Chapter 1
What Is Scale?

Overview
Scale is one of the big ideas that cross the science domains. Whether one is talking about the weight of a blue whale, the size of a galaxy or a molecule, or the age of a mountain range, scale is an essential tool in understanding the universe in a scientific way. But what exactly is scale, and why is it important? In this investigation students explore size and scale by examining the wide range of scales that are investigated in science.

Objectives
- To develop an understanding of the range of sizes and scales that exists.
- To understand the extremes of size for different living and nonliving things.

Process Skills
- Observing
- Predicting
- Analyzing data

Activity Duration
30 minutes total

Background
The American Association for the Advancement of Science has identified scale as one of the four major unifying themes of science in *Benchmarks for Science Literacy* (AAAS 1993). Understanding scaling is essential for learning life, physical, and Earth/space sciences. Not only are these ideas useful within the various science disciplines, but they also cut across the curriculum in such subjects as mathematics, history, or English literature. An understanding of scale can help students make cross-curricular connections in the different science domains.

This investigation is designed to interest students in thinking about scale and scaling by examining the amazing range of sizes and distances that scientists study today. After completing this introduction to scale, students should complete the investigation *Types of Scale* to survey the different types of scales and then invent their own unique scales.

Materials
Each student will need:
- Fact or Fiction Extreme Size Card tied with string
- Student Data Sheets

Engage
Ask students, *What was the largest animal ever to live on Earth? Was it the dinosaur, the whale, or perhaps the mammoth?* As they brainstorm, record their predictions and ideas about the sizes of very large animals on the board. You may want to discuss how to define *largest*. Would this be length, volume, or mass?

Ask the students, *How tall was the largest tree ever to live?* Encourage them to give their best estimation if they are uncertain.

Explain that in this investigation they will explore the wide range of sizes and distances that scientists investigate in doing research.

Also explain that one of the crucial skills in science is making estimates of scale. Sometimes these estimates are quite rough. Scientists sometimes call this an "order of magnitude estimate," which roughly translates as an estimate of which power of ten a number belongs to.

Explore

Part I

Begin the activity by passing out Student Data Sheet for Part I: Estimating Size. Ask each student to predict the truth of each statement by indicating whether it is fact or fiction. Answers should be recorded on the Student Data Sheet.

Part II

Give each student a Fact or Fiction Extreme Size Card. Instruct them to walk around the room and ask at least five other people to give their best estimate of whether the statement on the card is fact or is fiction and to discuss their responses. Each student should record the responses on Part II of the Student Data Sheet.

After students have had a chance to circulate and discuss the answers, have them return to their seats. Ask them to share their best guess as to whether the statement on their card is fact or fiction. Following the student responses, the correct answer can be shared and filled in on the Student Data Sheet.

Part III

Before engaging the students in the multiple-choice order of magnitude exercise of Part III, introduce the idea and motivation for such estimates. Sometimes we just want to know roughly how large a number is. Gaining this skill is very important to a student's development of a scientific sense. If absolute precision is emphasized too much, students will have the sense that they know nothing unless they know the exact number (the distance to the moon, or the weight of a blue whale). Knowing how to estimate roughly, based on prior knowledge, is usually more important than knowing a precise number. As we will explore in the *Errors in Measurement* investigation, often a precise number is not really known or cannot be known. You could provide an illustration to help the students understand this concept by asking the question, *How many people live on Earth today?* Explain that no one knows the answer to this to the nearest person or even to the nearest hundred. In fact, actual population is changing second to second (with deaths and births). However, we do know that there are between 6 billion and 7 billion people on Earth (in the "ones of

billions"). Knowing that there are a few billion people on Earth, rather than a few trillion or a few million, is what is important in this exercise.

The challenge problems require the students to do a rough calculation. This again is a crucial skill in science. Emphasize that to answer the challenge questions correctly, one does not need to measure the size of a piece of paper or the floor of the classroom precisely but does need to make a reasonably good guess. One should be able to do these challenge problems using pencil and paper but with no actual measurements.

Explain

It is important to tell students that the goal of this investigation is to develop a broad sense of number and scale and not to memorize exact numbers. For example, it is worth knowing approximately how many millions or billions of people there are on Earth but not critical to know the number to the exact person. Scientists often use what is known as an "order of magnitude estimate." This is a very rough assessment of the magnitude of a quantity. For example, a question might be posed this way: *Do you think the tallest tree in the world is several feet tall, several tens of feet tall, several hundreds of feet tall, or several thousands of feet tall?* Though imprecise, these types of estimates help scientists gauge the scale of a parameter that helps them refine questions and proceed deeper into a problem. It's also a very powerful exercise for helping students learn to think critically and creatively, rather than simply memorize magnitudes.

People have a natural fascination with extremes of size, and many of the examples given in this investigation can be found on the internet with accompanying photos and video clips. You may want to show students a photo of the giant dog that weighs 282 pounds or the rabbit with 31-inch ears (website references provided on the answer sheet). It is also worth pointing out that although these are the extremes of size today, there is always the potential for a new, record-breaking size to appear in the future.