

Rheology Comics #2

Your mouth is a rheometer!

Rheologists use a machine called a rheometer to measure material properties, but everyone already has one of the best rheometers in the world: it's your mouth.

Inspired by all the sticky, gooey, slimy, chewy food we've ever eaten, this comic explores how rheologists use rheometers in experiments, and how you can do the same at home.



Funded by the Society of Rheology's
2023 Rheology Venture Fund.

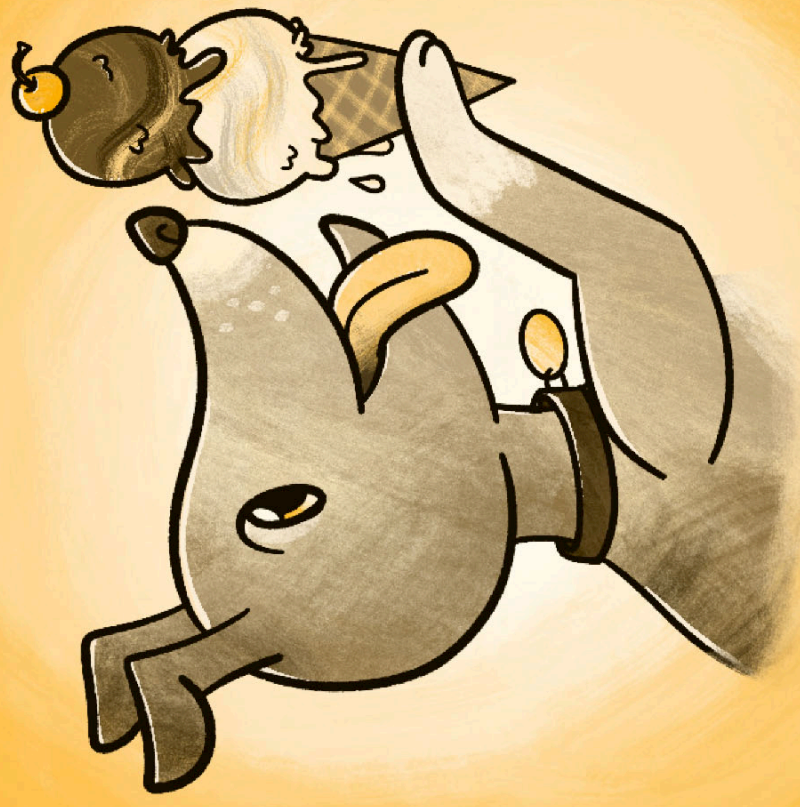
Learn more about rheology by following the QR code.

This comic is also available in:

Español • 日本語
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And more!

MOUTHFEEL



Your mouth is a rheometer

By Rob Campbell and Caroline Martin

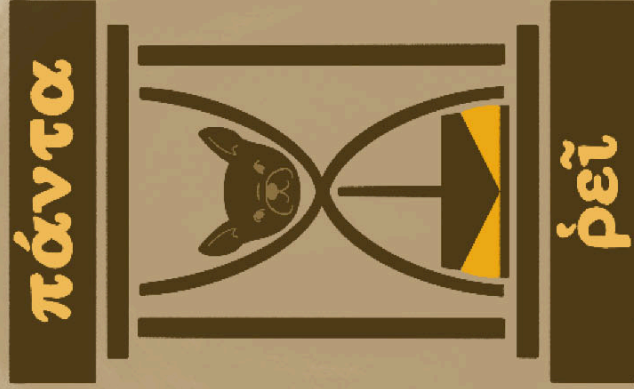


Thanks to the Society of Rheology and our educational consultants Victoria Russell and Kelsey Briselli.

Inspired by real research:

On Oreology, the fracture and flow of “milk’s favorite cookie®”
lead by Crystal Owens (2022)

Culinary fluid mechanics and other currents in food science
lead by Arnold Mathijssen (2023)



Glossary of **terms** in the back.

For more rheology, check out Rheology of Cats
rheologycomics.github.io/comic1-english

2024

v1.0

GLOSSARY

RHEOLOGY – the study of how things flow (especially materials in-between solid and liquid)

RHEOMETER – a tool that scientists and engineers use to measure the rheology of different materials

PARALLEL PLATE RHEOMETER – a material is sandwiched between two plates that twist. Good for gels and foams (ex: pudding, shampoo)

CONCENTRIC CYLINDER

RHEOMETER – a cylinder twists inside a cup and spreads a thin layer of material between them. Good for pourable or spreadable materials (ex: milk, paint)

VANE ROTOR RHEOMETER – blades, like a fan or a weather vane, rotate inside a cup that often has grooves. Good for chunky and greasy materials (ex: chunky peanut butter, cement slurry)

SHEAR STRESS – a force twisting or flowing across the surface of a material that pulls on the material (AKA the strength of the twist)

SHEAR RATE – how quickly or slowly the flow is changing in a certain space, like in between the parts of a rheometer (AKA the speed of the twist)

NORMAL FORCE – a force that pushes out from a surface. In a rheometer, shear force is the twist and normal force is the material pushing into the plate

Thanks for reading!



FOAM – a squishy material full of air bubbles (ex: bread, meringue, mousse, marshmallow)

GEL – a squishy solid that is full of liquid (ex. pudding, agar jelly, cooked pasta)

EMULSION – bubbles of one liquid floating in another liquid, sometimes making it act more solid (ex: salad dressing, mayonnaise)

RHEOPECTIC – when stress causes a liquid to temporarily become thicker and more elastic (ex: pancake batter, whipped cream)

YIELD STRESS FLUID AKA BINGHAM PLASTIC – a material that stays solid until enough stress is applied for it to flow (ex: curry paste, Nutella, tahini, peanut butter)

VISCOSITY – how “thick” a material is; it tells you how much stress needs to be added to change how the material flows

ELASTICITY – how springy a material is; it tells you how well a material bounces back to its original shape after you stop adding stress

VISCOELASTICITY – a mix of viscosity and elasticity; usually acting elastic over short times and viscous over long times

You can run these tests with your mouth! What will you study?

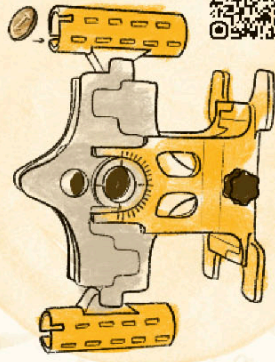
Think like a rheometer at your next meal, and measure:

- Plasticity:** How much does it change shape before it breaks? Does it hold together?
- Viscosity:** Is it easy to slurp off a spoon?
- Hardness:** How much force do you need to break it between your teeth?
- Elasticity:** Will it bounce back to its original shape between chews?
- Chewiness:** How many times do you need to chew it?
- Graininess:** Is it made of many small particles?
- Stickiness:** How much force does it take to remove it if it sticks to your mouth?
- Moisture:** Does it absorb saliva and make your mouth feel dry, or is it juicy?

Mouthcoating:

Does it feel like it coats your mouth after you eat it? (ex: fat, oil)

For technical measurements:
3D print your own parallel plate rheometer!



<https://github.com/crystalowens/oreometer>

Why do babies shove so many things in their mouths?

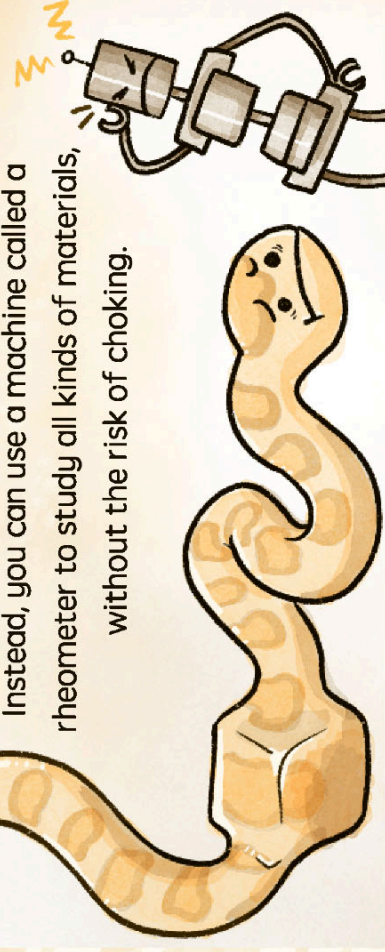
Adults use their hands and eyes to learn about the world. But babies like to use our best measuring tool —

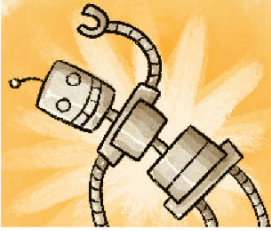


Our mouths are tools that tell us all about the structure and texture of the foods we eat. They measure the **rheology** of food so we know when it is safe to swallow.

But putting things in your mouth isn't always a good idea.

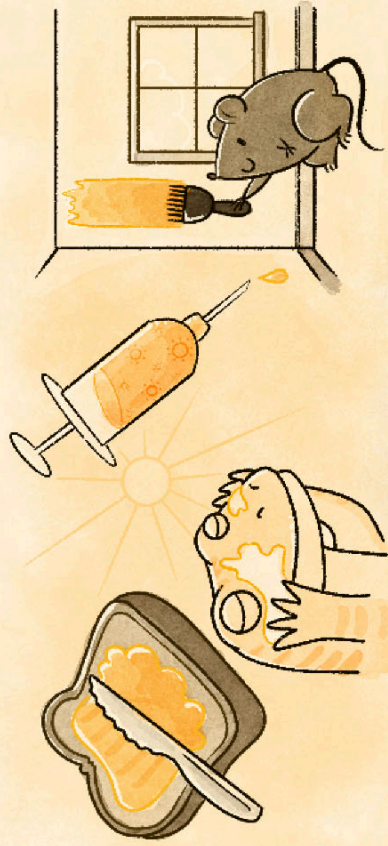
Instead, you can use a machine called a rheometer to study all kinds of materials, without the risk of choking.



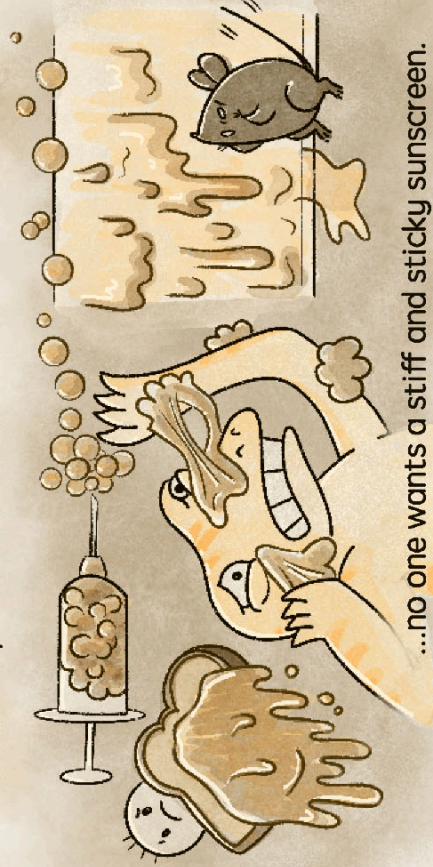


A **rheometer** is a tool that scientists and engineers use to measure how materials flow.

Those measurements help explain what's happening when we spread jam on toast, put sunscreen on our face, inject vaccines through a syringe, or paint a house.



And that information can help scientists and engineers decide if adding a new ingredient will help make spreadable materials better, instead of worse...



...no one wants a stiff and sticky sunscreen.

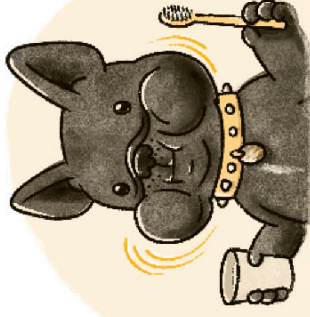
To study these complex textures with a rheometer, you need a lot of tests. Some of the most popular tests are:

How does it spread or squeeze?



Study **viscosity** with ROTATION tests
Measure shear stress or measure shear rate

What happens over time?



Study **viscoelasticity** with OSCILLATION tests
Small swish (small angle) or large swish (large angle)

How far can it stretch before it breaks?



Study **elasticity** with EXTENSION tests

Does it get stuck under pressure?



Study flow through a tube with PIPE FLOW tests

Since our mouths are such good rheometers, chefs have played with rheology and mouthfeel throughout history, transforming food to make it more complicated and fun!

Behold, my finest creations!

bread is a **foam**
air bubbles trapped in a solid or liquid

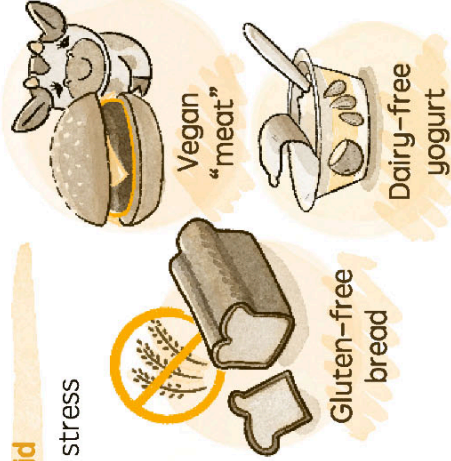
cooked pasta is a **gel**
a soft solid filled with liquid

salad dressing is an **emulsion**
bubbles of one liquid floating in another

pancake batter is **rheopectic**
it temporarily thickens when you mix it

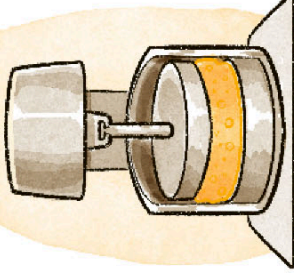
curry paste is a **yield-stress fluid**
it's solid until you add enough stress

And today, food rheologists use rheometers to help make new versions of food that mimic familiar textures.



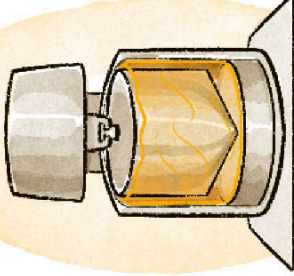
Different rheometers have different special abilities. Each one helps you study different types of materials. For example:

PARALLEL PLATE RHEOMETER



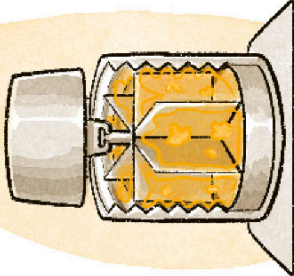
gels and foams
(pudding, shampoo)

CONCENTRIC CYLINDER RHEOMETER



pourable and spreadable materials
(milk, paint)

VANE ROTOR RHEOMETER



chunky or greasy materials
(chunky peanut butter, cement slurry)

But your mouth does all these things at the same time when it measures mouthfeel.

In fact, your mouth can recognize small changes in the texture and ingredients of food that even the best rheometers struggle to notice.



Why can I never win?

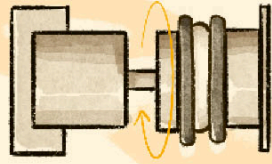
BODY VS. MACHINE

~the fight to enjoy a sandwich cookie~

[ROUND 1] THE TWIST

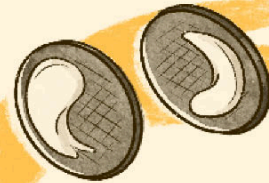


You can start by twisting apart the cookie, but how hard and how fast should you twist it? Can you twist it perfectly to split the cream between both halves?



Your hands and a parallel plate rheometer can both control the strength (**shear stress**) and speed (**shear rate**) of the twist.

And they both feel when the cream starts moving and the cookie starts twisting.



Different conditions (shear stresses, shear rates, or temperatures) can cause the cream to flow and split differently.

If you know these conditions, the twist tells you a lot about the rheology of the cream!

[ROUND 1 RESULT] TIE



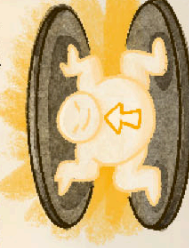
[ROUND 2] THE CHEW

When you chew and *eat* the cookie, your mouth feels every tiny change as the cookie crumbles into the cream and forms a single new material.

Your teeth and tongue quickly try many tests to find the best conditions to make this material safe to swallow.



A parallel plate rheometer gets some information about chew from the **normal force** that pushes back on it.



But until someone invents a rheometer that can do many tests at once, we still need many different rheometers to get close to learning the same amount of information your mouth learns in moments.

[ROUND 2 RESULT] MOUTH WINS!

