Mission 2
There's Power in Numbers! (Phase 1)

Journeys to Microworld and Macroworld Earth

Notes

In mission 1, *students journeyed* to *Mars, Earth, and Venus in* a *video image show. Size and distance in the video photographs were difficult* to *appreciate. No discussion of the search for life should take place with· out mention of the scales involved in* an *observation. The distance* to *another planet or satellite in the solar system is measured in tens of millions of kilometers, while the size of* a *carbon atom is measured in angstroms* (1 *angstrom =10,10 meters). Such large distances and small sizes are difficult* to *imagine because they are so far removed from daily life.*

Teacher's Note: Make sure all ZOOM! Cards are laminated.

Overview

In mission 2.1, students use ZOOM! Cards depicting Earth to explore scale and powers of 10. They develop a better understanding of scale and learn its importance to determining the type of life signs that might be detected. Students use the ZOOM! Cards to journey to "Microworld Earth." In mission 2.2, students use ZOOM! Cards to journey to "Macroworld Earth."

Mission 2.1
Materials

For a Class of 30

- "Journey to Microworld Earth" script

For Each Team

- Transparency marker or grease pen
- ZOOM! Cards for Microworld Earth
- ZOOM! Cards for Macroworld Earth

For Each Student

- “Journey to Microworld” worksheet
- Pencil

Getting Ready

1. If you have not yet done so, cut apart the individual cards on the sheets of ZOOM! Cards. If possible, to preserve them for future use, laminate the sheets of ZOOM! Cards before cutting them. (Clear contact paper works well, but be sure to cut apart the cards and cover each one separately, leaving a border.)Assemble six complete Earth decks (19 cards each). (This is a good time to make the six Mars decks and the six Venus decks that will be used in mission 4.)

2. Test the markers or grease pens to be sure that they can be wiped off of the laminate or contact paper.

3. Copy the worksheet “Journey to Microworld” for each student (or each team).

4. Study the Earth ZOOM! Cards to refresh your perception of distance and size. Read through the script “Journey to Microworld Earth,” anticipating students' questions.

Classroom Action

1. **Activity.** Divide the class into six groups. Give each team a deck of Earth ZOOM! Cards (19 cards total). Hand out a copy of the worksheet “Journey to Microworld” to each student (or each team). Have students shuffle their decks and lay all the cards face up on a table. Ask students to arrange the cards so that they are “in order.” Do not tell them what is meant by “in order” (largest scale to smallest scale). Ask them to sort the Earth ZOOM! Cards by looking only at the pictures. Arranging the Earth ZOOM! Cards in scale order should be easy because of familiarity with Earth. Students should be able to discover that the differences among the cards are the scales used in the picture. Also, each card shows either something that is smaller than a person or something that is bigger than a person. The ZOOM! Cards form a series of changes in scale, a series of enlargements (or reductions, depending on your perspective).

   After they have had an opportunity to discover this, tell them that each card is a power of 10. On this scale, 0 is “life-size.” Numbers with positive exponents are larger than life-size, and those with negative exponents are smaller than life-size. After they have had an opportunity to discover this, tell students that the view in each card represents a different scale: 3 inches, or about 8 cm (the width of each card) equals; distance in meters that is a power of 10 *(e.g.,* 10 meters, lo4 meters, meters). Each card has a different power of 10. On this scale, a power of B 0 is used for a picture of a child (the “10 meters” card), a power that is a positive number is used for something that is larger than the child (*e.g.*, the “lo4 meters” card showing an entire city), and a power that is a negative number is used for something that is smaller than the child (*e.g.*, the "10- meters" card showing muscle and blood tissue). If necessary, review exponential numbers and scientific notation with the class. Invite them to examine their cards again, looking for clues to scale. Ask them to make guesses about the size of the pictured things. At this point, do not reveal the correct order, even if students do not know where to place each card, or exactly what each card shows.

2. **Script.** Read or paraphrase the script "Journey to Microworld Earth" card by card. Tell students that this script will describe, in order, the first 11 of their cards. Ask groups to find each card as you discuss it, and organize their ZOOM! Cards into your order. (Many arrangements are proper.) Give students time to fill out their worksheets during the reading of the script. Encourage discussion of each card, especially about scale and any signs of life that can be seen at that scale. Have students use transparency markers or grease pens to mark the scale on each card.

3. **Clean-Up**. If another class will use the cards for mission 2, have students wipe them clean of marks. If not, keep the scales on the cards for use in mission 4. Gather up all the ZOOM! Card decks.

Materials

For a Class of 30

- Overhead projector
- "ZOOM! Cards" transparency
- "Journey to Macroworld Earth" script

For Each Team

- Transparency marker or grease pen
- ZOOM! Cards for Microworld Earth
- ZOOM! Cards for Macroworld Earth

For Each Student

- "Journey to Macroworld" worksheet
- Pencil

Getting Ready

1. Copy the worksheet "Journey to Macroworld" for each student (or each team).

2. Study the Earth ZOOM! Cards to refresh your perception of distance and size. Read through the script "Journey to Macroworld Earth," anticipating students' questions.

3. Prepare the “ZOOM! Cards” transparency and set up the overhead projector.

4. Reassemble the class into the previous six groups.

Classroom Action

1. **Activity.** Divide the class into the same groups that were formed for mission 2.1. Give each team a deck of Earth ZOOM! Cards (19 cards total). Hand out a copy of the worksheet “Journey to Microworld” to each student (or each team). Have students lay out their ZOOM! Cards “in order,” as they did in mission 2.1 (students will know the correct order for the first 11 cards).

2. **Transparency.** Show the overhead transparency “ZOOM! Cards.” Explain that these three cards show the same scene, but at a different magnification, as if you were backing away from or zooming in on the scene. If you are moving toward the scene (as a spacecraft approaching a planet, for example), which is the sequence from right to left for these three cards, the objects shown in the scene on each card are shown 10 times larger than on the previous card. Conversely, if you are backing away from the scene, which is the sequence from left to right, the objects on each card are shown 10 times smaller than on the previous card. If necessary, review exponential numbers and scientific notation with the class. On the transparency, draw a rectangle on the “lo0 meters” and the “10' meters” cards that represents the image that is seen on the “lo-' meters” card. For example, on the “lo0 meters” card, draw a rectangle around the girl's hand, which is all that can be seen on the card with the next increase in magnification (the “lo-' meters” card).

3. **Script.** Read or paraphrase the script “Journey to Macroworld Earth” card by card. Tell students that this script will describe, in order, the eight cards not described in mission 2.1. Have groups find each card as you discuss it, and organize their ZOOM! Cards in the proper order. Give students time to fill out their worksheets during the script. Encourage discussion of each card, especially about scale and any signs of life that can be seen at that scale. Have students use transparency markers or grease pens to mark the scale on each card.

4. **Clean-Up.** Have students wipe off any rectangles they have marked on the cards. If another class will use the cards for mission 2, wipe them clean of students' marks. If not, keep the scales on the cards for use in mission 4. Gather up all the ZOOM! decks.

Activity: Detecting “Life Objects”

Hand out one Earth ZOOM! Card to each team. Select the cards randomly, or choose specific cards. Some cards will be “easier” than others, such as plants, animals or artificial structures that student's can identify. Have each team brainstorm on impressive and unique “life objects” that exist on the scale of their card. **A** “life object” (something essential to life as we know it) need not be an individual animal or plant; it may be a body of water, or a carbon atom. They are not limited to the objects actually seen on their card; they should imagine new objects of the same scale. Challenge each team to explain why their scale is the best magnification to use when looking for life on another planet. Discuss which “life object” would best indicate life at each team's scale of observation. Remind students of their search for signs of life in the video images from mission 1; discuss any signs of life seen in the ZOOM! Cards.

Activity: Classroom Display

Ask groups to draw their “life objects” from the “Going Further” activity above onto blank 5-by-8- inch index cards. Hang up one set of Earth ZOOM! Cards and the groups' pictures of life objects along the front wall of the classroom. Use yarn to connect the life objects to the ZOOM! Cards that have the same scale. This is a useful tool for gauging scale throughout the remaining missions.

Activity: How Big Is It?

Cut pictures from magazines and give students several pictures of various objects, familiar and unfamiliar, or show the class images of these objects. Ask students how big each object is? How can they tell? If an object is familiar to students, they will rely on past experience and stored knowledge. Point this out to them and ask for clues to size and scale that could be used if they had never seen such an object.

Show and Tell: Scale Models

Students make or buy scale models all the time. Ask them to bring into the classroom some of these models. They should know the scale of the objects they bring in (*e.g.*, some doll-house furniture has a scale of 1 inch = 1 foot). Have students estimate the scales for their classmates' models. Some models should be larger than life-size (*e.g.*, plastic fly), while others should be smaller than life-size (e.g.? plastic dinosaur). Others should actually be life-size.

Activity: Microscopic Monsters

Ask students to use microscopes and prepared slides. Try a slide of a fruit fly, an amoeba, or a nematode worm. First, have students guess the size of a microscopic monster; then have them calculate its size. Ask students how this varies when they are using a low-power objective microscope. How does the apparent size vary with higher powers of magnification? (Do the microbes seem to be bigger when viewed at a higher magnification?) How is this important in our search for life on Mars or Venus? Would we need to look at Martian soil with a microscope? What magnification would we need?

Living microscopic monsters are even more fun. Pure cultures can be ordered from biological supply houses, but plenty of microbes can be found in pond water, aquarium water, hay infusions, or growing on slices of raw potato.

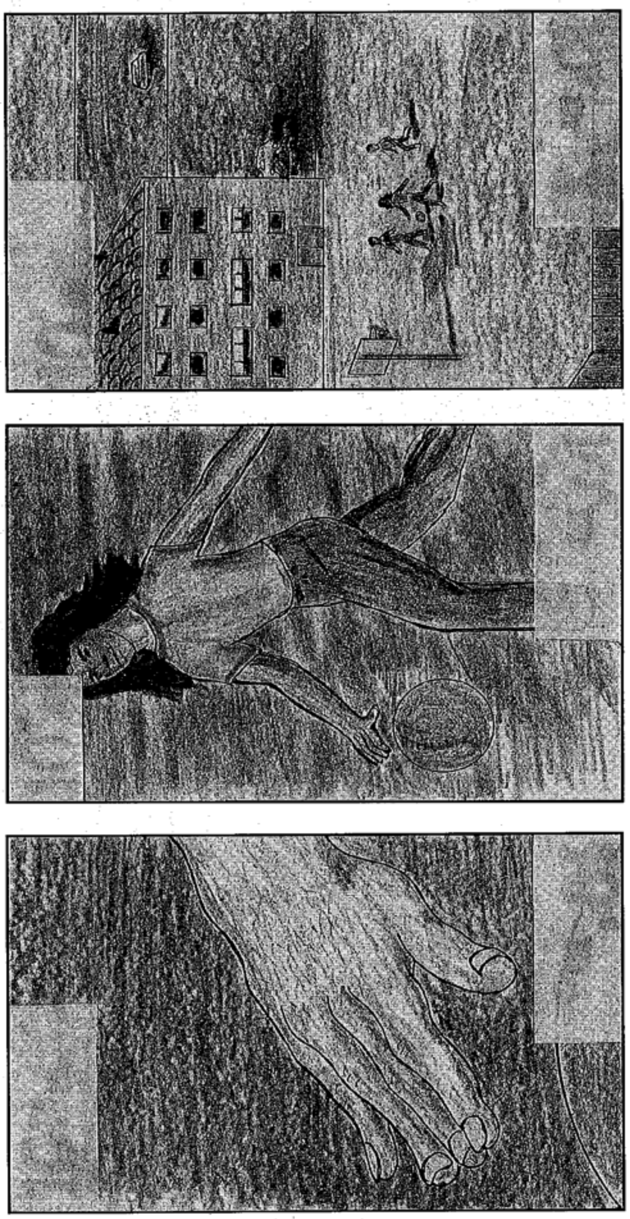
Activity

If your ZOOM! Cards are laminated, have students use transparency markers or grease pens to draw on each Earth ZOOM! Card a rectangle that represents the image that is seen on the card with the next increase in magnification. This will be easy for some cards, difficult for others.

There's Power in Numbers! (Phase I)
Journeys to Microworld and Macroworld Earth

ZOOM! Cards—Transparency

Figure 2.1—Three ZOOM! Cards.



Script for ZOOM! Cards

“Journey to Microworld Earth”

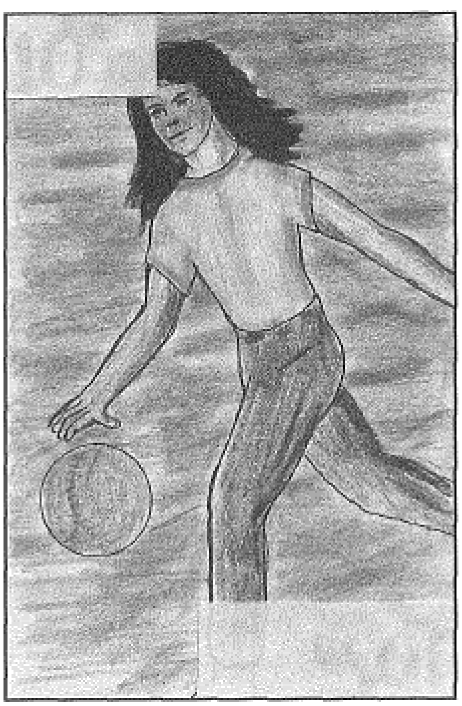
Today we will embark on a fantastic journey to a place that is not very far away. In fact, it is here, in this room, with us now! I am talking about the Microworld, the world of the very, very small. We will learn two things to help us in our search for extraterrestrial life: 1) what things look like at different scales, and 2) what signs of life can be detected at different scales.

We will begin our fantastic journey at a scale that we all understand very well, because it is the scale in which we live out our lives.

Today we will journey by powers of 10. Each card we see will have a magnification that is 10 times greater than the magnification in the previous card; that is, each object in a card will be 10 times larger than it was in the previous card. Try imagining that you are shrinking, like Alice entering Wonderland. Each time you shrink, you become 10 times smaller! How many times do you think you will need to shrink before you can “walk” into the Microworld? Of course, real people can't shrink themselves. But we can do something almost as incredible. By using magnifying lenses and microscopes, we can see the world of the very, very small. Let's take a look!

SCALE: 8 cm =100 meters 10° meters =1 meter

Figure 2.2-Earth Card # ll-A Child



Observed by: Human eye.

Description: We begin our journey, at the scale of 8 cm =100 meters, with a child playing with a ball. It is easy to think of many things that are a meter or two across. We can see these objects with our eyes (without the help of magnification), or take pictures of them with a wide-angle camera lens. But there are countless objects that are far larger and countless objects that are far smaller. Today we will look at those that are smaller.

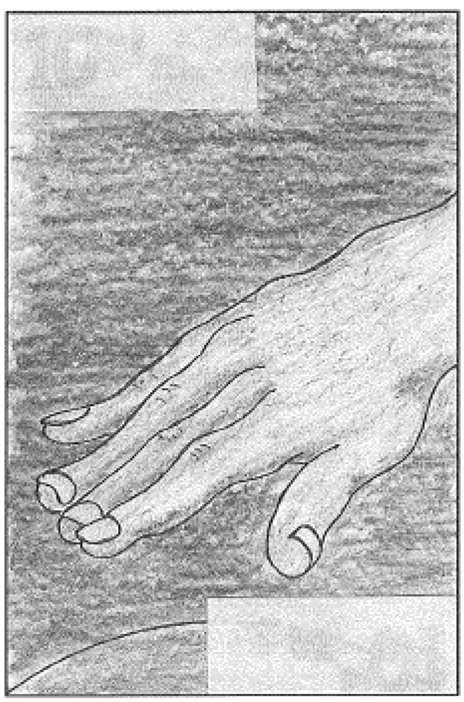
Life or Signs of Life: Yes. A recognizable human being.

Question: Is it possible to see the very largest and smallest things in the universe with a scale of 8 cm = 1 meter? *(No. This scale allows us to easily see things that are approximately the size of human beings.)*

Comment: 10^0 meters is a little over 1 yard long. A meter stick is about 4 inches longer than a yardstick.

SCALE: 8 cm = 10^{-1} meters
10^{-1} meters = 0.1 meter

Figure 2.3-Earth Card #10-A Hand



Observed by: Human eye.

Description: A magnification by 10 times to a scale of 8 cm = 10'1 meters reduces our view to a small portion of the previous image. We now see one-tenth of the girl. We only see her hand. This scale is life-size, which means that the hand in the picture is the size of the girl's real hand. Most of the objects that we use every day, such as books, tools, and toys, are the size of a hand. We can see this scale with our eyes (without the help of magnification).

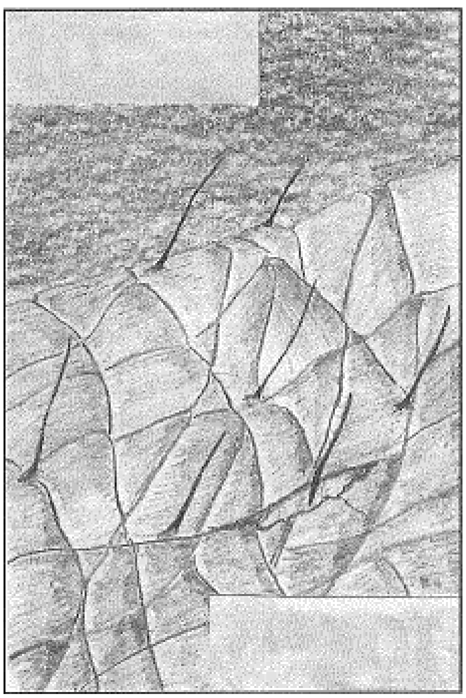
Life or Signs of Life: Any human being would recognize a hand as a sign of life. But consider how hard it might be for an extraterrestrial that has tentacles!

Question: How many hands would it take to cover the length of a football field (l00 yards)? *(If an average hand is* 8 *inches across, it would take 450 hands.)*

Comment: 10-2 meters is about 4 inches.

SCALE: 8 em $=10^{-2}$ meters
10^{-2} meters =.01 meters (l centimeter)

Figure 2.4-Earth Card # 9-Skin



Observed by: Human eye or magnifying glass.

Description: Another magnification by 10 times, to a scale of 8 cm =10-2 meters, takes us into a weird world. Would you recognize this image if you had only been given this card? You are now looking at a 1-centimeterwide section of the skin on the girl's hand. You see a complex structure, with skin folds, little hairs, and an open cut. Could you see this much detail with only your eyes? Try it! Look at your own hand in front of your face.

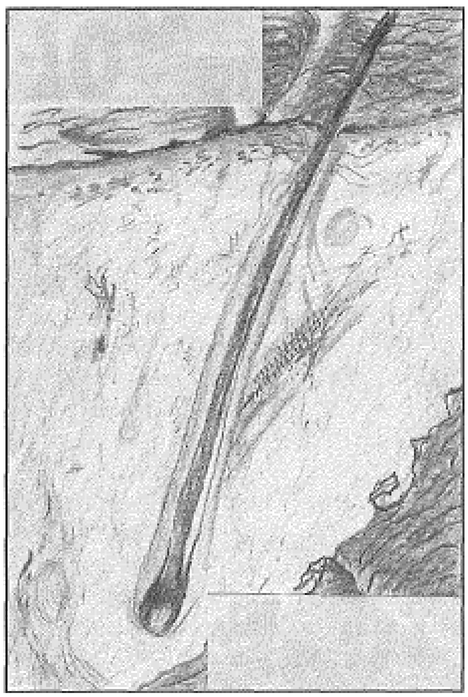
You will need a magnifying glass to see each tiny hair at the same detail as shown in the picture.

Life or Signs of Life: This is recognizable living tissue, composed of cells. A doctor or biologist would recognize these structures by their appearance.

Question: What does the prefix *centi-* (as in *centimeter)* mean? What other words begin with this prefix? (Centi- *means "hundred." A centipede is an animal with "100" legs [though usually they don't have exactly 100 legs]! A century is a period of 100 years. One cent is a penny;* 1 *out of* 100 *in a dollar.)*

Comment: Your fingers are each about 1 centimeter wide.

Figure 2.5-Earth Card # 8-One Hair



SCALE: 8 cm =10^{-3} meters
10^{-3} meters =.001 meters (1 millimeter)

Observed by: Magnifying glass.

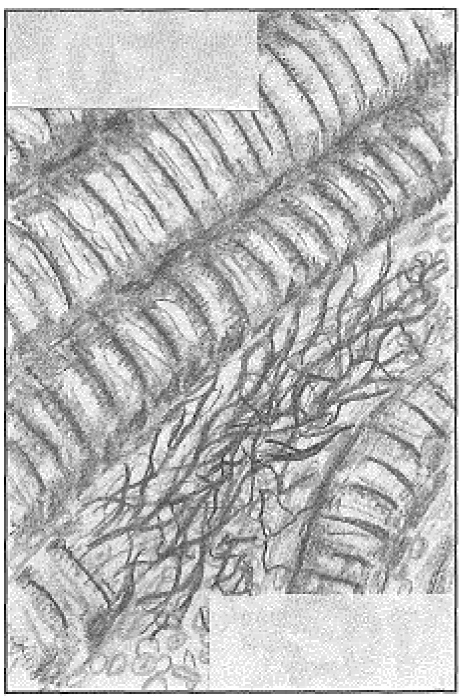
Description: An increase in magnification by 10 times, to a scale of 8 cm =10^{-3} meters, reduces our view to a small portion of the previous image. If you look carefully at this image, you will see another layer of skin beneath the surface layer; it is visible on the edge of the open cut. A single hair is visible growing from a base (called a follicle). Can you see where the hair begins beneath the skin and then pokes through to the surface? To the right of the hair is a tiny muscle. Blood is clotting in various spots in the cut; this is the beginning of the healing process.

Life or Signs of Life: These are recognizable living tissues, composed of cells. A doctor or biologist would recognize these structures by their appearance.

Question: What does the prefix *milli-* mean? What other words begin with this prefix? (Milli- *means "thousand." A millipede has "1,000" legs! A millennium" is 1,000 years.)*

Comment: A millimeter is the smallest division found on most rulers.

Figure 2.6-Earth Card # 7-Muscle and Blood Tissues.



SCALE: 8 em $=10^{-4}$ meters
10^{-4} meters = .0001 meters

Observed by: Optical (light) microscope.

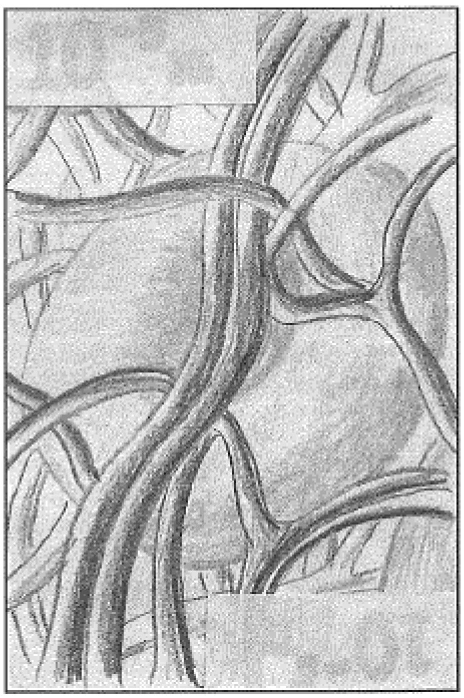
Description: Another increase in magnification by 10 times, to a scale of 8 cm $=10^{-4}$ meters, takes us into the microscopic world. You would need to look at the girl's hand through an optical microscope at low magnification to see this kind of detail. Your entire body is made of units called cells. At this magnification, you can see two types of cells. There are muscle cells, which form striped bands of muscle tissue. They are located next to the hair because they control the hair's movement. This muscle can raise or lower the hair. We now see that the blood is made up of red blood cells, which carry oxygen to the muscle. A group of red blood cells are forming a blood clot in the cut. Notice the tiny fibers that hold these red blood cells together.

Life or Signs of Life: These are recognizable living tissues.

Question: Why does blood clot? *(Blood clots so that a small wound will stop bleeding. This prevents the loss of too much blood from the organism.)*

Comment: 10^{-4} meters is a distance too small for any eye to see without a microscope.

Figure 2.7-Earth Card # **6-A** Red Blood Cell.



SCALE: 8 cm = 10^{-5} meters
10^{-5} meters = .00001 meters

Observed by: Optical (light) microscope.

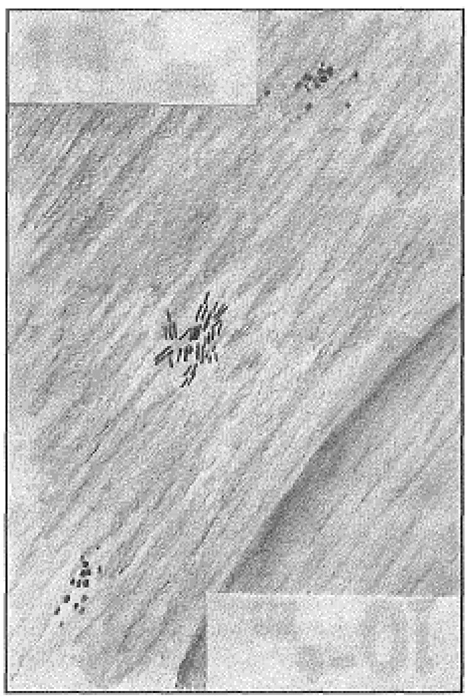
Description: Another increase in magnification by 10 times, to a scale of 8 cm = 10^{-5} meters reduces our view to a small portion of the previous image. You would need to look at the girl's hand through an optical microscope at a high magnification to see this kind of detail. A single red blood cell fills most of the view. The tiny fibers now appear to be much thicker. They are helping to form a scab by linking many red blood cells in a network of fibers. Doctors can examine red blood cells and other types of cells in a microscope to see if our bodies are functioning properly. All life on Earth is made of these living units, not just people.

Life or Signs of Life: A cell structure is a sign of life. Only life is made of cells.

Question: How many red blood cells lined up would it take to go across your hand? *(A red blood cell is about ,00001 meters across, which can be determined from the scale of the image on this card. If a hand is 10 centimeters across, it would take 1,000,000 red blood cells to equal that distance.)*

Comment: $l0^{-5}$ meters is 1 one-hundredth of a millimeter.

Figure 2.8-Earth Card # 5-Surface of a Red Blood Cell.



SCALE: 8 cm = 10^{-6} meters
10^{-6} = ,000001 meters
(1 micrometer)

Observed by: Optical (light) microscope or electron microscope.

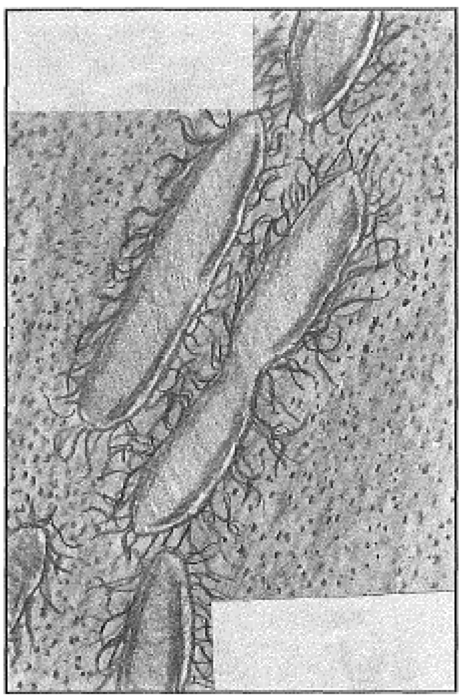
Description: Another increase in magnification by 10 times, to a scale of 8 cm = meters, takes us into a world almost too small to be seen with a microscope that uses light. **A** prepared sample could also be viewed through an electron microscope. This view shows only a small part of the surface of a single red blood cell. On the surface of this red blood cell, you can see some small brown dots. Are they small colonies of bacteria? Bacteria are everywhere in our bodies, all the time. Each bacterium is a single living cell-a microorganism or microbe.

Life or Signs of Life: Whole bacteria. Microbiologists would recognize these bacteria, if seen under a microscope, just as you would recognize a dog or cat on the street.

Question: If bacteria are everywhere, all the time, why aren't we sick all the time? *(Few bacteria are capable of making people sick. Most bacteria are harmless, and many are beneficial.)*

Comment: There are as many micrometers in a meter as meters in 1,000 kilometers.

Figure 2.9-Earth Card # 4-Bacteria.



SCALE: 8 cm = 10^{-7} meters
10^{-7} meters = .0000001 meter

Observed by: Electron microscope.

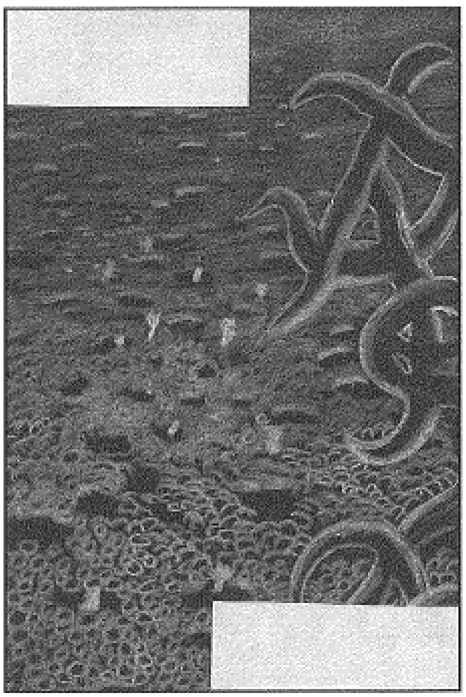
Description: Another increase in magnification by 10 times, to a scale of 8 cm = 10^{-7} meters reduces our view to a small portion of the previous image. The little brown dots are bacteria. Bacteria are single-celled life-forms that exist all over the Earth, not just in human bodies. In this scene, the bacteria are attaching themselves to the human red blood cell with tiny “hairs” (called cilia) around their edges. One bacterium is dividing to form two bacteria. This is how bacteria reproduce. Other kinds of bacteria live in soil or in water. Some even “fly” (by floating) through the air. Most kinds of bacteria are larger than these, and are visible even with an optical microscope!

Life or Signs of Life: Whole bacteria.

Question: Is each bacterium a unique individual or just a copy of all the others? *(Bacteria that have descended from one common ancestor are clones, or genetic copies. They are exactly the same, unless a mutation [which is rare] has occurred.)*

Comment: Placed end to end, over 10 million bacteria would fit into a distance of 1 meter.

Figure 2.10-Earth Card # 3- Surface of a Bacterium



SCALE: 8 cm = 10^{-8} meters
10^{-8} meters = .00000001 meters

Observed by: Electron microscope.

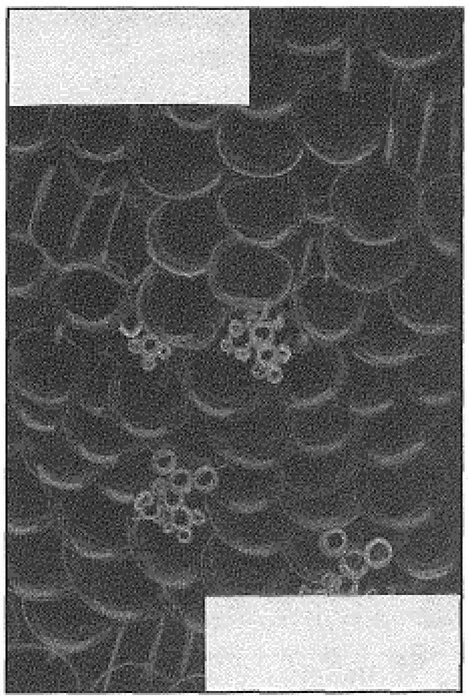
Description: Another increase in magnification by 10 times, to a scale of 8 cm = 10^{-8} meters, takes us into an even smaller world. Behind the bacterium's hairs, the bacterium's cell membrane is still visible. The surface of any cell is a membrane that has “openings” into the cell. All cells are enclosed by a cell membrane. You could not know if there was life on another planet just from looking at an image like this one. If you could see for sure that it was a cell, then it would be a sign of life. If you saw “an image *like* this one,” it might be a nonliving structure that only “looked like” a cell membrane. It might be hard to tell for sure.

Life or Signs of Life: A cell membrane is a sign of life.

Question: Why does a cell membrane have "openings" in it? *(So that molecules like water and protein that are necessary for life can enter the cell and so that wastes can leave the cell.)*

Comment: 10^{-8} meters is the size of the smallest living things. No living thing smaller than meters has ever been found.

Figure 2.1l-Earth Card # 2-Molecules.



SCALE: 8 cm = 10^{-9} meters
10^{-9} meters =.000000001 meters
(1 nanometer)

Observed by: Tunneling electron microscope.

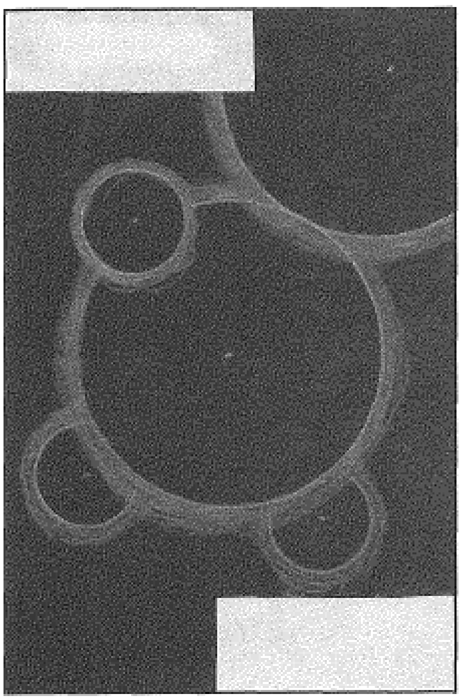
Description: Another increase in magnification by 10 times, to a scale of 8 cm =10^{-9} meters, reduces our view to a small portion of the previous image. Each cell is surrounded by a membrane that keeps some molecules in and some molecules out. Openings in the cell membrane allow molecules, such as the proteins shown, to go in and out of the cell. This lets "food" molecules enter, and "waste" molecules leave the cell. Protein molecules make up some of our food. There are protein molecules in chicken and in corn, for example. Our bodies themselves are made of protein molecules (among other types of molecules).

Life or Signs of Life: Proteins are organic molecules *produced* by life. So, the presence of protein molecules indicates the presence of life.

Question: Why do cells need to move materials in and out of them? *(This is necessary for metabolism, the chemical reactions that allow life to continue.)*

Comment: One billion scenes like this one could be lined up along the edge of a meter stick.

Figure 2.12-Earth Card # 1Atoms.



SCALE: 8 cm = 10^{-10} meters
10^{-10} meters =.0000000001 meters

Observed by: Tunneling electron microscope.

Description: Another increase in magnification by 10 times, to a scale of 8 cm =10^{-10} meters, takes us into the atomic world. Here, an atom of carbon is shown. It is bonded to three hydrogen atoms and to one oxygen atom. The same carbon atoms are found in both living and nonliving things on Earth. The carbon atom is the most important atom to a living organism because it can form bonds with up to four other atoms. Long chains of carbon atoms make complex organic molecules, such as carbohydrates and proteins. We end our journey into the Microworld here, but ask yourself this: Where would we be and what would we see if we went even farther into the Microworld? What would an atom look like at a scale of 8 cm $=10^{-11}$ meters? At a scale of 8 cm $=10^{-12}$ meters? Where do these increases in magnification end?

Life or Signs of Life: Carbon exists in both living and nonliving things. So, the presence of a carbon atom does not necessarily indicate the presence of life.

Question: Are the atoms in living things unique when compared to the atoms in rocks or air? *(No. They are exactly the same.)*

Comment: It would take 400 million billion atoms to circle the Earth.

There's Power in Numbers! (Phase 1)
Journeys to Microworld and Macroworld Earth

Journey to Micro world-Teacher's Key

Fill in the following data table as you journey into the Microworld.

Table 2.1-Microworld Data, Teacher's Key.

Earth Card	Scale	Observed By	Life or Signs of Life
# 11	10^{0} meter	Human eye or camera	Recognizable structure: a child
# 10	10^{-1} meter	Human eye or camera	Recognizable structure: a hand
# 9	10^{-2} meter	Magnifying glass	Cell structure and tissues
# 8	10^{-3} meter	Magnifying glass	Cell structure and tissues
# 7	10^{-4} meter	Light microscope	Cell structure
# 6	10^{-5} meter	Light microscope	Cell structure
# 5	10^{-6} meter	Light or electron microscope	Whole bacteria
# 4	10^{-7} meter	Electron microscope	Whole bacteria
# 3	10^{-8} meter	Electron microscope	Cell membrane
# 2	10^{-9} meter	Tunneling electron microscope	Protein molecules
# 1	10^{-10} meter	Tunneling electron microscope	Carbon atoms

Answers to student questions after they have completed their journey into the Microworld:

1. We enter the Microworld at the scale 8 cm = 10^{-4} meters.

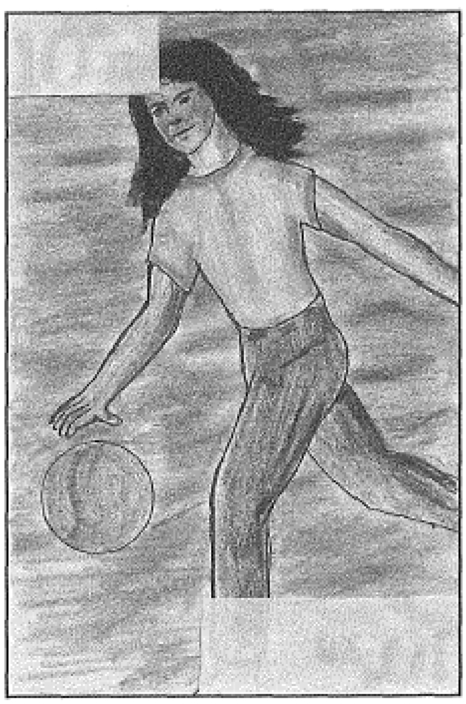
2. No. Bacteria are too small to see at a scale of 8 cm = 10^{0} meters.

Script for ZOOM! Cards

“Journey to Macroworld Earth”

Today we will embark on another fantastic journey to places that are far away. But it starts in this room, where we are nowl I am talking about the Macroworld, the world of the very, very large. As before, we will begin this fantastic journey at a scale that we all understand very well, because it is the scale in which we live out our lives. Scientists call this scale “1 meter = 10° meters,” or “1 meter = 1 meter” (which is to say that an object represented at this scale would be life-size). We have seen that reducing our scale, as from 8 cm = 10° meter to 8 cm = 10·meters, increases the magnification and lets us see a larger view of an object. Today we will take another journey by powers of 10. Each card we see today will have a magnification that is 10 times smaller than the magnification in the previous card; that is, each object in a card will be 10 times smaller than it was in the previous card. This means that each card will show 10 times as much as the previous card. Try imagining that you are growing, as Alice did inside the White Rabbit's house. Each time you grow, you become 10 times bigger and so everything else appears to shrink! Some things become so small that they can no longer be seen. How many times do you think you will need to grow before you can “walk” into the Macroworld?

Figure 2.13-Earth Card # 11 A Child



SCALE: 8 cm =10° meters
10° meters =1 meter

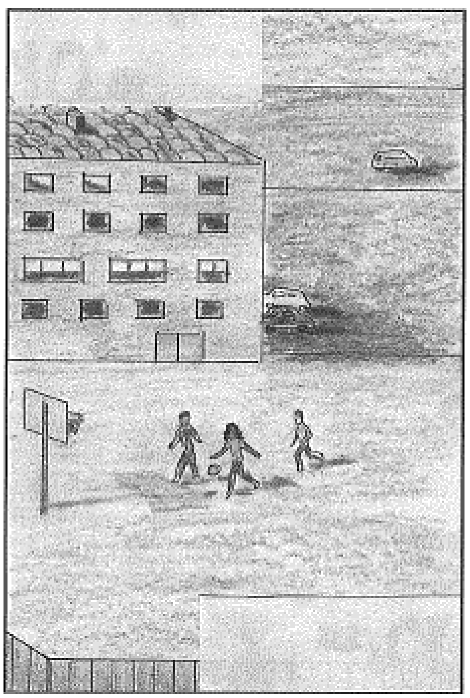
Observed by: Human eye.

Description: We begin this journey where we began our last journey, with the same child playing with the same ball. We can see these objects with our eyes (without the help of magnification), or take pictures of them with a wide-angle camera lens. But there are countless objects that are far larger and countless objects that are far smaller. Today we will look at those that are larger. Life or Signs of Life: Yes. A recognizable human being.

Question: If a spacecraft took a photograph of the surface of Mars, what would the scale of the photograph be? *(It would depend upon the magnification of the camera lens and the distance from the surface to the camera.)*

Comment: 10° meters is a little over 1 yard long. A meter stick is 4 inches longer than a yardstick.

Figure 2.14-Earth Card # 12Children in the Schoolyard



SCALE: 8 cm =101 meters
101 meters =10 meters

Observed by: Human eye.

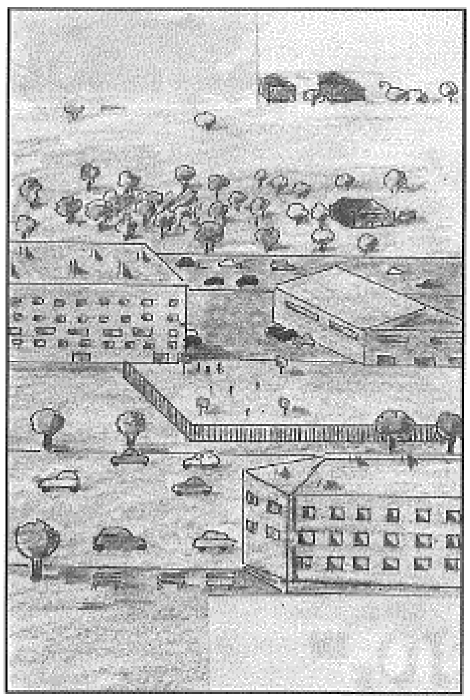
Description: A decrease in magnification by 10 times, to a scale of 8 cm =101 meters, enlarges our view well beyond the previous image. We now see 10 times as much as before. For instance, we see that the child has two friends, and that all three friends are playing in a schoolyard! Other nearby familiar objects, such as cars and buildings, are also now visible. You would see this scene if you were far away from the schoolyard.

Life or Signs of Life: Three recognizable "animal" (moving) forms can be seen. Cars are a sign of life because they appear unnatural, or manufactured. And because they move!

Question: Where would you have to be to see this view of the schoolyard? *(You would have to be some distance away, and looking down, perhaps from a building.)*

Comment: 101 meters is about the height of a two story family house.

Figure 2.15-Earth Card # 13-The Neighborhood.



SCALE: 8 cm =10^2 meters
102 meters =100 meters

Observed by: Hum**a**n eye

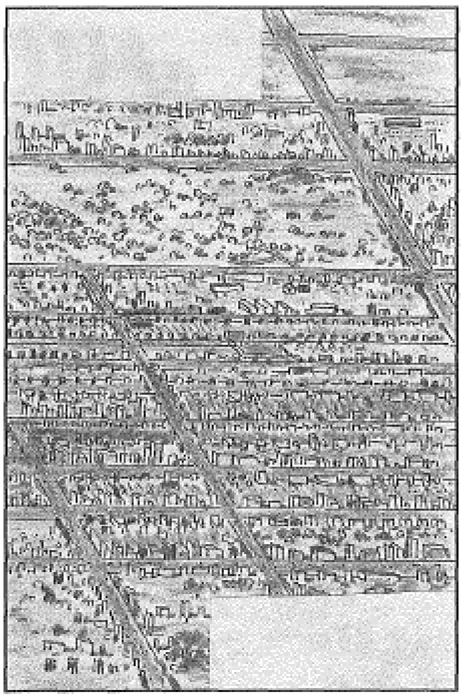
Description: Another decrease in magnification by 10 times, to a scale of 8 cm = 10^2 meters, takes us farther away from the child and her friends. We can now see more of the school and its neighborhood. The people look like ants! This alone should show you that the apparent size of things is not related to their true complexity or importance. Can you still see the three children playing in the schoolyard?

Life or Signs of Life: "Animal" forms can be seen. Trees and grass, because they are green, might be living things. Certain rocks and minerals are green. They are *not* alive.

Question: How could you recognize vegetation from far away? *(On Earth, the green pigment chlorophyll is necessary for most plants to make their food through photosynthesis, so green areas may be plants. Such areas would also change over time, and this change would be observable.)*

Comment: The world's fastest runners can run the length of a football field in less than 10 seconds.

Figure 2.16-Earth Card # I3-The Neighborhood.



SCALE: 8 cm = 10^3 meters
10^3 meters =1,000 meters (1 kilometer)

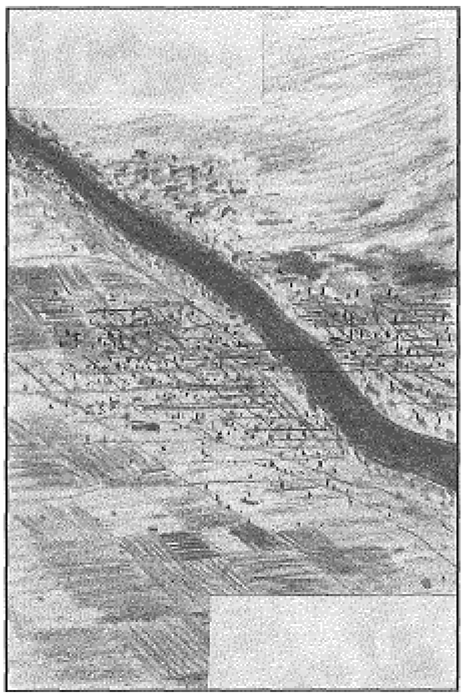
Observed by: Traffic helicopter.

Description: Another decrease in magnification by 10 times, to a scale of8 cm =10^3 meters, enlarges our view well beyond the previous image. The school is now seen as a small part of a city, which consists of many buildings linked by a network of streets. The streets are all straight, but the different kinds of buildings have different shapes, colors, and sizes. Some areas of the city have more vegetation than others. Can you find the school? The three friends? Life or Signs of Life: Identifiable cities are signs of life-intelligent life! A network of straight lines at right angles to one another looks artificial, which means it might have been created by intelligent life. The green areas look like vegetation.

Question: Why do some cities have curved streets? *(City streets may follow rivers, hills, valleys, or property lines.)*

Comment: 103 meters equals 1 kilometer; 1.6 kilometers equals 1 mile.

Figure 2.17-Earth Card # I5-The Entire City.



SCALE: 8 cm $=10^4$ meters
10^4 meters =10,000 meters

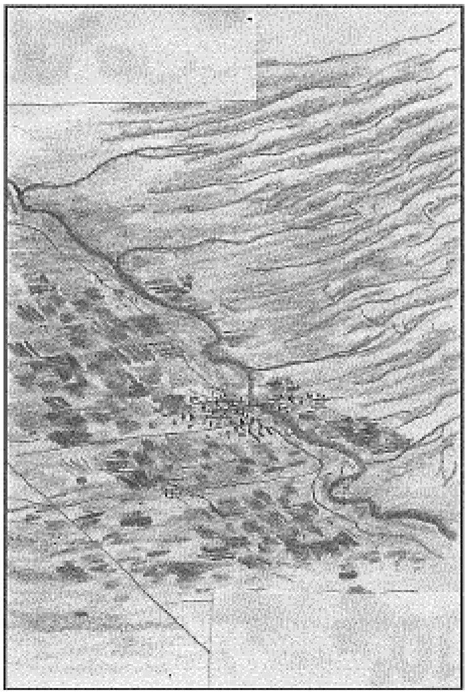
Observed by: Airplane.

Description: Another decrease in magnification by 10 times, to a scale of 8 cm $=10^4$ meters, takes us even farther away from the city. There is a huge river running through the heart of this city. The networks of roads spread out from the city into the country, and the buildings give way to farmlands. Different crops cause the fields to be different colors. To see this view of the city, you would have to be high in the air, much higher than the traffic helicopter. You may have seen views like this from an airplane window during takeoff or landing. Life or Signs of Life: The straight lines and right angles indicate life. The regular patterns made by crops also indicate life at work. The river is liquid water, which is necessary for life. The green areas look like vegetation.

Question: Why are so many cities built near water? *(Water is necessary for life and commerce.)*

Comment: 10^4 meters is how far a fast marathon runner travels in one hour.

Figure 2.18-Earth Card # 16-The Countryside.



SCALE: 8 cm $=10^5$ meters
10^5 meters =100,000 meters

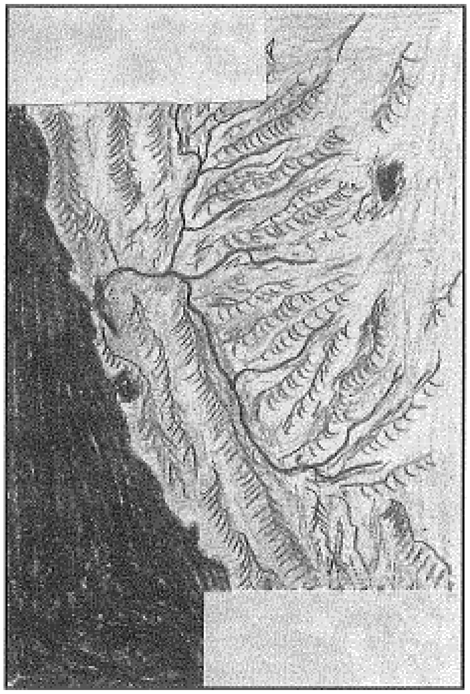
Observed by: Commercial aircraft.

Description: Another decrease in magnification by 10 times, to a scale of 8 cm $=10^5$ meters, enlarges our view well beyond the previous image. From an airplane, even an entire city seems small compared to the surrounding countryside. We can see many streams running out of the foothills, feeding the river. The colored pattern of fields in irrigated areas contrasts with the dry landscape. Life or Signs of Life: The regular patterns made by crops indicate life. The river is liquid water, which is necessary for life. The green areas are vegetation.

Question: How high would an airplane be flying to have this view? *(About 10,000 meters [33,000 feet].)*

Comment: 10^5 meters is the distance a car traveling 100 kilometers per hour (60 miles per hour) can travel in one hour.

Figure 2.19-Earth Card # 17California.



SCALE: 8 cm = 10^6 meters
10^6 meters =1 million meters

Observed by: Space shuttle or low Earth orbiting satellite.

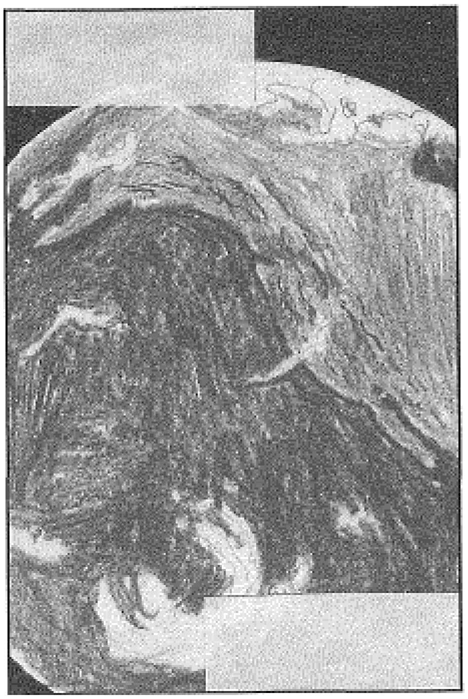
Description: Another decrease in magnification by 10 times, to a scale of 8 cm =10^6 meters, takes us farther away. Have you ever seen a view like this out of an airplane window? No way! The whole state of California is visible in this view, along with some of the dry, western part of the United States. A view comprising this much land could only be seen from an orbiting satellite or a spacecraft during its flight. Most of the landscape is hilly and brown. Irrigation is required for agriculture. Can you tell which of these rivers is the one that runs through the city where the three friends are playing? Are the three friends "invisible" now?

Life or Signs of Life: The river system is liquid water, which is necessary for life.

Question: Can you locate San Francisco Bay? Can you explain why it is such a good place for a port? *(San Francisco Bay is the upper bay, the one with the rivers feeding into it. [The lower one is Monterey Bay.] Ports are often built near bays because the water there is protected and calm.)*

Comment: 10^6 meters is about how far an airliner flies in one hour.

Figure 2.20-Earth Card # 18Planet Earth from Orbit.



SCALE: 8 cm =10^7 meters
10^7 meters =10 million meters

Observed by: Satellite orbiting Earth.

Description: Planet Earth is a little larger than 10^7 meters across. Satellites orbiting our planet have allowed us to observe our entire world at once! This is another decrease in magnification by 10 times, to a scale of8 cm =10^7 meters, which enlarges our view beyond the previous image. We can see much of the North American continent from here. San Francisco Bay has not only become smaller but it is now apparent that there are clouds above it. The clouds show that Earth has an atmosphere.

Life or Signs of Life: If the clouds have oxygen and water (which cannot be determined from a picture), then conditions would be favorable for the existence of life. However, this by itself would not necessarily indicate the presence of life.

Question: If Earth has so many mountains, valleys, and ocean waves, why does the edge look so perfectly round? *(This is a matter of scale. Mountain ranges may appear huge to us, but compared to the entire Earth, they are only tiny bumps.)*

Comment: 10^7 meters is about 6,000 miles.