TOPIC II
THE CHANGING ENVIRONMENT

The sudden release of energy, as in an earthquake, can be very destructive.

CHAPTER 3

You will know something about change in the environment if you can:

1. Explain how change can be described and measured.
2. Give some examples of cyclic changes.
3. Determine the direction of energy flow across an interface in a given example.
4. Apply what you have learned about change to the problems of environmental pollution.

The one thing we can count on in this universe is the occurrence of change. From moment to moment, from century to century, from one age to another, things change. They become different from what they were before. The earth scientist is interested in the changes that take place in the environment—the earth and the bodies of matter in the space around us.

CHARACTERISTICS OF CHANGE

The Events of Change. Every change or series of changes can be called an *event*. Events may occur almost instantaneously, as in the case of a lightning discharge or the breakdown of an atom. On the other hand, events may take place gradually over millions of years, as in the case of the wearing away of mountains and the drifting of continents. Regardless of the time span involved, an event is marked by some change in the properties of matter or in the properties of a system.

The earth scientist is interested, first of all, in *describing* the events of change that are occurring now and that have occurred in the past. Much detective work goes into figuring out just what these changes have been. But the earth scientist is even more interested in discovering the causes of change—the basic earth processes that explain the events that he describes. Your study of earth science will be concerned with both the events of change and the processes of change.

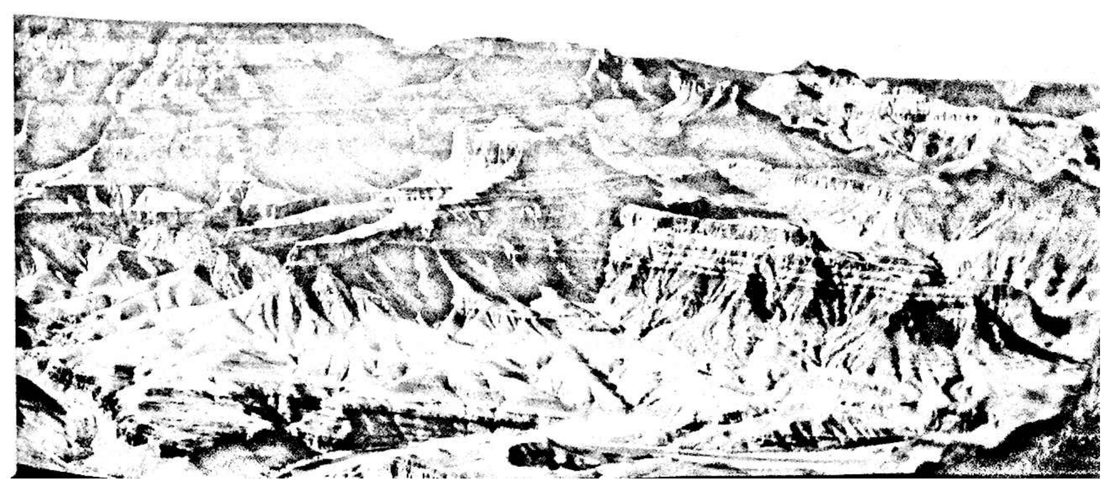
Frames of Reference for Change. Most changes that we observe and talk about are changes that occur in the course of time. That is, we observe that something is different from what it was like yesterday or last year. When looking back at past changes, such as the history of nations (or of mountains), we usually place the events of change on a time scale. In such cases, time becomes the *frame of reference* for describing the change.

There is, however, another kind of change that we observe, especially in earth science. It is the kind of change described by a sentence like the following:

"As you travel westward from the Great Plains of Kansas into Colorado, the landscape undergoes a dramatic change."

Actually, the landscape of Colorado doesn't change during your trip. This is an observed change that results from a change of location. In other words, the frame of reference is space, rather than time.

Figure 3-1. The Grand Canyon. The erosion of the Grand Canyon is such a gradual process that it is almost impossible to measure the rate at which it is occurring.



In describing a changing weather pattern, the frame of reference likewise can be either time or space. "Rain ending tonight, followed by clear and colder weather." That might be a forecast for your community. The frame of reference is time. "Cloudy in the western part of the state, sunny toward the east." That is a changing weather pattern with space, or location, as the frame of reference.

Rate of Change. When describing a change with respect to time, it is often useful to know the *rate of change*, or how much of a change takes place within a given period of time.

Some of the processes we study in earth science, such as the phases of the moon, change at rates that can be easily and accurately measured. Others, such as the erosion of the Grand Canyon, occur so gradually and over such a long period of time that they are almost impossible to measure.

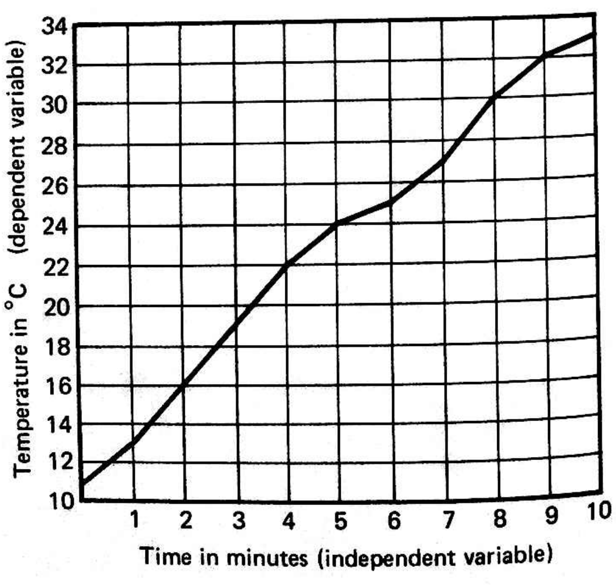
Graphing Change. A common way to represent change is in the form of a graph. A graph can give you a picture of what is happening. In this way it may be more useful for interpreting data than simple lists of numbers.

A graph shows you how one factor is changing with respect to another. Suppose you wanted to make a graph showing what happens to the temperature of a box of soil placed under a heat lamp for 10 minutes. You don't know what the temperature readings will be, but you do know that time will go from 0 to 10 minutes.

On this graph, time is the *independent variable*. You know in advance what the time measurement will be. The temperature readings, on the other hand, will vary with time. Thus temperature on this graph is the *dependent variable*. You know the values of the independent variable. The values of the dependent variable represent the data you are trying to find. You are drawing the graph because you want to see how the dependent variable changes.

Figure 3-2. Graphing change in temperature with time. The graph shows the general pattern of the relationship between temperature and time. This is a direct relationship.

TIME (in minutes)	TEMPERATURE (in °C)
0	11°
1	13°
2	16°
3	19°
4	22°
5	24°
6	25°
7	27°
8	30°
9	32°
10	33°



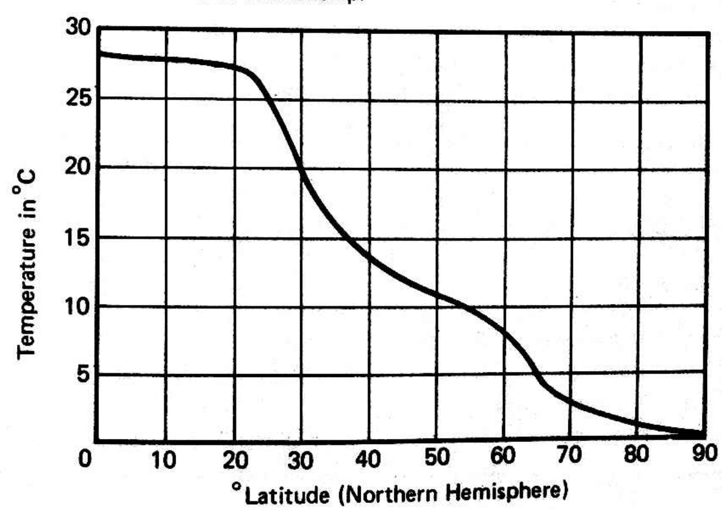
In drawing a graph, the independent variable is generally shown along the horizontal axis and the dependent variable along the vertical axis (see Figure 3-2). The next thing you have to do is decide on the scales along the two axes. This will depend on the range of the variables, and upon the precision of the data. The scales must be chosen so that all your data will fit inside the borders of your graph paper. At the same time, you would like to make maximum use of all the space on your sheet. Since the time variable goes from 0 (the starting time) to 10 minutes, you can choose a scale that puts 10 min. near the right-hand end of the horizontal axis, with 0 near the left end. If, however, you are planning to *extrapolate* your graph (extend it beyond the range of your actual data), you would use a smaller scale, to leave room beyond the 10-minute mark.

Another consideration is the precision with which the data was measured. If (as in this case) the temperature readings were made to the nearest 2°, there is no point in having a vertical scale marked off in 0.1° intervals. Your data is not precise enough to give meaning to such a refinement. On the other hand, a scale marked off in 10° intervals would be too coarse. You would not be able to get as much information from your graph as the data actually contains.

Interpreting Graphs. An important feature of any graph is that it shows the general nature of the relationship between the two variables. In this case, the two variables—time and temperature—show a *direct relationship*. The temperature increases as time increases. The line of the graph slants upward from left to right. If the temperature decreased with passing time, the two variables would show an *inverse relationship*. The line of the graph would slant *down* from left to right.

Figure 3-3 is a graph of average ocean temperatures observed between the equator (0° latitude) and the

Figure 3-3. Variations in average ocean temperature with latitude. From this graph you can see that ocean temperature generally decreases with increasing latitude. This is an inverse relationship.



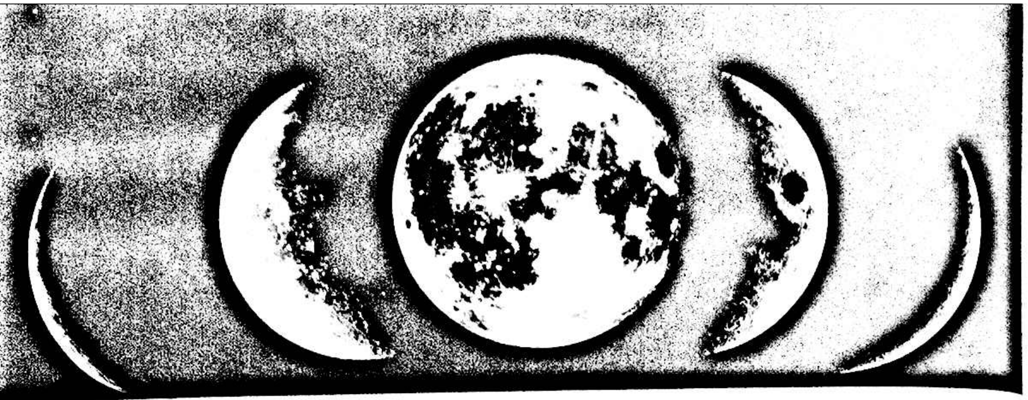


Figure 3-4. Some of the phases of the moon.

North Pole (90° north latitude). As you would expect, the temperature decreases as the latitude increases. This is therefore an inverse relationship, and the graph line slopes downward from left to right. Note, also, that this is an example of a change measured with reference to space, or location, rather than time.

Cyclic Changes. Figure 3-4 is a series of photos of the moon taken on different nights during a single month. Even if you have never given the subject much thought, you know that the appearance of the moon changes. These changes are called *phases*, and they follow a regular pattern, from crescent, through half-moon, through full moon, and back down to a crescent facing the other way. This cycle takes a quite definite period of time, and it repeats over and over in exactly the same way.

Table 3-1. Dates of the full moon during the first 6 months of a certain year.

Date	Day of Week	Interval
Jan 17	Saturday	
Feb 15	Sunday	29 days
Mar 16	Tuesday	30
Apr 14	Wednesday	29
May 13	Thursday	29
Jun 12	Saturday	30

Table 3-1 gives the dates of the full moon for six consecutive months in a certain year. You can see that the full moons seem to occur at intervals of either 29 or 30 days. With an observed pattern like this you can try to foretell the future. What is your prediction of the date of the next full moon in this series? If you guessed Sunday, July 11, you hit it on the nose. But do you think you could predict full moon dates for the later months of that year? Probably not. The pattern of 29- and 30-day intervals is not regular enough to do this with only six months of data. Table 3-2 shows the actual observations.

Many changes in the environment go through an orderly series of events that repeat at regular intervals, like the phases of the moon. Such changes are called *cyclic changes*. The cycles of day and night, the seasons, and the

Table 3-2. Dates of the full moon for the next 6 months of the year in Table 3-1.

Date	Day of Week	Interval
Jul 11	Sunday	29 days
Aug 9	Monday	29
Sep 8	Wednesday	30
Oct 8	Friday	30
Nov 6	Saturday	29
Dec 6	Monday	30

positions of stars and planets in the night sky are other examples of cyclic changes. Cyclic changes are observed with reference to space as well as to time. Ripple patterns produced in sand by waves or wind are often cyclic across a particular region (see Figure 3-5).

Some changes in the environment are not cyclic in nature. However, if you analyze them carefully, you may find that they follow a general pattern or trend. This information may enable you to make predictions about the future direction and nature of these changes.

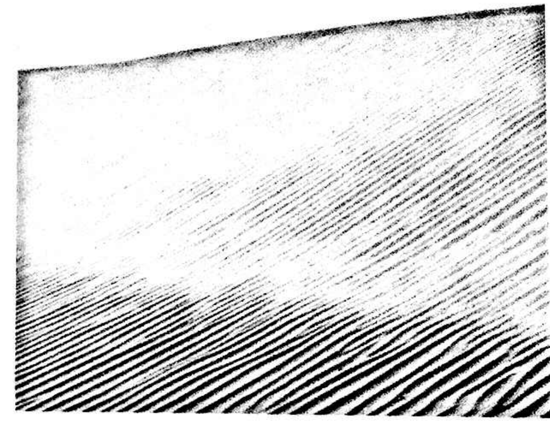


Figure 3-5. Ripple patterns in the sand.

SUMMARY

1. Every change or series of changes can be called an event.
2. Either time or space can be the frame of reference for describing change.
3. Change is often described in terms of the rate at which it occurs.
4. Graphing is often used to examine how one factor changes with respect to another.
5. In cyclic changes events repeat with reference to time or space.
6. If a change is cyclic or follows a particular trend, it is often possible to predict the amount and direction of future change.

CHANGE, ENERGY, AND INTERFACES

One aspect of change that we haven't mentioned up to this point is the relationship between change and energy. Energy is defined as the capacity to do work. Most changes cannot occur unless a flow of energy also takes place.

Almost all changes involve a flow of energy from one part of the environment to another. The part from which the energy flows loses energy, while the part to which the energy flows gains energy.

Where do changes and energy flow occur in the environment? They often occur along boundaries where different materials or systems come together. This type of boundary, where regions with different properties come together, is called an *interface*. Energy flow is generally across an interface.

Many interfaces are easy to recognize because they are sharp and distinct. An example is the interface between a stream and its bed (see Figure 3-6). At this interface, erosion occurs as kinetic energy from the water is transferred to soil and rock particles of the stream bed.

Sometimes, however, an interface is not so easily observed. Where is the

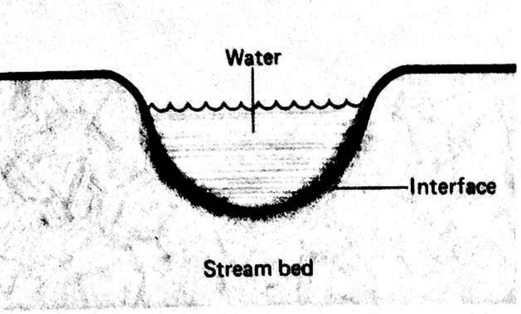


Figure 3-6. Distinct interface between water and stream bed.

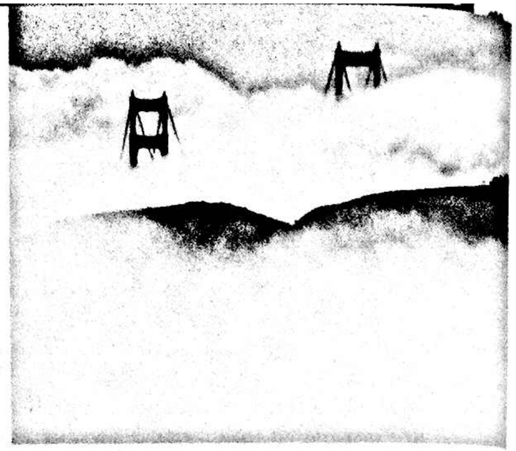


Figure 3-7. Diffuse interface between fog and clear air.

interface between the fog bank in Figure 3-7 and the clear air above it? Or where is the interface between the earth's atmosphere and the empty space beyond? The atmosphere gradually thins to almost nothing as you go higher in it, but it is hard to say just where the boundary is. Such "fuzzy" interfaces are said to be *diffuse*. You will encounter other diffuse interfaces in your study of earth science. But whether sharp or diffuse, it is at the interface that change usually occurs, and it is across the interface that energy associated with the change flows.

SUMMARY

1. Almost all changes involve a flow of energy from one part of the environment to another.
2. The boundary between regions with different properties is called an interface.
3. The exchange of energy and the processes of change occur at an interface.

ENVIRONMENTAL CHANGE

Figure 3-8 shows a tank with an inlet and an outlet for water and a control device for automatically regulating the flow of water into the tank. If the water level drops, the float opens the inlet valve to increase the flow of water. If the level rises, the float closes the valve to reduce the flow. In this way, the average level of the water in the tank is kept the same, even though changes are continuously occurring in the flow of water.

The conditions in the tank are called a state of *dynamic equilibrium*. In a dynamic equilibrium, changes are occurring, but there is a balance among the changes so that overall conditions remain the same. The natural environment is normally in a state of dynamic equilibrium. In a forest, for example, the numbers of various kinds of plants and animals tend to be about the same from year to year, even though the individual plants and

animals may change. This natural environmental equilibrium is often called the "balance of nature."

The environmental equilibrium may be upset frequently to a small extent or in a limited region, but in the course of time the natural balance is restored. Large-scale changes may be caused by natural disasters, such as volcanic eruptions or earthquakes, but even then a new equilibrium is eventually established.

Human activities, on the other hand, are tending more and more to cause permanent disruptions of the environmental equilibrium. What humans do to their environment may be compared to removing the float or turning off the water supply in the example of Figure 3-8. The forces that could restore the equilibrium are then no longer present.

Environmental Pollution. Pollution of the environment occurs when the concentration of a substance or form of energy becomes high enough to adversely affect people, their property, or plant or animal life. Things that pollute are called *pollutants*. Some pollutants are the results of natural processes—for example, ash from a volcano. Many others, however, are the result of human activities—for example, carbon monoxide from automobile exhausts.

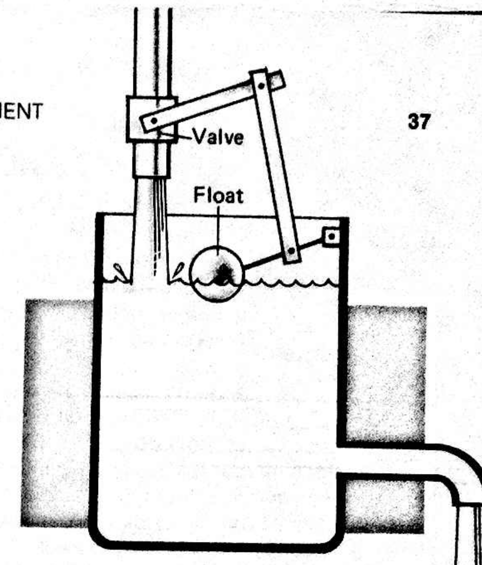


Figure 3-8. Dynamic equilibrium. The tank shown here is in a state of dynamic equilibrium. The individual water molecules are constantly changing, but the average level of water in the tank remains the same.

Pollutants may be solids, liquids, gases, biologic organisms, or forms of energy, such as heat, sound, and nuclear radiation. Pollutants are found in the air, on land, and in water. The amount of pollution present varies with time and place. It is greatest in highly populated and highly industrialized areas, and least in lightly populated, unindustrialized areas.

As we continue to look into the processes of change on the earth, we will have more to say about this vital subject of pollution and the other effects of human actions on the environment.

SUMMARY

1. The environment is in a state of natural equilibrium. This equilibrium is frequently altered on a small scale, but is then restored by natural processes.
2. Human technology can cause large-scale disruption of large portions of the environment.
3. The environment is considered to be polluted when the concentration of a substance or form of energy reaches such a concentration that it adversely affects man, his property, or plant or animal life.
4. Pollutants are being added to the environment by natural processes and by the activities of individuals, communities, and industrial processes.

REVIEW QUESTIONS

Group A

1. In terms of change, what is an *event*?
2. What are the *frames of reference* used for describing change?
3. Give one example of space and one example of time as a frame of reference for describing change.
4. Answer the following questions on the basic rules of drawing graphs.
   a. Which axis is used for the dependent variable? Which is used for the independent variable?
   b. How do you decide on the proper scale for a graph?
   c. Describe the general slope of a graph that shows a direct relationship between the variables plotted.
   d. Describe the general slope of a graph that shows an inverse relationship between the variables plotted.
5. What is a *cyclic change*? Give some examples of cyclic changes.
6. How is change related to energy flow?
7. What is the boundary between regions with different properties called?
8. Where do energy exchanges and processes of change occur?
9. What is meant by *dynamic equilibrium*? How does this term apply to the environment?
10. Are most natural changes in the environment small-scale changes or large-scale changes? What about changes caused by human technology?
11. What is meant by *pollution*?
12. What kinds of processes pollute the environment?

Group B

1. a. Explain how you would go about proving or disproving that a change is taking place in some part of your environment.
   b. Scientists attempt to give meaningful descriptions of change. In some situations, though, word descriptions are not enough for scientists. What else concerning change do they attempt to do?
   c. What kind of relationship (direct or inverse) exists between the following: A — The masses and the volumes of a number of different water samples of various sizes; B — The masses and the mileages (average number of miles that can be driven on a gallon of gas) of a number of cars of various sizes.
2. Which of the following are cyclic changes: (a) The change in water level caused by the ocean tides; (b) The change in the number of people living on earth at any given time since the year 1700.
3. Energy from the sun warms the sand on a beach. What interface is involved in this energy transfer and what is the direction of the energy flow?
4. "People are not the only polluters of the environment." Explain.

REVIEW EXERCISES

1. Make a list of ten changes that you have observed in your environment. Classify these changes according to their frame, or frames, of reference—either time, space, or both.
2. The data below show the time it takes for one type of earthquake wave to travel through the earth.

Distance of earthquake epicenter from observer	Travel time of earthquake waves
1,000 km	2 min
2,000 km	3 min 45 sec
3,000 km	5 min 30 sec
4,000 km	7 min
5,000 km	8 min 15 sec
6,000 km	9 min 30 sec
7,000 km	10 min 30 sec

   Graph the data and answer the following questions:
   a. Is this a cyclic or noncyclic change?
   b. Is there a direct or an inverse relationship between the distance and the time?
   c. What is the probable travel time for a distance of 10,000 km?
3. The data below show the position of a swinging pendulum as it was observed at 1-second intervals. Zero is the rest (vertical) position of the pendulum. Positive (+) distances are to the right; negative (−) distances are to the left.

Time in seconds	0	1	2	3	4	5	6	7	8	9	10	11	12
Distance from rest position (cm)	+10.0	0	−9.2	0	+8.4	0	−7.0	0	+6.6	0	−5.6	0	+5.2

   Graph the data and answer the following questions:
   a. Is the change of position of the pendulum cyclic or noncyclic?
   b. What regular change in the pattern of the pendulum motion do you observe?
   c. Predict the position of the pendulum at time 15 sec. At time 16 sec.
4. Make a list of ten pollutants that you have observed or that you know to exist in your environment. Classify them according to their source: natural (N), or man-made (M). Under those that are man-made, further identify the source of these pollutants by marking them: (I) for those caused by the activity of individuals; (C) for those caused by community activity; and (P) for those resulting from industrial processes.