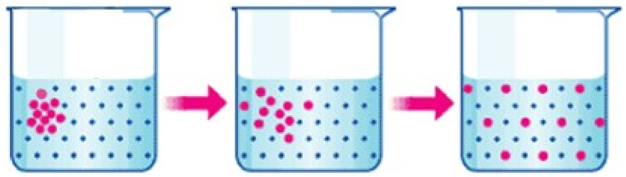
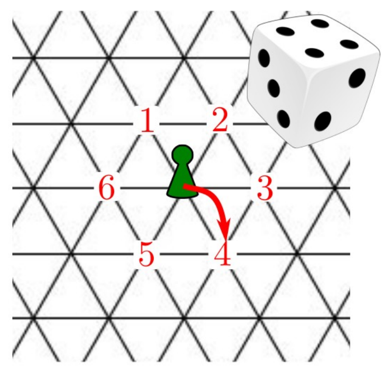
Diffusion: Spreading with Random Walks

- All small particles in a fluid jiggle around due to being kicked by fluid molecules and other particles. This makes them move in "random walks".
- **Diffusion**: randomly moving particles spread out from places where there are many (high concentration) to places where there are few (low concentration).
- **Density gradient:** in very dense regions, particles push out on each other and spread faster to less-dense regions



Part 1: Simulating Diffusion

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



1. Place a token on the central red star of your own printed triangular network (separate one for each student). The "walker", which represents a microscopic particle in water, will step along the network one line segment at a time.

2. Start rolling your dice, each time moving the walker in the direction shown.
All of the particles started at the center. 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 particles.
How many steps does it take for the particle to step outside the **blue** fence?

Walker	#1	#2	#3	#4	Average
Steps to leave blue fence					

Find the average steps to leave the blue fence (add up all the steps and divide by the number of walkers). Write your average up on the board to share with other groups.

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

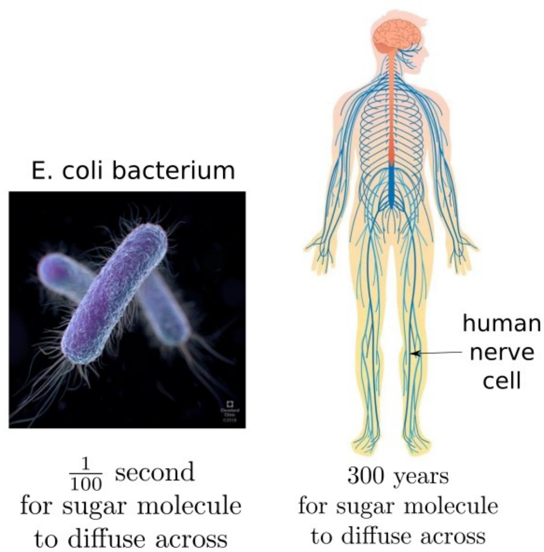
5. Start back at the center and keep rolling the dice.
How many steps does it take for the particle to step outside the **red** fence?

Walker	#1	#2	#3	#4	Average
Steps to leave red fence					

Calculate the average number of steps to leave the red fence.

Write your average on the board to share with other groups.

Diffusion is very slow for moving across large distances! Molecules can get across a small distance (like a bacterium) by diffusion alone. But to get across distances we can see, other ways of transport are needed to move particles around.



One way to spread molecules through a fluid faster is with a **density gradient**. In a region where there are a lot of dissolved particles, they will hit each other more often as they jiggle and so get pushed outward faster. Molds and mushrooms use this to help grow their underground `hyphae' (living threads).

6. Have all group members start their tokens at the center (on top of each other) on a single sheet. Take turns rolling, but this time the "molecules" will bounce off each other. If your token has to step to a spot that is blocked, move it in the opposite direction instead. (If the opposite direction is blocked too, do not move anywhere on that step). Keep track of how many steps each token has to take to leave the blue fence?

How many steps does it take for the particle to step outside the **blue** fence?

Walker	#1	#2	#3	#4	Average
Steps to leave blue fence					

When your tokens were running into each other (compared to by themselves), they spread out to the blue fence: faster, slower, the same ?

Part 2: Observing Spreading of Molecules in a Fluid

1. Put the petri dish on a blank sheet of paper. Place 6 skittles of assorted colors around the inside boundary of a petri dish.

2. Pour enough water into the petri dish to cover the bottom. Observe for a couple of minutes. Do not touch the dish or shake the table!

Discuss: what do you see?

Do the colors: spread out or stay put ?

What happens when different colored regions touch each other? Do the colors mix?
Yes / no

3. After a couple more minutes, pick up a skittle and look at the bottom.
What color do you see at the bottom of the skittles now? ________________

Discuss: Where did the original color molecules go?

As the skittle dissolves, sugar and coloring molecules break off the skittles and go into the water. They **diffuse** outward, from the place where there is high density (near the skittle) to where there is low density (further away).

Discuss: Why did the colors spread until they touched each other and then stop?

The spreading is fast at first, as the sugar molecules push outward on each other. This is motion due to a **density gradient.** Once the dissolving sugars from the different skittles meet, there is no more difference in density – they get pushed just as hard in all directions. The molecules will still move around and diffuse, but with no outward bias their spread is much slower!

4. If you have time: try putting a sugar cube in the middle where 2 or more colors join.
What happens? Can you explain why?