Week 1: Assignment Calendar

Monday	Tuesday	Wednesday	Thursday	Friday
4/20 Read Newsela article and answer questions. Turn in when complete.	4/21 Read Lesson 1 in Life and Times of Carbon reading booklet and complete lesson 1 in fillable pdf workbook.	4/22 Do Lesson 2 in fillable workbook. Question 2-instead of "in groups" do by yourself. Also do the first 2 pages of Lesson 3: Carbon flow observation log	4/23 Finish Lesson 3: What is Natural about Carbon? In fillable workbook	4/24 Read Lesson 4 in reading booklet. Complete Lesson 4 in workbook: Accounting for Change…
4/27 Read Lesson 5 in reading booklet. Start Lesson 5 in workbook.	4/28 Finish Lesson 5 in workbook.			

All students are responsible for completing the work following the assignment schedule. The teacher instructions for obtaining and submitting your work online are different for each teacher, so please make sure that you are following the directions for your teacher. If you are returning written work, you must drop it off at the school by the collection dates established by the district to receive credit. All online work must be submitted by the collection date as well for students to get credit. All online work may be submitted early to your teacher upon completion of article and workbook.

If you need help or have questions, office hours:

Dr. Libeu: Weekdays 1-3 pm. Zoom tutorials for each lesson will be announced on Schoology and will start at 1pm. If you are joining the tutorial, the expectation is that you will have completed the reading assignment before 1 pm so that you can participate in the discussion. For individual help: call (209)565-0124 between 2 pm and 3 pm, email cplibeu@tusd.net or message through Schoology. I will be answering emails and messages later in the afternoon.

Mrs. Shade Weekdays 10:00-10:30 Zoom (518-454-721), call 10:30 –11:00 AM or email other times jshade@tusd.net

Ms. Stewart: 8:00 – 10:00 by email kstewart@tusd.net or call (209) 625-9491 Monday – Friday

To obtain work online:

Dr. Libeu: Assignments with downloaded fillable pdfs are posted on Schoology

Mrs. Shade and Ms. Stewart: Download complete workbook with fillable pdfs and other materials from school website.

Online Submission of work instructions:

Dr. Libeu: Turn in your completed work to Schoology. There are individual assignments for each day.

Mrs. Shade and Ms. Stewart: Email the completed packet.

To obtain printed packets: Pick up at school following the directions on the district website.

Submission of written work from printed packets: Drop off at school following the directions on the district website.

Chemistry Assignment 1

Name: ____________ Period:_____ Teacher:____________________

What's the difference between weather and climate?

Do Part 1 before you read the article!

Part 1: Are they talking about climate or weather?

People like to talk about conditions that affect their lives. Climate and weather are two of those conditions. For the following statements, decide whether the statement has to do with weather or climate and click the appropriate bubble.

	Climate	Weather
1. What shall I wear today?	○	○
2. What equipment do I need for a camping trip next summer?	○	○
3. It has rained on my birthday for the past three years.	○	○
4. We just got three feet of snow in March. So much for global warming.	○	○
5. I wonder when I should plant the tomato seeds in my garden.	○	○
6. Our state experienced the worst drought since records began more than 120 years ago.	○	○
7. News Flash! The drought in California has ended with the first significant storm this year dumping more than 10 inches of rain in many locations and filling most of the reservoirs to pre-drought conditions.	○	○
8. We can't get low-cost flood insurance for our house anymore. The insurance company says this area is too big a risk.	○	○

Explain your thinking. What rule or reasoning did you use to decide if a statement is related to climate or weather?

Adapted from "Uncovering Student Ideas in Earth and Environmental science"
Paige Keeley and Laura Tucker, pg. 73

Do Parts 2 and 3 after you read the article!

Part 2: Read the article "What's the difference between weather and climate" and answer the following questions after you read the article.

It may seem counterintuitive, but cold weather events like these do not disprove global warming, because weather and climate are two different things.

1. Which sentence from the article BEST supports this idea?
   - ○ Weather refers to the short-term conditions of the lower atmosphere, such as precipitation, temperature, humidity, wind direction, wind speed, and atmospheric pressure.
   - ○ The atmospheric conditions that influence weather are always fluctuating, which is why the weather is always changing.
   - ○ While weather refers to short-term changes in the atmosphere, climate refers to atmospheric changes over longer periods of time, usually 30 years or more.
   - ○ Climate conditions vary between different regions of the world and influence the types of plants and animals that live there.

2. Which of the following claims does the author support the LEAST?
   - ○ Climate conditions vary between different regions of the world.
   - ○ Humans' burning of fossil fuels is a leading factor in climate change.
   - ○ The global climate has always been in a state of flux.
   - ○ Forecasts are important and useful for many reasons.

3. Which sentence BEST summarizes how the changing climate has affected weather?
   - ○ The changing climate has contributed to conditions that have made extreme weather events more intense and more frequent.
   - ○ The changing climate has increased the overall temperatures and amounts of rain locations around the globe are experiencing.
   - ○ The changing climate has created violent winds and dry conditions leading to the weather phenomenon called the Aurora Australis.
   - ○ The changing climate has allowed the weather in most locations to remain consistent and steady over the past 100 years.

4. What role does confusion over weather and climate play in the effort to address global warming?
   - ○ Because people sometimes confuse weather with climate, they try to make small changes to greenhouse gas emissions that have little effect on global warming.
   - ○ Because people sometimes confuse weather with climate, there has been little urgency to address global warming when the weather feels normal in the short term.
   - ○ Because people sometimes confuse weather with climate, efforts to fight global warming have only been embraced by a handful of countries directly affected by it.
   - ○ Because people sometimes confuse weather with climate, participation in panels on global warming and the Paris Agreement increases when the weather is hot.

Part 3: How did reading the article change your understanding of the difference between climate and weather?

Question 1: Review your answers for part 1. Do you still agree with all your answers?

a) If not, choose one statement and using evidence from the article explain why you now disagree with your answer.

b) If you do still agree with all your answers pick one statement from the list and using evidence from the article, explain how the article supports that your answer is correct.

Question 2: How would you revise your rule or reasoning to decide if a statement is related to climate or weather after reading this article?

What's the difference between weather and climate?

By National Geographic Society on 01.29.20
Word Count **1,073**
Level **MAX**

Weather events, like this hailstorm in Marion, Kansas, are not the same as the climate of a region. Image by Roger Hill/Science Source Image by Roger Hill/Science Source

Contrary to popular opinion, science is not divided on the issue of climate change. The overwhelming majority (97 percent) of scientists agree that global warming is real, and that it is largely caused by human activity. And yet we seem to be experiencing record-breaking cold winters; in January 2019, a polar vortex plunged parts of North America into Arctic conditions. It may seem counterintuitive, but cold weather events like these do not disprove global warming, because weather and climate are two different things.

Understanding Weather

Weather refers to the short-term conditions of the lower atmosphere, such as precipitation, temperature, humidity, wind direction, wind speed, and atmospheric pressure. It could be sunny, cloudy, rainy, foggy, cold, hot, windy, stormy, snowing – the list goes on.

The sun drives different types of weather by heating air in the lower atmosphere at varying rates. Warm air rises and cold air rushes in to fill its place, causing wind. These winds, along with water vapor in the air, influence the formation and movement of clouds, precipitation and storms.

The atmospheric conditions that influence weather are always fluctuating, which is why the weather is always changing. Meteorologists analyze data from satellites, weather stations, and buoys to predict weather conditions over the upcoming days or weeks. These forecasts are important because weather influences many aspects of human activity. Sailors and pilots, for example, need to know when there might be a big storm coming, and farmers need to plan around the weather to plant and harvest crops. Firefighters also keep track of daily weather in order to be prepared for the likelihood of forest fires. Weather forecasts are also useful for military mission planning, for features of trade, and for warning people of potentially dangerous weather conditions.

Understanding Climate

While weather refers to short-term changes in the atmosphere, climate refers to atmospheric changes over longer periods of time, usually 30 years or more. This is why it is possible to have an especially cold spell even though, on average, global temperatures are rising. The former is a weather event that takes place over the course of days, while the latter indicates an overall change in climate, which occurs over decades. In other words, the cold winter is a relatively small atmospheric perturbation within a much larger, long-term trend of warming.

While weather refers to short-term changes in the atmosphere, climate refers to atmospheric changes over longer periods of time, usually 30 years or more. This is why it is possible to have an especially cold spell even though, on average, global temperatures are rising. The former is a weather event that takes place over the course of days, while the latter indicates an overall change in climate, which occurs over decades. In other words, the cold winter is a relatively small atmospheric perturbation within a much larger, long-term trend of warming.

Despite their differences, weather and climate are interlinked. As with weather, climate takes into account precipitation, wind speed and direction, humidity, and temperature. In fact, climate can be thought of as an average of weather conditions over time. More importantly, a change in climate can lead to changes in weather patterns.

Climate conditions vary between different regions of the world and influence the types of plants and animals that live there. For example, the Antarctic has a polar climate with sub-zero temperatures, violent winds, and some of the driest conditions on Earth. The organisms that live there are highly adapted to survive the extreme environment. The Antarctic is known for a weather phenomenon called the Aurora Australis, a spectacular natural light show caused by charged particles interacting with gases in the atmosphere near Earth's magnetic poles.

By contrast, the Amazon rainforest enjoys a tropical climate. Temperatures are consistently warm with high humidity, plenty of rainfall, and a lack of clearly defined seasons. These stable conditions support a very high diversity of plant and animal species, many of which are found nowhere else in the world.

Our Climate Is Changing

The global climate has always been in a state of flux. However, it is changing much faster now than it has in the past, and this time human activities are to blame. One of the leading factors contributing to climate change is the burning of fossil fuels such as coal, gas and oil, which we use for transport, energy production and industry.

Burning fossil fuels releases large amounts of carbon dioxide (CO_2) into the atmosphere; CO_2 is one of a group of chemicals known as greenhouse gases. They are named as such because they allow heat from the sun to enter the atmosphere but stop it from escaping, much like the glass of a greenhouse. The overall effect is that the global temperature rises, leading to a phenomenon known as global warming.

Global warming is a type of climate change, and it is already having a measurable effect on the planet in the form of melting Arctic sea ice, retreating glaciers, rising sea levels, increased frequency and intensity of extreme weather events, and a change in animal and plant ranges. The planet has already heated by about 0.8 degrees Celsius (1.4 degrees Fahrenheit) in the last century, and temperatures have continued to rise.

Scientists cannot directly attribute any extreme weather events to climate change, but they are certain that climate change makes extreme weather more likely. In 2018, at least 5,000 people were killed and 28.9 million more required aid as a result of extreme weather events. The Indian state of Kerala was devastated by flooding; California was ravaged by a series of wildfires; and the strongest storm of the year, super-typhoon Mangkhut, crashed into the Philippines. It is likely that more frequent and more severe weather events are on the horizon.

Climate change is not a new concept, and yet little seems to have been done about it on a global scale. The greenhouse effect was first discovered in the 1800s, but it was not until 1988 that the global community galvanized to form the Intergovernmental Panel on Climate Change. Since then, leaders from around the world have committed to a series of goals to combat climate change, the latest of which is the Paris Agreement in which 185 countries have pledged to stop global temperatures from rising by more than 2 degrees Celsius (3.6 degrees Fahrenheit) above preindustrial levels. In 2015, all United Nations member states agreed to the 17 Sustainable Development Goals (SDGs) designed to "provide a shared blueprint for peace and prosperity for people and the planet, now and into the future." SDG 13 in particular commands member states to "take urgent action to combat climate change and its impacts."

Part of the reason the global community has been so slow to act on climate change could be the confusion surrounding distinctions between weather and climate. People are reluctant to believe that the climate is changing when they can look outside their window and see for themselves that the weather appears typical.

The following article originally appeared in the San Diego Union-Tribune on February 17, 2008. (It is reprinted here with author's permission.) Although the funding for biofuels research that the article attributes to President George W. Bush did not materialize, the federal government does provide numerous incentives and tax breaks to producers of biofuels and substantial funding for research. Fuel refiners are also required to blend biofuels into petroleum-based fuels, which provides additional government support for this industry.

The Promise of Biofuels: Hype or a Real Solution?

With gas prices approaching $4 a gallon and industries searching for new ways to reduce carbon dioxide emissions, biofuels—fuels, such as ethanol derived from corn and other plant sources rather than petroleum—are becoming an increasingly attractive option to help mitigate the impacts of climate change and reduce our oil imports.

The promise of powering our cars exclusively with green energy from plants prompted President Bush to ask Congress recently for $225 million for biofuels research—a 19 percent increase over this year's federal spending level. And it brought more than 300 scientists and business leaders from around the nation to a meeting here recently hosted by the University of California San Diego to discuss new ways of producing ethanol from plants and other promising avenues of biofuels research.

Cornfield

Everyone seems to be touting the benefits of biofuels these days: Midwestern farmers, environmentalists, state and federal legislators, Gov. Arnold Schwarzenegger, business leaders, venture capitalists and university scientists. But can corn-based ethanol—the primary focus of current biofuels efforts—deliver what we need to accomplish? And are the promises of biofuels more hype than real?

We now know that Earth's climate is changing, caused by the accelerating use of fossil fuels that started at the time of the Industrial Revolution. The dramatic changes in land use—the conversion of natural ecosystems to agricultural fields—that accompanied the growth of human population also contributed substantially by releasing carbon stored in the vegetation and in the soils. These activities caused an increase in atmospheric carbon dioxide that has not been seen in the past 400,000 years. This increase is responsible for the so-called greenhouse effect, the warming of the land and the oceans with resulting changes in wind, rain and storm patterns. The evidence supporting this interpretation is both overwhelming and unequivocal.

Biofuels can help mitigate this global climate change phenomenon because they are made from plants and algae that absorbed carbon dioxide in the process of photosynthesis. When we burn fossil fuels, we add carbon dioxide to the atmosphere, but burning biofuels releases carbon dioxide that was taken out of the atmosphere by plants or algae a few days, weeks or years earlier. So, we create a carbon cycle, helping to prevent further buildup of carbon dioxide in the atmosphere. The United States has a strong biofuels industry based largely on ethanol derived from corn grain and made possible by the high price of petroleum, generous farm subsidies and a stiff tariff on imports of sugar and ethanol.

Unfortunately, all biofuels are not created equal when we look at the extent to which they mitigate greenhouse gas buildup. The reason is that growing plants and converting plant material into biofuel also takes energy. And at the moment that energy comes mostly from electricity generated by fossil fuels. So much energy is required to produce the two main biofuels now being utilized in the United States—ethanol made from cornstarch and biodiesel made from canola and soybeans—that the net effect of their use on greenhouse gases is negative rather than positive.

The reasons are complex: corn and canola require a lot of nitrogen fertilizer to grow, and making nitrogen fertilizers is very energy intensive. Furthermore, whenever nitrogen fertilizer is used soil bacteria cause nitrous oxide to be released into the atmosphere. In the case of corn ethanol, distilling the ethanol requires energy. We can't make ethanol pipelines because ethanol is corrosive, so ethanol has to be transported in trains and trucks. For these and other reasons, the greenhouse gas balance—greenhouse gases removed from the atmosphere minus greenhouse gases released—is unfavorable for corn ethanol. In Europe, opposition to biofuels derived from food crops is already developing because they contributed to the recent rise in food prices. When fuel is derived from crops, food prices rise. Also, when croplands are converted for growing biofuel crops, a rise in food prices is unavoidable.

Ethanol factory

Fortunately, new technological developments are on the horizon. Ethanol can also be made from cellulose, the large linear molecule of plants consisting entirely of glucose that is the most abundant natural material in the world. Cellulose is the main ingredient in wood and in the new so-called biomass crops, such as *Miscanthus* (a large perennial grass) that do not require much nitrogen fertilizer and can have yields of 15 tons of biomass per acre when grown on good soils. The University of California at Berkeley has major research projects funded by the State of California and British Petroleum to develop the processes that convert cellulosic biomass into biofuels.

Scientists reported at our biofuels conference that sugar can also be fermented directly into gasoline-like molecules, such as alkanes, that do not need to be distilled. This would require us to create new superbugs. Remember the superbugs that ate oil spills? Our new superbugs would produce oil-like molecules for transportation.

Also, oil can be produced by microalgae living in shallow ponds using the nutrients in municipal wastewater. With such plant and algal sources and with new industrial processes and fermentations, we could have a true greenhouse gas neutral transportation system that prevents further buildup of carbon dioxide and the two other greenhouse gases released as a result of agricultural practices—methane and nitrous oxide—into the atmosphere. Indeed, the other greenhouse gases have to be counted as well. Jeff Severinghaus, of UCSD's Scripps Institution of Oceanography, reported at the meeting that for those crops that require nitrogen fertilizers, such as corn, canola and switchgrass, the release of nitrous oxide by soil bacteria may negate the positive effect of carbon dioxide absorption by photosynthesis.

So, when can we implement those solutions that promise to reduce greenhouse gases? Major technological breakthroughs are still needed to make these biofuels a reality. For one, the new crops need to be bred and selected—domesticated—for high biomass production. We still need to find the best genes and create the most efficient bacteria that would carry out these novel fermentations to produce alkanes rather than ethanol. We also need to develop more economical methods for the large-scale cultivation of algae and ways of extracting the new fuel molecules. Unfortunately, research on plants, algae and microbes has been woefully underfunded for decades as the nation focused its research dollars on human health and diseases.

By the end of the conference many in the audience realized that stark choices are being forced upon us. Fuel or tortillas, beef or biodiesel, which shall it be? When our lawmakers and the public at large understand that such choices are on our doorstep, then this funding trend could be reversed. Hopeful signs are the president's proposed budget already mentioned and a recent report by the National Research Council urging much greater funding for plant genetics, the basis of all crop improvement for food, fuel or fiber.

What should our focus be here in Southern California where transportation accounts for 40 percent of carbon dioxide release? Two research and development goals are clearly within the grasp of the University of California, San Diego and other San Diego-area scientists: oil produced by microalgae and novel fermentations that convert cellulose-derived sugars into oil-like molecules. Our intellectual resources include world-renowned microbiologists, geneticists, engineers and experts on algae. San Diego biotechnology companies, such as Synthetic Genomics, Verenium and Sapphire Energy have already acquired impressive expertise. We also have some unusual, but ideal, physical

Algal bloom in pond

resources—degraded land around the Salton Sea that has become unsuitable for agriculture, but suitable for algae ponds—and abundant sunshine. The R&D (research and development) done right here in San Diego can help our local energy company, Sempra Energy Utilities, meet California's mandated climate change guidelines for renewable energy.

So, are biofuels hype or can they be a real solution to climate change and carbon dioxide abatement? They will certainly play an important role, but let's not ignore the fact that society needs to simultaneously undertake many other initiatives to reduce carbon dioxide emissions and stabilize the climate. We will need to retrofit and redesign our buildings, emphasize mass transit, capture the carbon dioxide that is now emitted from our power plants and greatly increase the energy efficiency of all industrial processes. Although some biofuel crops can be grown on marginal soils not now used for agriculture, when such lands are put to the plow substantial amounts of carbon dioxide are released by the decomposition of the vegetation and the soil organic matter.

The scientists and business leaders attending our conference came to the realization that these are challenging times. And those of us at UCSD and other research institutions on the Torrey Pines mesa who can contribute to the long-term development of new biofuels are now eager to get to work and meet that challenge. This is one case where biologists really can make a difference by working with chemical engineers and ecologists to solve a major societal problem.

Sugar cane

Article by Dr. Maarten Chrispeels and Dr. Steve Kay. Dr. Chrispeels is a professor in UCSD's Division of Biological Sciences. Dr. Kay is dean of UCSD's Division of Biological Sciences.

Aspirin:
$C_9H_8O_4$
(acetylsalicylic acid)

Breath of air:
CO_2
(about 4% carbon dioxide)

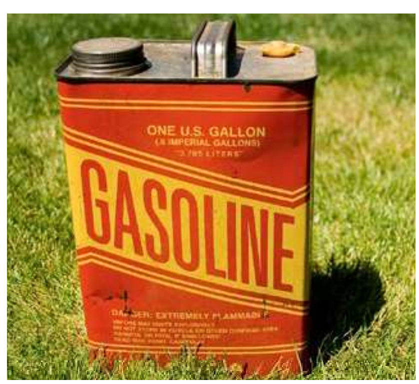
Carbonated beverage:
H_2CO_3

CD:
$C_{16}H_{14}O_3$
(repeating chains composed of carbon, hydrogen, and oxygen). These chains are called “polymers.”

Charcoal: C
85–98% carbon

Corn:
$C_6H_{12}O_6$
(carbohydrate)

Cotton:
$C_6H_{10}O_5$
Cotton is a form of carbohydrate that is nearly 100% cellulose fiber.



Gasoline:
C_8H_{18}
(hydrocarbon)

Glass:
SiO_2
(silicon dioxide)

Water:
H_2O

Hot dog (protein):
$C_2H_4O_2NR$
Where R is any amino acid side chain.

Limestone (cement):
$CaCO_3$
(Ca is “calcium”)

Pencil lead:
graphite C
(pure carbon)

Plant material:
(carbohydrate):
$C_6H_{12}O_6$

Plastic:
$CH_2{=}{=}CH_2$
The typical plastic water bottle is a simple hydrocarbon polymer.

Seashells:
$CaCO_3$
(calcium carbonate)

Stainless steel:
Fe_3C (one of many possible formulas). Stainless steel varies but, usually contains between 0.2-2.1% carbon.

Vegetable oil (fat or lipid):
$CH_3(CH_2)_{16}COOH$

Wood:
$C_6H_{10}O_5$

Chemistry Assignment # 2

Name: ________________________________ Period: Teacher:____________________

Where Can We Find Carbon?

Carbon compounds are everywhere around us. They are in our foods, plastics, soils, in water, in the air, and in our bodies. Carbon compounds can come in three physical forms: gas, liquid, and solid. Plants take up carbon dioxide from the air, and use photosynthesis to turn carbon dioxide into carbohydrates. Carbohydrates are carbon compounds that store energy in the forms we call "starches" and "sugars." About three-fourths of the dry weight of plants is carbohydrates. In other words, when you look at plant matter (the stem, leaves, roots, and grains) you are looking largely at carbohydrates. Animals (including humans) get their carbohydrates by eating plants, but they do not store much of what they consume. In fact, less than 1% of the body weight of animals is made up of carbohydrates.

The main forms of carbon are: nonliving (abiotic) in rocks, soils, and sediments, and in water, such as bicarbonate, carbonate; living (biotic), such as plant and animal matter and dead organic matter; and carbon-based gases, such as carbon dioxide (CO_2), methane (CH_4), and carbon monoxide (CO).

Chemists use a special system to describe compounds. They use a chemical formula of symbols that indicate the elements that make up chemical compounds. A chemical formula is also called a "molecular formula." The chemical formula of carbon dioxide is CO_2 indicating one carbon atom bonded to two oxygen atoms. The symbol for carbon is C; for hydrogen is H; for oxygen is O; for silica is Si.

Coal heap

Name: ______________________________

Part 1

Instructions: Use the Carbon Information Cards in the Lesson 1 materials to complete the following table.

	A	B	C
	Item	**Chemical Formula**	**How Natural Systems or People Use Carbon in This General Form**
1	Aspirin		
2	Breath of air		
3	Carbonated beverage		
4	CD		
5	Charcoal		
6	Corn		
7	Cotton		
8	Gasoline		
9	Glass Water		

Name: ____________________

	A	B	C
	Item	**Chemical Formula**	**How Natural Systems or People Use Carbon in This General Form**
10	Hot dog (protein)		
11	Limestone (cement)		
12	Pencil lead (graphite)		
13	Plant material		
14	Plastic		
15	Seashells		
16	Stainless steel		
17	Vegetable oil (fat or lipid)		
18	Wood		

Name: ___________________________________

Part 2

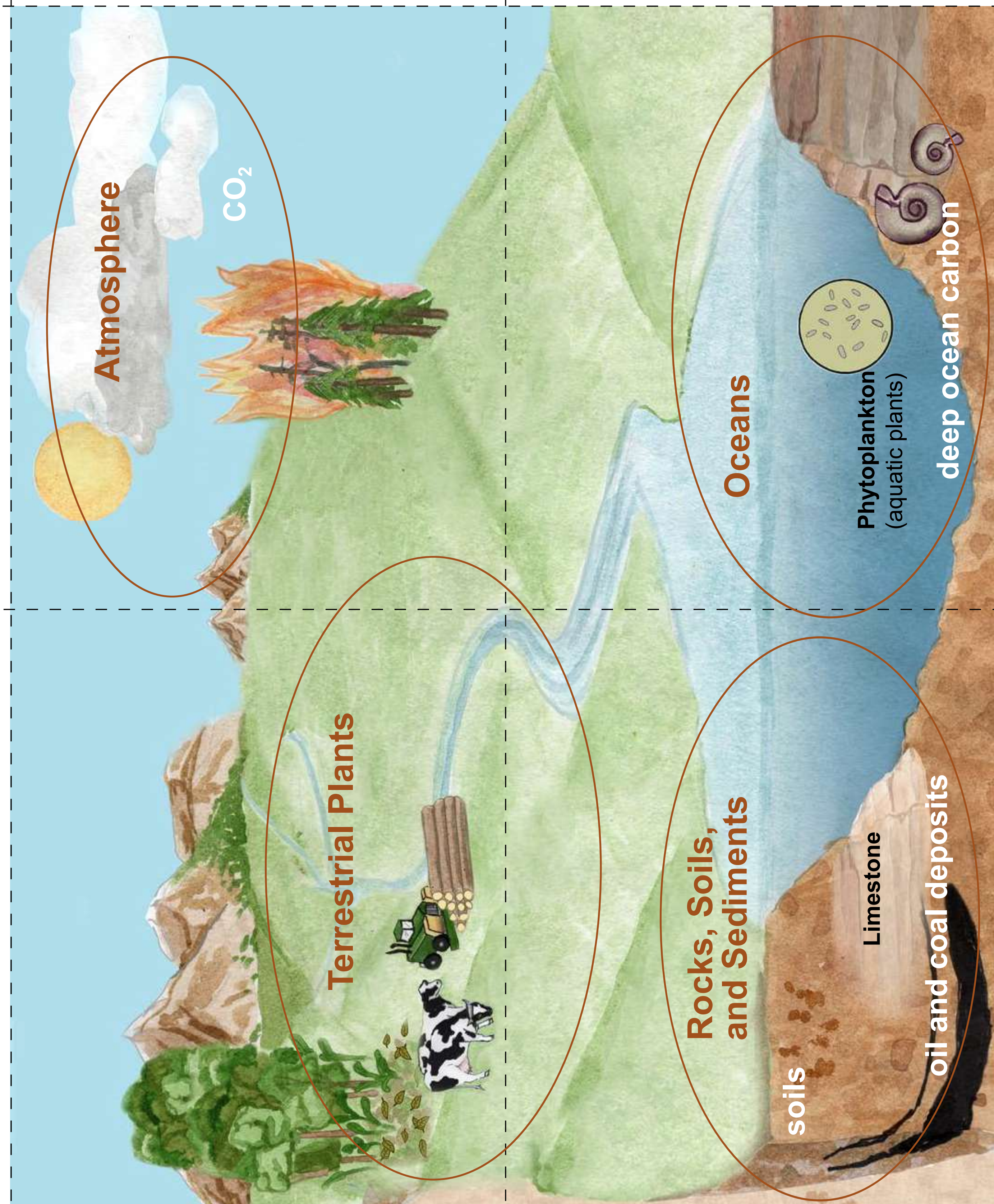
Instructions: After you have **finished with the Carbon Information Cards**, brainstorm how carbon is used in different forms in nature and by people. Make notes in Column C on the **Collecting Carbon** chart. (3 points each)

Part 3

Instructions: Independently, review your responses in Column C above and develop a summary statement that explains the importance of carbon to living organisms. (6 points)

Carbon Reservoir Cards

Lesson 2 | *front*



Oceans

Carbon dioxide (CO_2) from the atmosphere is mixed into the top surface of oceans by waves and wind. This CO_2 is taken up by small aquatic plants that live near the ocean's surface called "phytoplankton." They take up CO_2 and convert it into "plant" carbon matter. Using satellite imagery, scientists have measured huge algae "blooms" that show how carbon is distributed throughout the ocean. Overall, oceans are Earth's second largest carbon reservoir, holding 38,000–40,000 billion metric tons of carbon. Most of this is sunk down to the deep ocean.

Aquatic animal bodies are made up of various carbon compounds. Some are able to convert carbon into calcium carbonate to form protective shells.

When aquatic organisms die, they are consumed and decomposed by microbes, and much of this matter sinks to the ocean bottom. Layers upon layers of carbon-containing seashells become compressed under the weight of the ocean and, in time, become the sedimentary rock we call limestone or marble.

Atmosphere

Earth's atmospheric gases originated during a very active volcanic period billions of years ago. Volcanoes released carbon dioxide (CO_2), water vapor, and other gases into the atmosphere. Early plants were algae. Algae took up gaseous CO_2 and, with sunlight, water, and the process of photosynthesis, produced oxygen and plant matter. As more complex plants and animals evolved, atmospheric CO_2 levels became fairly well-balanced by the natural processes of photosynthesis, respiration, and decomposition. Today's atmosphere holds 766 billion metric tons of carbon.

Atmospheric CO_2 levels have gone up and down throughout Earth's history. Fossils tell us that CO_2 levels have been as low as 180 parts per million (ppm, a percentage of all atmospheric gases). Today they are at 384 ppm. CO_2 is a greenhouse gas that regulates Earth's temperature. High levels of greenhouse gases cause Earth to be warmer, while low levels cause Earth to be cooler. Other carbon-based gases found in the atmosphere include, methane (CH_4) and carbon monoxide (CO).

Rocks, Soils, and Sediments

The world's soils hold 1100 to 1600 billion metric tons of carbon. This is more than twice the carbon stored by living vegetation or in the atmosphere. Yet, this figure is small compared to marine sediments and sedimentary rocks: they hold between 66,000,000–100,000,000 billion metric tons of carbon! Fossil fuels were formed 354 to 290 billion years ago when plants became buried under sediments and oceans. Fossil fuel deposits hold another 4000 billion metric tons.

Soil carbon comes mostly from the decomposition of plants by microbes. "Leaf litter" accumulates year after year and results in much of the carbon becoming buried and trapped in lower layers of soil.

Forests produce a lot of leaf litter, resulting in soils high in carbon. Tropical forests grow year-round and are mega-warehouses of carbon.

At the bottom of wetlands there is little or no oxygen. Here, the decomposition process is very slow. Wetlands, peat bogs, and permafrost (wet frozen lands) store tremendous amounts of carbon.

Terrestrial Plants

Plants take up carbon dioxide from the atmosphere during photosynthesis. Carbon is stored by plants in leaves, stems, roots, and woody material, even roots. Because of their size, trees are able to store a large amount of carbon as "wood." Forests are often called "the lungs of the world" because they convert so much carbon dioxide gas into oxygen. Terrestrial (land) forests of North and South America are massive carbon reservoirs.

Trees are definitely the largest forms of plants, but all plants store carbon, from small aquatic algae and alpine moss-like lichen to grasses, shrubs, and cactus. In total, the terrestrial plant reservoir stores 540–610 billion metric tons of carbon.

Animals depend on the oxygen created by plants, and animals eat plants or other animals. This "consumption" moves carbon up the food chain and throughout the food web.

Even though animals (including people) store carbon in various carbohydrate compounds within our bodies, the amount is very small compared to that stored by vegetation. Therefore, scientists do not consider "animals" as a carbon reservoir.

Chemistry Assignment #3

Name: ___________________________________ Period:____ Teacher:___________________

Moving Through the Global Carbon Cycle

Lesson 2 | *page 1 of 2*

Instructions: Read and complete the tasks below.

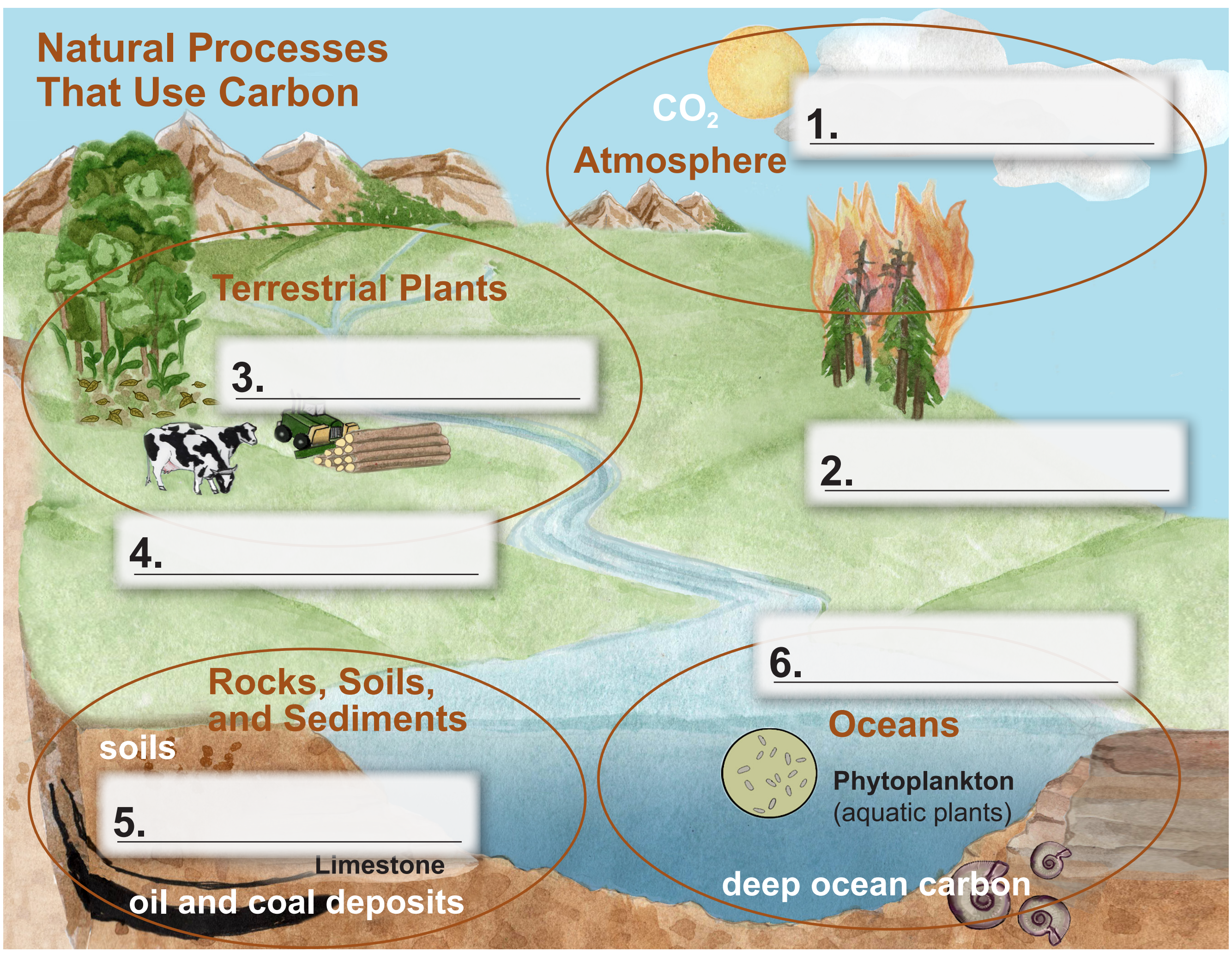
1. List the four main carbon reservoirs, from greatest to smallest according to how much carbon each currently holds. (1 point each)

   ___________________________________ ___________________________________

   ___________________________________ ___________________________________

2. Brainstorm how carbon moves from one reservoir to another. Use the following questions to guide your discussion:
   - What function does carbon serve in each reservoir?
   - What are the different natural processes involved in carbon movement?
   - How do people or natural systems benefit from these functions?

   On each of the lines in the illustration identify a natural process that moves carbon to or from the reservoir. (1 point each)



Name: ___________________________________

3. On the drawing shown add arrows between the processes and reservoirs to show the movement of carbon and carbon energy from one reservoir to another. (4 points)

4. Briefly describe how people and other living organisms depend on the global carbon cycle for life. Explain how carbon cycles through each carbon reservoir and describe how carbon plays an important part in our communities, our lifestyles, and our economy. (10 points)

5. Notice that fossil fuel deposits, such as coal, petroleum, and natural gas, are deep within the rocks, soils, and sediments reservoir. Fossil fuels were formed from buried dead plants and animals during the Carboniferous period about 354 to 290 million years ago. If people had not extracted fossil fuels from Earth to use as energy, would this carbon be "cycling" within the global carbon cycle we have defined today? Explain your answer. (6 points)

Carbon Flow Game Instructions

1. Center the game board between all players; set the **Carbon Flow Scenario Cards** facedown to one side.
2. Arrange the carbon game pieces (poker chips) according to the following guide:
   - The red chips represent fossil fuels. Place all three in the "Rocks, Soils, and Sediments" reservoir.
   - Add 11 more poker chips to "Rocks, Soils, and Sediments" reservoir.
   - Place six chips in the "Ocean" reservoir.
   - Place two chips in the "Atmosphere" reservoir.
   - Place two chips in the "Terrestrial Plants" reservoir.
   - Select someone from your group to start the game and then take turns clockwise.
3. During their turn, players draw one **Carbon Flow Scenario Card** from the stack, read it aloud, and move the carbon game pieces to show how carbon moves from one reservoir to another during different processes. (*Note: There may be situations where the carbon does not move.*)
4. During each turn, players record how they believe carbon moves on their individual **Carbon Flow Observation Log**.
5. After all cards have been drawn, leave the game pieces on the board in place to refer to during the group discussion that follows.

Feel the Burn

Every year, fires burn about 2 million square miles of Earth's land surface and release more than 1 billion tons of carbon into the atmosphere in the form of carbon dioxide. In 2006, a record-setting number of 96,385 wildfires destroyed nearly 10 million acres of forest in the United States alone.

Scientists estimate that for every acre burned, between 30 and 77 metric tons of carbon is released to the atmosphere. Most is in the form of CO_2, but carbon monoxide and methane are also released.

Large forests are able to store massive amounts of CO_2. Once burned, the lost forests and vegetation are not taking up CO_2 through photosynthesis. After a fire, new vegetation grows on the burned land. Even though new vegetation takes up CO_2 and stores carbon, the new grasses, shrubs, and small trees are not as effective at taking up CO_2 as larger trees.

Fires result in ….
(Move one carbon piece to a new reservoir.)

Seeing the Forest Through the Trees

The process of photosynthesis takes up carbon dioxide from the atmosphere and stores the carbon as plant material. Because of the large amount of carbon stored as wood, forests are one of the largest reservoirs of carbon on Earth.

There are currently more forests in the United States today than there were 100 years ago. During early colonization of North America, people cut down huge amounts of forests to grow crops and for wood to build early cities and homes. Over the past 100 years, North American forests have regrown. Some farming practices have become more efficient and require less land. Appropriate forest management based on sustained yields can also help. In the past decade, forests have been getting larger in Europe and China, as well. In Europe, forests are increasing by 32 million acres each year, an area about the size of Alabama. In China, forests are increasing by 4½ million acres each year, an area about the size of Delaware.

More forests results in …
(Move one carbon piece to a new reservoir.)

Our Changing Landscape

There are 6.8 billion people on the planet today and, by 2030, this number is expected to be 9 billion. Rapid human population growth, combined with increasing resource consumption, has resulted in the widespread transformation of Earth's land surface. We call this "land use change."

People change the land: we build homes, cities, and roads. We clear land to grow crops and manage livestock. Worldwide, people have cleared lands about the size of South America just to grow crops. We use even more land for ranching, to graze livestock, such as cattle, goats and sheep.

Recently, the largest land use changes have occurred in developing nations, such as South America and Malaysia. People are burning or cutting tropical forests to grow food crops or to raise cattle. In recent years, people have turned to growing crops to produce ethanol, which can be made from corn, soybeans, sugar cane, and other food crops. There has been research suggesting that it might be possible to store carbon in farm and grasslands by moving to "no-till agriculture" (which reduces soil disturbance).

Both burning trees and disturbing the soil release carbon into the atmosphere. A second carbon penalty is that once a tree is cut, it can no longer take up atmospheric carbon.

Land use changes result in...
(Move two carbon pieces to new reservoirs.)

Fossil Fuels "Old-Growth" Carbon

Fossil fuels were formed 354–290 million years ago during the Carboniferous period, when dead plants became buried and compressed. Before they died, these plants harnessed the Sun's energy and stored it as plant material. The carbon from these buried plants became concentrated in "fossil" fuels, such as coal, petroleum, and natural gas.

Like a ship of gold lost at sea, this buried treasure has not been part of the global carbon cycle for hundreds of millions of years. In fact, until people began extracting fossil fuels, this carbon was "out of the loop" with regard to the global carbon cycle.

Now we burn fossil fuels to use their stored energy to power our cars, electric power plants, and more. One of the waste products of combustion is the carbon dioxide that comes out our tailpipes and chimneys.

The ocean absorbs a lot of this "extra" carbon.
Where does the rest go?
(Move two red carbon pieces to new reservoirs.)

Pumping Carbon

The ocean is the second largest carbon reservoir on Earth. In fact, with regard to the global carbon cycle, the ocean is taking in *much* more carbon than it releases. This is partly because it covers three-quarters of Earth's surface, but also because it is so deep and is teeming with life.

It is the smallest life forms that are the real work horses. These include tiny organisms are called phytoplankton: microscopic algae that drift near the ocean's surface. Phytoplankton take up CO_2 and, through photosynthesis, convert it into biomass and oxygen. Phytoplankton play an important role in the biological pump that takes atmospheric carbon and sinks it into the deep ocean sediments.

One idea scientists have is to "fertilize" the ocean with nutrients that would cause more phytoplankton to grow. More phytoplankton will take up more atmospheric CO_2, but researchers warn that this plan might backfire: scientists believe that increased phytoplankton pumping CO_2 to the deep ocean triggered past ice ages. However, a bigger concern today is that the pumping will not work and will negatively affect ocean biology. For now, it might be better not to mess with nature's biological pump.

The natural biological pump results in…
(Move one carbon piece to new reservoir.)

How Permanent Is Permafrost?

Permafrost is land that is frozen for at least two years in a row. Permafrost is common on land near Earth's poles, in northern regions and on alpine mountains. Like the name suggests, this ground contains frozen water.

Some plants have adapted to grow in permafrost during the short summers. When these slow-growing plants die, they are quickly frozen and buried. Winter comes quickly in permafrost regions, so the plant material does not decompose very much. In other words, the carbon stored within the plant fibers is trapped beneath a frozen blanket. Permafrost soil is full of carbon dioxide and methane (CH_4)—another form of carbon.

It is the frosty conditions that keep carbon locked in permafrost. When permafrost thaws, it releases carbon to the atmosphere. The past decade has seen record summer heat, and scientists predict the warming trend to continue.

Thawing permafrost will result in …
(Move one carbon piece to a new reservoir.)

A Wetland "Wasteland?"

Wetlands are areas that are underwater for at least some part of the year. Wetlands are filled with plants that have adapted to grow well in wet soil. When the vegetation dies, some will decay, releasing carbon dioxide and another carbon compound—methane (CH_4)—to the atmosphere. But the vegetation can build up as sediment, forming a reservoir of carbon.

Wetlands used to be thought of as wasted land, and they were drained and filled for development. Between the 1780s and 1980s, 60 acres of wetlands were lost every hour across the country. In California alone, less than 9% of the state's historic wetlands remain. Today, most California wetlands are protected from further development.

For saltwater wetlands, such as salt marshes, legal protection is not enough. Rising sea levels can flood shoreline vegetation. Even though salt marsh plants are adapted to salt water, most cannot survive under constantly flooded conditions. Shoreline vegetation acts like a shock absorber against waves. When shoreline vegetation is lost, erosion is more prevalent. Lost wetlands decrease photosynthesis and expose sediments and soils to erosion.

Wetland loss results in…
(Move one carbon piece to a new reservoir.)

Cement, Our Modern Building Block

Concrete is a building material which is made from a mixture of cement, clay, gravel, sand, and water. Cured concrete is like stone, and so buildings, bridges, and roads are expected to last a long time.

Cement is made from lime, which is made from limestone. Remember that limestone is sedimentary rock formed from the fossilized calcium carbonate remains of marine organisms. To make lime out of limestone, concrete factories heat limestone to very high temperatures. In the process of converting calcium carbonate into lime, carbon dioxide is given off and released to the atmosphere.

Overall, the cement industry produces 5% of global human-made CO_2 emissions. This comes to about 900 kg of CO_2 released to the atmosphere for every 1,000 kg of concrete produced.

The top three annual producers of concrete are China with 704 million metric tons, India with 100 million metric tons, and the United States with 91 million metric tons. This translates into about half the world's total production of concrete.

Producing concrete results in…
(Move one carbon piece to a new reservoir.)

Made of Wood Is Good

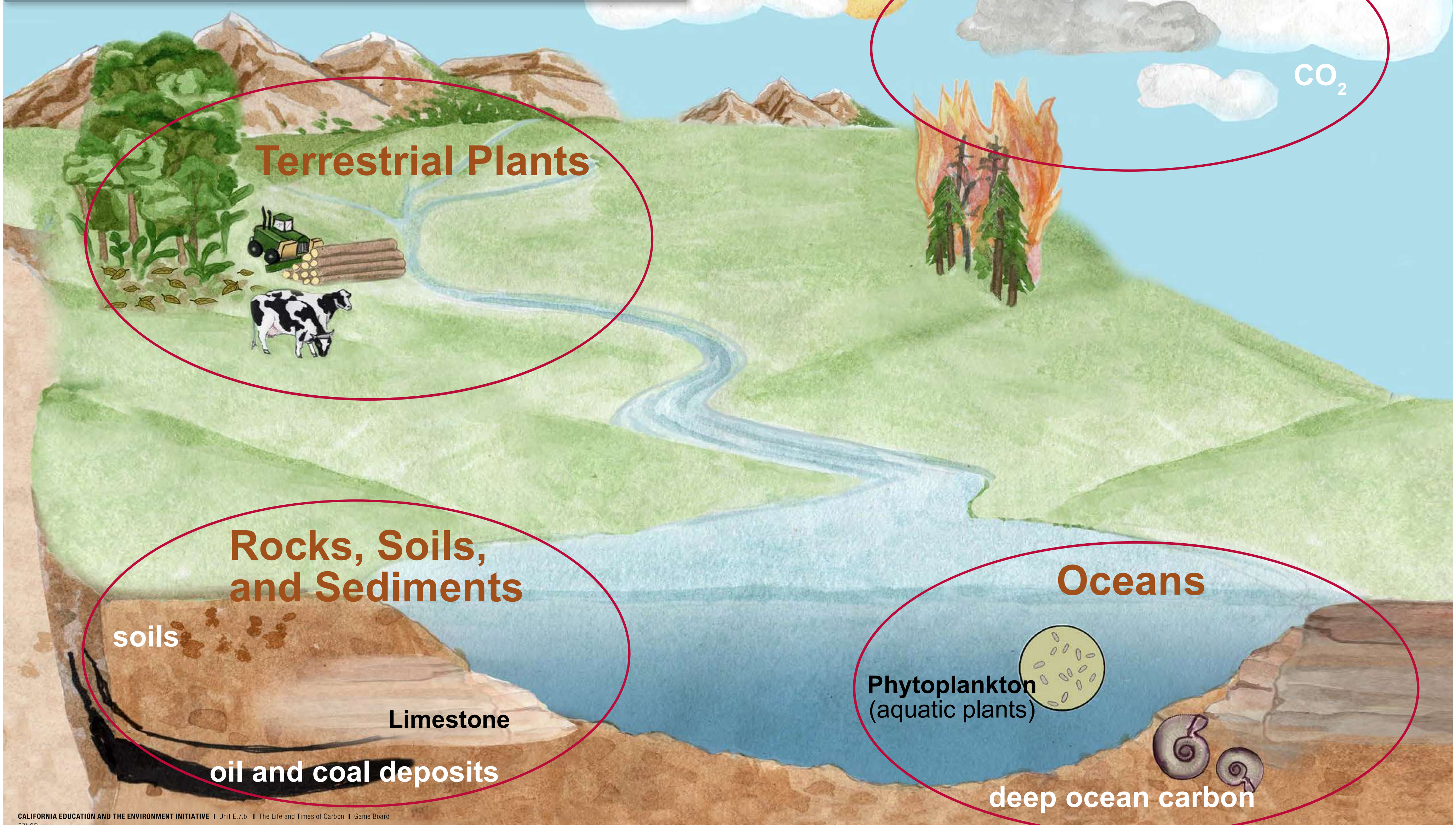
Wood is a reservoir for carbon whether is it alive or dead. This means that wood used for building materials and furniture is still storing some of the carbon that was in the original tree (about one-third of the original tree is able to be converted into furniture). In fact, dry wood is about 50% carbon. To make paper products, woody fibers are partially broken down to a pulp. Paper stores much less carbon than wood that is cut for use in construction or to make furniture.

Forests can be managed to protect them as a valuable ecosystem, but they can also be managed to store as much carbon as possible. Trees in their middle years convert more carbon dioxide than when they are small saplings or slow-growing, large, old growth trees.

Forest managers believe that we can manage the amount of carbon dioxide that is in the atmosphere by maintaining and managing trees.

Cutting trees for use in construction, furniture, and other wood products results in…
(Move one carbon piece to a new reservoir.)

Carbon Flow Game Board



Name: ________________________________

Instructions: Complete the following task in the chart below.

Carbon flow is the movement of carbon in gaseous, dissolved, or solid form from one carbon reservoir to another. As you play the **Carbon Flow Game**, describe the processes at work in each scenario and record how you believe carbon flows from reservoir to reservoir in the global carbon cycle.

Carbon Flow Observation Log

Carbon Flow Card	Reservoir: Carbon Started Here	Reservoir: Carbon Moved Here
Feel the Burn		
Seeing the Forest Through the Trees		
Our Changing Landscape		
Fossil Fuels "Old-Growth" Carbon		

Name: ______________________________

Carbon Flow Observation Log

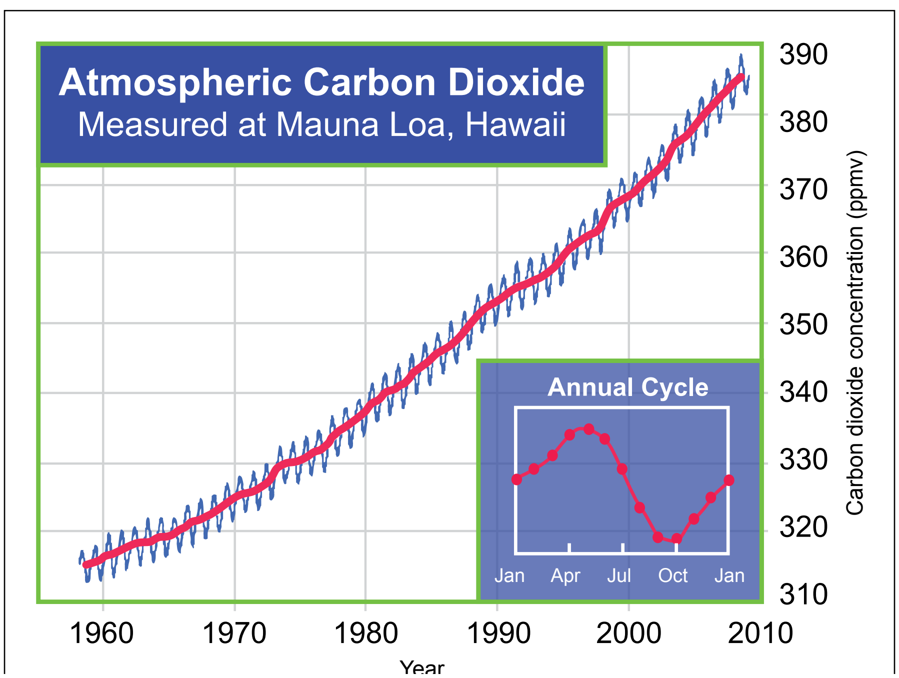
Carbon Flow Card	Reservoir: Carbon Started Here	Reservoir: Carbon Moved Here
Pumping Carbon		
How Permanent Is Permafrost?		
A Wetland "Wasteland?"		
Cement, Our Modern Building Block		
Made of Wood Is Good		

Name: ______________________________

What Is Natural About Carbon Flow?

We know that photosynthesis results in the production of plant biomass and oxygen (O_2). Biomass is the green and brown stuff of plants—leaves, stems, trunk growth, and roots. Decomposition, on the other hand, is the breakdown of biomass—including animal matter. Decomposing plant and animal matter releases CO_2 to soils, the atmosphere, and the ocean. Most photosynthesis happens in the spring and summer months (the growing season), while most plant decomposition happens in fall and winter, when trees have lost their leaves.

Scientists have measured the annual differences in CO_2 uptake by photosynthesis and CO_2 emission by decomposition and respiration, and have discovered that it appears as if the Northern Hemisphere's photosynthesizers are "breathing"—an inhale of CO_2 in spring and summer, and an exhale of CO_2 in the fall.



Graph 1. Changes in atmospheric carbon dioxide from 1958 to present. Source: R. F. Keeling, S. C. Piper, A. F. Bollenbacher, and S. J. Walker, Carbon Dioxide Research Group, Scripps Institution of Oceanography, La Jolla, California, February 2009

Scientists have measured the annual carbon flow since 1958. The graph below shows that atmospheric carbon dioxide levels are highest in May just before plants rapidly increase their rates of photosynthesis, and atmospheric carbon dioxide levels are lowest near the end of the active growing season in October, before rapid decomposition releases CO_2 back into the atmosphere. This "breathe in" and "exhale out" is measured in this zigzag pattern each year.

Plants provide just one example of global carbon flow. Carbon dioxide is released to the atmosphere by a variety of natural sources, and together these sources account for over 95% of Earth's total CO_2 emissions.

Name: ______________________

Analyzing the Carbon Flow Game

Instructions: Using the **Carbon Flow Observation Log** (Student Workbook, page 10), compare your "Before Game" carbon data to the "After Game" carbon data, and complete the tasks below.

1. Complete the **Carbon Flow Summary Chart** below. To calculate the percentage change for each reservoir, divide the amount of "change of carbon" by the "before game carbon" amount. (For example, the "Rocks, Soils, and Sediments Reservoir" started with 14 total carbon pieces and ended with 8 total carbon pieces, for a change of -6 carbon stored.) (6 points)

$$-6 \div 14 = -42.9\% \text{ change}$$

Carbon Flow Summary Chart

Reservoir	Before Game Carbon	After Game Carbon	Change in carbon	Percentage Change in Total Carbon Storage
Rocks, Soils, and Sediments	14	8		
Ocean	6	8		
Atmosphere	2	7		
Terrestrial Plants	2	1		

2. Based on your calculations, what is the order of the carbon reservoirs from most changed to least changed? (1 point)

3. Which reservoir(s) took up more carbon than it released? (1 point)

4. As a percentage of change, which reservoir experienced the most loss of carbon? (1 point)

5. A "carbon sink' is a reservoir that is taking up more carbon than it is releasing. Based on the scenarios played in this game, which reservoirs might we consider being carbon sinks? (1 point)

Name: ___________________________________

Instructions: Use the diagram below to complete the tasks on the next two pages.

Cycling for Carbon

Earth's natural systems are very good at conserving energy and matter. The conservation of energy and matter is done through different natural cycles. Some scientists describe the movement of matter through cycles as a giant recycling station, where the "trash" products from one system are the "treasure" for another.

Name: ______________________________

6. Write a brief explanation of what is meant by the phrase, “In the carbon cycle, the waste products of one system are the stuff of life for another.”
   Include the following:
   - At least one example in your answer should describe one of following natural processes: the solubility pump, decomposition, forest fires, photosynthesis, respiration, sedimentation, subduction, or weathering. (1 point)
   - Explain how the global carbon cycle results in a movement of carbon matter and energy. (1 point)
   - Identify one carbon “sink” and describe why or how it acts as a carbon sink. (1 point)
   - Use the following vocabulary words in your response. (1 point each)

carbon	energy	reservoir
carbon flow	global carbon cycle	sink

Name: ______________________________

7. In a sentence or two, hypothesize about the effects of too much carbon in the atmosphere. (1 point)

Pasture Patties, Meadow Muffins, Cow Pies, and Buffalo Chips

The Great Plains were once home to tens of millions of American bison, more commonly called "buffalo."

These animals traveled in great herds constantly in search of fresh grass. It was not hard to track a buffalo herd: they left behind a mile-wide trail of chomped grass and "buffalo chips"—the inevitable pie-sized droppings that come after an herbivore (plant eater) eats a good meal.

Early settlers had many names for these large droppings: "pasture patties," "meadow muffins," "cow pies" and "buffalo chips" are just a few. Across the treeless Great Plains, these dried droppings were gathered like firewood and used as fuel to warm a weary traveler or to cook the evening meal. Animal chips burn surprisingly well—especially those from grass-eating herbivores, such as buffalo, cattle, wildebeest, elephants, and others. Like corn ethanol or firewood, animal dung is a form of carbon-based biofuel.

Women in northern France in the 1900s gather and dry dung

Most people in the United States are able to heat their homes by turning up the thermostat that tells the furnace or boiler to kick up the heat. We flip the light switch in our kitchen, pop yesterday's leftovers into the microwave, and "zap," we have a hot meal. "Cooking out" often means lighting a gas or charcoal grill, or maybe roasting marshmallows or hot dogs over a wood fire during a campout. But today, in the United States, "go gather some kindling" never means filling a basket full of dried cow manure.

It is hard for us to imagine cooking food and boiling water over animal dung, but 2.4 billion people still do this today. Most people who rely on dung as fuel live in rural areas of developing countries where electricity is not available, is too expensive, or is unreliable. In regions with trees, firewood is preferred—for obvious reasons. In many regions, there are not enough fallen limbs or driftwood to go around, so people cut scarce trees for firewood. This has led to deforestation in many regions, such as Pakistan (a dry and mountainous region), Malaysia (tropical islands), and Madagascar (an island off the coast of eastern Africa). In Madagascar, only 10% of the forests remain. The loss of even a few trees in dry regions makes dry conditions worse: without vegetation and tree roots to hold soils together, once-fertile land becomes sandy and can lead to desertification—changing arable (farmable) land to desert.

American Bison or "Buffalo"

It all started with fire: ancestors to *Homo sapiens* burned wood nearly 2 million years ago. When wood or other organic matter is heated in the absence of air, charcoal is created. This black residue was first used about 8,000 years ago. Because this concentrated carbon fuel was able to burn very hot, blacksmiths used charcoal to heat metal to get it hot enough for shaping. The discovery of uses for coal came about roughly 3,000 years ago. The development of the steam engine in the mid 1700s made coal the most common energy source. Today, coal is used to produce 40% of the world's electricity, and petroleum gasoline or diesel is used in most of our automobiles and trucks.

However, all carbon energy sources are not equal: some sources contain more carbon than others. Compared to wood, dung is a loosely packed, less dense material. The small amount of carbon in dung burns faster than the more densely packed carbon in wood. Charcoal contains more carbon than wood, and fossil fuels are the result of extremely compacted plant material. This means that, pound for pound, fossil fuels are a more efficient source of energy than dung or wood. (Energy efficiency refers to the amount of energy produced during burning.) Burning dung and wood also releases soot and pollutants that are dangerous to inhale. In countries where people depend on firewood and charcoal for heating and cooking, the second leading cause of death (after diseases carried by polluted water) is respiratory diseases related to exposure to the harmful pollutants from burning these smoky, inefficient fuel sources.

In addition to carbon-based energy sources being unequal to each other with regard to energy efficiency, there is another key difference between them: their age and how long they have been or will be a part of one reservoir. What does this mean? Turn to a partner and discuss how carbon can be "young," "old," or even "ancient." Consider this: your metabolism burns carbohydrates with the same release of energy (and carbon dioxide) as if you had lit the food with a match. In fact, the calorie content of foods is determined by drying and burning the foods in a controlled space to reveal how much heat is generated. Decomposition of biomass is also a slow burning process. While the temperature of the burn does not produce flames, decomposition releases the same heat and carbon dioxide (and methane and other carbon gases) as burning. This is why some people say burning biomass does not add carbon dioxide to the atmosphere—because it would eventually get there through decomposition.

You might want to start your discussion by comparing a cow pie to a lump of coal. Where did the energy originate from? Where did it go? How long was it there before people burned it? Where does the carbon go after it has been burned? What would happen to the carbon source if it was not intentionally burned by humans? How does burning fossil fuels versus biomass affect the reservoirs in the carbon cycle differently?

Villagers collect firewood for fuel

Chemistry Assignment #5

Name: ______________________________ Period: ___ Teacher: ______________

Accounting for Changing Levels of Atmospheric Carbon Dioxide

Lesson 4 | *page 1 of 4*

Instructions: Read the following information, review the table below, and examine the diagram on the next page as you prepare to complete this assignment.

You have studied the different forms carbon takes (gases, rocks, plants, carbohydrates, proteins, fossil fuels, plastics, and others), the four major reservoirs that hold carbon, and the many different biogeochemical processes that move carbon throughout the global carbon cycle. Carbon is essential to living organisms, including people. The cycling of carbon by many different natural processes makes it available in different forms for us to use.

In the last lesson, you learned that a change in the amount of carbon that is moved from one reservoir to another is called carbon flow. In this lesson, we will look more closely at the "accounting" of carbon flow: the amount of carbon cycled, and the timescales involved. Finally, we will consider recent changes in carbon flow, and how this affects the natural balance of the global carbon cycle.

The table below summarizes the distribution of carbon in the four major reservoirs on Earth: rocks, soils, and sediments; the atmosphere; the ocean; and terrestrial plants. (*Note: A gigaton is one billion metric tons.*)

Worldwide Annual Carbon Flow Between the Atmosphere and Other Reservoirs (gigatons)

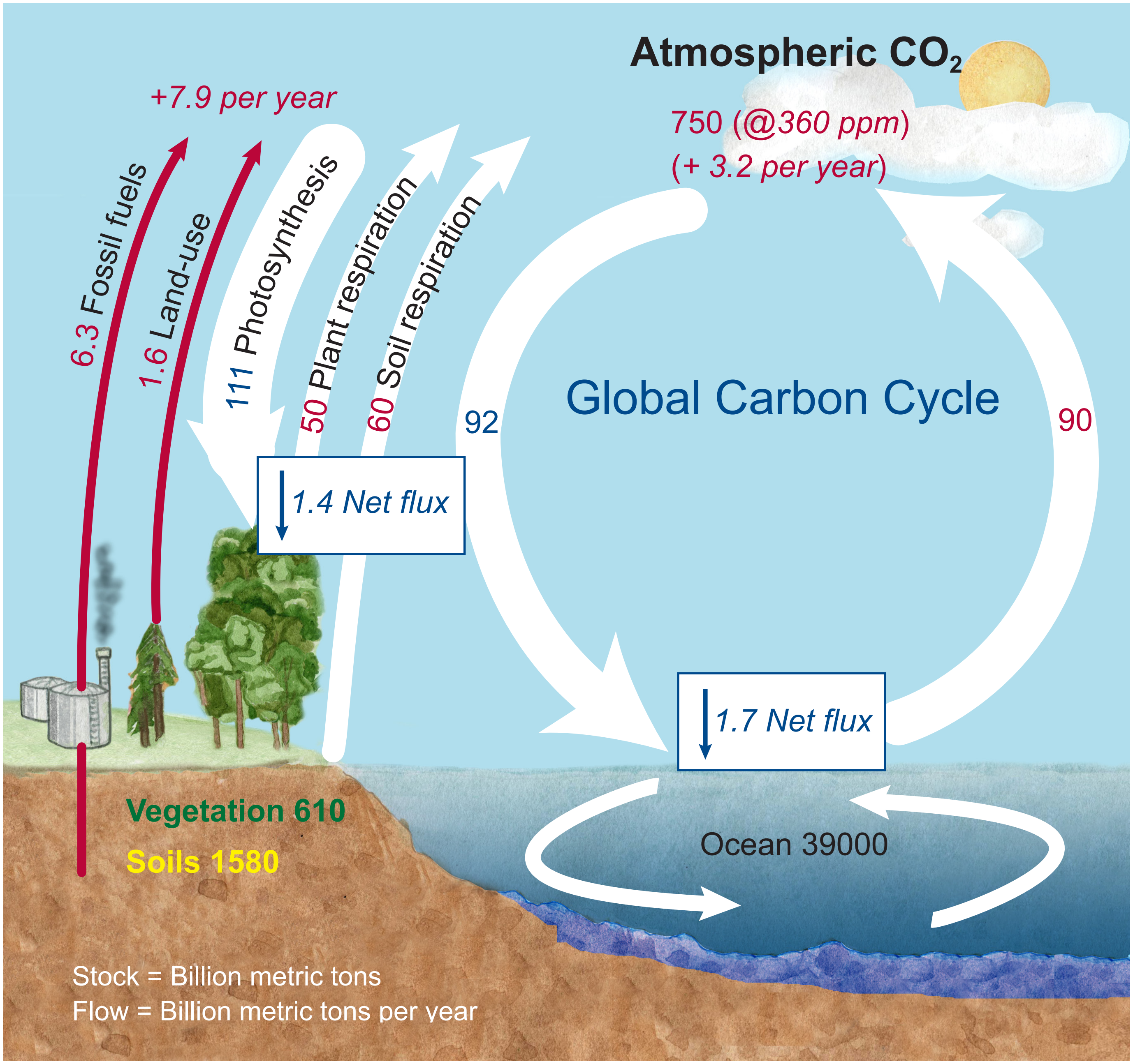
Reservoir	Amount of Carbon Released into the Atmosphere (Emissions)	Amount of Carbon Stored from the Atmosphere (Uptake)
Rocks, Soils, and Sediments	Carbon emission by soil respiration (decomposition by soil microbes): 60 CO_2 from land use changes and burning fossil fuels: 8 (*Note: This is not considered a "natural" process, but is the result of human activities.*)	Measurements vary too much from location to location to accurately report data.
Ocean	Released back to atmosphere from respiration and decomposition: 90	Annual CO_2 uptake by biological and solubility pump processes: 92
Terrestrial Plants	Carbon emission by decomposition/respiration: 50	CO_2 uptake by photosynthesis: 111

Amount of carbon in each reservoir (gigatons):
Rocks, Soils, and Sediments: 66,000,000 to 100,000,000
Fossil Fuels: 4,000
Ocean: 38,000 to 40,000
Terrestrial Plants: 540 to 610
Atmosphere: 766
(The CO_2 concentration in the atmosphere is currently increasing by about 3.2 parts per million every year.)

Name: ______________________________

Global Carbon Cycle: This diagram shows carbon flow and includes both natural processes and human activities.

Carbon Flow Data



Source: http://www.globalchange.umich.edu/globalchange1/current/lectures/kling/carbon_cycle/carbon_cycle.html

Name: ______________________________

Instructions: Use the data provided on the **Worldwide Carbon Flow Chart** (page 1) and the **Carbon Flow Data** diagram (page 2) to answer the following questions.

1. Figure out the total natural carbon flow in gigatons from the reservoirs in the table provided. Compare the total carbon uptake from the atmosphere into other reservoirs by natural processes to total emissions into the atmosphere from other reservoirs by natural processes. To do the math, add up carbon stored and subtract carbon released as presented in **Worldwide Annual Carbon Flow Between the Atmosphere and Other Reservoirs.** (*Note: The stored carbon, or natural uptake, should be represented as a negative number, since it is carbon that leaves the atmosphere. The emissions, or carbon that enters the atmosphere, is represented as a positive number.*) (3 points)

   Natural uptake (-) ______________________
   Natural emissions ______________________
   Net natural carbon uptake = ______________________

2. Data Analysis: Even though rocks, soils, and sediments comprise the largest carbon reservoir, the amount of carbon flow to and from this reservoir is very small. Explain why this is. (2 points)

3. How do overall natural carbon emissions compare to overall natural carbon uptake? Would you expect this degree of "balance" in a natural cycle? In other words, does this "make sense" when you think about how a natural cycle should function? (5 points)

4. Consider the influence of human activities on the global carbon cycle: Figure the total carbon emissions from the combustion of fossil fuels (and biomass burning) and land use changes. Use **Global Carbon Cycle** on page 2 for fossil fuel emissions and emissions from land use to figure total emissions from human activities. (3 points)

   Fossil fuel emissions (+) ____________________
   Emissions from land use (+) ____________________
   Emissions from human activities = ____________________

5. Data Analysis: Where are most of these carbon emissions going? What carbon reservoir is taking up this carbon? (2 points)

Name: ______________________________

6. Figure out the "Total Carbon Flow" to or from the atmosphere including flow from human activities. (*Note: A positive number indicates carbon entering the atmosphere and a negative number indicates carbon leaving the atmosphere.*) (3 points)

   Carbon flow from natural systems ________________
   Carbon flow from human activities (+)________________
   = ________________

7. Data Analysis: What is the end result (in gigatons) of the "Total Carbon Flow"? (2 points)

8. What is the significance of "extra" atmospheric carbon dioxide in Earth's atmosphere? (2 points)

9. What is really happening? Scientists are measuring an annual 3.2 billion metric tons of carbon dioxide entering our atmosphere from human activities on an annual basis. Scientists say that we are lucky: the ocean is currently taking up more carbon dioxide than it did under preindustrial conditions. Based on what you know about emissions of carbon dioxide due to human activities, explain why levels of atmospheric CO_2 have steadily increased the entire time CO_2 has been measured. (3 points)

10. Bringing it all together: Comparing "young" carbon to "ancient" carbon:
    Scientists can measure and track the amount of carbon dioxide human activities emit to the atmosphere. Our activities are like a carbon footprint: the carbon is what our activities "leave behind." Compare the carbon footprint of using cow pie (biomass) for energy to using fossil fuels. Compare the origin of each energy source; is it "young" or "ancient?" With regard to the global carbon cycle, why does using young versus ancient carbon energy matter? (5 points)

Redesigning Life to Make Ethanol

MIT's *Technology Review*, Saturday, July 1, 2006

Producing ethanol fuel from biomass is attractive for a number of reasons. At a time of soaring gas prices and worries over the long-term availability of foreign oil, the domestic supply of raw materials for making biofuels appears nearly unlimited. Meanwhile, the amount of carbon dioxide dumped into the atmosphere annually by burning fossil fuels is projected to rise worldwide from about 24 billion metric tons in 2002 to 33 billion metric tons in 2015. Burning a gallon of ethanol, on the other hand, adds little to the total carbon in the atmosphere, since the carbon dioxide given off in the process is roughly equal to the amount absorbed by the plants used to produce the next gallon.

It's Corn vs. Soybeans in a Biofuels Debate

Adapted from *New York Times*, July 12, 2006

The study published by the National Academy of Sciences found that neither ethanol nor biodiesel can replace much petroleum without having an effect on food supply. If all American corn and soybean production were used to make biofuels, that fuel would replace only 12% of our gasoline needs and 6% of diesel needs, the study notes. Researchers in Minnesota write that with the expected doubling of worldwide need for food within the next 50 years and an even greater expected need for transportation fuels, "there is a great need for renewable energy supplies that do not cause a lot of harm and do not compete with worldwide food supplies."

Food Versus Fuel

Washington Post, December 12, 2007

During the past year, prices of basic grains, such as wheat and corn have soared…It is the extra demand for grains to make biofuels, driven heavily in the United States by government tax subsidies and fuel mandates, that has pushed prices dramatically higher. Since 2000, the share of the U.S. corn crop devoted to ethanol production has increased from about 6% to about 25%—and is still headed up.

Farmers benefit from higher prices. Up to a point, investors in ethanol refineries also gain from the mandated use of corn ethanol (though high corn prices have eroded or eliminated their profits). But who else wins is unclear. Although global biofuel production has tripled since 2000, it still accounts for less than 3% of worldwide transportation fuel, reports the U.S. Agriculture Department. Even if all U.S. corn were diverted into ethanol, it would replace only about 12% of U.S. transportation fuel, according to one study.

Biofuels became politically fashionable because they combined benefits for farmers with popular causes: increasing energy "security" and curbing global warming. But substituting corn-based ethanol for gasoline results in little reduction in carbon dioxide emissions. Indeed, the demand for biofuels encourages deforestation in developing countries; the *New York Times* recently reported the clearing of Indonesian forests to increase palm oil production for biofuel.

The Promise of Biofuels—Hype or a Real Solution?

Adapted from an article by Maarten Chrispeels and Steve Kay,
San Diego Union-Tribune, Feb. 17, 2008

But, all biofuels are not created equal. If we look at the amount of energy needed to produce different types of ethanol, some are better than others. The reason is that growing plants and converting plant material into biofuel also takes energy. And at the moment that energy comes mostly from electricity generated by fossil fuels. So much energy is needed to grow and produce corn ethanol, that this biofuel option does not reduce carbon dioxide emissions when compared to fossil fuels. The reasons are complex: corn needs a lot of nitrogen fertilizer to grow, and making nitrogen fertilizers is very energy intensive. In the case of corn ethanol, distilling the ethanol requires energy. We do not have ethanol pipelines, so ethanol has to be transported in trains and trucks. For these and other reasons, the greenhouse gas balance—greenhouse gases removed from the atmosphere minus greenhouse gases released—is unfavorable for corn ethanol. In Europe and in other countries, many people and governments are against making biofuels from food crops, such as corn, because they can cause food prices to go up. The good news is that new technology for making biofuels is being studied around the world. One feedstock that looks promising is ethanol made from cellulose. Cellulose is the main ingredient in wood and in the new so-called biomass crops, such as switchgrass, that do not need fertilizer.

So, when can we start using some of these options that promise to reduce carbon dioxide emissions? First, we will need to improve our technology so that the energy to produce better biofuels is not wasted. We need to continue to develop corn and other crops that produce high yields because with an ever growing population, we need these crops for food, as well as fuel. We also need to finish the work started on developing ethanol from switchgrass and other cellulose.

The reality of some of these biofuel options is that in the past, this type of research has not been well funded. It is clear that hard choices are going to be made: fuel or tortillas, beef or biodiesel, foreign oil or home-grown biofuel, which shall it be? When our lawmakers and the public at large understand that such choices are on our doorstep, then the problem with a lack of funds for biofuel research could be turned around.

Chemistry Assignment #6

Name: ________________________________ Period:___ Teacher:_______________

Examining Decision Factors

Lesson 5 | *page 1 of 4*

Instructions: Read the assigned **Biofuel News Clips** (Lesson 5 materials) and answer the related questions in the spaces provided.

Redesigning Life to Make Ethanol

1. Identify the trade-offs presented in the news clip.

2. Does the author suggest a cause for the issue presented?

3. Which decision category(ies) does the group feel this issue presents: environmental, social, political, or economic?

4. What is the “big idea” of this news clip?

Name: ______________________________

It's Corn vs. Soybeans in a Biofuels Debate

5. Identify the trade-offs presented in the news clip.

6. Does the author suggest a cause for the issue presented?

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Name: ______________________________

Food Versus Fuel

9. Identify the trade-offs presented in the news clip.

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11. Which decision category(ies) does the group feel this issue presents: environmental, social, political, or economic?

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Name: ______________________________

The Promise of Biofuels—Hype or a Real Solution?

13. Identify the trade-offs presented in the news clip.

14. Does the author suggest a cause for the issue presented?

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Name: ___________________________________

Instructions: Read the text below and answer the questions on the following page.

Is Ethanol Getting a Bum Rap?

By John Carey. *Business Week*, May 1, 2008.

There are grains of truth in this backlash, experts say. "There are bad biofuels and good biofuels," says Daniel Sperling, director of the Institute of Transportation Studies at the University of California at Davis. Corn-based ethanol ranks as mediocre. Yet it is only a minor cause of high food prices, and better biofuels are on the horizon. The transition to these superior fuels will get a boost from policies now being developed, with California leading the way…

Instead of throwing out biofuels, the key is to speed up the transition from corn to crops that offer more benefits. There's a surprisingly simple way to do it: Judge fuels on how much greenhouse gas is emitted during their entire production and transport, including emissions caused by converting land from food crops and other uses to fuel crops. Then ratchet down the amount of carbon that's allowed…

This low-carbon fuel standard approach sets the market free to pick the best fuels to meet the standard. It immediately rules out biofuels from palm oil plantations carved out of the rainforest, for instance. It would also steer farmers away from corn because of corn ethanol's lack of substantial greenhouse gas benefits. "Almost all of the pathways for using food crops to make energy will look very bad with a carbon metric," explains UC Davis' Sperling, who has worked on the approach. "The low-carbon fuel standard is one of the most outstanding policy instruments we have ever developed," he says. Make this approach widespread, and it should be possible to have our biofuels and eat our crops, too.

Name: ______________________________

Instructions: Answer the following questions in the spaces provided.

1. Identify the trade-offs presented in the news clip. (1 point)

2. What does the author suggest as a cause for the issue presented? (1 point)

3. Which decision category(ies) does this issue represent: environmental, social, political or economic? Identify one and use evidence from the article to justify your answer. (4 points)

4. What is the "big idea" of this news clip? (1 point)

5. People often use the analogy of "growing on trees" (or in this case, stalks) to say that something is free. In the case of biofuels, there is concern about <u>all</u> the costs involved. What are some of them? (3 points)