Unit 1

Carbon We Live By

You will die but the carbon will not; its career does not end with you. It will return to the soil, and there a plant may take it up again in time, sending it once more on a cycle of plant and animal life.

—*Jacob Bronowski*

Phase I First Sight

Video I Why Is Carbon the Key to Life?

New Words and Phrases

polymer /'pɒlɪmə(r)/ *n.* [高分子] 聚合物

molecule /'mɒlɪkjuːl/ *n.* 分子

scaffolding /'skæfəldɪŋ/ *n.* 脚手架

graphite /'græfaɪt/ *n.* 石墨

promiscuous /prə'mɪskjuəs/ *adj.* 杂乱的；混杂的

chlorine /'klɔːriːn/ *n.* 氯气；氯

nitrogen /'naɪtrədʒən/ *n.* 氮气；氮

sulfur /'sʌlfə(r)/ *n.* 硫；硫黄

hydrogen /'haɪdrədʒən/ *n.* 氢气；氢

tetrahedral /ˌtetrə'hiːdrəl/ *adj.* 四面体的

phosphorus /'fɒsfərəs/ *n.* 磷

silicon /'sɪlɪkən/ *n.* 硅

periodic table 元素周期表

oxidize /'ɒksɪdaɪz/ *v.* 使氧化

stoke /stəʊk/ *v.* 煽动；激起

enzyme /'enzaɪm/ *n.* 酶

cytochrome /'saɪtəʊˌkrəʊm/ *n.* 细胞色素

1. Watch the video and choose the best answer.

(1) Which of the following statements is **NOT** true?

A. DNA and proteins are based on carbon.

B. Fats and sugars are based on carbon.

C. All the molecule cells are based on carbon.

D. All known life forms are based on carbon.

(2) Which of the following is **NOT** the reason why carbon occupies a special place among the elements on the Earth?

A. Carbon can form bonds with many other elements.

B. Carbon can only form molecules of flat shape.

C. Carbon can bond in a bunch of different ways.

D. Carbon can form incredibly long polymers.

(3) According to the video, silicon _____.

A. is the major building block for life in the universe

B. is one of the two alternatives to forming life

C. can create stable bonds with other elements

D. shares many similarities with carbon

(4) When silicon forms a bond with oxygen, it _____.

A. creates a solid which is known as sand

B. creates a gas which is easy for plants to access

C. creates a gas from which sugar is made

D. suggests evidence to form silicon-based life

2. Watch the video again and complete the sentences with the words you hear.

(1) No known life on the Earth does not use carbon as the basic _____ of its own existence.

(2) Carbon can form less stable, more _____ bonds with elements, like oxygen.

(3) It's not inconceivable that, somewhere in the universe, elements other than carbon could be _____ blocks for life.

(4) Silicon, right below carbon on the periodic table, has popped up as a potential _____.

(5) Some life can already use silicon, though, like in these beautiful shells. And scientists are evolving _____ that can use it in other ways too.

(6) Using a technique called _____ evolution, scientists generated mutations in an enzyme called cytochrome.

(7) Over several generations, the mutated bacteria were able to produce 20 different _____ with silicon-carbon bonds.

(8) Trying to measure the _____ from a planet trillions of kilometers away, when it's sitting right next to the Sun, is a chemical trick we haven't quite figured out yet.

3. Answer the following questions according to the video.

(1) What are the similarities between carbon and silicon?

(2) Why is it hard to find alien life forms outside the solar system?

Video II Keep Up with Carbon

New Words

crust /krʌst/ ***n.*** 硬层；硬表面

photosynthesis /ˌfəʊtəʊ'sɪnθəsɪs/ ***n.*** 光合作用

nutrient /'nju:triənt/ ***n.*** 营养素；营养物

decay /dɪ'keɪ/ ***v.*** 腐烂；腐朽

offshore /ˌɒf'ʃɔ:(r)/ ***adv.*** 向海地；离岸地

phytoplankton /ˌfaɪtə'plæŋktən/ ***n.*** 浮游植物

regulator /'regjuleɪtə(r)/ ***n.*** （温度）自动调节器

gradient /'greɪdiənt/ ***n.*** （温度）变化率

ecosystem /'iːkəʊsɪstəm/ ***n.*** 生态系统

1. Watch the video and judge whether the following statements are TRUE or FALSE.

(1) _____ Carbon on the Earth is only stored in the ocean, the atmosphere, and the crust of the planet.

(2) _____ Plants and animals give carbon back to the soil when they die and decay.

(3) _____ The ocean holds a much greater amount of carbon than the atmosphere.

(4) _____ In the past several million years, the Earth has rarely witnessed such a high level of CO_2 in the atmosphere.

(5) _____ Climate change gives rise to warmer water and weak circulation which will affect marine life and the ecosystem.

2. Watch the video again and fill in the blanks with the words you hear.

At the ocean surface, CO_2 from the atmosphere (1) _____ the water. Tiny marine plants called phytoplankton use this CO_2 for photosynthesis. Phytoplankton are the (2) _____ of the marine food web. After animals eat the plants, they breathe out carbon or pass it up the (3) _____.

Sometimes phytoplankton die, (4) _____, and are recycling in the surface waters. Phytoplankton can also sink to the ocean floor, carrying carbon as they (5) _____. Over long time scales, this process has made the ocean floor the largest (6) _____ of carbon on the planet.

Most of the ocean's nutrients are in cold deep water. In a process called (7) _____, currents bring nutrients and carbon up to the surface. Carbon can then be released as a gas back into the atmosphere, continuing the (8) _____.

3. Answer the following questions according to the video.

(1) Why are the oceans actually a great regulator, a controller of the Earth's climate?

(2) Why will oceans become less effective at removing carbon from the atmosphere in the future?

Phase II Getting to Know

Warm-up Activity

Explain the following terms according to what you've explored before class.

- carbon sink
- carbon cycle
- photosynthesis
- greenhouse gases

Active Reading

The Carbon Cycle

1 Carbon is the backbone of life on Earth. We are made of carbon, we eat carbon, and our civilizations, our economies, our homes, and our means of transport are built on carbon.

2 **Forged** in the heart of aging stars, carbon is the fourth most abundant element in the universe. Most of the Earth's carbon — about 65,500 billion **metric tons** — is stored in rocks. The rest is in the ocean, atmosphere, plants, soil, and fossil fuels.

3 Carbon flows between each reservoir in an exchange are called the carbon cycle. Any change in the cycle that shifts carbon out of one reservoir puts more carbon in the other reservoirs. Changes that put carbon gases into the atmosphere result in warmer temperatures on the Earth.

4 Over the long term, the carbon cycle seems to maintain a balance that prevents all of the Earth's carbon from entering the atmosphere or from being stored entirely in rocks. This balance helps keep the Earth's temperature relatively stable, like a **thermostat**.

5 On very long time scales (millions to tens of millions of years), the movement of **tectonic** plates and changes in the rate at which carbon **seeps** from the Earth's

interior may change the temperature on the thermostat. The Earth has undergone such a change over the last 50 million years, from the extremely warm climates of the Cretaceous[1] to the glacial climates of the Pleistocene[2].

The Slow Carbon Cycle

[6] Through a series of chemical reactions and tectonic activity, carbon takes between 100 to 200 million years to move between rocks, soil, ocean, and atmosphere in the slow carbon cycle. On average, 10^{13} to 10^{14} grams (10 to 100 million metric tons) of carbon move through the slow carbon cycle every year. In comparison, human emissions of carbon to the atmosphere are on the order of 10^{15} grams, whereas the fast carbon cycle moves 10^{16} to 10^{17} grams of carbon per year.

[7] The movement of carbon from the atmosphere to the **lithosphere** begins with rain. Atmospheric carbon combines with water to form a weak acid — **carbonic acid** — that falls to the surface in rain. The acid **dissolves** rocks — a process called **chemical weathering** — and releases **calcium**, **magnesium, potassium**, or **sodium ions**. Rivers carry the ions to the ocean.

[8] In the ocean, the calcium ions combine with **bicarbonate** ions to form **calcium carbonate**, the active **ingredient** in **antacids** and the chalky white substance that dries on your **faucet** if you live in an area with hard water.

[9] In the modern ocean, most of the calcium carbonate is made by shell-building organisms (such as corals) and **plankton**. After the organisms die, they sink to the ocean floor. Over time, layers of shells and **sediment** are cemented together and turn to rock, storing the carbon in stone — **limestone** and its **derivatives**.

[10] Only 80 percent of carbon-containing rock is currently made this way. The remaining 20 percent contains carbon from living things (organic carbon) that have

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1 Cretaceous：白垩纪，地质年代中中生代的最后一个纪，开始于 1.45 亿年前，结束于 6 600 万年前。

2 Pleistocene：更新世，亦称洪积世（2 588 000 年前 — 11 700 年前），属于地质时代第四纪的早期。

been **embedded** in layers of mud. Heat and pressure compress the mud and carbon over millions of years, forming sedimentary rock such as **shale**. In special cases, when dead plant matter builds up faster than it can decay, layers of organic carbon become oil, coal, or natural gas instead of sedimentary rock like shale.

[11] The slow cycle returns carbon to the atmosphere through volcanoes. The Earth's land and ocean surfaces sit on several moving crustal plates. When the plates collide, one sinks beneath the other, and the rock it carries melts under the extreme heat and pressure. The heated rock recombines into **silicate** minerals, releasing carbon dioxide.

[12] When volcanoes erupt, they **vent** the gas into the atmosphere and cover the land with fresh silicate rock to begin the cycle again. At present, volcanoes emit between 130 and 380 million metric tons of carbon dioxide per year. For comparison, humans emit about 30 billion tons of carbon dioxide per year — 100–300 times more than volcanoes — by burning fossil fuels.

[13] Chemistry regulates this dance between ocean, land, and atmosphere. If carbon dioxide rises in the atmosphere because of an increase in volcanic activity, for example, temperatures rise, leading to more rain, which dissolves more rock, creating more ions that will eventually **deposit** more carbon on the ocean floor. It takes a few hundred thousand years to rebalance the slow carbon cycle through chemical weathering.

[14] However, the slow carbon cycle also contains a slightly faster component: the ocean. At the surface, where air meets water, carbon dioxide gas dissolves in and **ventilates** out of the ocean in a steady exchange with the atmosphere. Once in the ocean, carbon dioxide gas reacts with water molecules to release hydrogen, making the ocean more acidic. The hydrogen reacts with carbonate from rock weathering to produce bicarbonate ions.

The Fast Carbon Cycle

[15] The time it takes carbon to move through the fast carbon cycle is measured in a lifespan. The fast carbon cycle is largely the movement of carbon through life

forms on the Earth, or the **biosphere**. Between 10^{15} and 10^{17} grams (1,000 to 100,000 million metric tons) of carbon move through the fast carbon cycle every year.

[16] Carbon plays an essential role in biology because of its ability to form many bonds — up to four per atom — in a seemingly endless variety of complex organic molecules. Many organic molecules contain carbon atoms that have formed strong bonds with other carbon atoms, combining into long chains and rings. Such carbon chains and rings are the basis of living cells. For instance, DNA is made of two **intertwined** molecules built around a carbon chain.

[17] The bonds in the long carbon chains contain a lot of energy. When the chains break apart, the stored energy is released. This energy makes carbon molecules an excellent source of fuel for all living things.

[18] Plants and plankton are the main components of the fast carbon cycle. They take carbon dioxide from the atmosphere by absorbing it into their cells. Using energy from the Sun, both plants and plankton combine carbon dioxide and water to form sugar (CH_2O) and oxygen.

[19] Four things can happen to move carbon from a plant and return it to the atmosphere, but all involve the same chemical reaction. Plants break down the sugar to get the energy they need to grow. Animals (including people) eat the plants or plankton, and break down the plant sugar to get energy. Plants and plankton die and decay at the end of the growing season. Or fire consumes plants. In each case, oxygen combines with sugar to release water, carbon dioxide, and energy.

[20] In all four processes, the carbon dioxide released in the reaction usually ends up in the atmosphere. The fast carbon cycle is so tightly tied to plant life that the growing season can be seen by the way carbon dioxide **fluctuates** in the atmosphere. In the Northern Hemisphere winter, when few land plants are growing and many are decaying, atmospheric carbon dioxide concentrations climb. During the spring, when plants begin growing again, concentrations drop. It is as if the Earth is breathing.

[21] Left **unperturbed**, the fast and slow carbon cycles maintain a relatively steady concentration of carbon in the atmosphere, land, plants, and ocean. But when