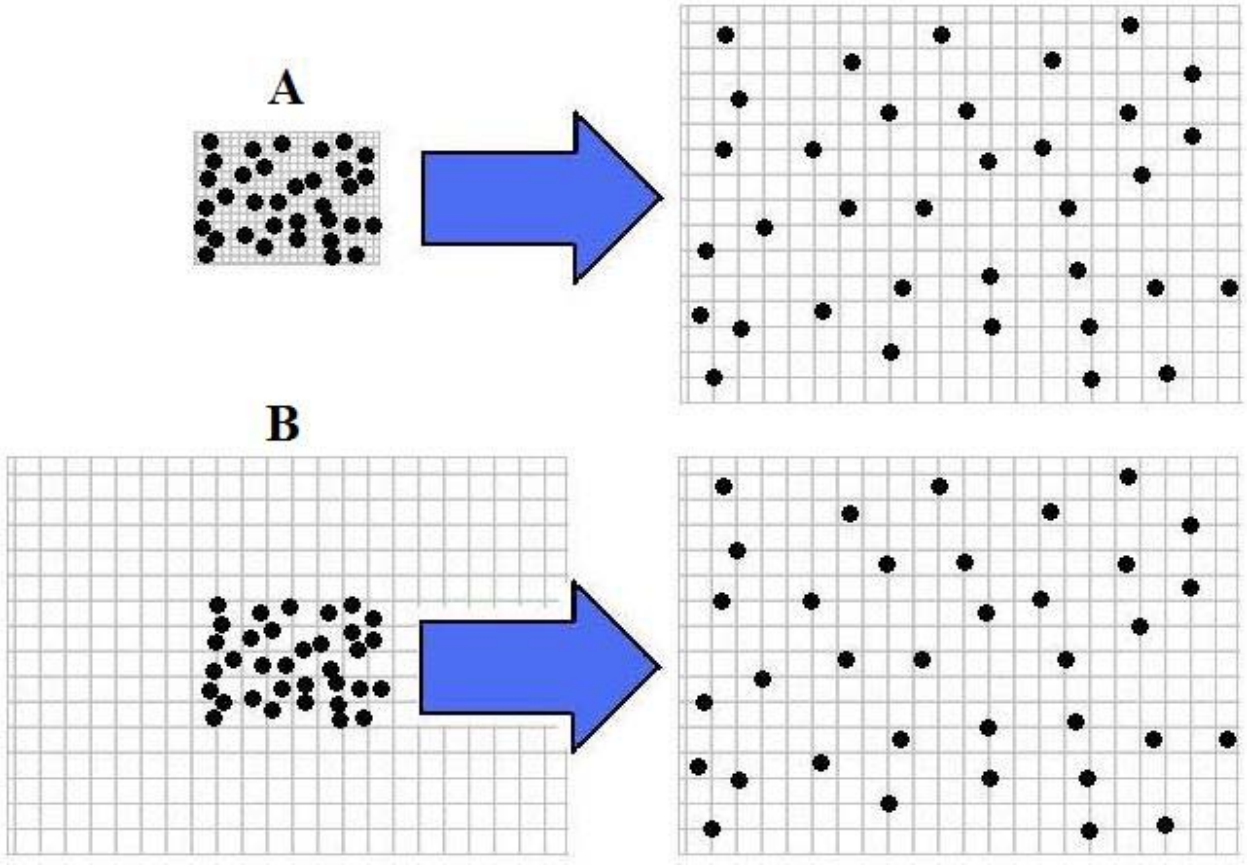
The Big Bang

Consider the drawings provided below. Drawings A and B each represent a different way of thinking about how regions of the universe change over time. The dots in each drawing represent pieces of matter.



1) Which drawing, A or B is a better representation of the universe we observe? Explain your reasoning.

2) In Diagram A, is the universe becoming bigger, smaller, or staying the same size over time?

3) In Diagram B, is the universe becoming bigger, smaller, or staying the same size over time?

4) Two students are debating their answers to Questions 2 and 3:

Student 1: *Both diagrams show the universe becoming bigger. In Diagram A, the grid has expanded and become larger. In Diagram B, the pieces of matter have spread out and take up a greater amount of space.*

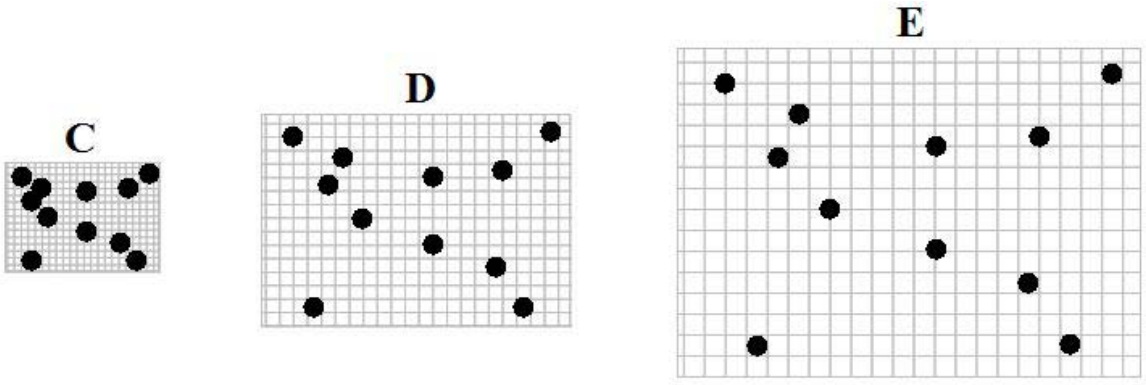
Student 2: *I disagree. Only Diagram A shows the universe becoming bigger. In Diagram B the size of the grid doesn't change. The pieces of matter are just moving into an already existing empty space in a universe whose size doesn't change.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

5) Both drawings show the distance between matter increasing over time.
a) Which of the drawings shows this happening as the result of space expanding and which is a result of an outward explosion?

b) Which of the drawings is a more correct representation of our universe? Is your answer to this question consistent to your answer to Question 1? Explain your reasoning.

Consider the three drawings (C, D and E) shown below. These diagrams each represent a single region of the universe, but at different times during the history of the universe.



6) Draw an arrow below drawings C, D, and E. The arrow should point from the drawing that represents the earliest time in the universe's history to the drawing that represents the latest time in the universe's history.

7) In which drawing does the region of space have:
a) the highest density?

b) the greatest concentration of energy?

c) the highest temperature?

Explain your reasoning.

8) Imagine you could watch the history of the universe like a movie playing backward. The movie starts today and ends at the beginning of the universe. Describe what you would see for every region of the universe as the movie played and you looked further back in time. Your answer should discuss how regions of the universe change in terms of temperature, and density, and size.

Your answers to the previous questions are all part of the *Big Bang Theory*. The Big Bang Theory does not say what the universe was like at the very first moment of time, which was about 13.7 billion years ago. It does, however, tell us how the universe changed after its first moment of existence.

9) Three students are discussing their understandings of the Big Bang Theory:

Student 1: *I think I understand the Big Bang now. At the beginning, all the matter in the universe was compacted into a small, hot, dense ball. This ball of matter then exploded into empty space. When we look at the universe, we see galaxies moving away from us. The Big Bang model explains this, since all matter should be flying away from the center point of the explosion.*

Student 2: *I disagree. I think what the Big Bang Theory is saying is that all the matter in the universe was once compacted into a really dense and hot object that expanded over time. But there wasn't an explosion of matter into empty space. Instead, the universe carried pieces of matter away from each other as it expanded in size.*

Student 3: *You're both wrong. I agree that the universe was once smaller in size and that pieces of matter have been carried away from each other by the expansion of the universe. But remember how we learned from Einstein's equation $E = mc^2$ that matter can be converted into energy and energy can be converted into matter? I think this means that if we go back to the beginning of the universe, it would be so incredibly dense and hot that matter itself couldn't exist. I bet at the very beginning, the universe would have been composed of pure energy with no matter there at all.*

Which students do you agree or disagree with? Explain your reasoning.

10) Based on your previous answers, complete the following sentences:

The Big Bang Theory says that the universe started out with a/an _____ temperature and a/an _____ density. Originally, there was no _____, only pure _____. From this initial state, each region of the universe _____ in size. This caused its temperature and density to _____. When the temperature was cool enough, energy could transform into _____.

11) Look at drawing A again. Next to drawing A, make a drawing of what you think that region of the universe would have looked like at the very first instant it existed.