For the past few thousand years, scientists can obtain these data by examining tree rings, which with careful study can reveal a record of both temperature and the atmospheric carbon dioxide concentration. The record can be extended much further back with studies of ice cores drilled out of the Antarctic ice sheet. Ice cores are made up of accumulated layers of ancient, compressed snow. Because snow falls seasonally, each thin layer represents a single year, much as each tree ring represents a single year in the life of a tree. By studying air bubbles trapped in the ice core layers, scientists can reconstruct the past history of temperatures and carbon dioxide concentration. (The carbon dioxide concentration can be measured fairly directly from the air bubbles, while the temperatures are measured through careful study of oxygen isotopes in the air bubbles: heavier isotopes aren't transported through the air as easily when temperatures are lower, so the ratio of heavy isotopes to the lighter ones allows researchers to estimate temperatures in the distant past.)

The results are striking. As you can see in the lower graph on the left side of Figure 3.61, the ice core data provide a record of temperatures and carbon dioxide concentration going back more than 400,000 years, a period during which Earth went through numerous ice ages and warm periods. At least three conclusions should jump out at you as you study the figure:

1. There is a correlation between temperature and carbon dioxide concentration: Periods of higher temperature tend to also be periods of higher carbon dioxide concentration. Although this does not prove that a rise in carbon dioxide concentration *causes* the higher temperature, it certainly makes it seem likely that the two go together—which means it makes sense that the recent rise in the carbon dioxide concentration has been accompanied by a corresponding rise in temperature.
2. Both the temperature and the carbon dioxide concentration vary substantially and naturally with time. Global average temperatures have risen or fallen by more than 10°C (about 18°F) several times during the past few hundred thousand years, and the carbon dioxide concentration has varied naturally between less than 200 and nearly 300 parts per million (ppm).
3. When we compare the recent carbon dioxide data on the right side of the graph to the past data on the left, we find we are in completely new territory: The current carbon dioxide concentration is far above anything that our planet has seen in the past 400,000 years. Indeed, recent data have preliminarily extended the ice core record back more than 1 million years, and we find the same basic idea: Since the dawn of the industrial age, we have raised Earth's atmospheric carbon dioxide concentration far above the levels that have occurred naturally during any of the warm periods or ice ages of the past million years.

Even without precise predictions of the expected future changes in the global climate, these data provide a sobering message. The difference between an ice age in which most of the United States is buried under glaciers and our current more balmy conditions is only a few degrees Celsius, and the ice core data tell us that even larger temperature changes have occurred in the past with changes in carbon dioxide concentrations much smaller than the change that is under way today. If the past trends are indicative of what we can expect in the future, then unless we act soon to stop the buildup of carbon dioxide, our children and grandchildren will inhabit a world with a climate quite different from the one we live in today.

QUESTIONS FOR DISCUSSION

1. Study Figure 3.61 carefully. How does the carbon dioxide concentration today compare to that of 1750? How does that of 1750 compare to that during the past 400,000 years? What conclusions can you draw from your answers to these questions?
2. Discuss some of the factors that will affect the future concentration of carbon dioxide in the atmosphere. What do you think should be done to slow or stop the growth in the carbon dioxide concentration?