# *Timberlane High School Science Summer Reading Assignment:*

## Course: Meteorology

### Instructions

Please read the following selection(s) from the book A Short History of Nearly Everything by Bill Bryson.

- Please provide written answers (short essay style) to the questions at the end of the reading

  •Questions adapted from Random House Publishing Inc.
  https://www.randomhouse.com/catalog/teachers_guides/9780767908184.pdf

- The written assignment is to be turned into your teacher by **Thursday, September 5th and Friday, September 6th**, for potential full credit. Accepted until Sept 12th with 10% deduction in grade per day. Not accepted after Sept 12th.
- This is a graded assignment worth up to 3% of your quarter 1 grade. **Grading Rubric:**

The writing will be assessed on the following 0 to 3 scales

- Each answer should be in a short essay style (minimum one paragraph).
  - 1: most answers are short one word answers.
  - 3: complete thoughts and sentences that fully convey the answers.
- Each answer should demonstrate evidence of reading to comprehension.
  - 1: answers indicate that the reading was not completed o 3: answers show clear comprehension of the reading
- Each answer should be correct, relevant to the topic, should strive for detail and completeness.
  - 1: answers are not relative to question or reading o 3: Answers demonstrate clear relevancy to passage and get to the heart of the rationale for question in relation to subject area.
- Each answer should refer to a specific statement or include a quote from the reading.
  - 1: the writing is vague, incomplete and contains little detail o 3: writing is detailed, complete and references specific statements or quotes from the reading passage.
- Each answer should be original (no plagiarism)

### Tips on how to read science text for comprehension:

Break the reading into more than one session (2 to 4 pages per day). This should take about 15 minutes each time. Read slowly! Understand each sentence before reading the next. Be sure to examine unfamiliar words and concepts; try to determine meaning from the reading (or look them up). Make notes on each paragraph! It is OK to reread as you go or even reread the entire text. Read to understand, think about the ideas as you read and relate to what you already know, and what you may want to find out.

## 17 INTO THE TROPOSPHERE

THANK GOODNESS FOR the atmosphere. It keeps us warm. Without it, Earth would be a lifeless ball of ice with an average temperature of minus 60 degrees Fahrenheit. In addition, the atmosphere absorbs or deflects incoming swarms of cosmic rays, charged particles, ultraviolet rays, and the like. Altogether, the gaseous padding of the atmosphere is equivalent to a fifteen-foot thickness of protective concrete, and without it these invisible visitors from space would slice through us like tiny daggers. Even raindrops would pound us senseless if it weren't for the atmosphere's slowing drag.

The most striking thing about our atmosphere is that there isn't very much of it. It extends upward for about 120 miles, which might seem reasonably bounteous when viewed from ground level, but if you shrank the Earth to the size of a standard desktop globe it would only be about the thickness of a couple of coats of varnish.

For scientific convenience, the atmosphere is divided into four unequal layers: troposphere, stratosphere, mesosphere, and ionosphere (now often called the thermosphere). The troposphere is the part that's dear to us. It alone contains enough warmth and oxygen to allow us to function, though even it swiftly becomes uncongenial to life as you climb up through it. From ground level to its highest point, the troposphere (or "turning sphere") is about ten miles thick at the equator and no more than six or seven miles high in the temperate latitudes where most of us live. Eighty percent of the atmosphere's mass, virtually all the water, and thus virtually all the weather are contained within this thin and wispy layer. There really isn't much between you and oblivion.

Beyond the troposphere is the stratosphere. When you see the top of a storm cloud flattening out into the classic anvil shape, you are looking at the boundary between the troposphere and stratosphere. This invisible ceiling is known as the tropopause and was discovered in 1902 by a Frenchman in a balloon, Léon-Philippe Teisserenc de Bort. Pause in this sense doesn't mean to stop momentarily but to cease altogether; it's from the same Greek root as menopause. Even at its greatest extent, the tropopause is not very distant. A fast elevator of the sort used in modern skyscrapers could get you there in about twenty minutes, though you would be well advised not to make the trip. Such a rapid ascent without pressurization would, at the very least, result in severe cerebral and pulmonary edemas, a dangerous excess of fluids in the body's tissues. When the doors opened at the viewing platform, anyone inside would almost certainly be dead or dying. Even a more measured ascent would be accompanied by a great deal of discomfort. The temperature six miles up can be -70 degrees Fahrenheit, and you would need, or at least very much appreciate, supplementary oxygen.

After you have left the troposphere the temperature soon warms up again, to about 40 degrees Fahrenheit, thanks to the absorptive effects of ozone (something else de Bort discovered on his daring 1902 ascent). It then plunges to as low as -130 degrees Fahrenheit in the mesosphere before skyrocketing to 2,700 degrees Fahrenheit or more in the aptly named but very erratic thermosphere, where temperatures can vary by a thousand degrees from day to night—though it must be said that "temperature" at such a height becomes a somewhat notional concept. Temperature is really just a measure of the activity of molecules. At sea level, air molecules are so thick that one molecule can move only the tiniest distance—about three-millionths of an inch, to be precise—before banging into another. Because trillions of molecules are constantly colliding, a lot of heat gets exchanged. But at the height of the thermosphere, at fifty miles or more, the air is so thin that any two molecules will be miles apart and hardly ever come in contact. So although each molecule is very warm, there are few interactions between them and thus little heat transference. This is good news for satellites and spaceships because if the exchange of heat were more efficient any man-made object orbiting at that level would burst into flame.

Even so, spaceships have to take care in the outer atmosphere, particularly on return trips to Earth, as the space shuttle Columbia demonstrated all too tragically in February 2003. Although the atmosphere is very thin, if a craft comes in at too steep an angle—more than about 6 degrees—or too swiftly it can strike enough molecules to generate drag of an exceedingly combustible nature. Conversely, if an incoming vehicle hit the thermosphere at too shallow an angle, it could well bounce back into space, like a pebble skipped across water.

But you needn't venture to the edge of the atmosphere to be reminded of what hopelessly ground-hugging beings we are. As anyone who has spent time in a lofty city will know, you don't have to rise too many thousands of feet from sea level before your body begins to protest. Even experienced mountaineers, with the benefits of fitness, training, and bottled oxygen, quickly become vulnerable at height to confusion, nausea, exhaustion, frostbite, hypothermia, migraine, loss of appetite, and a great many other stumbling dysfunctions. In a hundred emphatic ways the human body reminds its owner that it wasn't designed to operate so far above sea level.

"Even under the most favorable circumstances," the climber Peter Habeler has written of conditions atop Everest, "every step at that altitude demands a colossal effort of will. You must force yourself to make every movement, reach for every handhold. You are perpetually threatened by a leaden, deadly fatigue." In The Other Side of Everest, the British mountaineer and filmmaker Matt Dickinson records how Howard Somervell, on a 1924 British expedition up Everest, "found himself choking to death after a piece of infected flesh came loose and blocked his windpipe." With a supreme effort Somervell managed to cough up the obstruction. It turned out to be "the entire mucus lining of his larynx."

Bodily distress is notorious above 25,000 feet—the area known to climbers as the Death Zone—but many people become severely debilitated, even dangerously ill, at heights of no more than 15,000 feet or so. Susceptibility has little to do with fitness. Grannies sometimes caper about in lofty situations while their fitter offspring are reduced to helpless, groaning heaps until conveyed to lower altitudes.

The absolute limit of human tolerance for continuous living appears to be about 5,500 meters, or 18,000 feet, but even people conditioned to living at altitude could not tolerate such heights for long. Frances Ashcroft, in Life at the Extremes, notes that there are Andean sulfur mines at 5,800 meters, but that the miners prefer to descend 460 meters each evening and climb back up the following day, rather than live continuously at that elevation. People who habitually live at altitude have often spent thousands of years developing disproportionately large chests and lungs, increasing their density of oxygen-bearing red blood cells by almost a third, though there are limits to how much thickening with red cells the blood supply can stand. Moreover, above 5,500 meters even the most well-adapted women cannot provide a growing fetus with enough oxygen to bring it to its full term.

In the 1780s when people began to make experimental balloon ascents in Europe, something that surprised them was how chilly it got as they rose. The temperature drops about 3 degrees Fahrenheit with every thousand feet you climb. Logic would seem to indicate that the closer you get to a source of heat, the warmer you would feel. Part of the explanation is that you are not really getting nearer the Sun in any meaningful sense. The Sun is ninety-three million miles away. To move a couple of thousand feet closer to it is like taking one step closer to a bushfire in Australia when you are standing in Ohio, and expecting to smell smoke. The answer again takes us back to the question of the density of molecules in the atmosphere. Sunlight energizes atoms. It increases the rate at which they jiggle and jounce, and in their enlivened state they crash into one another, releasing heat. When you feel the sun warm on your back on a summer's day, it's really excited atoms you feel. The higher you climb, the fewer molecules there are, and so the fewer collisions between them.

Air is deceptive stuff. Even at sea level, we tend to think of the air as being ethereal and all but weightless. In fact, it has plenty of bulk, and that bulk often exerts itself. As a marine scientist named Wyville Thomson wrote more than a century ago: "We sometimes find when we get up in the morning, by a rise of an inch in the barometer, that nearly half a ton has been quietly piled upon us during the night, but we experience no inconvenience, rather a feeling of exhilaration and buoyancy, since it requires a little less exertion to move our bodies in the denser medium." The reason you don't feel crushed under that extra half ton of pressure is the same reason your body would not be crushed deep beneath the sea: it is made mostly of incompressible fluids, which push back, equalizing the pressures within and without.

But get air in motion, as with a hurricane or even a stiff breeze, and you will quickly be reminded that it has very considerable mass. Altogether there are about 5,200 million million tons of air around us—25 million tons for every square mile of the planet—a not inconsequential volume. When you get millions of tons of atmosphere rushing past at thirty or forty miles an hour, it's hardly a surprise that limbs snap and roof tiles go flying. As Anthony Smith notes, a typical weather front may consist of 750 million tons of cold air pinned beneath a billion tons of warmer air. Hardly a wonder that the result is at times meteorologically exciting.

Certainly there is no shortage of energy in the world above our heads. One thunderstorm, it has been calculated, can contain an amount of energy equivalent to four days' use of electricity for the whole United States. In the right conditions, storm clouds can rise to heights of six to ten miles and contain updrafts and downdrafts of one hundred miles an hour. These are often side by side, which is why pilots don't want to fly through them. In all, the internal turmoil particles within the cloud pick up electrical charges. For reasons not entirely understood the lighter particles tend to become positively charged and to be wafted by air currents to the top of the cloud. The heavier particles linger at the base, accumulating negative charges. These negatively charged particles have a powerful urge to rush to the positively charged Earth, and good luck to anything that gets in their way. A bolt of lightning travels at 270,000 miles an hour and can heat the air around it to a decidedly crisp 50,000 degrees Fahrenheit, several times hotter than the surface of the sun. At any one moment 1,800 thunderstorms are in progress around the globe—some 40,000 a day. Day and night across the planet every second about a hundred lightning bolts hit the ground. The sky is a lively place.

Much of our knowledge of what goes on up there is surprisingly recent. Jet streams, usually located about 30,000 to 35,000 feet up, can bowl along at up to 180 miles an hour and vastly influence weather systems over whole continents, yet their existence wasn't suspected until pilots began to fly into them during the Second World War. Even now a great deal of atmospheric phenomena is barely understood. A form of wave motion popularly known as clear-air turbulence occasionally enlivens airplane flights. About twenty such incidents a year are serious enough to need reporting. They are not associated with cloud structures or anything else that can be detected visually or by radar. They are just pockets of startling turbulence in the middle of tranquil skies. In a typical incident, a plane en route from Singapore to Sydney was flying over central Australia in calm conditions when it suddenly fell three hundred feet—enough to fling unsecured people against the ceiling. Twelve people were injured, one seriously. No one knows what causes such disruptive cells of air.

The process that moves air around in the atmosphere is the same process that drives the internal engine of the planet, namely convection. Moist, warm air from the equatorial regions rises until it hits the barrier of the tropopause and spreads out. As it travels away from the equator and cools, it sinks. When it hits bottom, some of the sinking air looks for an area of low pressure to fill and heads back for the equator, completing the circuit.

At the equator the convection process is generally stable and the weather predictably fair, but in temperate zones the patterns are far more seasonal, localized, and random, which results in an endless battle between systems of high-pressure air and low. Low-pressure systems are created by rising air, which conveys water molecules into the sky, forming clouds and eventually rain. Warm air can hold more moisture than cool air, which is why tropical and summer storms tend to be the heaviest. Thus low areas tend to be associated with clouds and rain, and highs generally spell sunshine and fair weather. When two such systems meet, it often becomes manifest in the clouds. For instance, stratus clouds—those unlovable, featureless sprawls that give us our overcast skies—happen when moisture-bearing updrafts lack the oomph to break through a level of more stable air above, and instead spread out, like smoke hitting a ceiling. Indeed, if you watch a smoker sometime, you can get a very good idea of how things work by watching how smoke rises from a cigarette in a still room. At first, it goes straight up (this is called a laminar flow, if you need to impress anyone), and then it spreads out in a diffused, wavy layer. The greatest supercomputer in the world, taking measurements in the most carefully controlled environment, cannot tell you what forms these ripplings will take, so you can imagine the difficulties that confront meteorologists when they try to predict such motions in a spinning, windy, large-scale world.

What we do know is that because heat from the Sun is unevenly distributed, differences in air pressure arise on the planet. Air can't abide this, so it rushes around trying to equalize things everywhere. Wind is simply the air's way of trying to keep things in balance. Air always flows from areas of high pressure to areas of low pressure (as you would expect; think of anything with air under pressure—a balloon or an air tank—and think how insistently that pressured air wants to get someplace else), and the greater the discrepancy in pressures the faster the wind blows.

Incidentally, wind speeds, like most things that accumulate, grow exponentially, so a wind blowing at two hundred miles an hour is not simply ten times stronger than a wind blowing at twenty miles an hour, but a hundred times stronger—and hence that much more destructive. Introduce several million tons of air to this accelerator effect and the result can be exceedingly energetic. A tropical hurricane can release in twenty-four hours as much energy as a rich, medium-sized nation like Britain or France uses in a year.

The impulse of the atmosphere to seek equilibrium was first suspected by Edmond Halley—the man who was everywhere—and elaborated upon in the eighteenth century by his fellow Briton George Hadley, who saw that rising and falling columns of air tended to produce "cells" (known ever since as "Hadley cells"). Though a lawyer by profession, Hadley had a keen interest in the weather (he was, after all, English) and also suggested a link between his cells, the Earth's spin, and the apparent deflections of air that give us our trade winds. However, it was an engineering professor at the École Polytechnique in Paris, Gustave-Gaspard de Coriolis, who worked out the details of these interactions in 1835, and thus we call it the Coriolis effect. (Coriolis's other distinction at the school was to introduce watercoolers, which are still known there as Corios, apparently.) The Earth revolves at a brisk 1,041 miles an hour at the equator, though as you move toward the poles the rate slopes off considerably, to about 600 miles an hour in London or Paris, for instance. The reason for this is self-evident when you think about it. If you are on the equator the spinning Earth has to carry you quite a distance—about 40,000 kilometers—to get you back to the same spot. If you stand beside the North Pole, however, you may need travel only a few feet to complete a revolution, yet in both cases it takes twenty-four hours to get you back to where you began. Therefore, it follows that the closer you get to the equator the faster you must be spinning.

The Coriolis effect explains why anything moving through the air in a straight line laterally to the Earth's spin will, given enough distance, seem to curve to the right in the northern hemisphere and to the left in the southern as the Earth revolves beneath it. The standard way to envision this is to imagine yourself at the center of a large carousel and tossing a ball to someone positioned on the edge. By the time the ball gets to the perimeter, the target person has moved on and the ball passes behind him. From his perspective, it looks as if it has curved away from him. That is the Coriolis effect, and it is what gives weather systems their curl and sends hurricanes spinning off like tops. The Coriolis effect is also why naval guns firing artillery shells have to adjust to left or right; a shell fired fifteen miles would otherwise deviate by about a hundred yards and plop harmlessly into the sea.

Considering the practical and psychological importance of the weather to nearly everyone, it's surprising that meteorology didn't really get going as a science until shortly before the turn of the nineteenth century (though the term meteorology itself had been around since 1626, when it was coined by a T. Granger in a book of logic).

Part of the problem was that successful meteorology requires the precise measurement of temperatures, and thermometers for a long time proved more difficult to make than you might expect. An accurate reading was dependent on getting a very even bore in a glass tube, and that wasn't easy to do. The first person to crack the problem was Daniel Gabriel Fahrenheit, a Dutch maker of instruments, who produced an accurate thermometer in 1717. However, for reasons unknown he calibrated the instrument in a way that put freezing at 32 degrees and boiling at 212 degrees. From the outset this numeric eccentricity bothered some people, and in 1742 Anders Celsius, a Swedish astronomer, came up with a competing scale. In proof of the proposition that inventors seldom get matters entirely right, Celsius made boiling point zero and freezing point 100 on his scale, but that was soon reversed.

The person most frequently identified as the father of modern meteorology was an English pharmacist named Luke Howard, who came to prominence at the beginning of the nineteenth century. Howard is chiefly remembered now for giving cloud types their names in 1803. Although he was an active and respected member of the Linnaean Society and employed Linnaean principles in his new scheme, Howard chose the rather more obscure Askesian Society as the forum to announce his new system of classification. (The Askesian Society, you may just recall from an earlier chapter, was the body whose members were unusually devoted to the pleasures of nitrous oxide, so we can only hope they treated Howard's presentation with the sober attention it deserved. It is a point on which Howard scholars are curiously silent.)

Howard divided clouds into three groups: stratus for the layered clouds, cumulus for the fluffy ones (the word means "heaped" in Latin), and cirrus (meaning "curled") for the high, thin feathery formations that generally presage colder weather. To these he subsequently added a fourth term, nimbus (from the Latin for "cloud"), for a rain cloud. The beauty of Howard's system was that the basic components could be freely recombined to describe every shape and size of passing cloud—stratocumulus, cirrostratus, cumulocongestus, and so on. It was an immediate hit, and not just in England. The poet Johann von Goethe in Germany was so taken with the system that he dedicated four poems to Howard.

Howard's system has been much added to over the years, so much so that the encyclopedic if little read International Cloud Atlas runs to two volumes, but interestingly virtually all the post-Howard cloud types—mammatus, pileus, nebulosis, spissatus, floccus, and mediocris are a sampling—have never caught on with anyone outside meteorology and not terribly much there, I'm told. Incidentally, the first, much thinner edition of that atlas, produced in 1896, divided clouds into ten basic types, of which the plumpest and most cushiony-looking was number nine, cumulonimbus.[1] That seems to have been the source of the expression "to be on cloud nine."

For all the heft and fury of the occasional anvil-headed storm cloud, the average cloud is actually a benign and surprisingly insubstantial thing. A fluffy summer cumulus several hundred yards to a side may contain no more than twenty-five or thirty gallons of water—"about enough to fill a bathtub," as James Trefil has noted. You can get some sense of the immaterial quality of clouds by strolling through fog—which is, after all, nothing more than a cloud that lacks the will to fly. To quote Trefil again: "If you walk 100 yards through a typical fog, you will come into contact with only about half a cubic inch of water—not enough to give you a decent drink." In consequence, clouds are not great reservoirs of water. Only about 0.035 percent of the Earth's fresh water is floating around above us at any moment.

Depending on where it falls, the prognosis for a water molecule varies widely. If it lands in fertile soil it will be soaked up by plants or reevaporated directly within hours or days. If it finds its way down to the groundwater, however, it may not see sunlight again for many years—thousands if it gets really deep. When you look at a lake, you are looking at a collection of molecules that have been there on average for about a decade. In the ocean the residence time is thought to be more like a hundred years. Altogether about 60 percent of

[1] If you have ever been struck by how beautifully crisp and well defined the edges of cumulus clouds tend to be, while other clouds are more blurry, the explanation is that in a cumulus cloud there is a pronounced boundary between the moist interior of the cloud and the dry air beyond it. Any water molecule that strays beyond the edge of the cloud is immediately zapped by the dry air beyond, allowing the cloud to keep its fine edge. Much higher cirrus clouds are composed of ice, and the zone between the edge of the cloud and the air beyond is not so clearly delineated, which is why they tend to be blurry at the edges.

water molecules in a rainfall are returned to the atmosphere within a day or two. Once evaporated, they spend no more than a week or so—Drury says twelve days—in the sky before falling again as rain.

Evaporation is a swift process, as you can easily gauge by the fate of a puddle on a summer's day. Even something as large as the Mediterranean would dry out in a thousand years if it were not continually replenished. Such an event occurred a little under six million years ago and provoked what is known to science as the Messinian Salinity Crisis. What happened was that continental movement closed the Strait of Gibraltar. As the Mediterranean dried, its evaporated contents fell as freshwater rain into other seas, mildly diluting their saltiness—indeed, making them just dilute enough to freeze over larger areas than normal. The enlarged area of ice bounced back more of the Sun's heat and pushed Earth into an ice age. So at least the theory goes.

What is certainly true, as far as we can tell, is that a little change in the Earth's dynamics can have repercussions beyond our imagining. Such an event, as we shall see a little further on, may even have created us.

Oceans are the real powerhouse of the planet's surface behavior. Indeed, meteorologists increasingly treat oceans and atmosphere as a single system, which is why we must give them a little of our attention here. Water is marvelous at holding and transporting heat. Every day, the Gulf Stream carries an amount of heat to Europe equivalent to the world's output of coal for ten years, which is why Britain and Ireland have such mild winters compared with Canada and Russia.

But water also warms slowly, which is why lakes and swimming pools are cold even on the hottest days. For that reason there tends to be a lag in the official, astronomical start of a season and the actual feeling that that season has started. So spring may officially start in the northern hemisphere in March, but it doesn't feel like it in most places until April at the very earliest.

The oceans are not one uniform mass of water. Their differences in temperature, salinity, depth, density, and so on have huge effects on how they move heat around, which in turn affects climate. The Atlantic, for instance, is saltier than the Pacific, and a good thing too. The saltier water is the denser it is, and dense water sinks. Without its extra burden of salt, the Atlantic currents would proceed up to the Arctic, warming the North Pole but depriving Europe of all that kindly warmth. The main agent of heat transfer on Earth is what is known as thermohaline circulation, which originates in slow, deep currents far below the surface—a process first detected by the scientist-adventurer Count von Rumford in 1797.[2] What happens is that surface waters, as they get to the vicinity of Europe, grow dense and sink to great depths and begin a slow trip back to the southern hemisphere. When they reach Antarctica, they are caught up in the Antarctic Circumpolar Current, where they are driven onward into the Pacific. The process is very slow—it can take 1,500 years for water to travel from the

[2] The term means a number of things to different people, it appears. In November 2002, Carl Wunsch of MIT published a report in Science, "What Is the Thermohaline Circulation?," in which he noted that the expression has been used in leading journals to signify at least seven different phenomena (circulation at the abyssal level, circulation driven by differences in density or buoyancy, "meridional overturning circulation of mass," and so on)-though all have to do with ocean circulations and the transfer of heat, the cautiously vague and embracing sense in which I have employed it here.

North Atlantic to the mid-Pacific—but the volumes of heat and water they move are very considerable, and the influence on the climate is enormous.

(As for the question of how anyone could possibly figure out how long it takes a drop of water to get from one ocean to another, the answer is that scientists can measure compounds in the water like chlorofluorocarbons and work out how long it has been since they were last in the air. By comparing a lot of measurements from different depths and locations they can reasonably chart the water's movement.)

Thermohaline circulation not only moves heat around, but also helps to stir up nutrients as the currents rise and fall, making greater volumes of the ocean habitable for fish and other marine creatures. Unfortunately, it appears the circulation may also be very sensitive to change. According to computer simulations, even a modest dilution of the ocean's salt content—from increased melting of the Greenland ice sheet, for instance—could disrupt the cycle disastrously.

The seas do one other great favor for us. They soak up tremendous volumes of carbon and provide a means for it to be safely locked away. One of the oddities of our solar system is that the Sun burns about 25 percent more brightly now than when the solar system was young. This should have resulted in a much warmer Earth. Indeed, as the English geologist Aubrey Manning has put it, "This colossal change should have had an absolutely catastrophic effect on the Earth and yet it appears that our world has hardly been affected."

So what keeps the world stable and cool?

Life does. Trillions upon trillions of tiny marine organisms that most of us have never heard of—foraminiferans and coccoliths and calcareous algae—capture atmospheric carbon, in the form of carbon dioxide, when it falls as rain and use it (in combination with other things) to make their tiny shells. By locking the carbon up in their shells, they keep it from being reevaporated into the atmosphere, where it would build up dangerously as a greenhouse gas. Eventually all the tiny foraminiferans and coccoliths and so on die and fall to the bottom of the sea, where they are compressed into limestone. It is remarkable, when you behold an extraordinary natural feature like the White Cliffs of Dover in England, to reflect that it is made up of nothing but tiny deceased marine organisms, but even more remarkable when you realize how much carbon they cumulatively sequester. A six-inch cube of Dover chalk will contain well over a thousand liters of compressed carbon dioxide that would otherwise be doing us no good at all. Altogether there is about twenty thousand times as much carbon locked away in the Earth's rocks as in the atmosphere. Eventually much of that limestone will end up feeding volcanoes, and the carbon will return to the atmosphere and fall to the Earth in rain, which is why the whole is called the long-term carbon cycle. The process takes a very long time—about half a million years for a typical carbon atom—but in the absence of any other disturbance it works remarkably well at keeping the climate stable.

Unfortunately, human beings have a careless predilection for disrupting this cycle by putting lots of extra carbon into the atmosphere whether the foraminiferans are ready for it or not. Since 1850, it has been estimated, we have lofted about a hundred billion tons of extra carbon into the air, a total that increases by about seven billion tons each year. Overall, that's not actually all that much. Nature—mostly through the belchings of volcanoes and the decay of plants—sends about 200 billion tons of carbon dioxide into the atmosphere each year, nearly thirty times as much as we do with our cars and factories. But you have only to look at the haze that hangs over our cities to see what a difference our contribution makes.

We know from samples of very old ice that the "natural" level of carbon dioxide in the atmosphere—that is, before we started inflating it with industrial activity—is about 280 parts per million. By 1958, when people in lab coats started to pay attention to it, it had risen to 315 parts per million. Today it is over 360 parts per million and rising by roughly one-quarter of 1 percent a year. By the end of the twenty-first century it is forecast to rise to about 560 parts per million.

So far, the Earth's oceans and forests (which also pack away a lot of carbon) have managed to save us from ourselves, but as Peter Cox of the British Meteorological Office puts it: "There is a critical threshold where the natural biosphere stops buffering us from the effects of our emissions and actually starts to amplify them." The fear is that there would be a runaway increase in the Earth's warming. Unable to adapt, many trees and other plants would die, releasing their stores of carbon and adding to the problem. Such cycles have occasionally happened in the distant past even without a human contribution. The good news is that even here nature is quite wonderful. It is almost certain that eventually the carbon cycle would reassert itself and return the Earth to a situation of stability and happiness. The last time this happened, it took a mere sixty thousand years.

***Chapter 17: Into the Troposphere***

Discussion Questions:

1.Why is it a good thing that we have an atmosphere?

2.What is the danger of living at high altitudes?

3.What are the layers of the atmosphere?

4.Why does it get colder as you climb a mountain?

5.What influences air movement in the atmosphere?

6.How are clouds classified?

7.What was the "salinity crisis?"

8.How do the oceans influence climate and weather?

9.How does the Gulf Stream influence weather?

10.What is "thermohaline circulation?"

11.Does life help keep the world hospitable? Are we humans disrupting this balance?