SCIENCE OF COOKING

Connecting microscale properties to macroscale behavior

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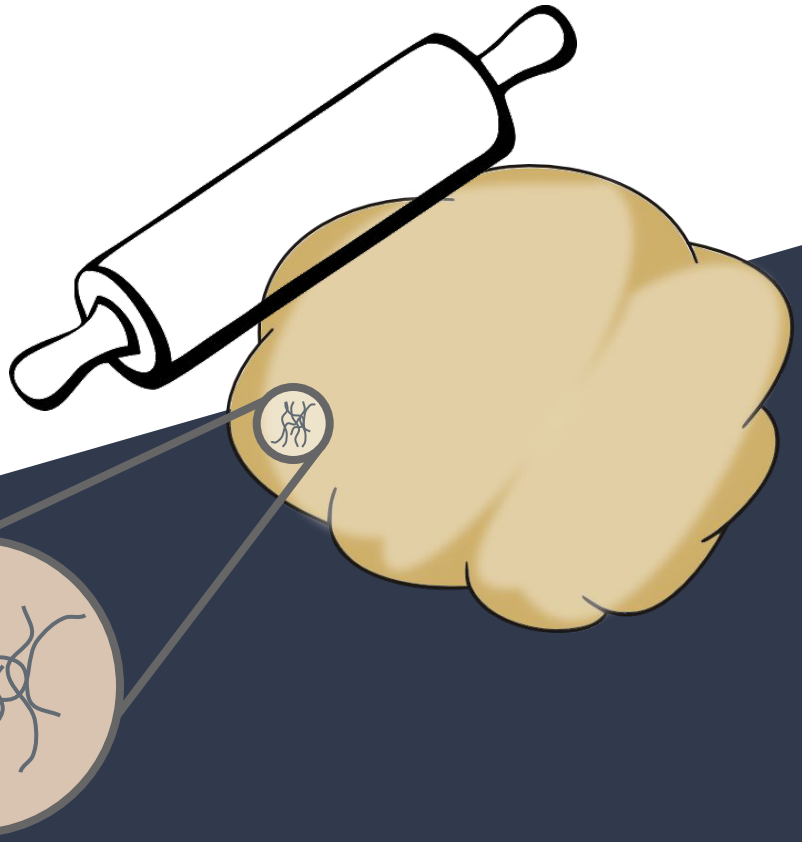
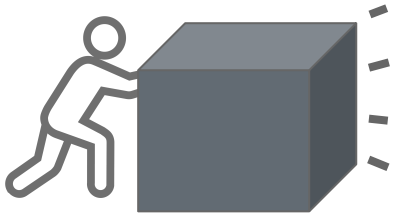
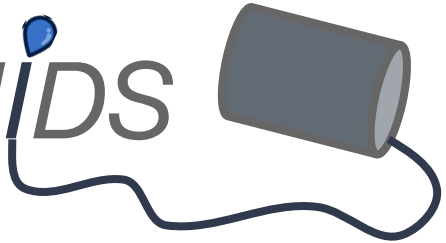


Before we begin

We will do experiments and they will be messy.

If you are concerned about spilling on your computer, wait until after the talk to do the experiments!

Are the following

SOLIDS  **or** *LIQUIDS* 

1. Bread Dough
2. Cornstarch+Water
3. Ketchup
4. Toothpaste

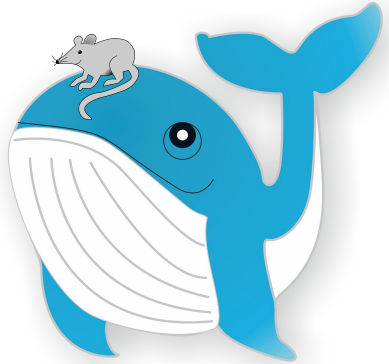
It’s a trick question; they are both!

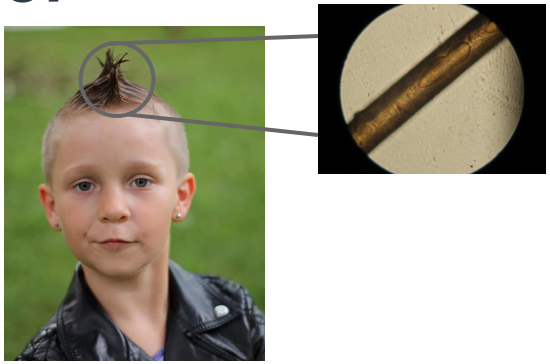
SHEAR THICKENING

IN COOKING

Size can dramatically change behavior

- **Small or large… compared to what?**
  - Whale 10^8 [cm^3]
  - Mouse 10^2 [cm^3]
  - Whale is 1,000,000 times larger.
- **What role does size play the behavior of particles?**
  - Sand 2000 [microns]
  - Cornstarch 10 [microns]
- **What about ratios in cooking?**





Newtonian Fluid - Water

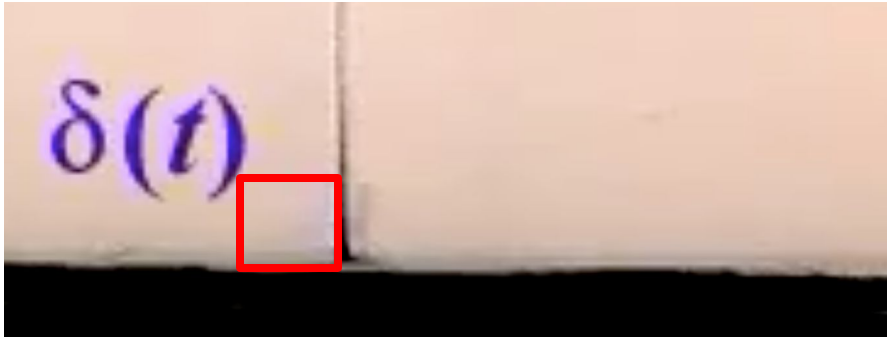
Viscous stresses acting on each fluid element are linearly related to the local strain rate.

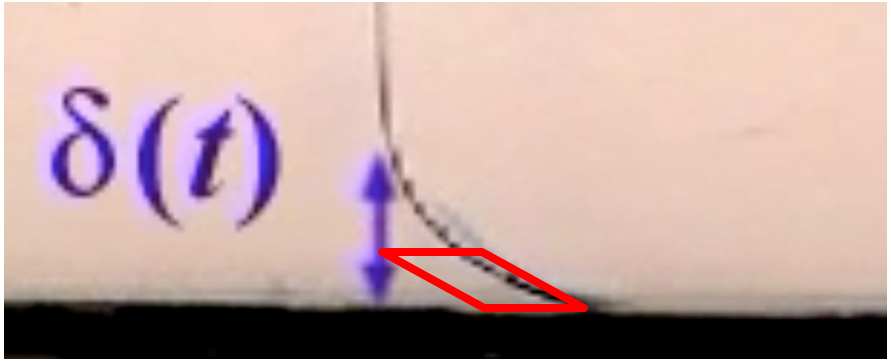
Viscous Stresses = Friction

Strain Rate = Deformation

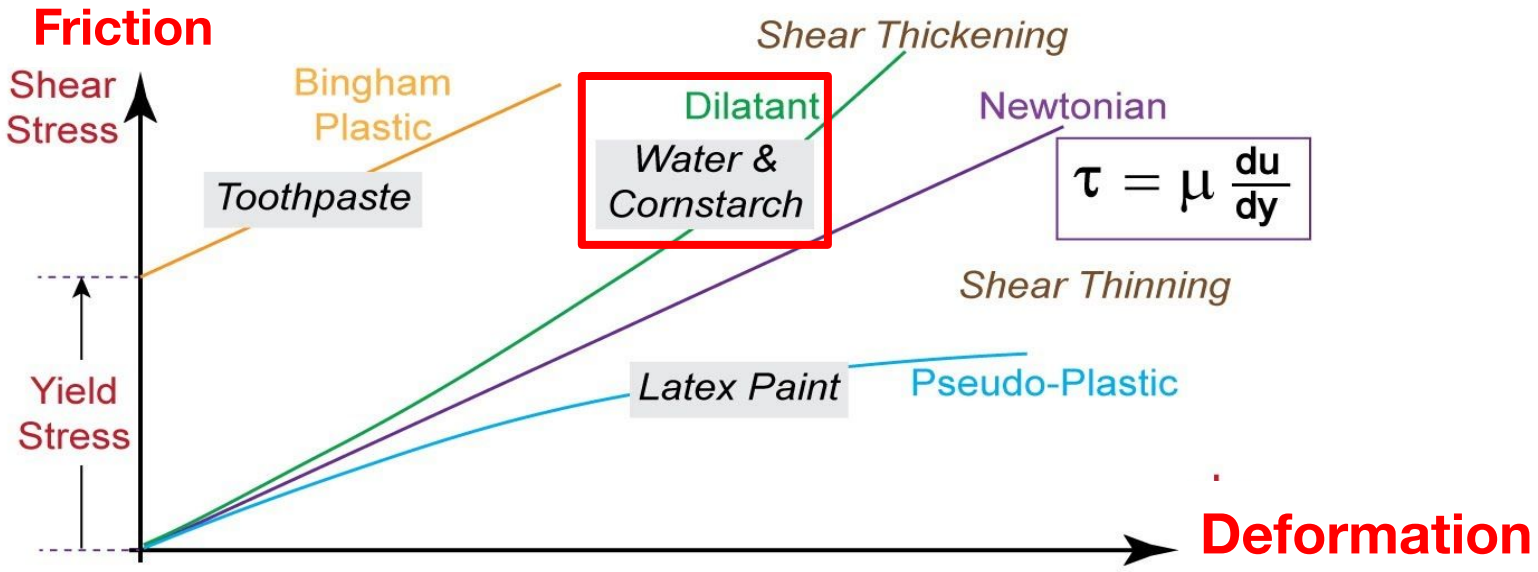
Friction in a fluid increases the faster you deform it

Strain Rate = Deformation





Non-Newtonian Fluids

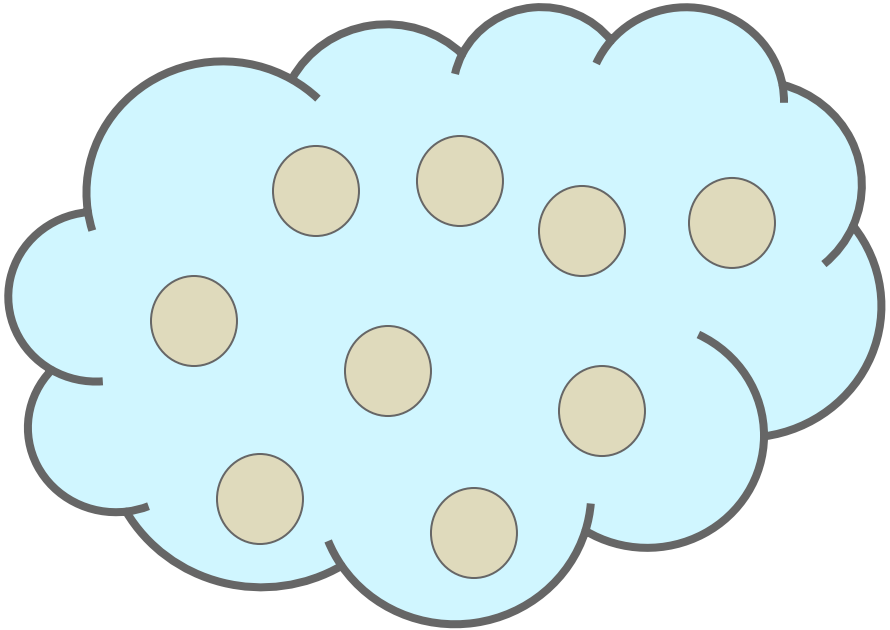


Linear Relationship - Buying Items or Spring
Nonlinear Relationship - Freefall Speed

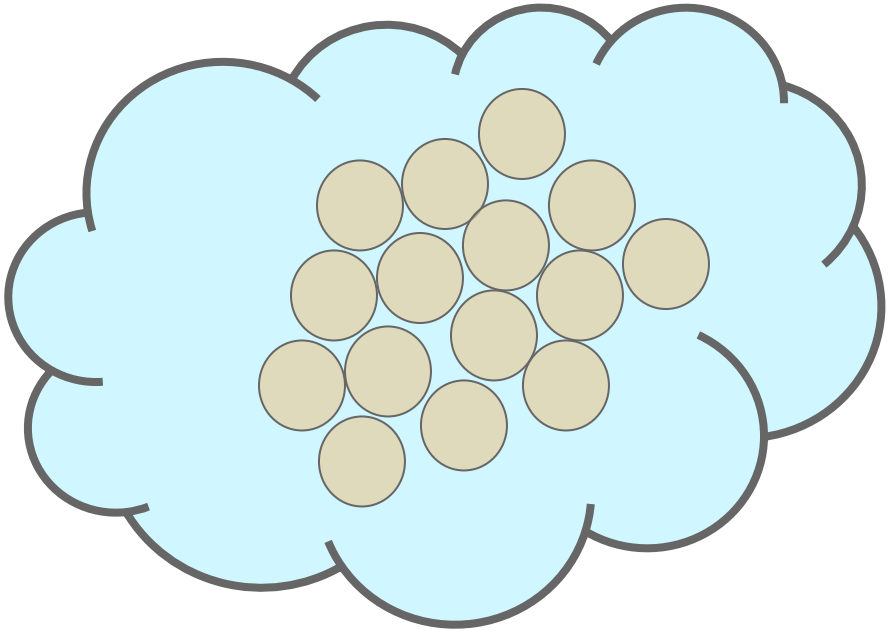
Experiment Time

1. Get a bowl and fill it with 1/2 cup of water.
2. Add a small bit of cornstarch.
    a. Continuous shear thickening
3. Mix around fast and slow is there a significant difference?
4. Add more and more slowly until it feels like stirring honey when you do it slowly.
    a. Discontinuous shear thickening.

Why?



Gentle Mixing (Water)



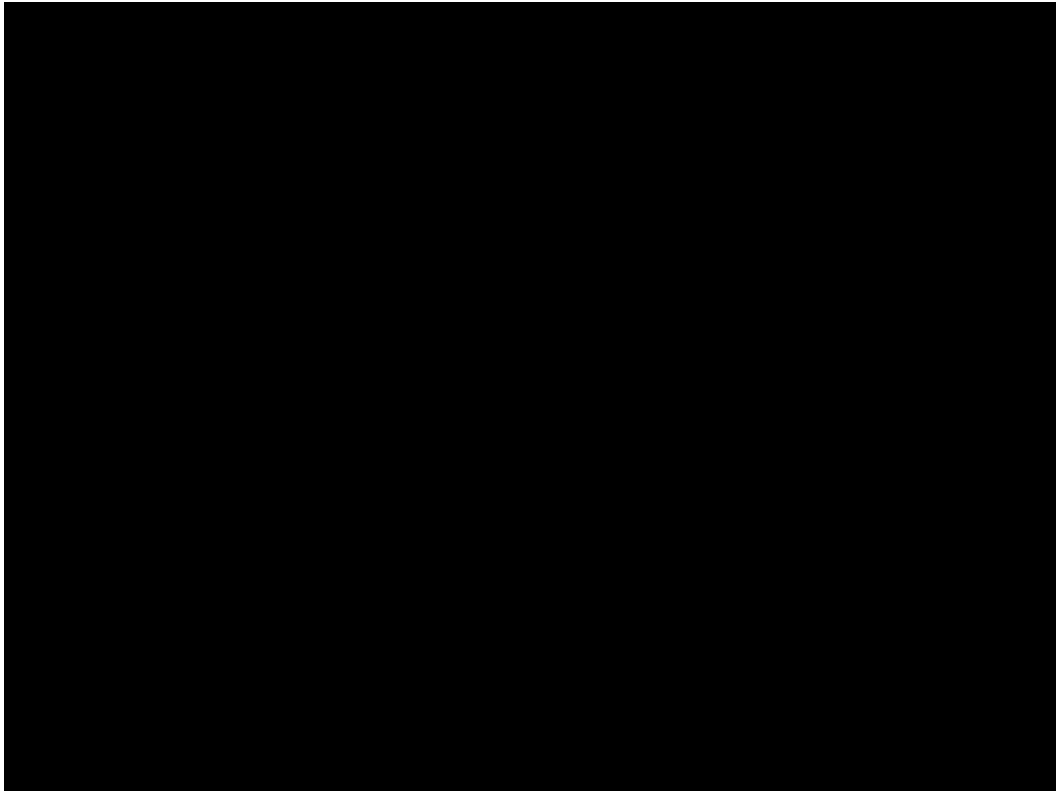
Violent Mixing (Sand)

When?

Conservation of Mass

Momentum Balance

Energy Balance



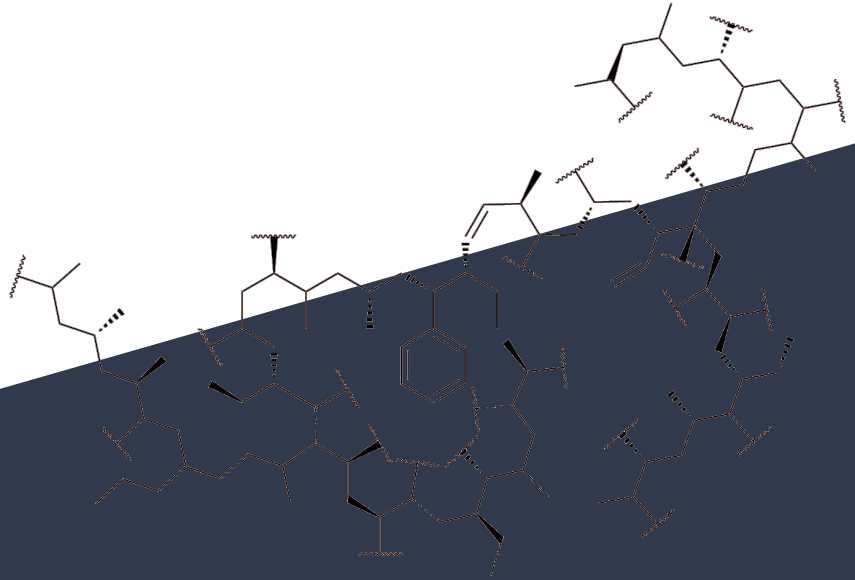
Cooking with Cornstarch

Thickener – Puddings, gravies, and sauces.

Baking – Anti-caking and adhesive films.

SHEAR THINNING

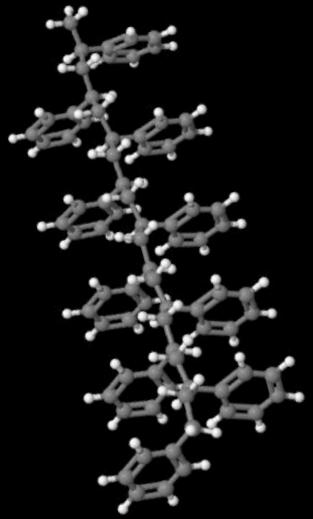
IN COOKING

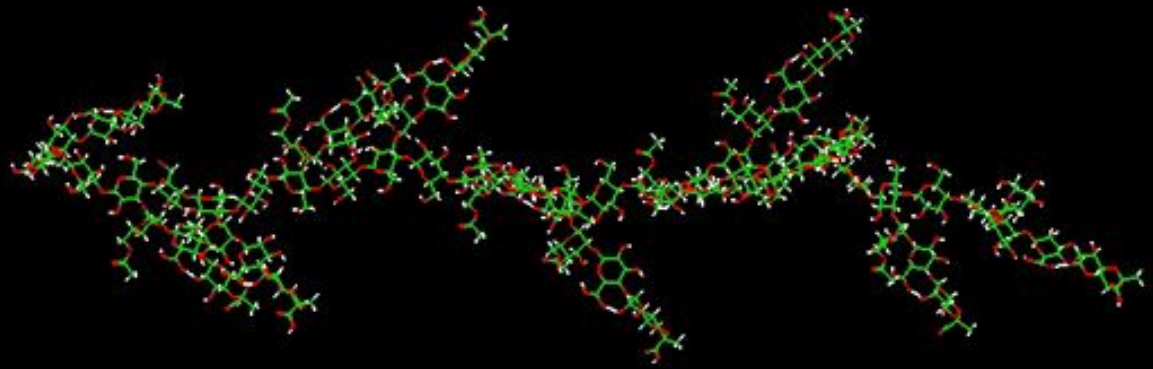


Shear Thinning - Ketchup

Polymers

Long-chain molecules - from plastics to proteins

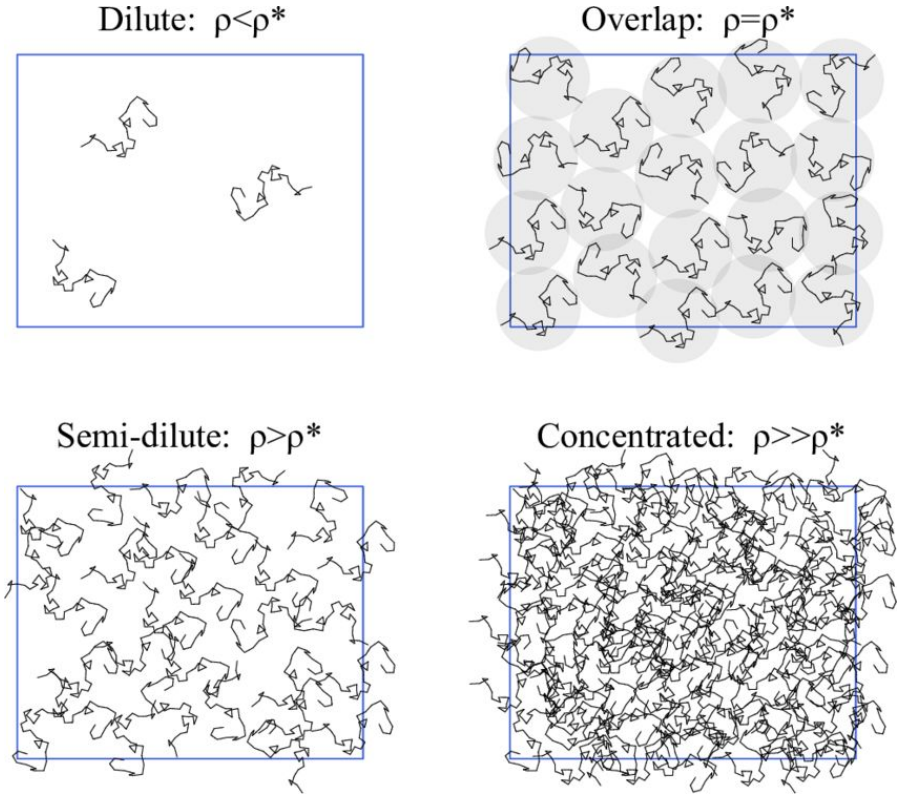




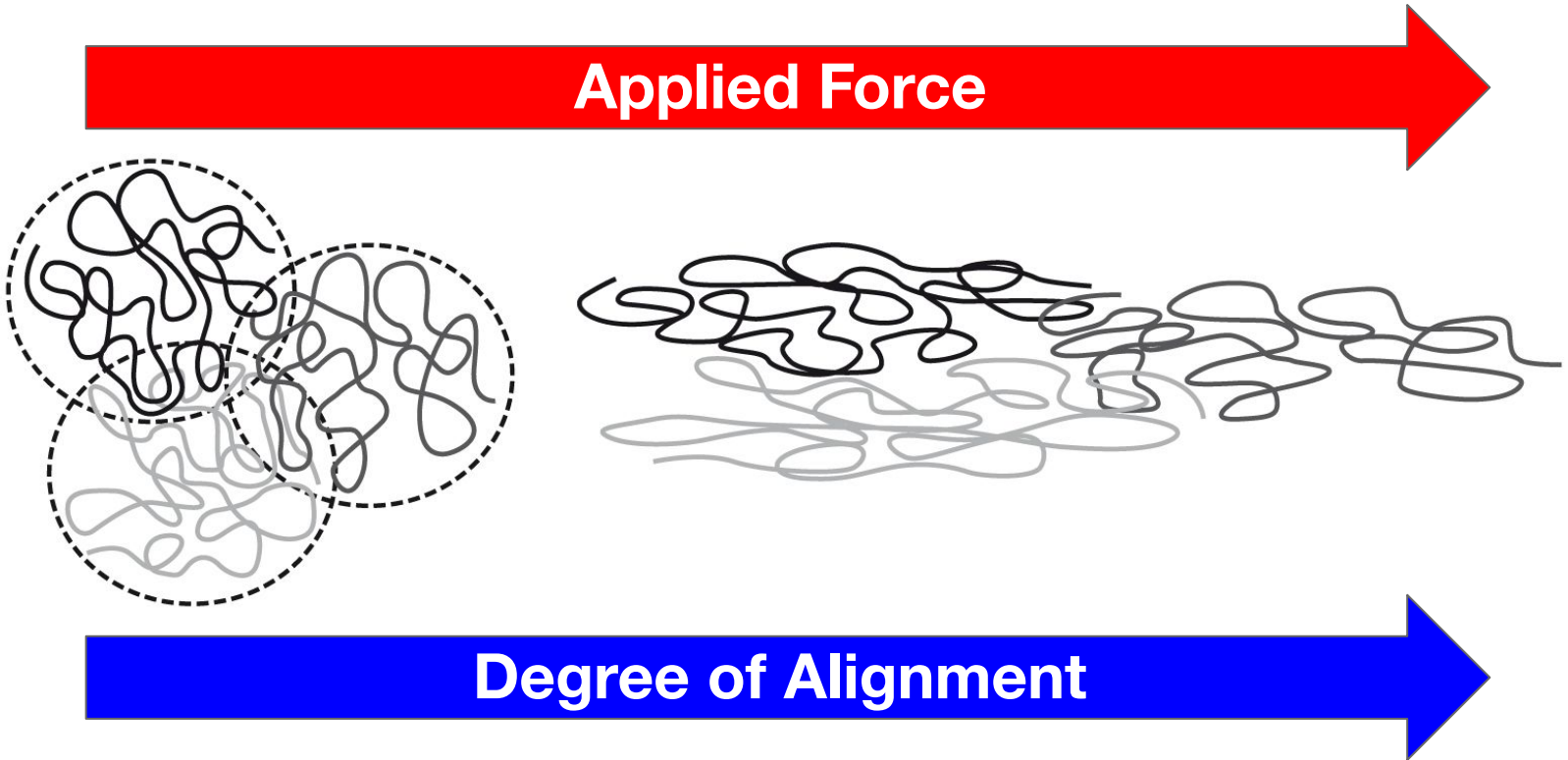
Polymer Entanglement

Polymers form “blobs” in water

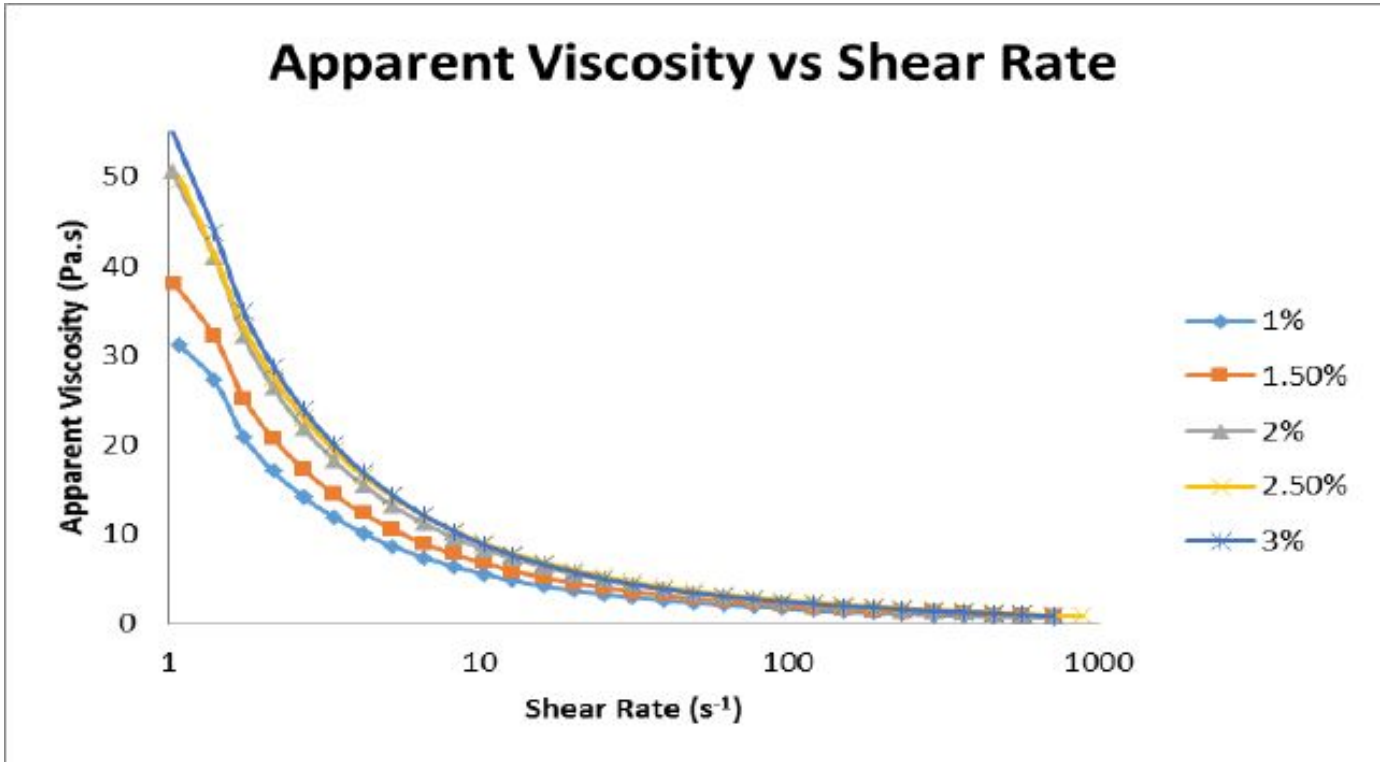
At high concentrations, they get tangled



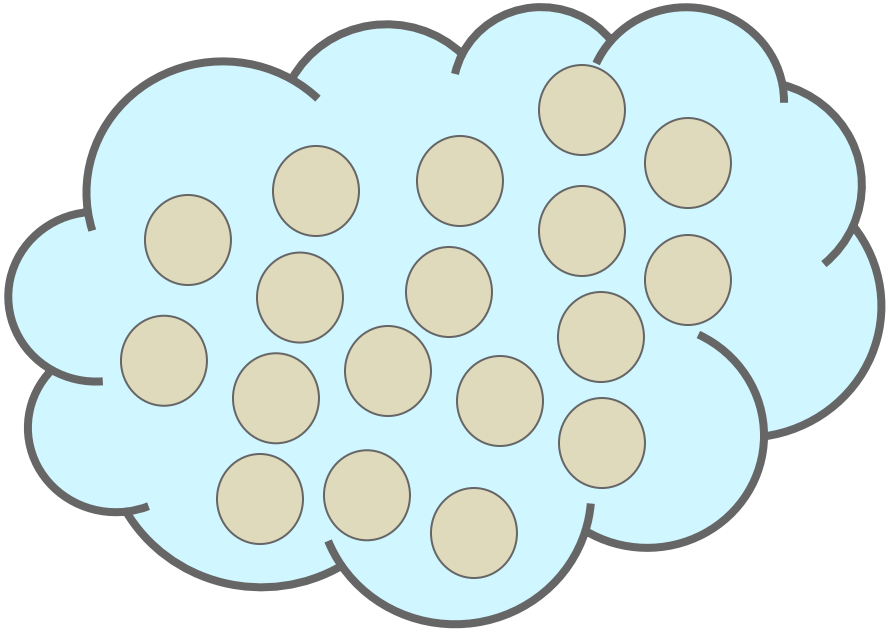
Origin of Shear Thinning



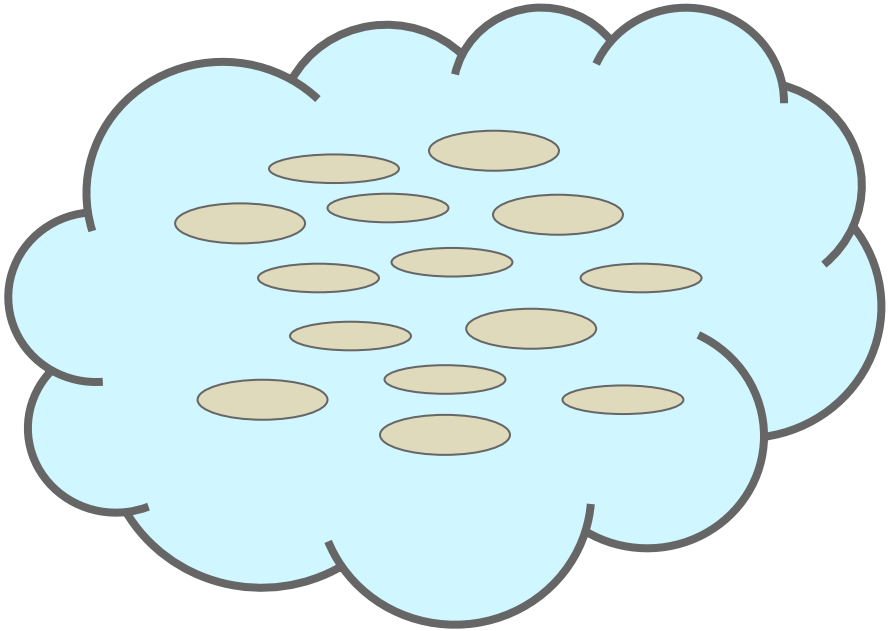
Shear Thinning in Ketchup



Ketchup vs. Corn Starch



Stationary Ketchup



With Applied Force

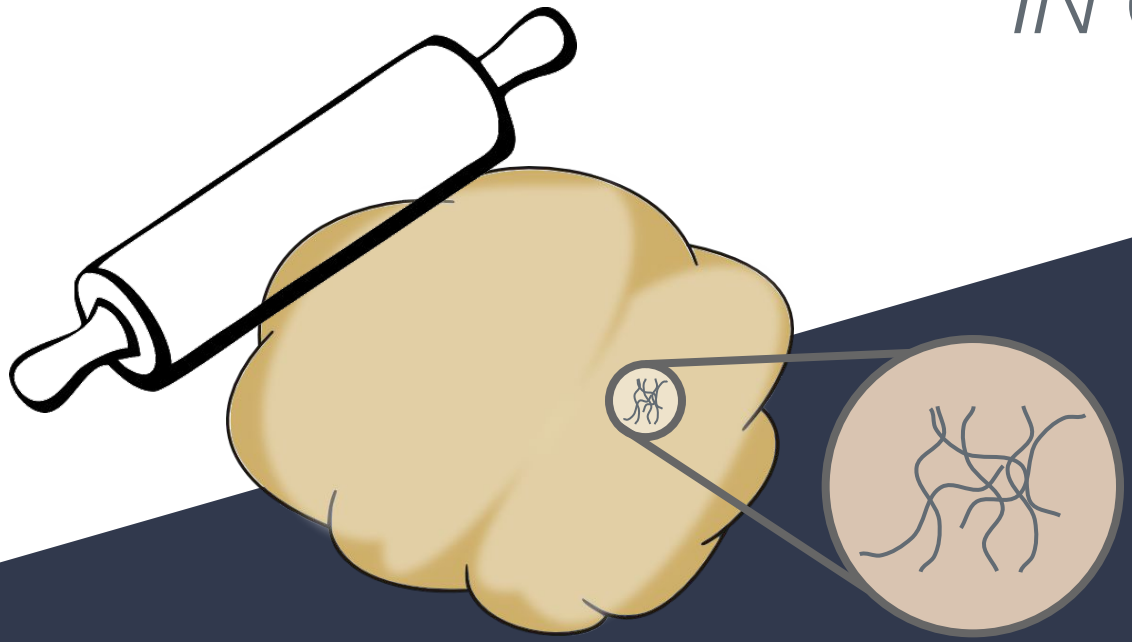
Experiment Time

1. Get a small bowl or plate and some ketchup
2. Draw a face with your ketchup - it’ll hold its shape!

Experiment Round 2...

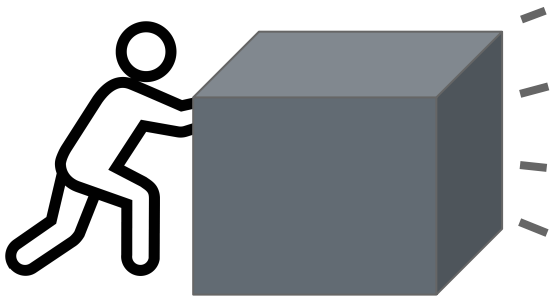
VISCOELASTICITY

IN COOKING

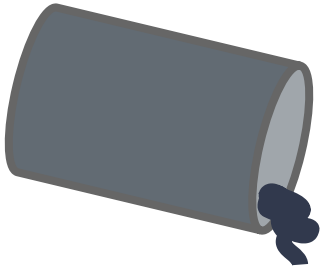


Bread dough is a...

SOLID



AND A

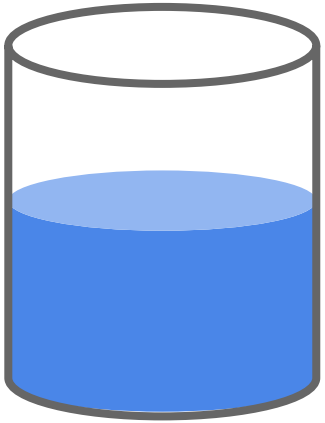


LIQUID

Viscoelasticity

VISCOUS

(liquid)



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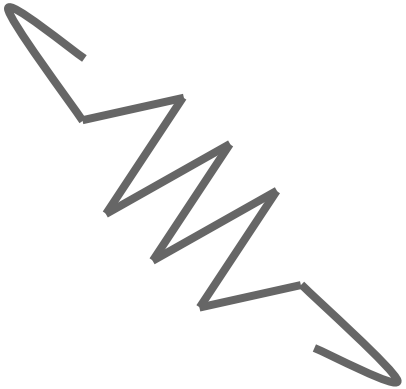


ELASTIC

(solid)

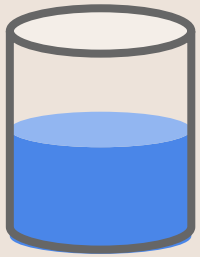
LET'S TALK CHEMISTRY

1. Flour
2. Water
3. Salt
4. Yeast

LET'S TALK CHEMISTRY

1. Flour

2. Water

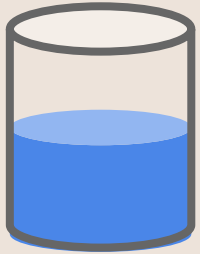


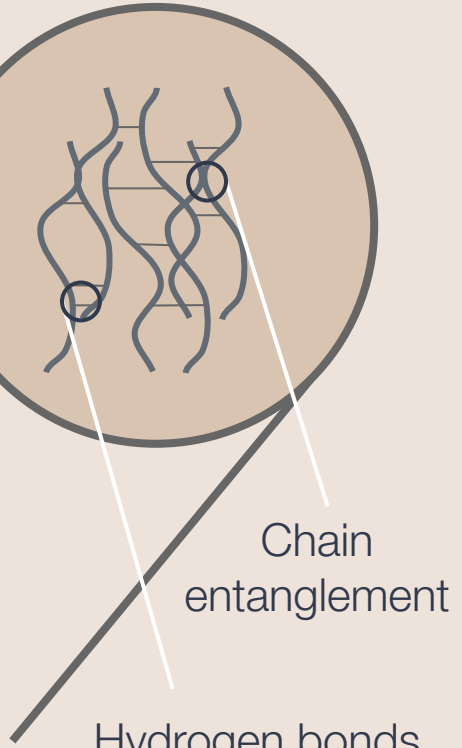
3. Salt

4. Yeast

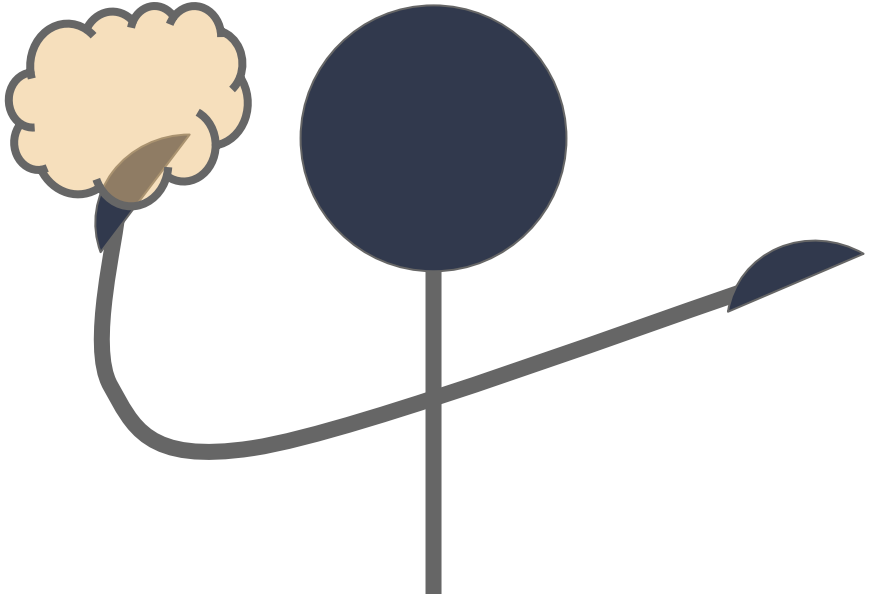
LET'S TALK CHEMISTRY

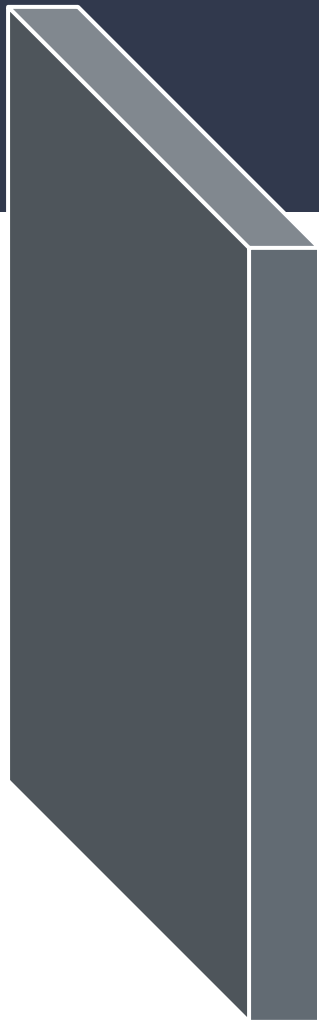
1. Flour
2. Water
3. Salt
4. Yeast





Thought experiment





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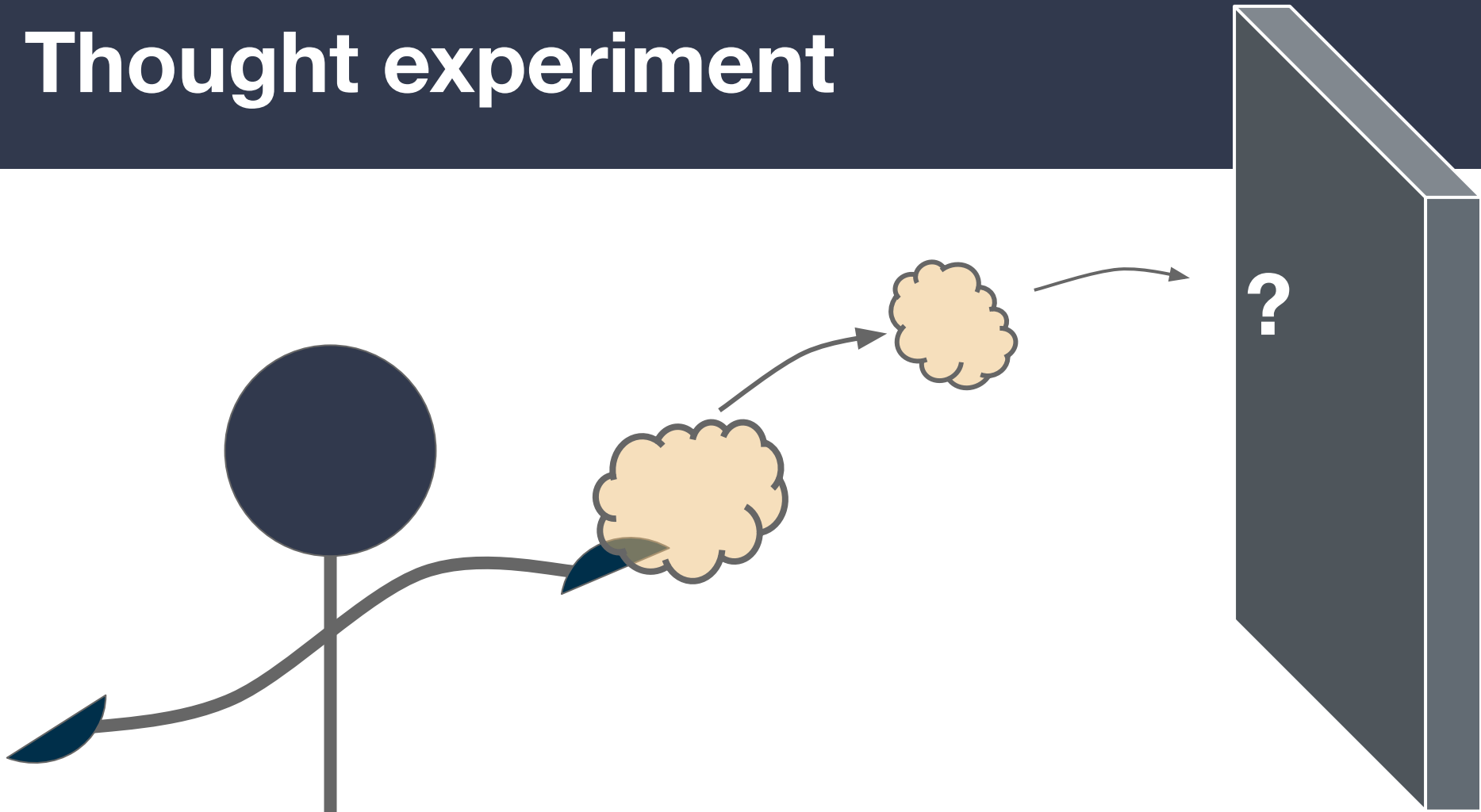

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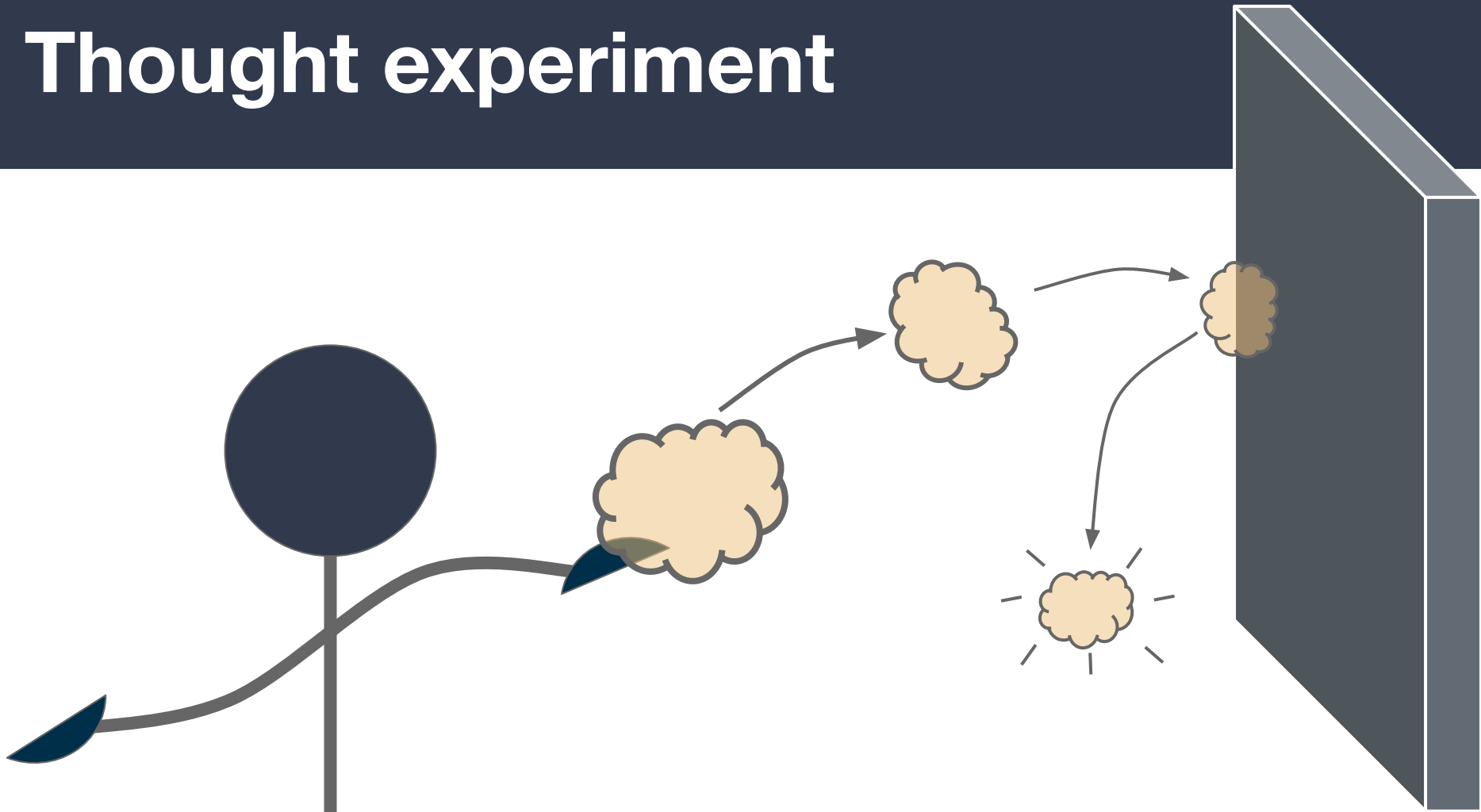

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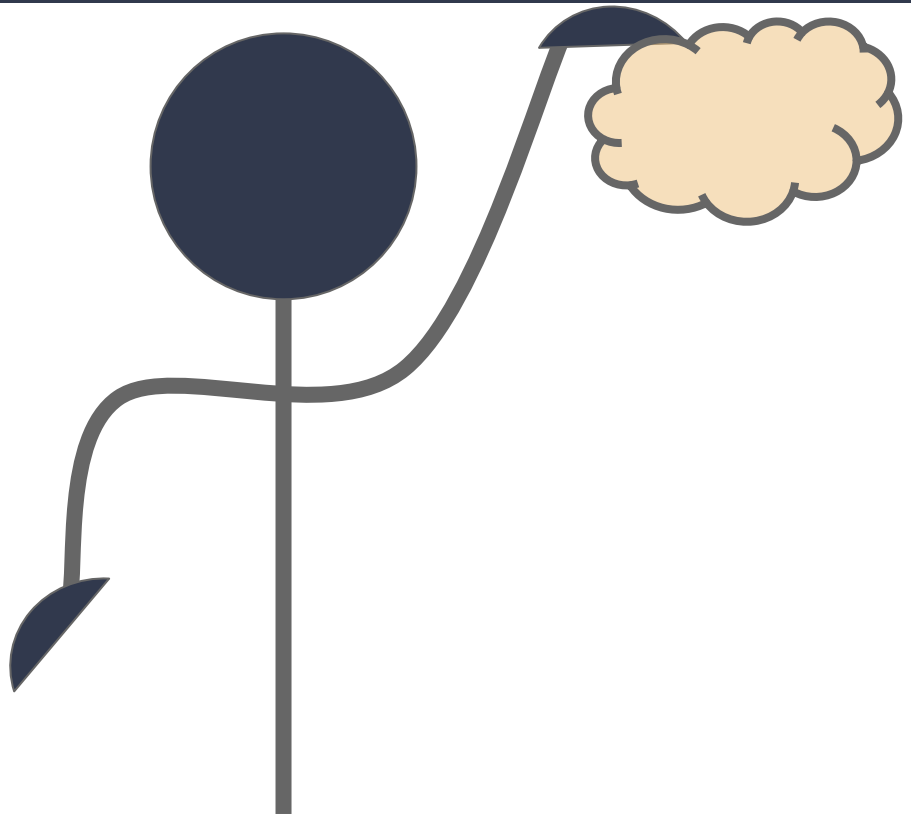
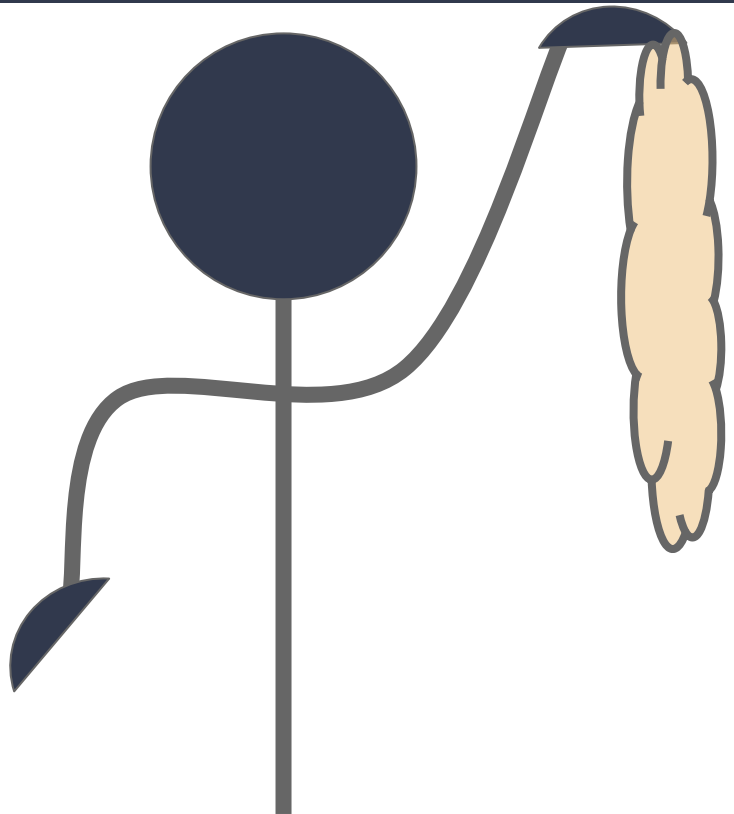
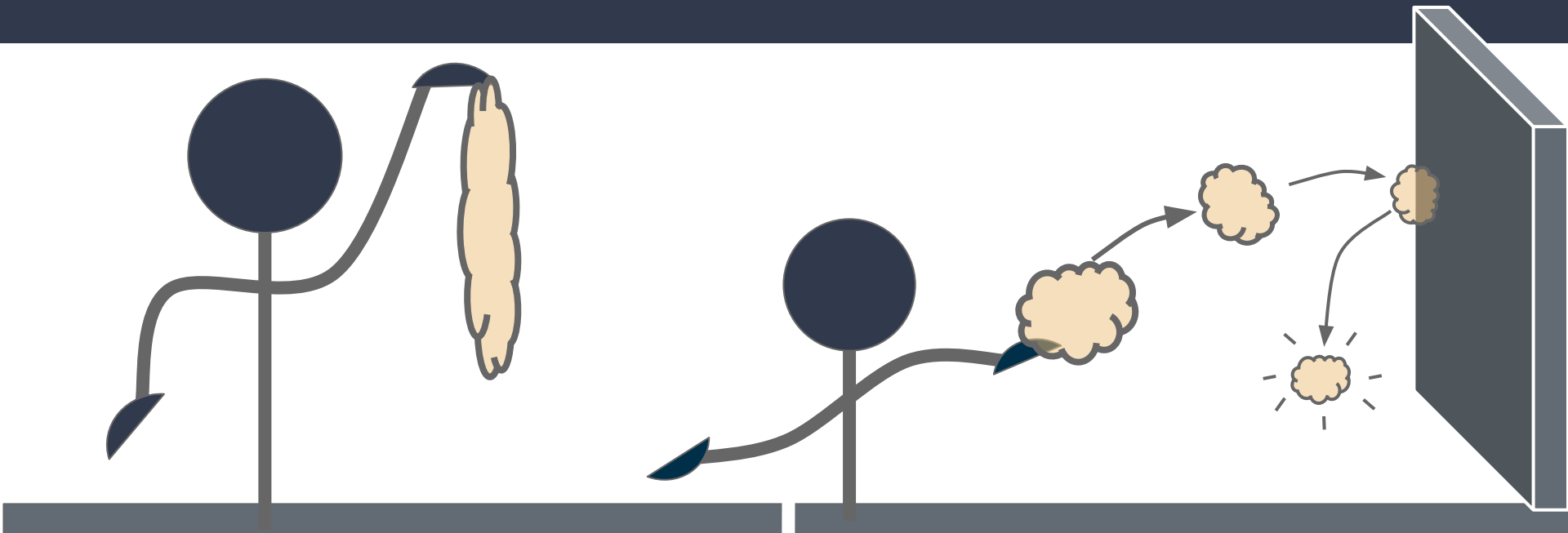


Thought experiment



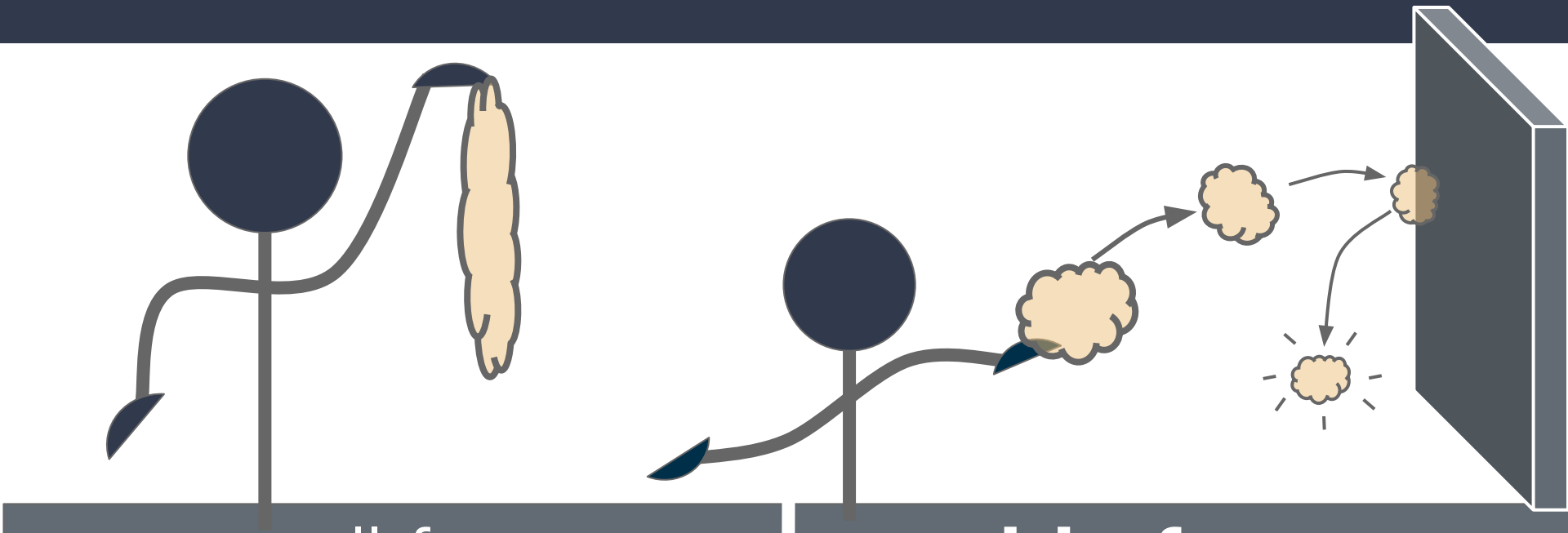
What's the difference?



small force

big force

What's the difference?



small force
big time

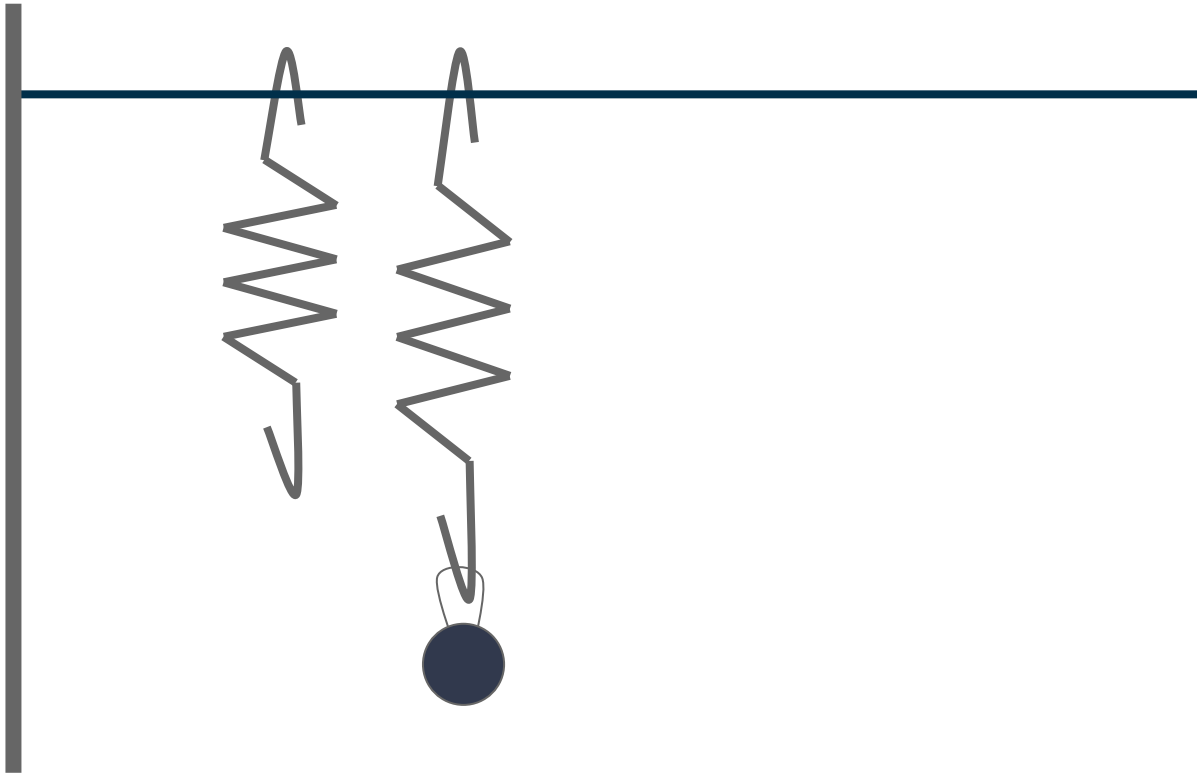
big force
small time

Models

ELASTIC
SPRING

Models

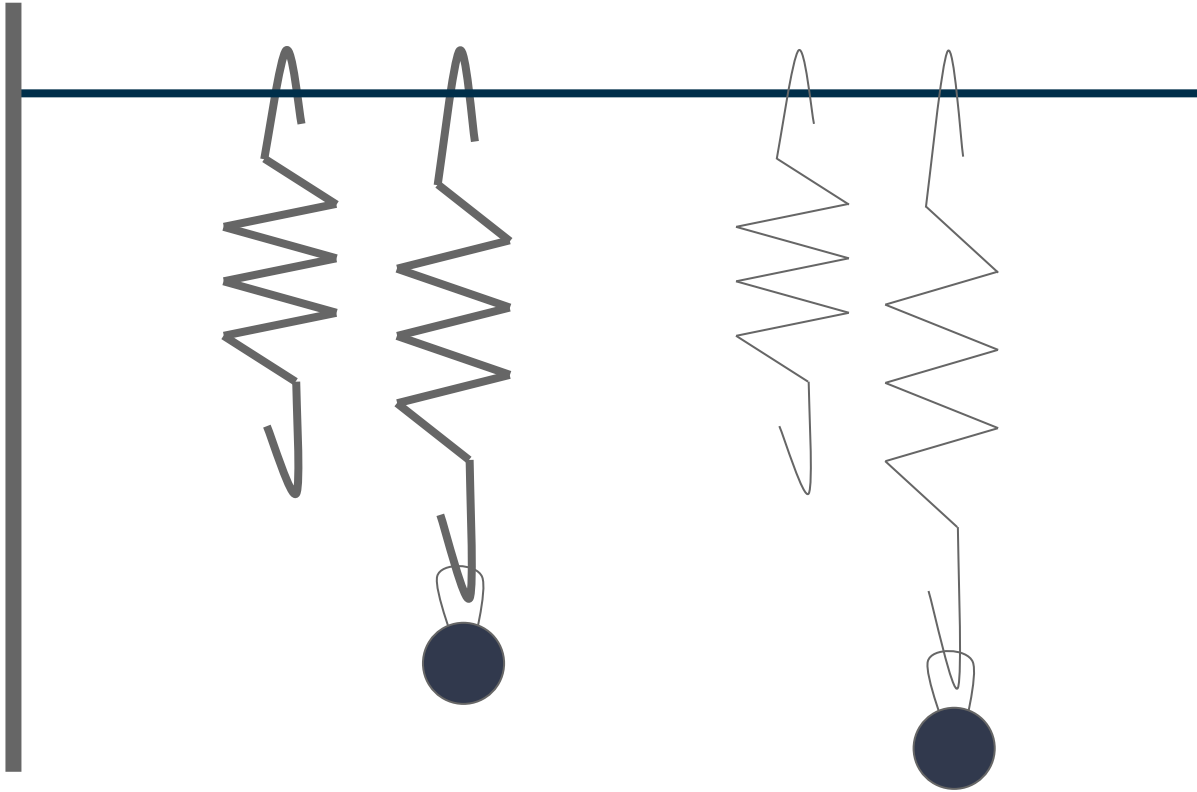
ELASTIC
SPRING



Models

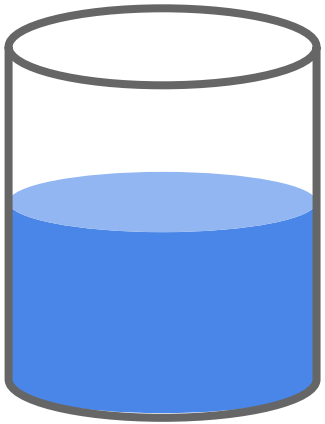
"spring constant"

ELASTIC
SPRING



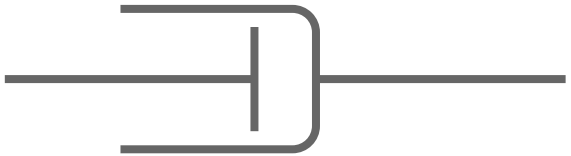
Models

VISCOUS
DASHPOT



Models

VISCOUS
DASHPOT



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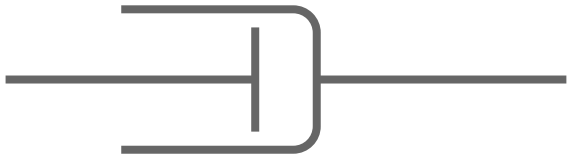
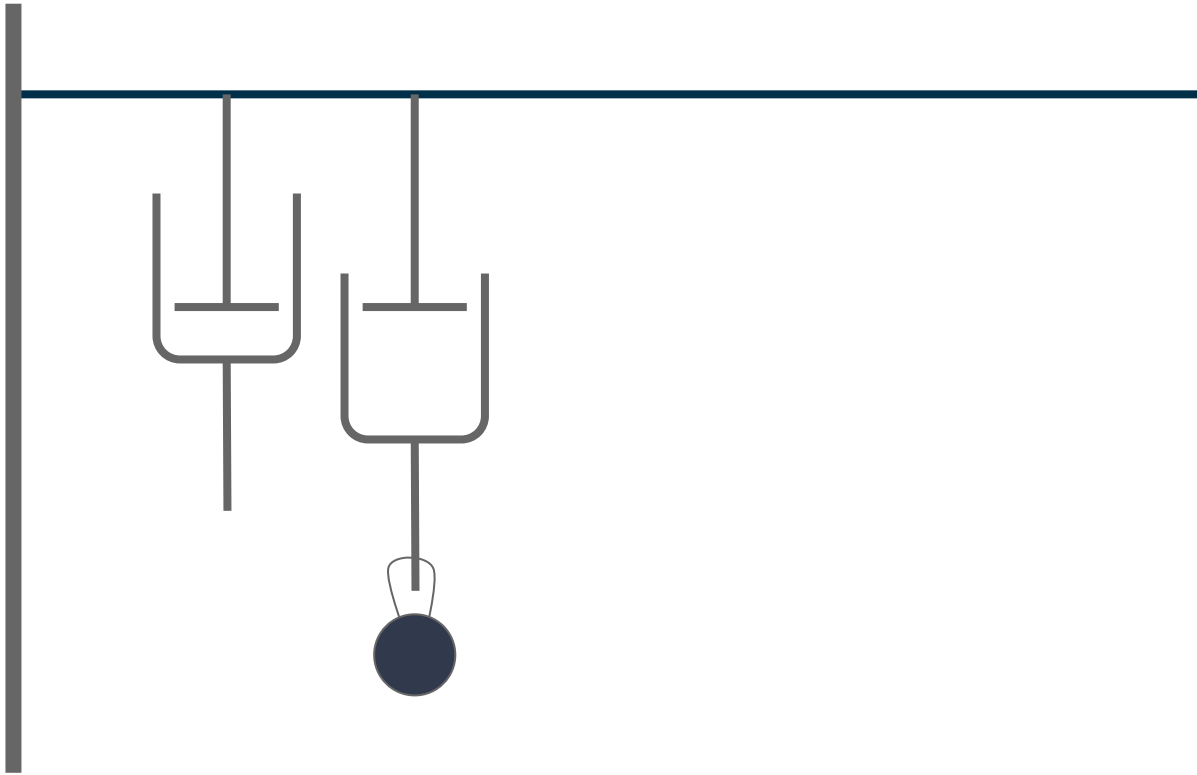
Models

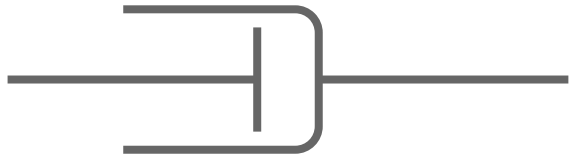
VISCOUS
DASHPOT

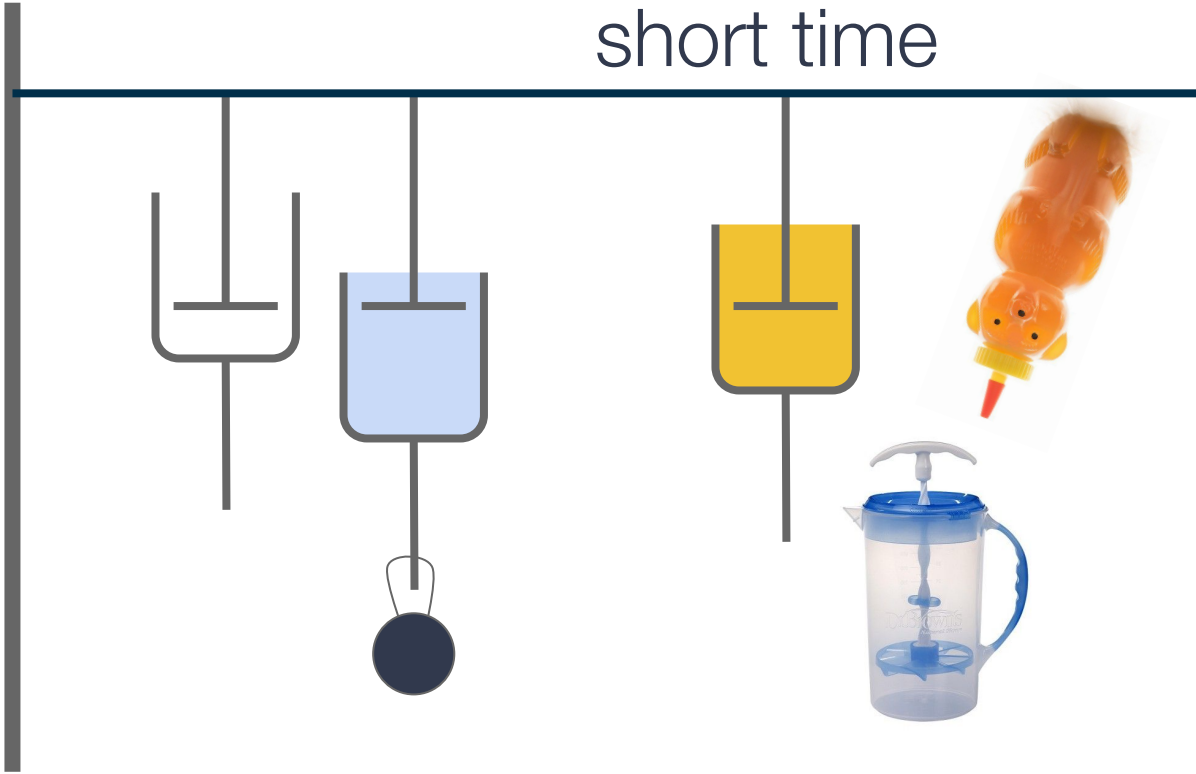




Models

VISCOUS
DASHPOT





Models

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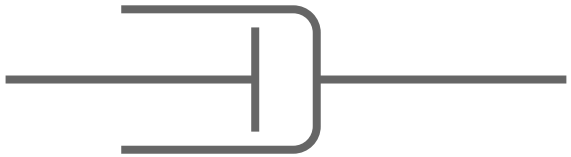
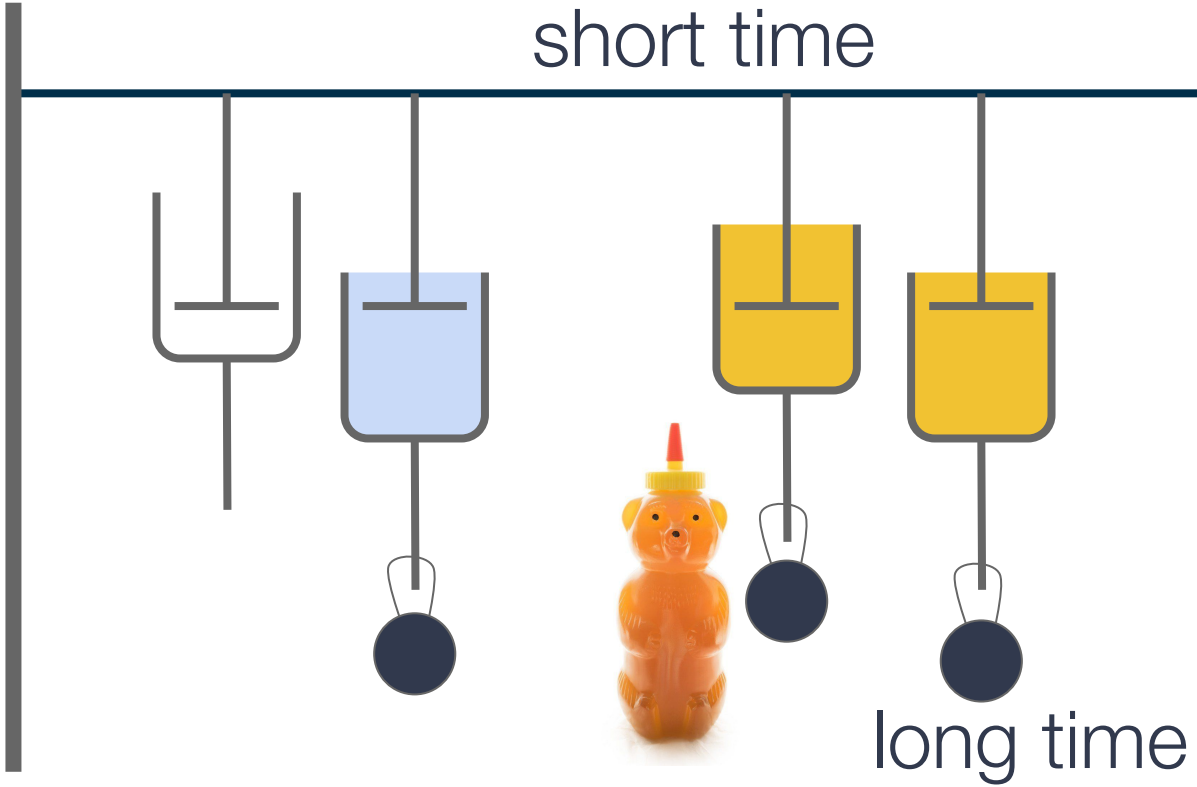
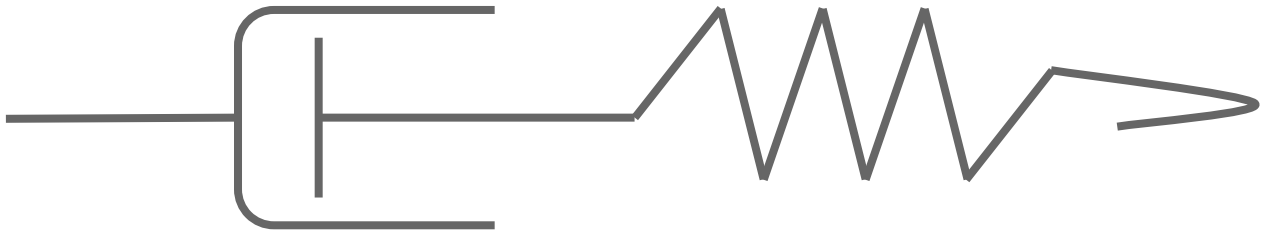


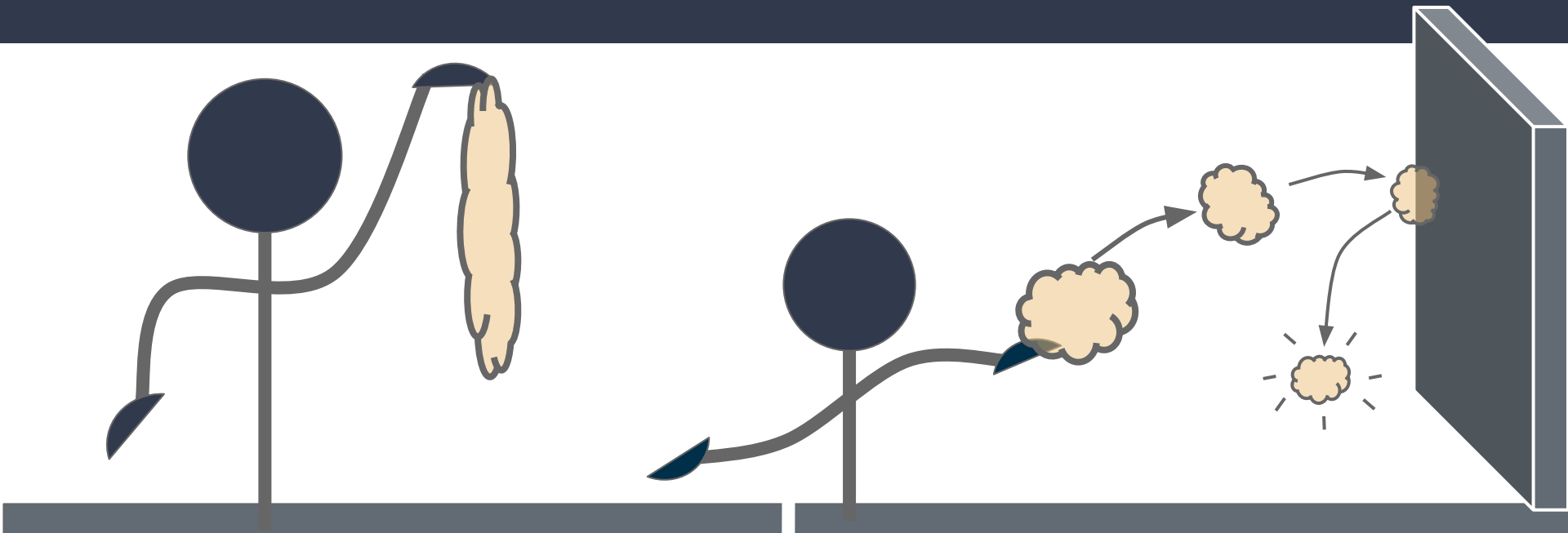


Maxwell model



VISCOUS + ELASTIC

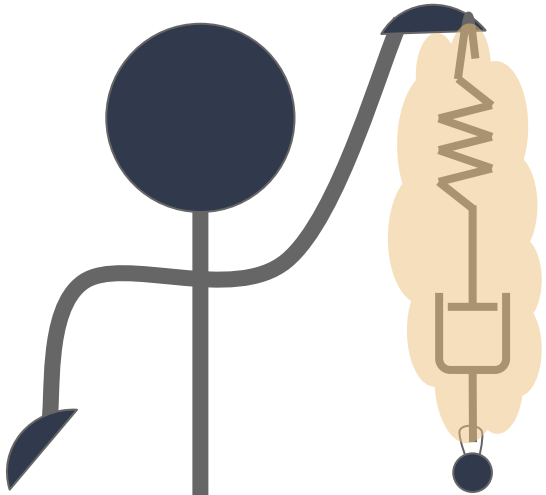
Recall our thought experiment



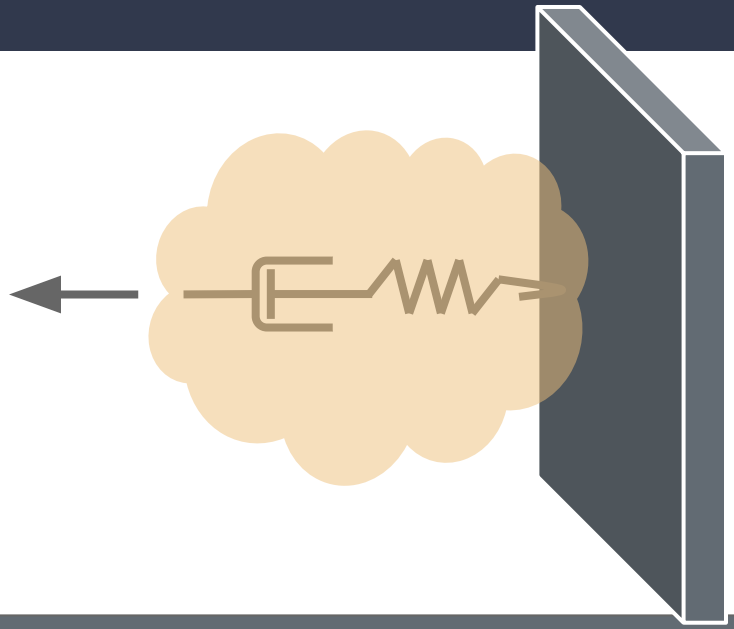
small force

big force

Recall our thought experiment

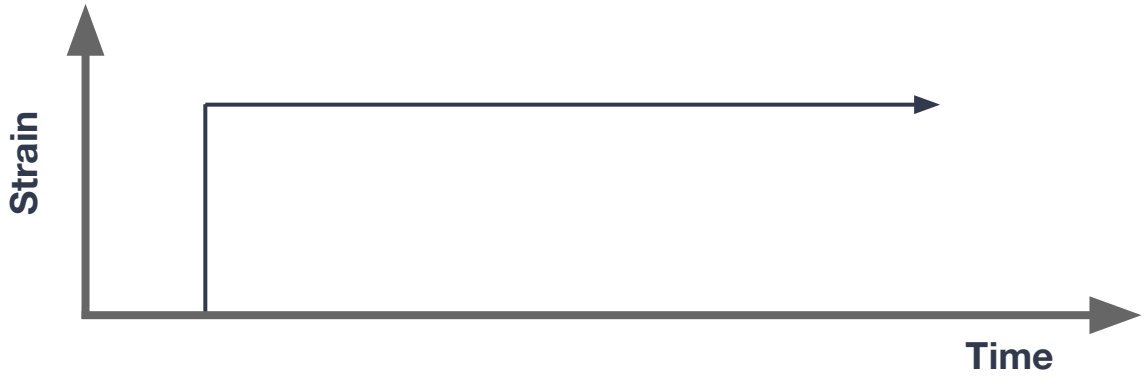


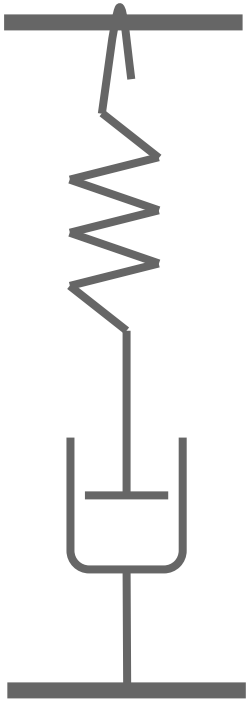
small force
big time



big force
small time

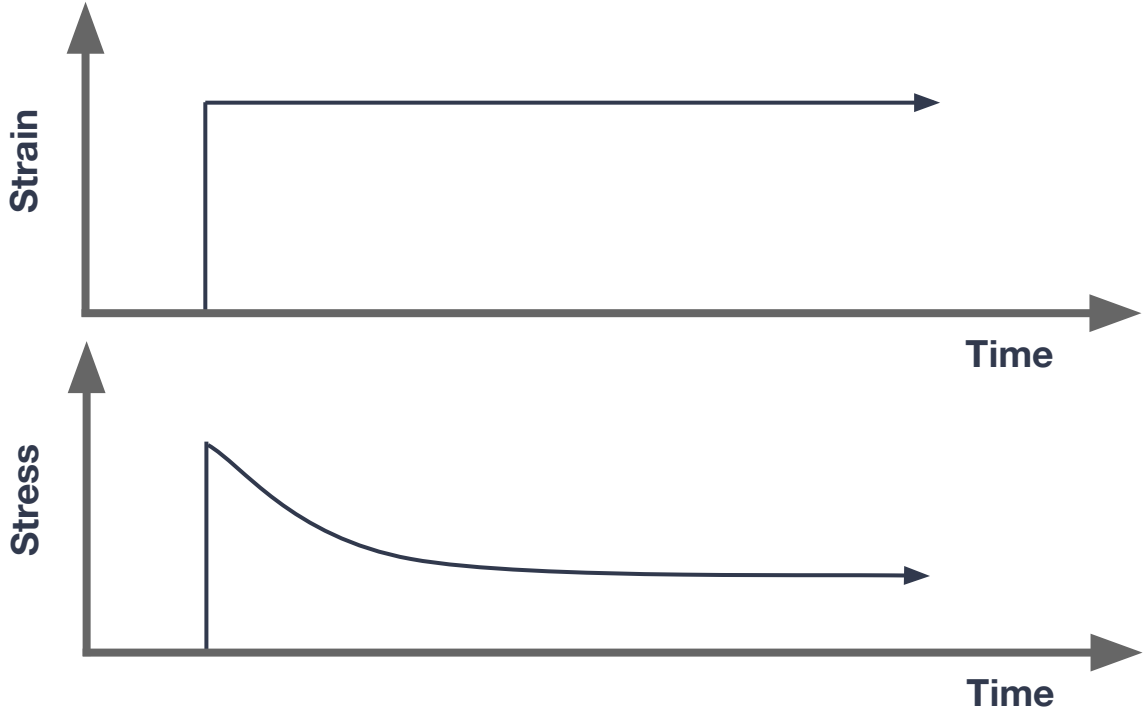
Stress relaxation

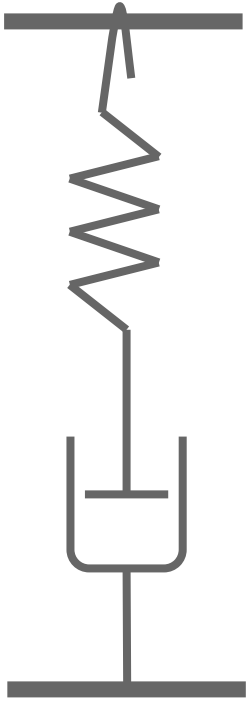




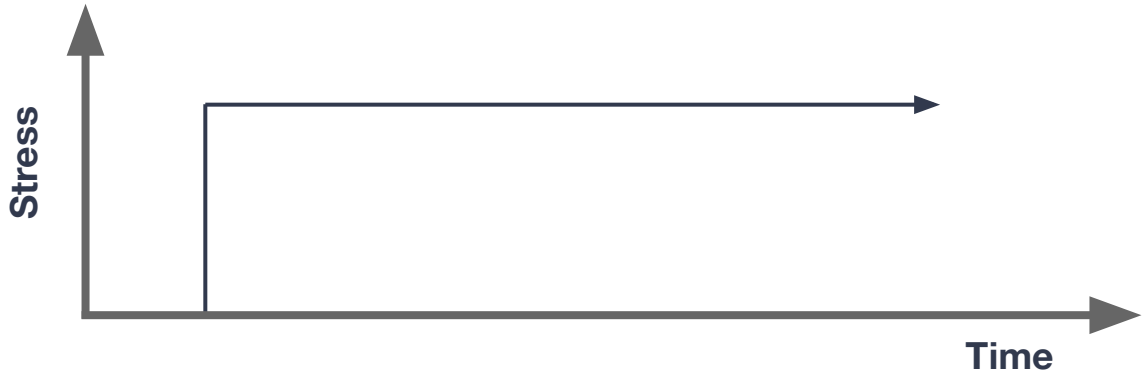
EX: rubber band around a newspaper

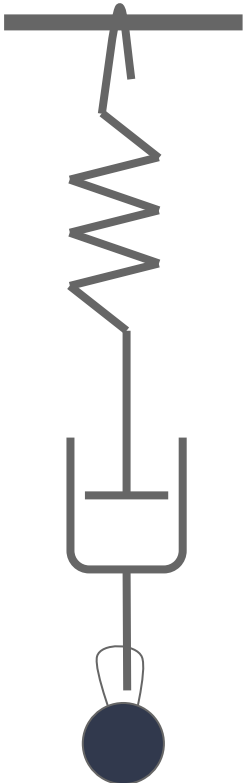
Stress relaxation





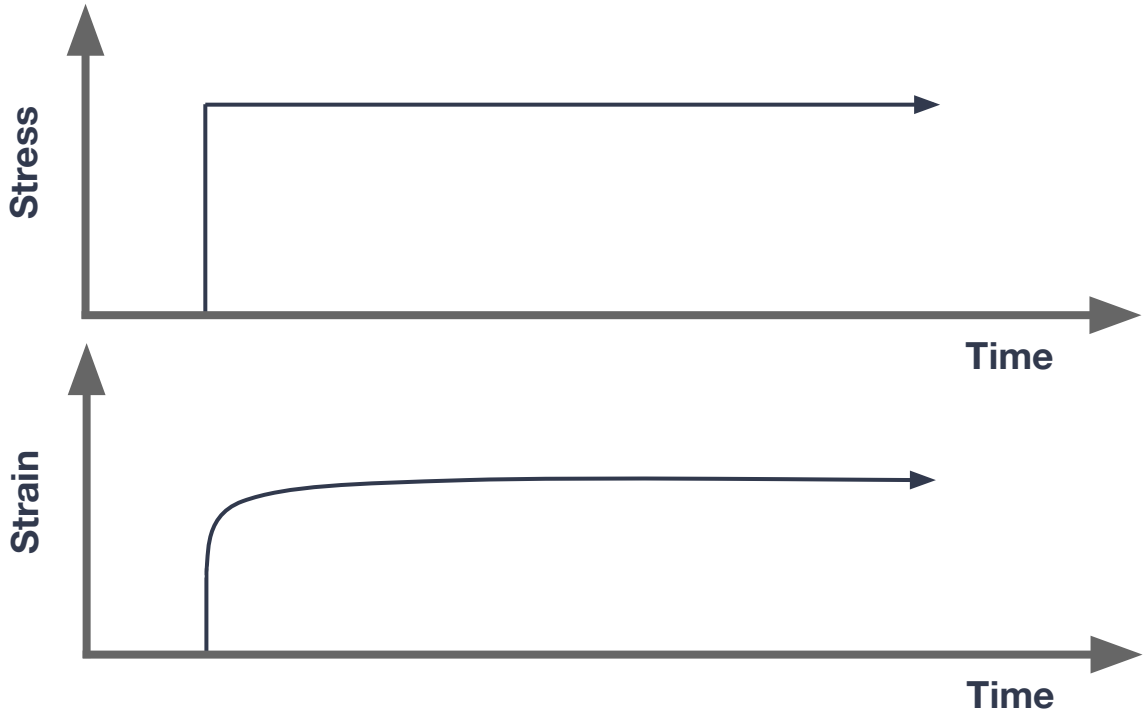
Creep

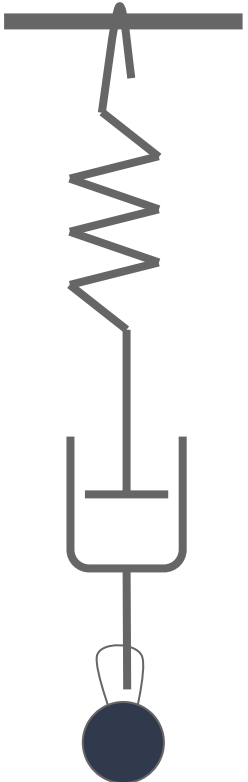




EX: rubber band hanging an ornament

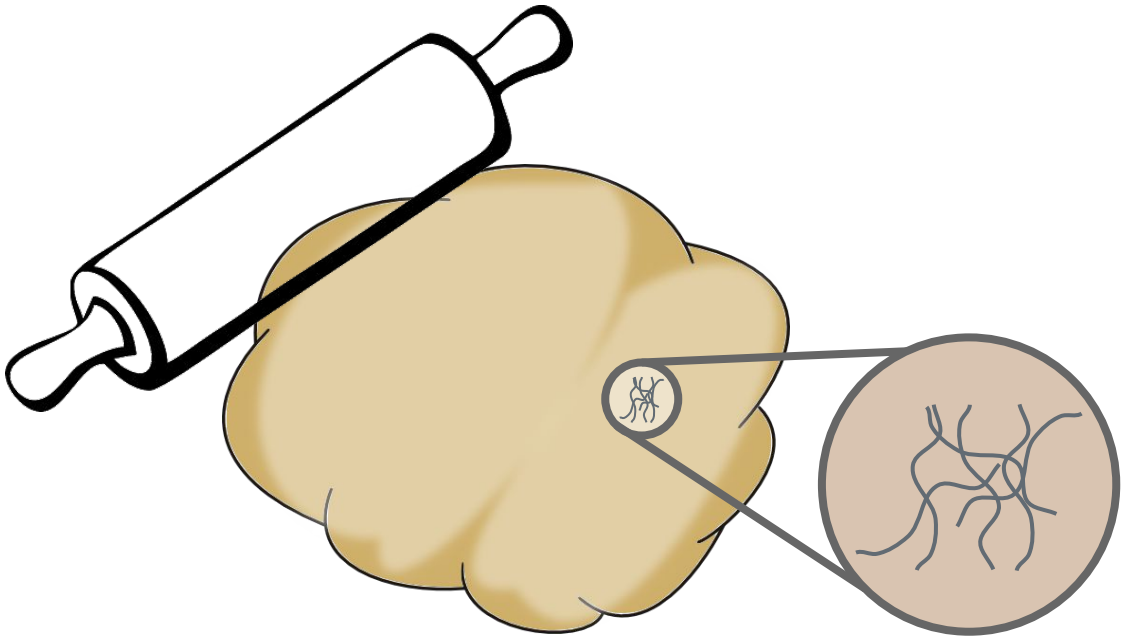
Creep





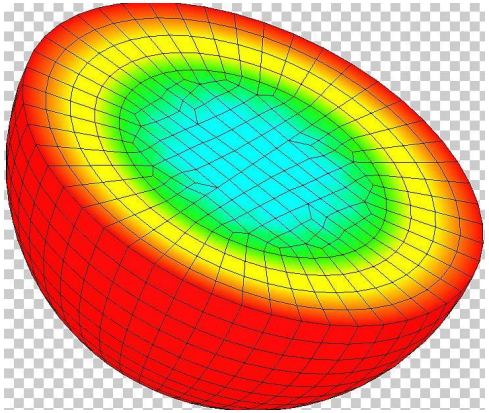
Main Point

- **Microstructure determines macrostructure**



Topics We Missed

- Heat Conduction
- Diffusion
- Microwaves
- Pressure Cooking
- Searing
- Emulsions



Lessons Beyond Science of Cooking

- Seemingly simple problems…
  - have complex solutions
  - are not well understood by modern science
- Top researchers ask the same questions you do