

The Jiggle That Would Not Stop: Reading the Evidence for Moving Particles

Learning target: I can use evidence from a reading to explain how scientists learned that particles are always moving, and how temperature is linked to their average motion.

Reading with evidence

About 40 min

Individual

MS-PS1-4 · practice

MS-PS3-4 · supports

reading

writing

Name _____

Date _____

Period _____

Directions

Read the passage once straight through. Then read it again with a pencil: the paragraphs are numbered, so mark each place where someone tests an idea and each place where the passage connects motion to temperature. Answer the questions in complete sentences. When a question asks for evidence, quote or closely paraphrase the passage and give the paragraph number in brackets, like this: [3].

You will need: This worksheet, Pencil, Highlighter (optional)

The Jiggle That Would Not Stop

[1] In the summer of 1827, the Scottish botanist Robert Brown was studying pollen from a wildflower under his microscope. He had placed the pollen grains in a drop of water, and he noticed something strange. Tiny specks that had come out of the grains were trembling and darting about. They never settled down. Each speck zigzagged a little one way, then a little another way, and it kept going for as long as Brown watched.

[2] Brown's first thought was that the specks might be alive. Pollen comes from living plants, and living things move. So he tested the idea. He ground up bits of glass and rock, materials that had never been alive, and put those specks in water too. They jiggled in exactly the same restless way. Whatever was causing the motion, it was not life. Brown described what he saw with great care, but he could not explain it. For almost eighty years the jiggling, now called **Brownian motion**, stayed a puzzle.

[3] In 1905 a young physicist named Albert Einstein proposed an explanation. Suppose, he reasoned, that water is made of particles far too small to see, and that those particles are always moving in every direction. A speck like the ones Brown saw is enormous compared with a water molecule, thousands of times wider, but it is still small enough to feel the hits. Every instant, a huge number of water molecules crash into it from all sides. At any moment, slightly more of them happen to strike one side than the other, so the speck gets nudged. A moment later the uneven push comes from a different side, and the speck lurches a new way. The speck is not moving by itself. It is being bumped by the invisible particles around it.

[4] Einstein's idea did more than explain. It made predictions that could be checked, including how far a speck should wander in a given time. Around 1908 the French physicist Jean Perrin tracked tiny

particles under a microscope, recorded their paths and measured how far they drifted. His results matched Einstein's predictions. Perrin's measurements persuaded most of the remaining doubters that atoms and molecules are real, and in 1926 he received the Nobel Prize in Physics.

[5] Brownian motion also shows how temperature and particle motion are linked. When the same kind of specks are watched in warm water, they jiggle more vigorously than in cold water. A thermometer cannot see molecules, but what it reports depends on them: the higher the temperature of a sample, the faster its particles are moving **on average**. Those two words matter. In any glass of water, some molecules are moving quickly and others slowly at each moment, and they keep trading speed as they collide. Warming the water raises the average speed; cooling it lowers the average.

[6] The same restless motion explains how a drop of food coloring can spread through water that no one stirs. Moving water molecules keep knocking the dye particles about, and the dye particles are moving too, so over time they wander away from the crowded spot where the drop landed and toward places where there are fewer of them. Spreading caused only by this random motion is called **diffusion**. In warmer water the particles move faster on average, so diffusion is faster. In a real cup, gentle currents in the water also help carry the color, but the random motion of the particles never stops.

[7] Every state of matter has this motion, although it looks different in each one. In a gas such as air, the particles are far apart and fly freely; specks of smoke drifting in still air jiggle just as Brown's specks do in water. In a liquid, the particles stay close together but slide past one another. In a solid, particles are held in place, yet they still vibrate back and forth around their positions. Cooling a sample slows its particles, and warming it speeds them up. Not one particle changes its size along the way. What changes is how fast the particles move and how freely they can move past one another.

An original passage written for this worksheet. The dates and names are historical; Brown, Einstein and Perrin are real scientists.

Part A: Find the evidence

1. According to paragraph 2, what was Brown's first explanation for the jiggling? Describe the test he ran and explain why its result ruled that explanation out.

2. Paragraph 3 says the speck 'is not moving by itself.' What is actually making it move, and why does the speck change direction again and again? Cite the paragraph.

3. Paragraph 3 says the speck is thousands of times wider than a water molecule but 'still small enough to feel the hits.' Why would a much larger object, such as a grain of sand, sit still in the same water even though it is being hit too?

4. Brown described the motion very carefully, yet the passage says Perrin's work is what persuaded most doubters. Using paragraph 4, explain what Perrin did that Brown did not do.

5. Which statement about a glass of water at 20 °C is best supported by paragraph 5?

- ☐ A. Every molecule in the glass is moving at exactly the same speed.
- ☐ B. The molecules are moving at many different speeds, and 20 °C reflects their average.
- ☐ C. The molecules stop moving once the water stops swirling.
- ☐ D. The thermometer measures the speed of the single fastest molecule.

6. True or false: according to the passage, the particles of a solid do not move at all. Give the paragraph number that supports your answer.

☐ True ☐ False Explain your thinking:

Part B: Use the evidence

7. Predict what you would see if you watched Brown's specks in a drop of water that is slowly cooled from 30 °C to 5 °C (still a liquid). Explain your prediction using paragraph 5.

8. Paragraph 6 says that in a real cup, 'gentle currents in the water also help carry the color.' Why is it still fair to say that diffusion happens faster in warmer water? Describe a way to spread dye in water where currents could not help.

9. Paragraph 7 says that as a sample is cooled or warmed, 'not one particle changes its size.' Then what does change when ice melts into liquid water? Use two ideas from paragraph 7.

10. Does the passage give evidence that particles move in **every** state of matter? Write a short argument. Use evidence from at least two different paragraphs, and point out one part of the claim that the passage states without showing any evidence for it.

A map of the passage

Before answering, fill in this map in the margin. Paragraphs 1-2: what Brown saw and how he tested it. Paragraphs 3-4: who explained it and who checked the explanation. Paragraph 5: the link to temperature. Paragraph 6: the link to dye spreading. Paragraph 7: the three states. When a question names a paragraph, start your answer by rereading only that paragraph.

Why Perrin's measurements counted

Einstein predicted that a speck's typical distance from where it started does not grow in step with time: if you watch four times as long, the speck has typically wandered only about twice as far. Explain why a zigzag path made of random steps would wander away from its start more slowly than a speck moving in a straight line. Then describe how Perrin could have used a microscope, a grid and a clock to check this prediction, and say what result would have shown Einstein was wrong.