

SCENE: PLAYING “HALFSIES” RAISES BIG QUESTIONS ABOUT TINY THINGS

Setting: Adam and Zena are over at their Aunt Lucy's house after school, with their friend Olivia.

Adam: Hey, Aunt Lucy! These are the best brownies ever. Thanks for baking them.

Aunt Lucy: *(from another room)* You're welcome. You guys can go ahead and finish them up.

Zena: There are just two left. Olivia, you're the guest here, so you can have one. Adam, let's make the other one last a while. Let's play halvesies.

Olivia: *(with a mouthful of brownie)* What's “halfsies”?

Zena: That's where one of us takes half, and then the other takes half of what's left, and we go back and forth like that forever, so that we're never completely done eating the brownie.

Adam: Well, that's unfair, because whoever goes first gets half of the whole, plus more pieces later. But on top of that, the whole idea is crazy because we would have to finish the brownie sooner or later. Eventually, someone will eat the last crumb.

Zena: I'll let you go first, so you don't have to worry about the fairness thing. It's worth it to me because it's not ridiculous. Playing halvesies will make the brownie last forever. Forever, I tell you! *(She laughs like a mad scientist in a movie. Adam rolls his eyes.)* There will always be another half left, no matter how small a half it is. There's no such thing as a smallest **particle** of brownie. It might take a magnifying glass, a razor blade, and a steady hand, but we'll keep cutting those crumbs in half!

Adam: That's the goofiest idea I've ever heard. Obviously at some point, the remaining crumb of brownie would get too small to see, even with a magnifying glass. And at some point, you would get down to a crumb that was smaller than the width of the edge of a razor blade. So you couldn't cut it.

Zena: *(waving her hand dismissively)* I don't care about those practical problems. In fact, you can have the whole brownie for all I care, but only if you admit that I'm right in **theory**. Just for the sake of argument, imagine that every time we cut the brownie in half, we also got a magnifying glass that was twice as powerful as the one we used before, and a knife that was twice as sharp as the one we used before. With those magical tools, we could keep dividing the brownie in half no matter how small it got, and we'd never be done.

Olivia: Um, if you guys are just going to talk, can I have that last brownie?

Zena and Adam: No!

Adam: Even if we could always use greater magnification and a sharper knife, I think at some point we would come to a smallest piece of brownie.

Zena: Why? Whatever piece you've got must have two halves, right? Just like in math, there's no number so small that you can't divide it by two.

Adam: I'm saying that once you cut the brownie enough times, you would get to a **particle** so tiny that if you cut it apart, you wouldn't have brownie any more. Instead you'd have...I don't know...maybe tiny pieces of the ingredients that went into the brownie in the first place. You'd be cutting a tiny piece of sugar away from a tiny piece of flour, salt, baking powder, egg, or chocolate. A brownie is only a brownie if it has all those things, so you'd be breaking your teeny-weeny crumb into parts that aren't brownie substance anymore.

It's like if you take a parking lot full of cars and keep dividing it in half, you still have cars for a while. But at some point, you get down to one car. After that, if you keep dividing, you end up with some part of a car—a wheel or a bumper or something—but that's not a car anymore.

Zena: A car is made of separate parts, but I think that's different from a brownie. A brownie is made of ingredients, but they're all blended together into a smooth batter, and when you cook the batter, they all sort of dissolve and melt together and puff up in some kind of chemical **reaction**, right? And it all becomes—ta da!—solid brownie through and through. And then it's halvesies, baby, forever and ever!

Adam: I bet Aunt Lucy would know about this. She took a lot of chemistry in college for her engineering degree, didn't she? Hey, Aunt Lucy—

Aunt Lucy: *(coming into the room)* Hey, yeah, I couldn't help overhearing your conversation. Actually, you two are repeating a very old argument about the nature of matter. Back in ancient Greece, there was a philosopher named Democritus who believed that everything was made of tiny **particles** he called **atoms**. He thought an **atom** was the smallest piece of something and couldn't be cut in half.

Olivia: So that's like Adam's **theory**, right?

Aunt Lucy: Right, Adam's **theory** of **atoms**. But not everyone agreed with Democritus. Another philosopher named Aristotle had an especially negative **reaction** to **atomic theory**. Aristotle couldn't imagine absolutely empty space between **particles** of matter. He wrote that “nature abhors a vacuum,” meaning there is no such thing as space without any matter in it. Since he couldn't imagine empty space between **atoms**, he didn't believe in **atoms**. He thought matter had to be **continuous** instead of separated into **particles**. So for Aristotle, there was no smallest possible piece of a substance.

Olivia: That's like Zena's **theory** that brownies could be divided in half infinitely, if you had a sharp enough knife.

Aunt Lucy: Right. Aristotle thought of matter as being **continuous**, flowing together without any gaps, like water. Democritus thought of matter as being made of **particles**. He compared the basic structure of all matter to sand, not water. Democritus thought even water was like sand, if only we could look at it closely enough.

But Aristotle was much more famous and influential than Democritus. So people believed for thousands of years that Aristotle was right about matter being **continuous**, not particulate. It wasn't until the start of the nineteenth century that chemists started taking **atomic theory** seriously again.

Zena: The nineteenth century is the 1800s, right? Why did scientists start believing in **atoms** then?

Aunt Lucy: Scientists observed various things about the behavior of matter that were easier to explain with **atomic theory** than without it. The evidence convinced them **atoms** were real.

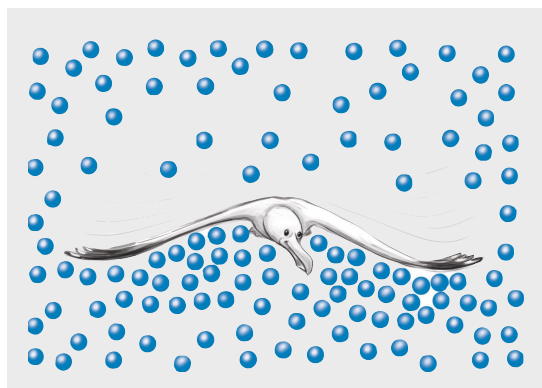
Adam: What sort of evidence?

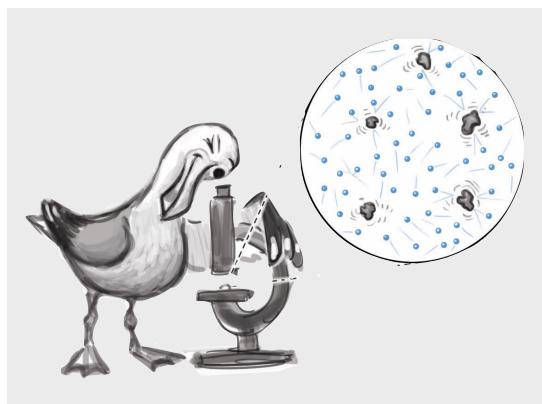
Aunt Lucy: *(leaving the room)* Why don't you three look into that?

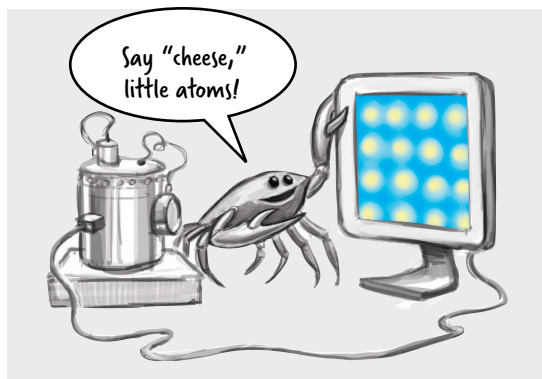
Olivia: So...Do you guys want to go thirdsies on that last brownie?

Adam and Zena: No!

TURN AND TALK: Do these illustrations seem to support Democritus or Aristotle?







olivia, Adam, and Zena went on to do a little more research and found three cartoons they thought might be relevant...