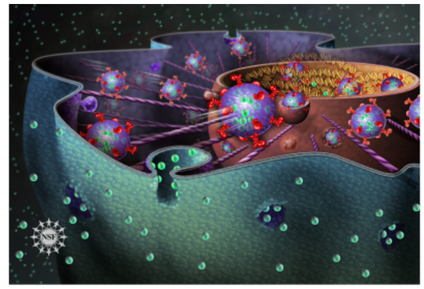
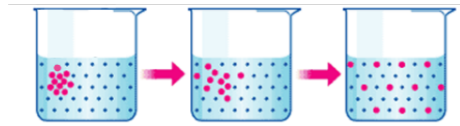
Diffusion and Mixing in the Intracellular World





- All small particles jiggle around due to being kicked by moving molecules. This "random walk" motion is called **diffusion.**
- Diffusion makes particles spread from where there are many to where there are few. But it is very slow over long distances.
- **Viscoelastic** materials are partly solid, partly liqud. They slow diffusion and are hard to mix.
- Living cells rely on churning by active chemical reactions to help mix their interior.

Part 1: Complex Fluids

1. Pour enough milk into a bowl to cover the bottom.

2. Make two identical batches of oobleck as follows:
Add <u>4 tbsp cornstarch</u> to each bowl.
Add $2\frac{1}{2}$ tbsp of vinegar to each bowl, mixing it into the cornstarch.

You should get a very thick gooey substance that is hard to stir and can be "ripped" apart with a stick.

What happens when you drag a stick through the milk?:
(a) it flows around the stick (b) it pushes back

What happens if you try to drag a stick quickly through the Oobleck?
(a) it flows around the stick (b) it pushes back

What about if you drag the stick slowly through the Oobleck?

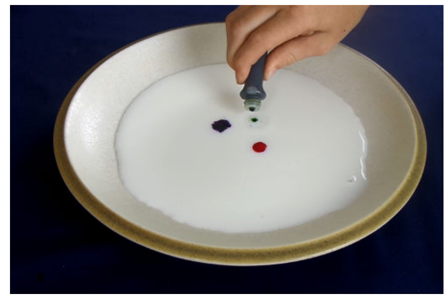
Suppose you push on a substance and it flows freely around your finger. Is that something: a solid? a liquid? a gas?

Suppose you push on a substance it resists the push and springs back when released. Is that something: a solid? a liquid? a gas?

The milk is a liquid – it easily flows and changes shape. The Oobleck is a **viscoelastic** material. It behaves like liquid and flows when pushed slowly, but like a fluid that pushes back when pushed quickly.

Can you think of other viscoelastic materials that flow if pulled slowly but can spring back if pulled fast?

3. Dissolve 2 drops food coloring in 1 spoon water. It should make a very dark liquid.
4. Put a drop of food coloring on the center surface of the milk and one of the Oobleck bowls. Set the second Oobleck bowl aside for now.



5. Measure the width of the colored spots on the surface.

Width of colored spot in milk: _______________ mm
Width of colored spot in Oobleck: _______________ mm
(enter your numbers on the group spreadsheet)

Leave the bowls where they are, undisturbed.

Make a prediction: when we come back to the bowls in about 30 minutes, how big do you think the colored spots will be?
in milk: _______________ in Oobleck: ________________

Part 2: Simulating Diffusion

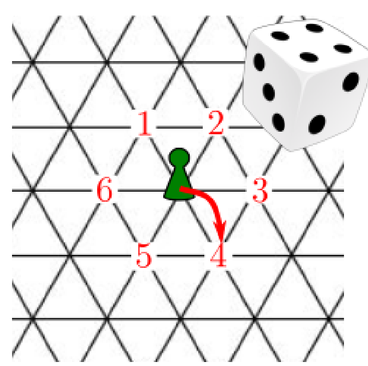
We will use a simulation to understand the behavior of tiny diffusing particles.

1. Place your random walker on the central red star.

Suppose you could move make the walker step in whatever direction you wanted.
How many steps would it take for it to move outside blue fence? _____________
How many steps would it take for it to move outside the red fence? ___________

Now your walker will represent a microscopic particle undergoing **diffusion**.

2. Start rolling the dice, each time moving the walker in the direction shown.



Where is your walker after 5 steps?
Row ___________, Diagonal ___________

(Enter your position on the group spreadsheet)

All of our particles started at the same point. What happened to them after they had a chance to diffuse? Circle one:
(a) They stayed in the same place
(b) They stayed together
(c) They spread out, with some staying nearby and others moving further
(d) They all moved the same distance away from the center

3. Start back at the center. Keep rolling the dice and moving your particle.

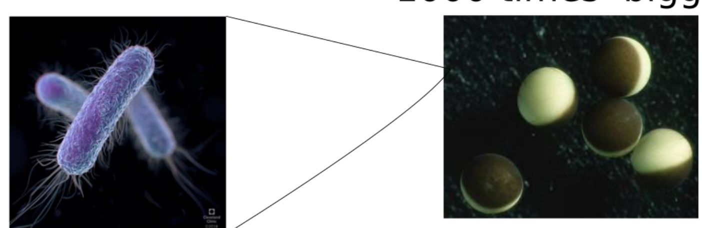
How many steps does it take for the particle to step outside the blue fence? ________
(enter your number in the group spreadsheet)

Make a prediction: on average, how many steps do you think it will take for the particle to step outside the red fence? ___________

5. Start back at the center and keep rolling the dice.

How many steps does it actually take for the particle to step outside the red fence?
(enter your number in the group spreadsheet)
Be patient --- this can take a while! If you finish early, do another run so we can get more data.

Diffusion is very slow for moving molecules across large distances. Small cells (like bacteria) can wait for diffusion to mix their molecules around. But large cells (like frog eggs or human nerve cells) can't rely on diffusion alone!



Part 3: Diffusion and Mixing in Complex Fluids

1. Measure the width of the colored spots in your bowl of milk and oobleck.

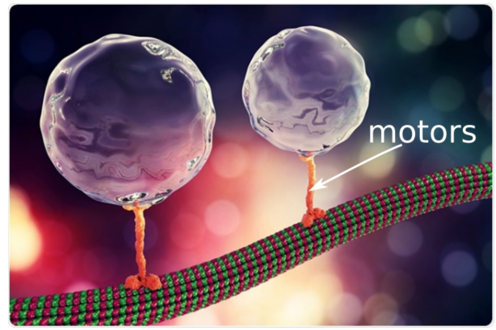
Final width of spot in soy milk:________________
Final width of spot in cow milk: ________________
(enter your results in the spreadsheet)

Which spot spread out more?

Why do you think the spots spread out at all?

Does diffusion spread out particles faster in a liquid or in a viscoelastic material? Why do you think this is?

Cells are full of viscoelastic materials. This makes it very slow for particles to spread across the cell by diffusion alone. Instead, a cell uses "motor" molecules to drag particles in whatever direction is needed.



Next, we'll have you serve as the motors responsible for mixing up a cell's interior.

2. Put a drop of undiluted food coloring on the center surface of each Oobleck.

3. In one of the bowls, try mixing the food coloring into the Oobleck. Mix the best you can for 30 seconds.

Were you able to make your Oobleck look **homogeneous** (an even color with no stripes or splotches)?

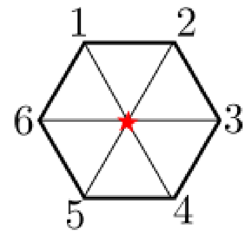
Cells have the same problem – it is very hard to mix something when the fluid is highly viscous (slow to flow) and partly elastic (pushes back). Diffusion is slow and even pulling material through by force leaves unmixed gaps behind.

4. Sprinkle 1 heaping teaspoon of baking soda over the surface of the other bowl. Mix the baking soda and the colored spot for 30 sec.

What happens?

Which bowl ended up better mixed?   with baking soda   without baking soda

The fluid inside a cell might be viscoelastic, but it is also **active** there is a constant churning of chemical reactions that pushes material around and mixes up the interior. Cells rely on this to speed up how quickly molecules can find each other. In fact, when you kill a cell or deprive it of energy, the cell interior freezes up and everything starts moving and mixing much more slowly.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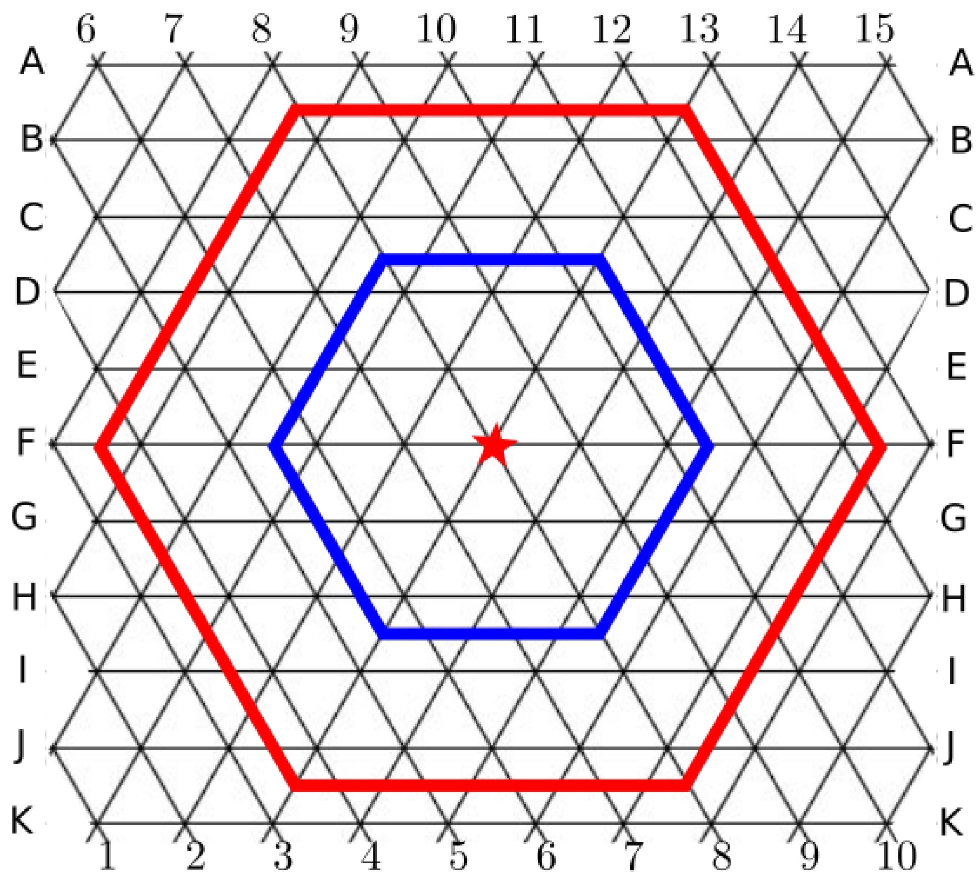
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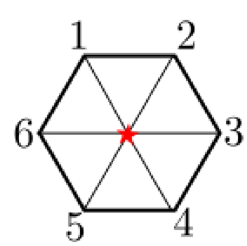
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