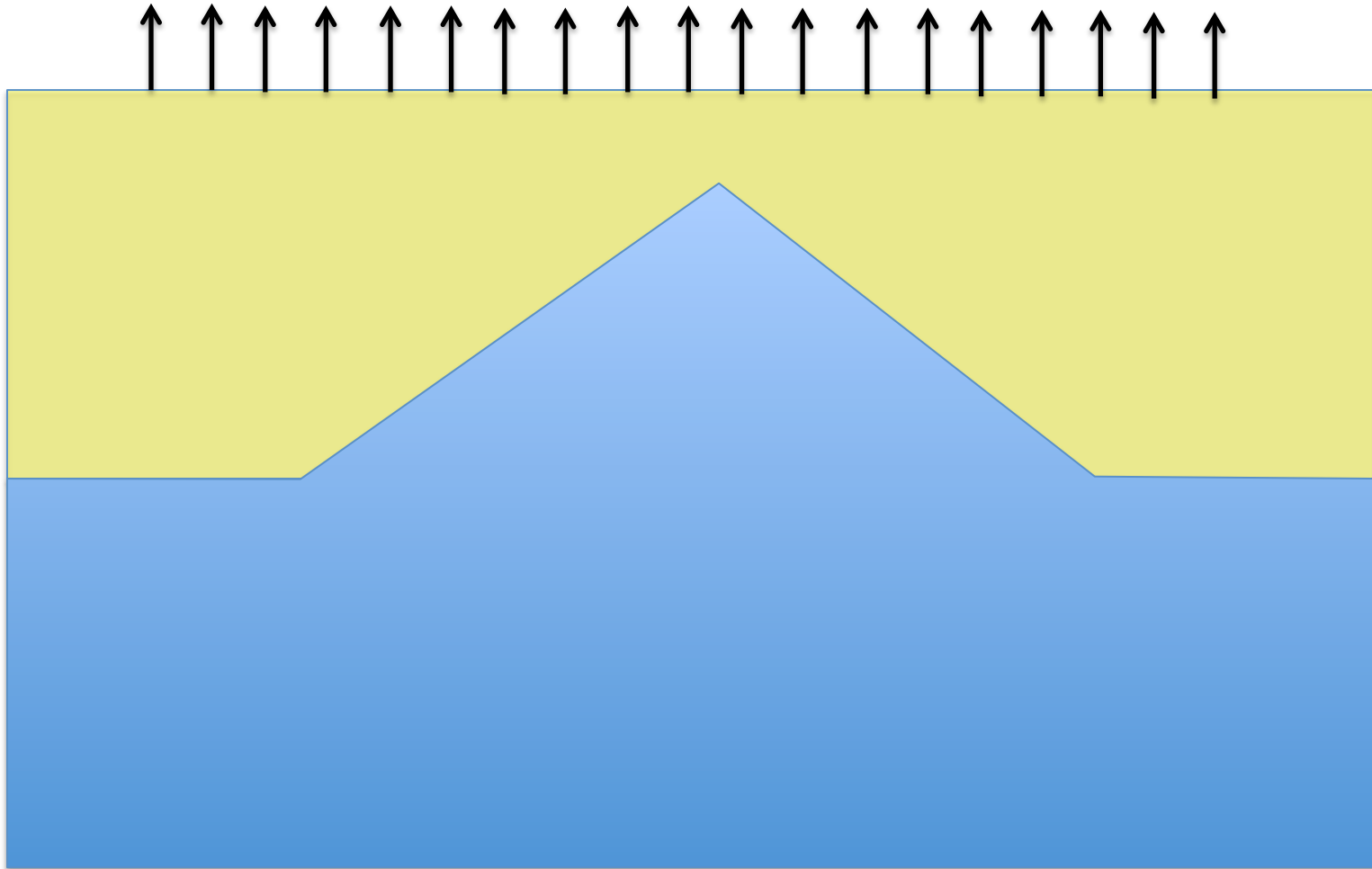
Why Viscous fingers form



Will it grow ?

NO → homogenous state stable → **no pattern**

Why Viscous fingers form



Will it grow ?

YES → homogenous state unstable → **pattern formation**

Wavelength law for viscous fingers (λ)

Physical quantity	symbol	Dimensions (units)	Stabilizing (S) Destabilizing (D)
Velocity	v	[Length] / [Time]	D
Viscosity contrast	$\Delta \eta$	[Energy]*[Time] / [Length]^3	D
Surface tension	σ	[Energy] / [Length]^2	S
Channel width	a	[Length]	S

$$[\lambda] = [\text{Length}]$$

$$\lambda \sim \frac{\sigma a^2}{V \Delta \eta}$$

Summary (I)

- **Interdisciplinary experience:**
an overarching principle for pattern formation in distinct systems
- **Applicability**
e.g. metrology of ultrathin films
- **Math skills:**
plot data --> fit to elementary functions --> discover new physical laws

Outline

- Why do we study patterns
- Pattern formation theory in a nutshell
- **A glimpse at some work at UMass Amherst**

What do you see ?



Chocolate ??

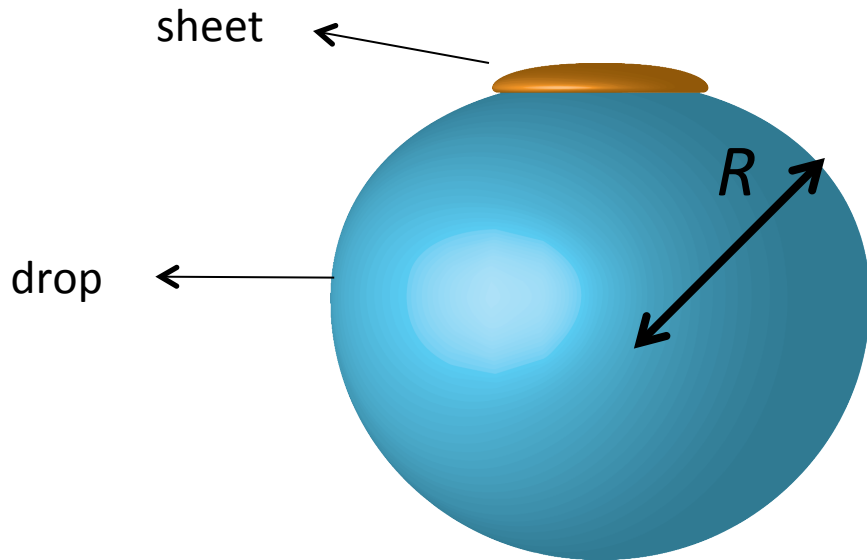
What do you see ?



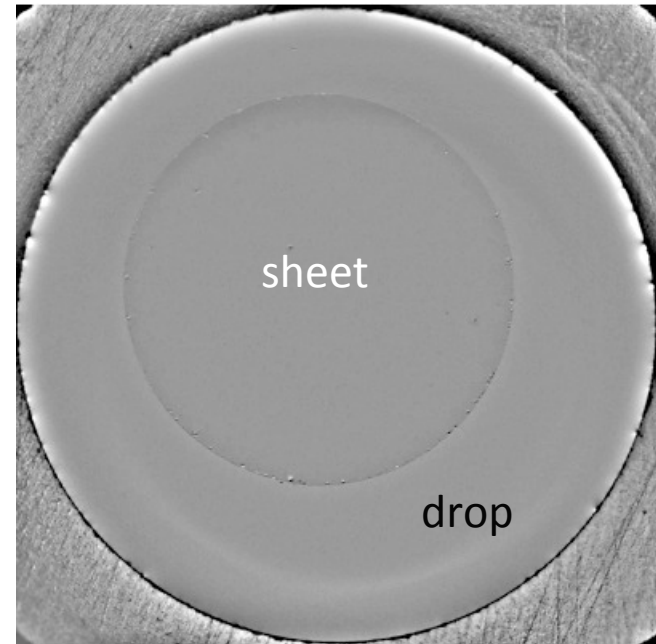
**spontaneous pattern
formation:**

*Wrinkles,
Crumples,
Folds,
Blisters,
Creases, ...*

A sheet on a drop

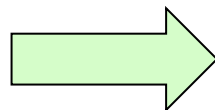


side view
(schematic)

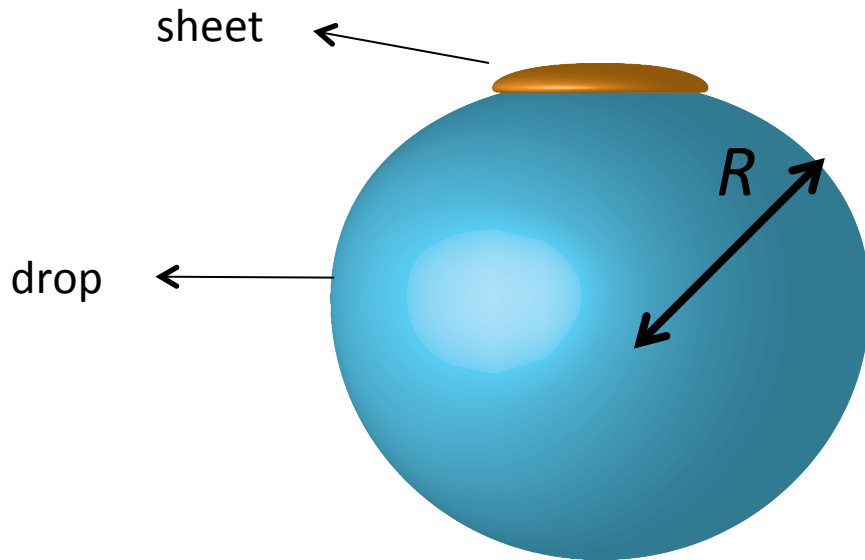


top view
(experiment)

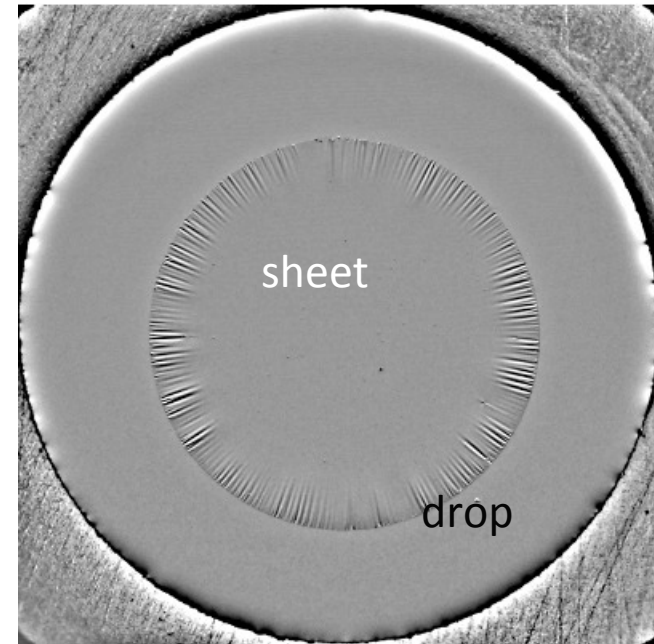
Decreasing drop's radius R ...



A sheet on a drop

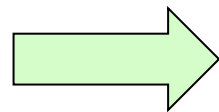


side view
(schematic)

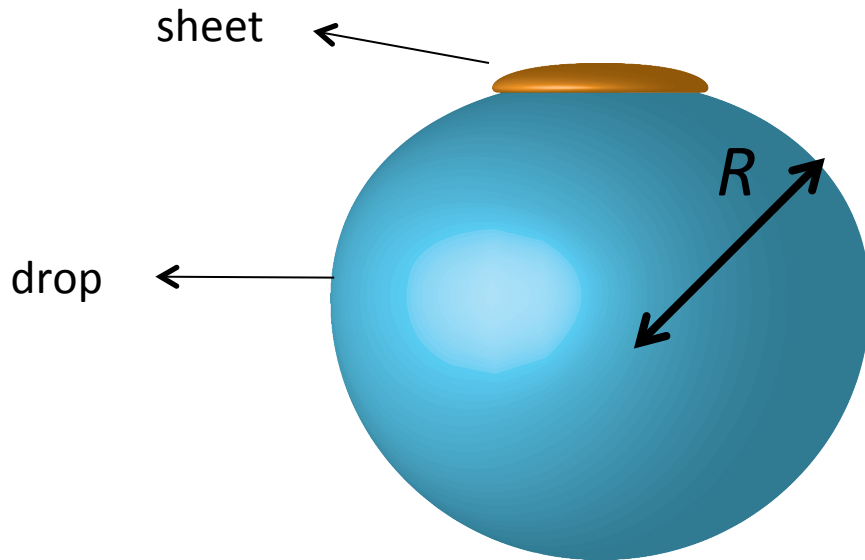


top view
(experiment)

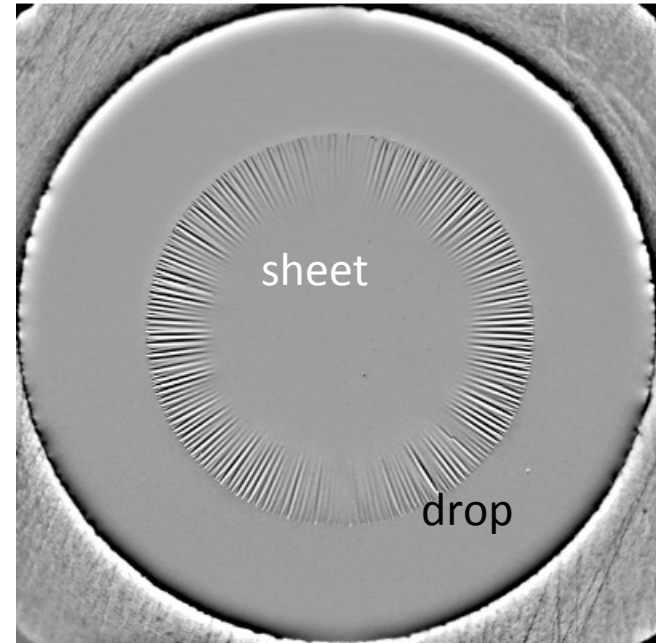
Decreasing drop's radius R
further ...



A sheet on a drop

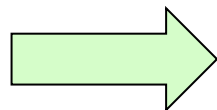


side view
(schematic)

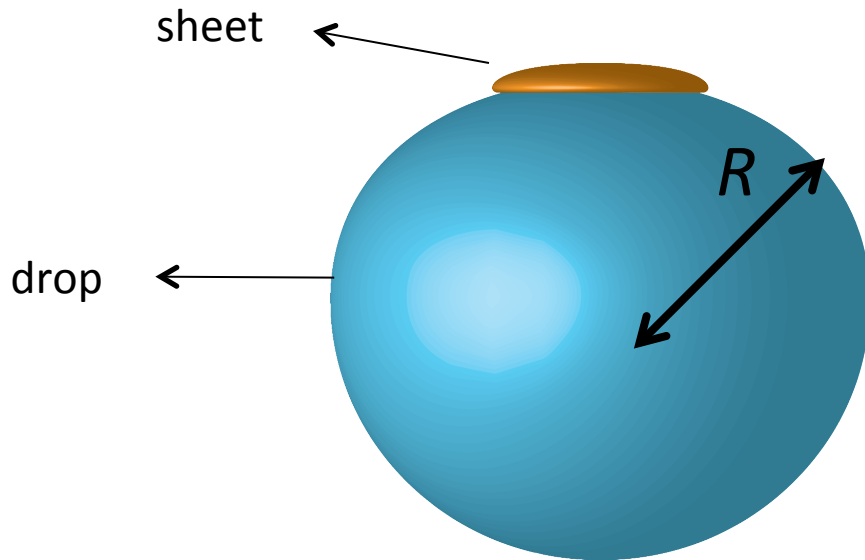


top view
(experiment)

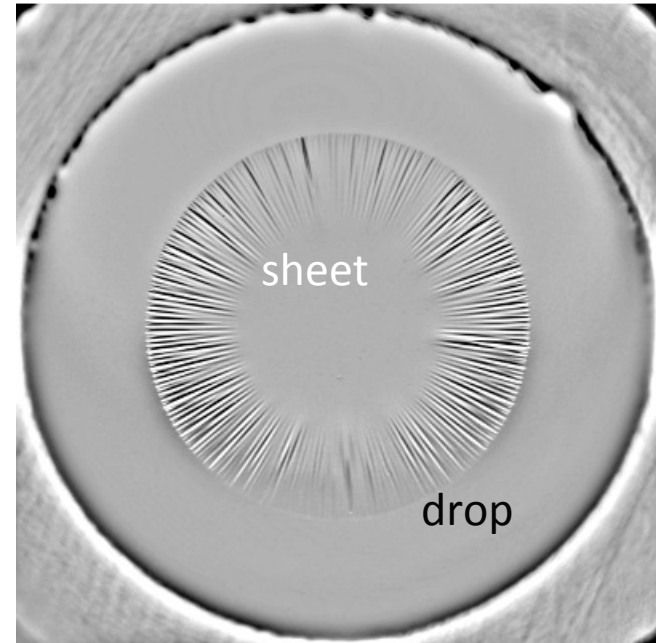
Decreasing drop's radius R
even further ...



A sheet on a drop

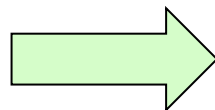


side view
(schematic)

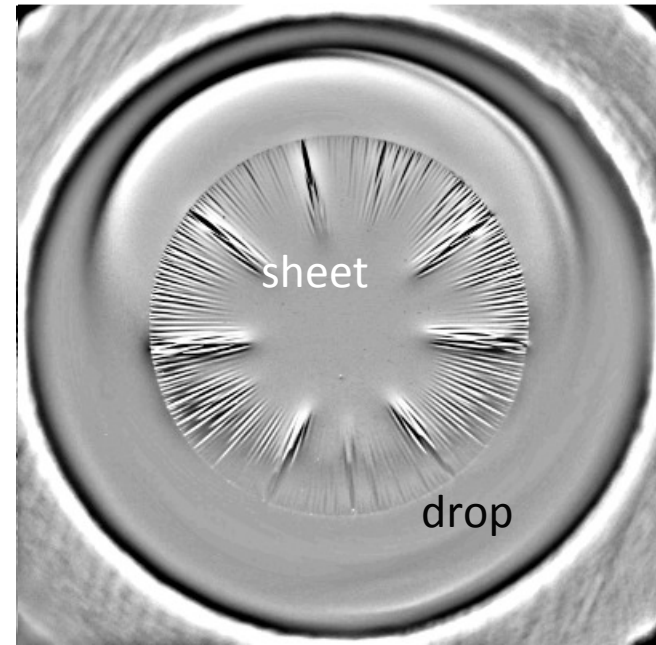
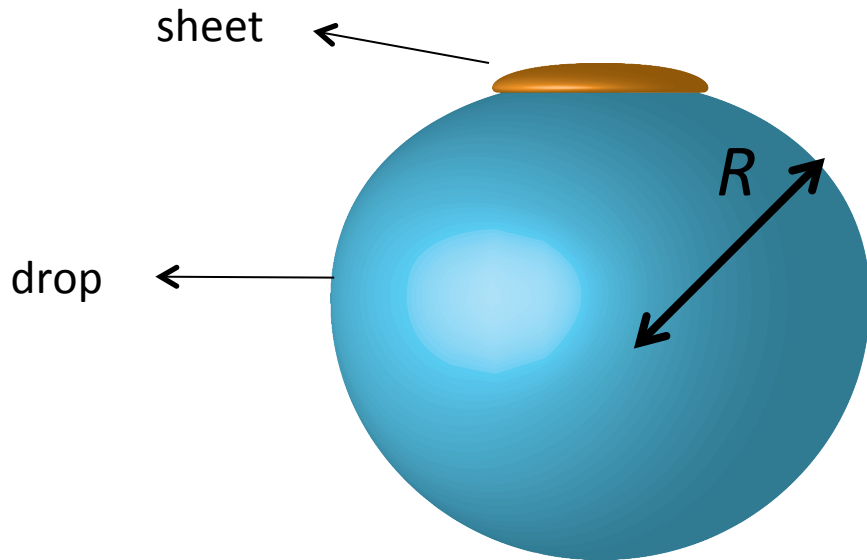


top view
(experiment)

Finally ...



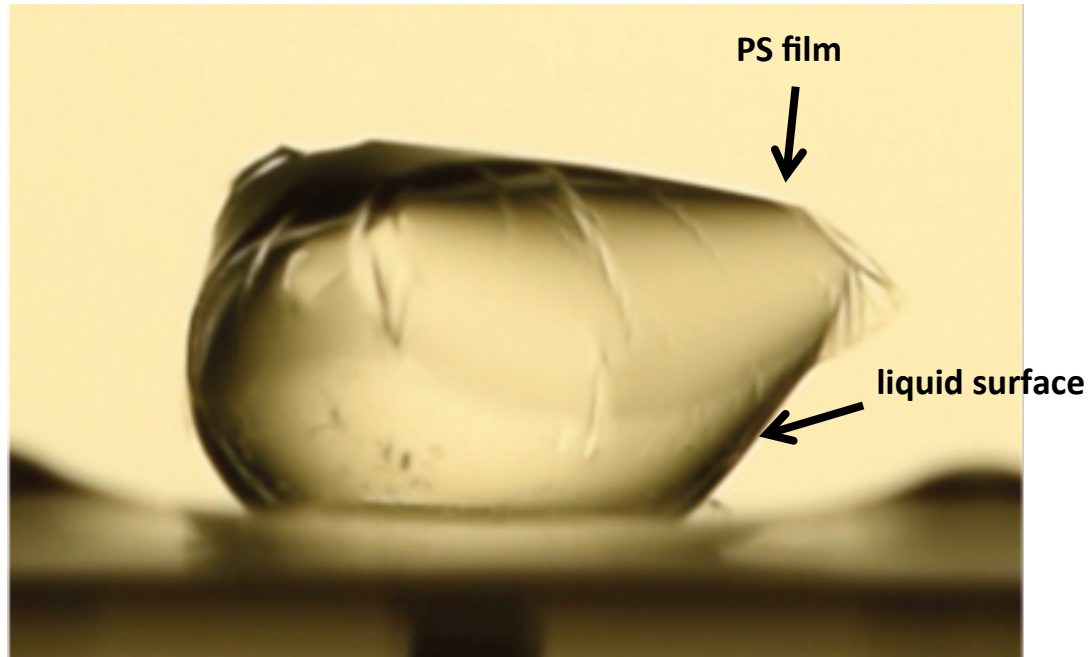
A sheet on a drop



From **wrinkling** to **crumpling**

Wrapping liquid drop by PS film

Paulsen et al. (UMass) Nature Materials 2015



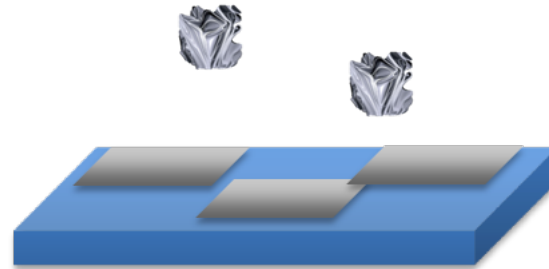
UMass scientists awarded \$1M Keck Foundation grant

By: JEFFREY OKERMAN | March 05, 2013 | [ShareThis](#)

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A group of University of Massachusetts physicists were recently awarded a three-year \$1 million grant from the W.M. Keck Foundation to carry out research on ultra-thin films, according to a University press release.

Physicists Narayanan Menon, Benny Davidovitch and Christopher Santangelo, along with polymer scientist Thomas Russell, were recently awarded the grant in order to explore and develop the science behind delivering ultra-thin films into liquids.

According to the release, the W.M. Keck Science and Engineering Program seeks to extend funding to programs with “endeavors that are distinctive and novel in their approach. It encourages projects that are high-risk with the potential for transformative impact.”

Menon and his team will work on a series of projects over the three-year period, with each project “more difficult than the release said.

Their main focus will be creating a material that will begin crumpled up, but once the materials are introduced to a partic environment, will expand to create a super thin barrier between two materials.

In the release, Menon describes a situation where a ball, which appears to be a simple crumpled piece of paper, “instantly when thrown at a wall, covering the wall in a sheet of paper that is up to “10,000 times thinner” than a normal sheet of pa



Courtesy of UMass.edu

Summary

- Spontaneous pattern formation is cool !
- Thanks you for listening !