



OUTCOMES SCIENCE 4

EARTH & BEYOND

INSTRUCTIONAL MODULE 5: LESSON 4

TARGET YEAR GROUPS: 8 / 9 / 10 / 11 / 12

Student Name:

Tutorial Group:

In this E & B Lesson, you will be expected to analyse a number of Global Carbon Cycle models, of increasing complexity, emphasising the enhanced greenhouse effect, and then to make a study of global warming.

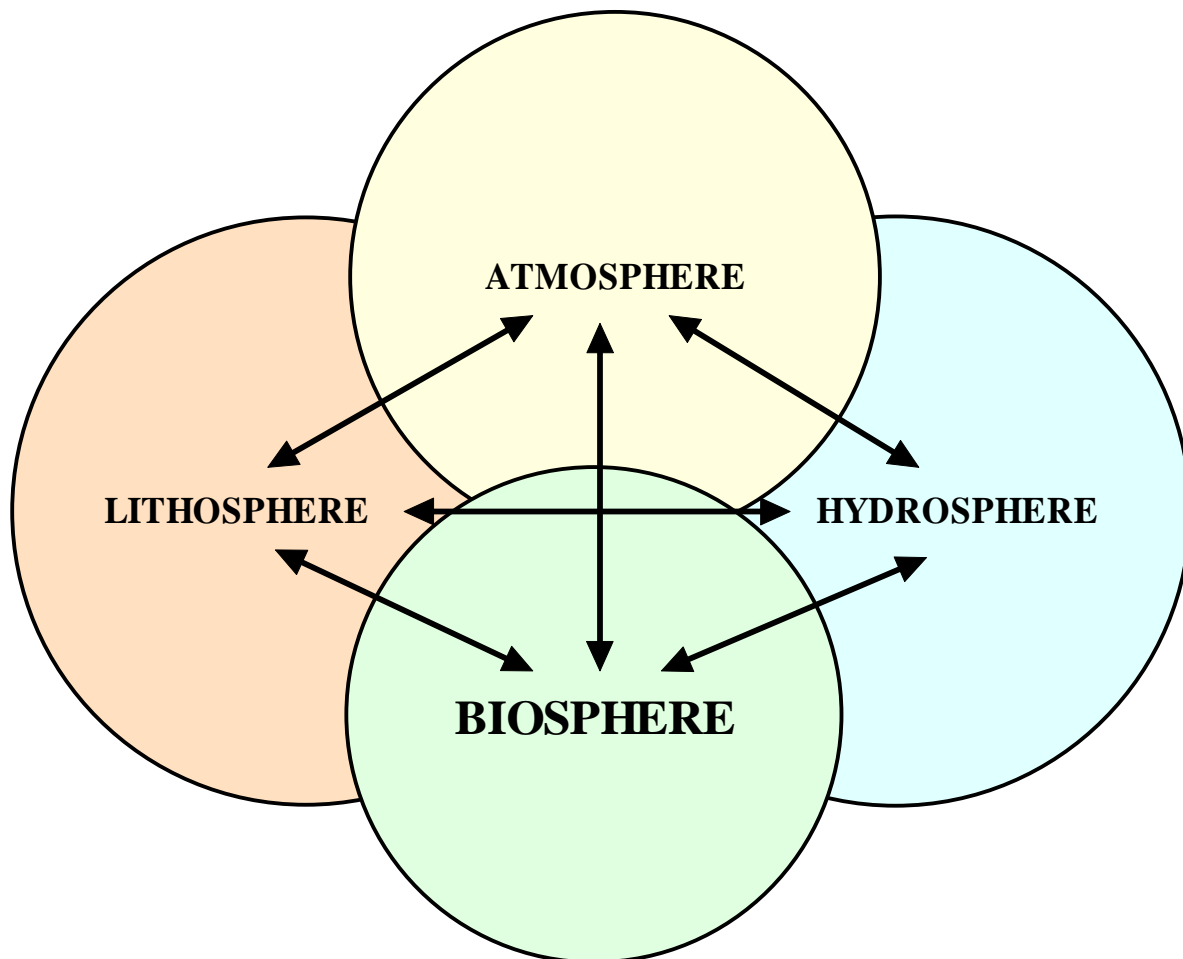


FIGURE 1: SUBSYSTEMS AND CARBON CYCLING

FIGURE 1, given above, is a systems view of the Global Carbon Cycle showing the exchange of elemental carbon within System Earth, with each idealised two-way carbon flow represented by a double-headed arrow.

What is the Global Carbon Cycle?

The Global Carbon Cycle (GCC) is the sum total of all the interacting physical, biological, geological and chemical processes, collectively known as biogeochemical processes, which control the exchange of elemental carbon, in both organic and inorganic compounds, between the atmosphere, the lithosphere, the hydrosphere and the biosphere.

1. Can you **identify** carbon-containing organic and inorganic chemical compounds that are exchanged between the subsystems of System Earth? Can you also **identify** the biogeochemical processes by which these carbon-containing compounds are exchanged between the coupled subsystems?

Students in each Learning Group now answer Question 1 by completing TABLE 1, given below. My intention of asking you to complete TABLE 1, at this early stage, is to probe your existing knowledge of the Global Carbon Cycle. Do NOT worry if you experience some difficulty in trying to complete TABLE 1. As your knowledge of the Global Carbon Cycle develops, from studying this E & B Lesson, you will be given further opportunities to complete TABLE 1.

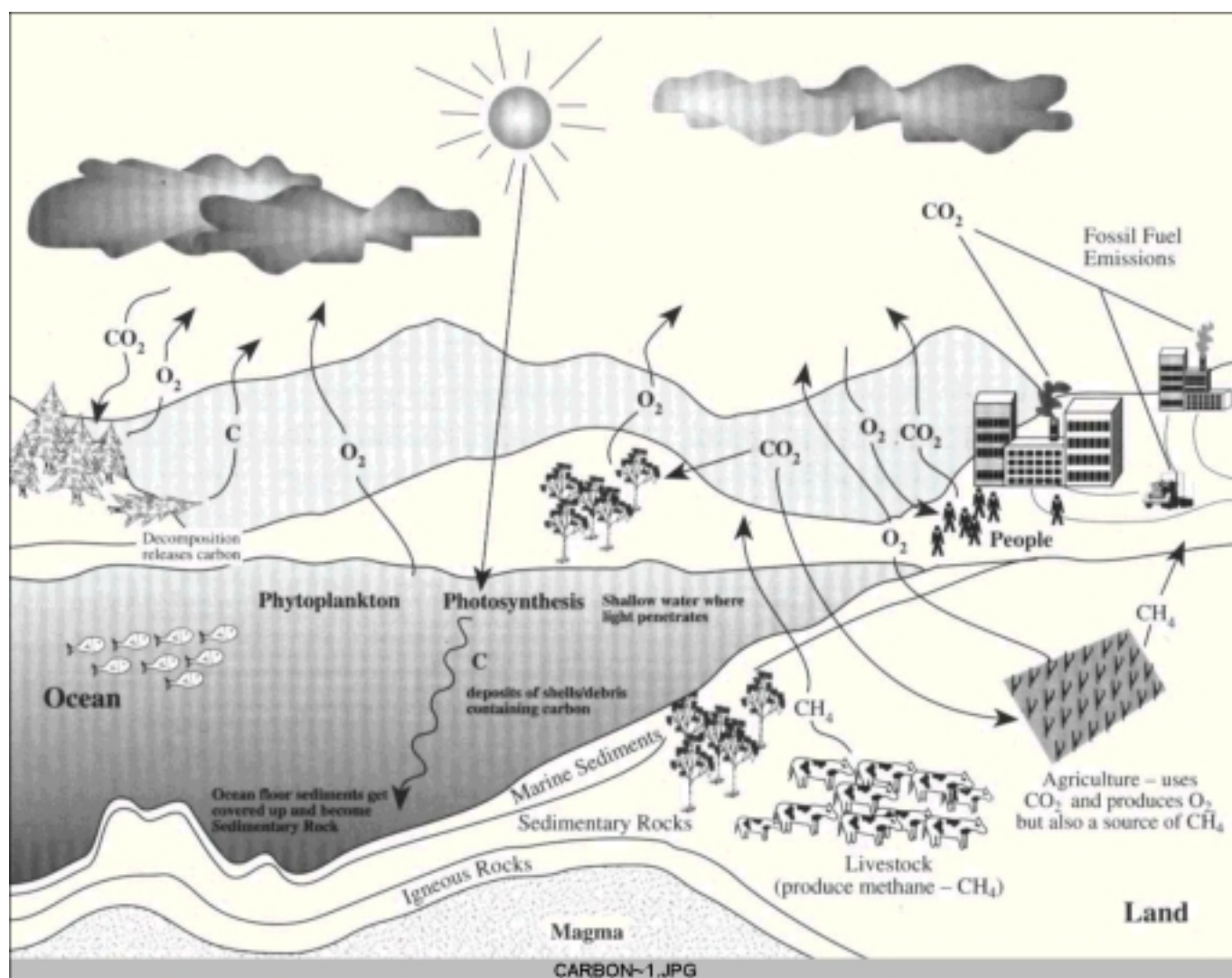
TABLE 1: CARBON FLOWS BETWEEN SUBSYSTEMS

| SUBSYSTEMS COUPLED | CARBON COMPOUNDS & BIOGEOCHEMICAL PROCESSES |
|---------------------------|--|
| Biosphere-Atmosphere | |
| Biosphere-Hydrosphere | |
| Biosphere-Lithosphere | |
| Atmosphere-Hydrosphere | |
| Atmosphere-Lithosphere | |
| Hydrosphere-Lithosphere | |

I have asked you to analyse FIGURE 1, an abstract systems diagram, with the intention of NOT restricting your preliminary analysis of the Global Carbon Cycle.

However, should you require help in interpreting my systems diagram of the carbon cycle, you could now study the JPEG drawing of the carbon cycle, copied with permission, from the SeaWiFS Project web site.

1. http://seawifs.gsfc.nasa.gov/SEAWIFS/LIVING_OCEAN/carbon_cycle.jpeg
2. http://seawifs.gsfc.nasa.gov/SEAWIFS/LIVING_OCEAN/LIVING_OCEAN.html



Students in each Learning Group should now carefully study and analyse the CARBON~1.JPG carbon cycle sketch, given above, to identify all the carbon flows and the processes controlling them. They should then refer back to TABLE 1, from the previous page, adding the new knowledge that they have gained from their study of the JPEG sketch.

Students in each Learning Group should now describe, in more detail, each biogeochemical process that they have identified within the carbon cycle by completing TABLE 2, given on the next page.

TABLE 2: BIOGEOCHEMICAL PROCESSES WITHIN THE CARBON CYCLE

| Biogeochemical Process | Description of each Biogeochemical Process |
|---|---|
| Volcanism | |
| Photosynthesis | |
| Respiration | |
| Physical mixing and Dissolving and Diffusion | |
| Weathering | |
| Organic and Inorganic Carbonate Precipitation | |
| Burial of Carbonate and Organic carbon in Sediments | |
| Metamorphism of Carbonate and Organic carbon in Sediments | |
| Combustion and Industrial Processes | |
| Deforestation (Biomass Burning) | |

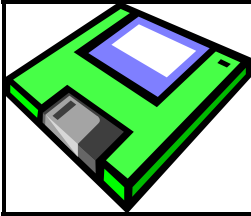


Students in each Learning Group should now extend their understanding of the Global Carbon Cycle by researching information with which to complete TABLE 1 (given on page 2) and TABLE 2 (given on page 4).

You may obtain the information necessary to complete the Tables by visiting web sites whose Internet Addresses (URL's) are listed below.

1. <http://www.igc.org/wri/climate/carboncy.html>
2. <http://library.thinkquest.org/11226/>
3. <http://www.smy.fi/koulut/carbon/>
4. <http://www.cotf.edu/ete/modules/carbon/efcarbon.html>
5. <http://www.arm.gov/docs/education/globwarm/carbcyexpert.html>
6. <http://www.whrc.org/science/carbon/carbon.htm>
7. <http://www.geog.ouc.bc.ca/physgeog/contents/9r.html>
8. <http://gfd.gly.bris.ac.uk/enviro-geochem/envgeo/lecture3/lecture3.html>
9. <http://www.brynmawr.edu/Acads/Geo/Geo103/ccycles.html>
10. <http://www.sciborg.uwaterloo.ca/~cchieh/cact/applychem/ccycle.html>
11. <http://geochange.er.usgs.gov/pub/carbon/fs97137/>
12. <http://earthobservatory.nasa.gov/Study/BOREAS/>

In order to understand and predict global environmental change, Earth System scientists are developing more and more sophisticated computer-run, mathematical models of the Global Carbon Cycle. On the next page, I have listed some URL's that provide examples of 'simple' carbon cycle mathematical models.



Students in each Learning Group may like to learn about computer-run, mathematical modelling of the carbon cycle. If you do, you should visit the web sites whose Internet Addresses (URL's) are listed below?

1. http://www.acad.carleton.edu/curricular/GEOL/DaveSTELLA/Carbon/carbon_intro.htm

2. http://wufs.wustl.edu/pathfinder/path201/notes/notes_10_31_00.htm

3. <http://www.nehs.org/pages/carbon.shtml>

4. <http://geosys.mit.edu/~chem/>

Should you wish to download a demonstration of STELLA Software, you may like to visit the HPS Education Solutions web page?

5. <http://www.hps-inc.com/edu/stella/stella.htm>

Students in each Learning Group should also visit this USGCRP web site to be informed of current research activities in Carbon Cycle Science.

6. <http://www.carboncyclescience.gov/>

2. Can you now **draw a concept map** of the carbon cycle? You may recall that a concept map **displays** and **describes** the links between a number of related concepts, like those involved in the global carbon cycle as shown in the JPEG sketch on page 3? Print this page.

Students in each Learning Group should now evaluate their carbon cycle concept maps by visiting the web sites whose Internet Addresses (URL's) are listed below. You should also compare and contrast your concept map with those of other students in your Learning Group and from other learning groups.

Please be informed that a biologist has constructed the carbon cycle concept map provided at web site #1.

1. <http://www.schoolnet.edu.mo/general/biology/temp/cmap/carbon.html>

2. <http://www.schoolnet.edu.mo/general/biology/temp/cmap/cmapguid.html>

3. In my opinion, in the carbon cycle concept map at web site #1, there is an overemphasis of biological processes to the exclusion of other important biogeochemical processes involved in the carbon cycle. What do you think? What important processes do you think have been omitted from the carbon cycle concept map provided at web site #1?

As an alternative to sketching a concept map of the carbon cycle, you may wish to download a copy of INSPIRATION Software, on a trial basis? Then construct (and print) your carbon cycle concept maps using the INSPIRATION System.

1. <http://www.inspiration.com/theory/howtomap.html>

2. <http://www.inspiration.com/betaform.html>

Concept mapping is a very effective strategy for identifying and describing the links between related concepts. However, in using concept mapping to analyse the complex carbon cycle to better understand its component processes, we must not lose sight of the holistic nature of the carbon cycle.

Analysis, a powerful tool of reductionist science, breaks down complex systems into their component subsystems in order to study and understand them. However, we are practising Earth System Science, which emphasises the holistic nature of total systems, like the carbon cycle.

We must now put the carbon cycle back together by identifying cycles within it, and not its component biogeochemical processes, as was done in TABLE 2 on page 4.

What is the **connection between** the global carbon cycle and the rock cycle? Can you **identify** processes within the carbon cycle, which also occur in the rock cycle?

On page 15 of Lesson 8 in E & B Instructional Module 2, I defined the rock cycle as restated below.

The Rock Cycle is the sum total of all the geologic processes of change occurring within and upon the Earth's lithosphere. Within the rock cycle, rocks are formed, weathered, eroded, deposited, reformed and uplifted.

On page 7 of Lesson 12 in E & B Instructional Module 2, I provided the rock cycle diagram given as FIGURE 2 below.

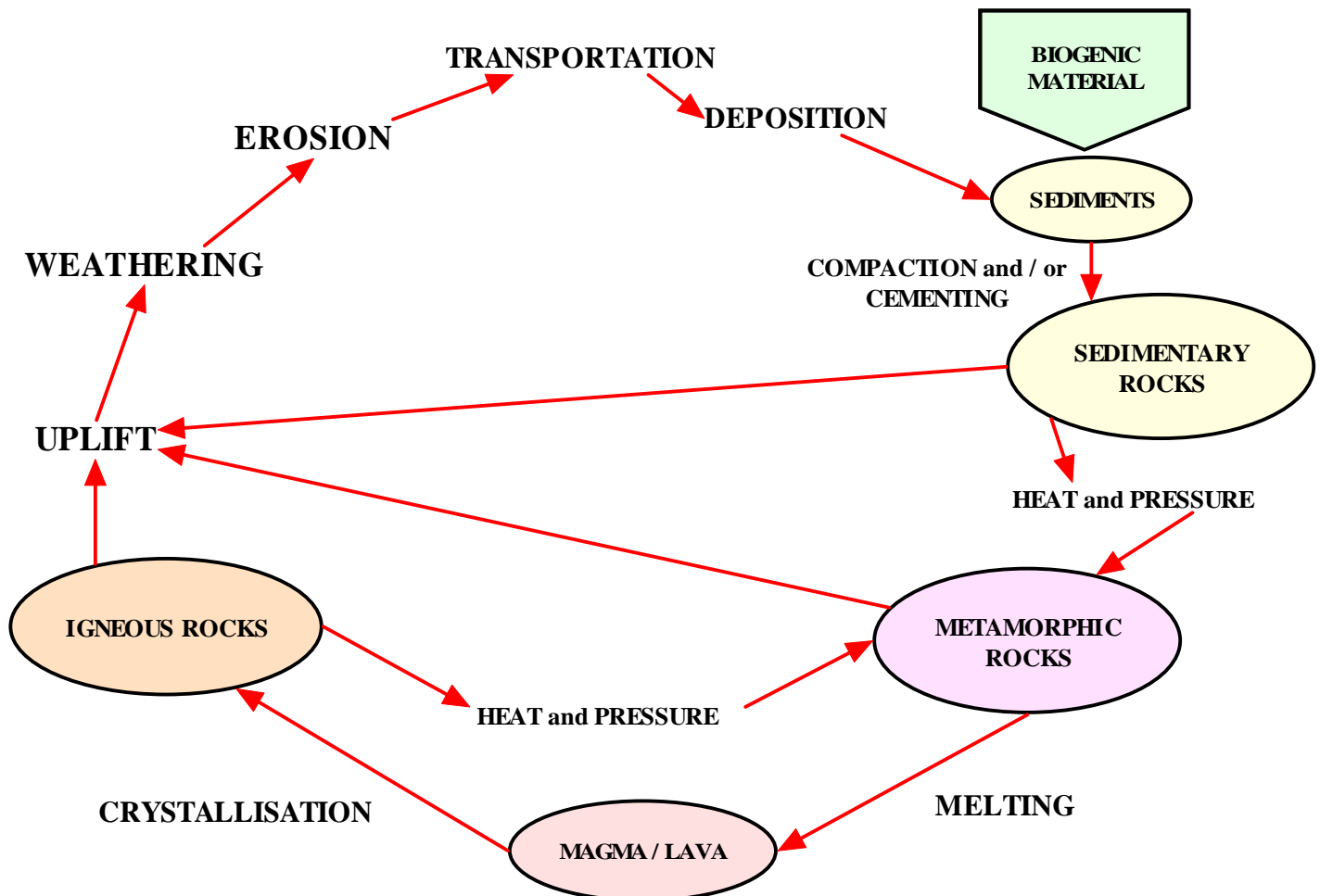
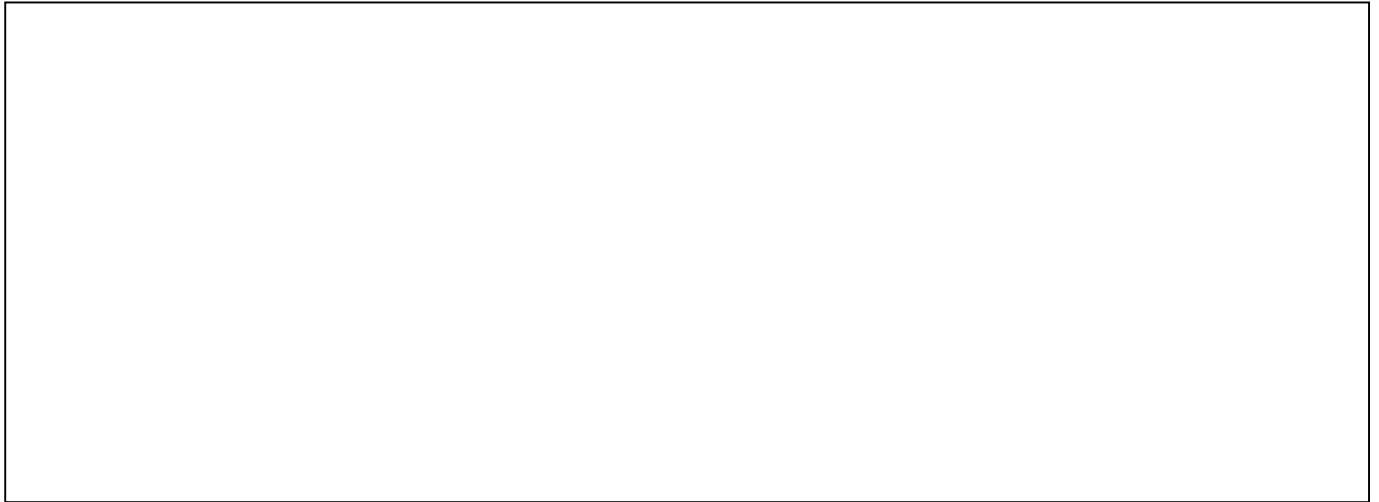


FIGURE 2: THE ROCK CYCLE

4. Now refer back to TABLE 2 on page 4. What is the **connection between** the global carbon cycle and the rock cycle? What processes are common to both the carbon cycle and to the rock cycle?

5. Can you **explain** how the lithospheric rock cycle transports and exchanges carbon, in both organic and inorganic carbon compounds, between the atmosphere, the hydrosphere and the biosphere?



Students in each Learning Group should now study the diagram of the rapid Carbon-Oxygen Cycle shown in FIGURE 3, given below. Refer back to the JPEG sketch given on page 3. Can you locate the rapid carbon-oxygen cycle within the global carbon cycle shown in the JPEG sketch?

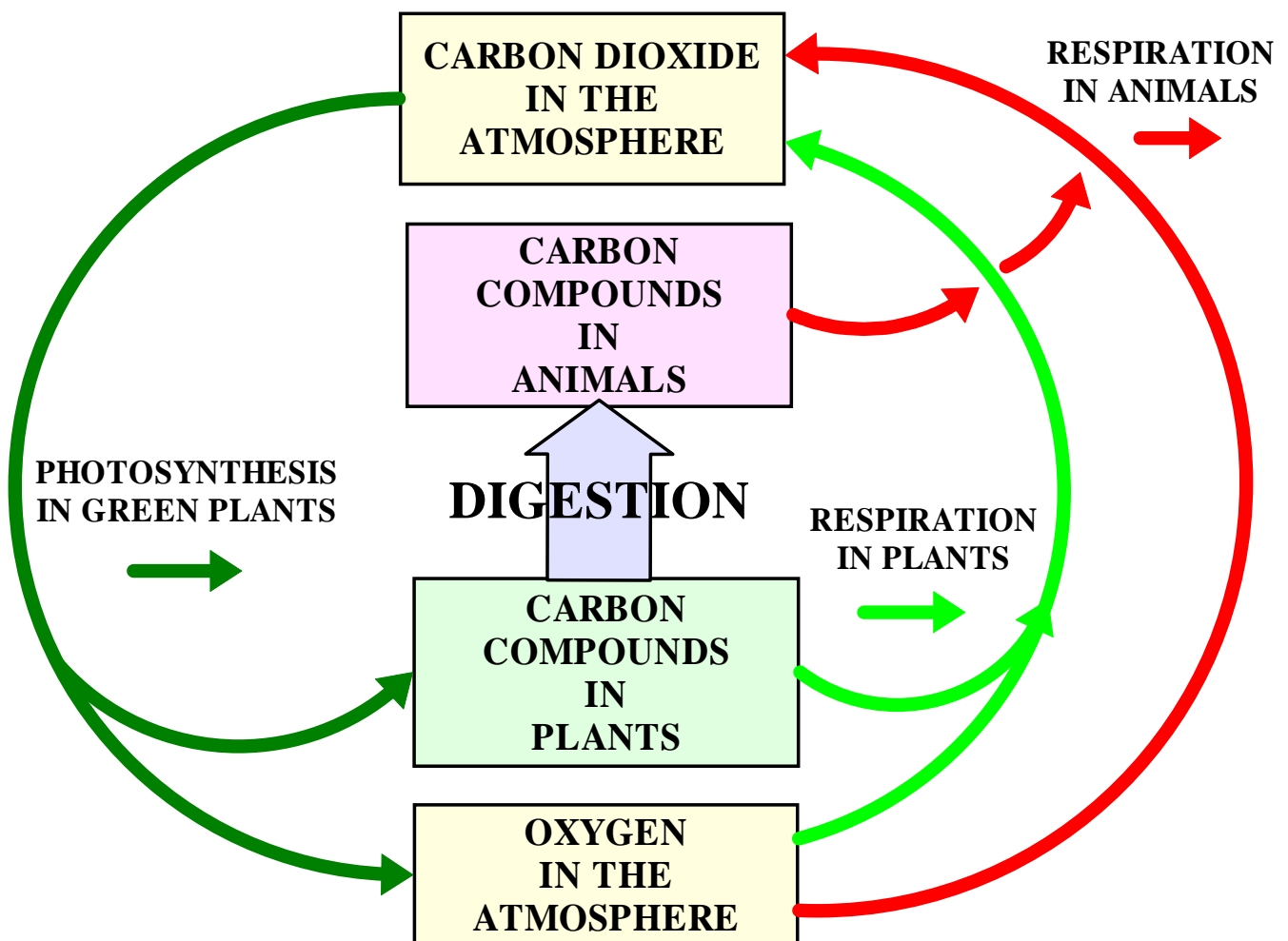


FIGURE 3: THE RAPID CARBON-OXYGEN CYCLE

6. Can you explain the rapid carbon-oxygen cycle? Clarify your ideas about FIGURE 3, and then **explain** what it means to the other members of your Learning Group.

The cyclical nature of the rapid carbon-oxygen cycle is revealed in TABLE 3, given below.

| TABLE 3: Outcomes of Photosynthesis and Respiration | |
|--|----------------------------|
| Photosynthesis | Respiration |
| ● Absorbs energy | ● Releases energy |
| ● Uses up carbon dioxide | ● Produces carbon dioxide |
| ● Produces carbon compounds | ● Uses up carbon compounds |
| ● Produces oxygen | ● Uses up oxygen |

You should now **have an understanding** that the global carbon cycle essentially involves two naturally occurring sub-cycles interacting with each other, and with the Anthropogenic (human) forcings system as shown in FIGURE 4, given below.

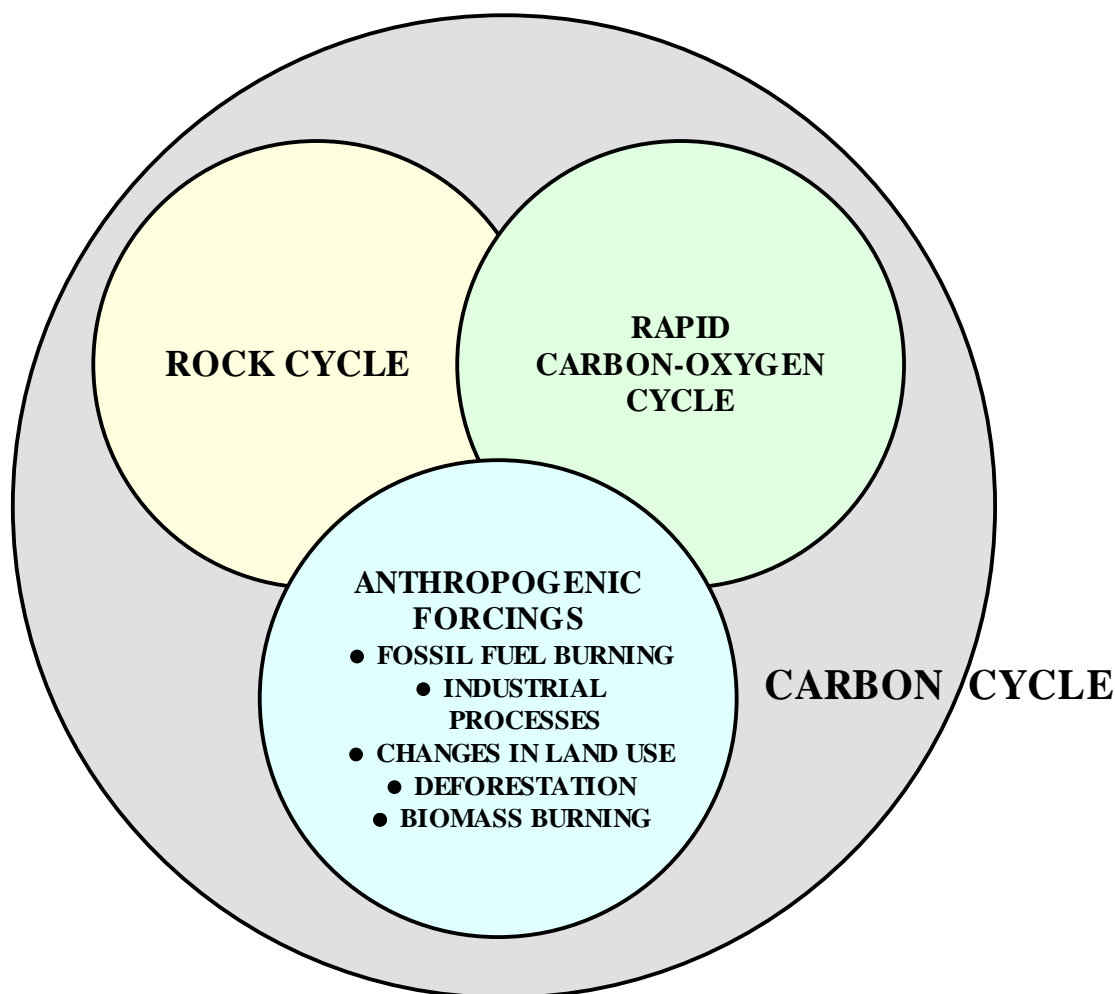


FIGURE 4: SUB-CYCLES IN THE CARBON CYCLE



Students in each Learning Group should now produce an electronic group report on one (1) topic only, selected on the basis of mutual interest from the following list of topics related to the carbon cycle.

They should conduct research at relevant web sites selected from the Internet Addresses (URL's) listed under the topic headings given below.

Volcanic Gases, the Carbon Cycle and Climate

1. http://vulcan.wr.usgs.gov/Projects/Emissions/vgas_fsheets.html
2. <http://volcanoes.usgs.gov/Hazards/What/VolGas/volgas.html>
3. http://geochange.er.usgs.gov/pub/volcanoes/OFR_97-262/

Ocean Carbon Cycle Modelling

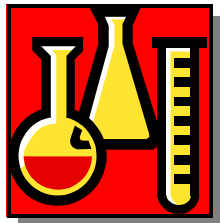
4. <http://earthobservatory.nasa.gov/Newsroom/MediaAlerts/2000/200001271631.html>
5. <http://greenwood.cr.usgs.gov/pub/fact-sheets/fs-0058-99/>
6. <http://www.metoffice.gov.uk/sec5/OA/Carbon/CarbonCycle.html>
7. <http://www.llnl.gov/ees/atm/ASD/C-cycle/aboutocc.html>

Fossil Fuel Burning and the Carbon Cycle

8. http://www.fe.doe.gov/issues/climatechange/globalclimate_energy.html
9. http://www.fe.doe.gov/coal_power/sequestration/
10. <http://www.gcrio.org/CONSEQUENCES/vol4no1/carbcycle.html>

On page 17 of Lesson 8 in E & B Instructional Module 2, I defined chemical weathering as restated below.

Chemical Weathering is the chemical breaking down or decomposition of rocks and minerals at the Earth's surface resulting from chemical changes occurring when air, water and acids attack rocks.



[EB: IM5: L4: Activity 1] Students in each Learning Group now plan and conduct a practical investigation into the effects of dissolving carbon dioxide gas in seawater.

They produce the carbon dioxide gas by the chemical weathering of calcium carbonate rock with acid.

Your teacher will provide the following materials to each Learning Group.

- ✓ Two (2) Large test tubes, one (1) fitted with a rubber stopper and delivery tube.
- ✓ About twenty (20) grams of marble chips [Calcium carbonate $\text{Ca}^{2+}\text{CO}_3^{2-}$ (s)].
- ✓ About 100 mL of 4M Hydrochloric acid [H^+Cl^- (aq)] in a capped storage bottle.
- ✓ One (1) Dropping bottle of Universal indicator.
- ✓ One (1) Test tube rack.
- ✓ A Wooden board to protect the bench top.
- ✓ Access to a graphics calculator and a data logger (CBL or DAS) fitted with a pH probe.
- ✓ Access to a fresh supply of seawater.

NOTES OF CAUTION

1. Handle the Hydrochloric acid with care, as it is a very corrosive chemical.
2. Do NOT discard the marble chips, left after reaction, down the laboratory sink.

1. HOW ARE YOU GOING TO CARRY OUT YOUR INVESTIGATION?

2. WHAT DO YOU PREDICT WILL HAPPEN TO THE pH OF THE SEAWATER AS CO_2 GAS DISSOLVES IN IT? WHY WILL IT HAPPEN? WRITE CHEMICAL EQUATIONS.

3. WHAT OBSERVATIONS HAVE YOU MADE? (Are they the same as your prediction?)

4. WHAT WILL HAPPEN TO THE H_2CO_3 , HCO_3^- AND CO_3^{2-} CONCENTRATIONS AS CO_2 GAS DISSOLVES IN THE SEAWATER? WHY WILL IT HAPPEN?

You can partially check your answers to Questions 2 and 4 by conducting research at the web site whose Internet Address (URL) is listed below.

<http://www.awi-bremerhaven.de/Carbon/cycle1.html>

What is the chemical composition of seawater? What chemical species (ions) does seawater contain and in what concentration? How can we find an answer to this Question?

http://www.britanica.com/bcom/eb/article/single_table_inline/0,5716,1123,00.html

I only found one web site that provides the answer. Open the web site and research the relative concentration of calcium ions compared to chloride ions.

5. What happens to the calcium ion concentration when CO_2 gas dissolves in seawater?

6. With an increasing concentration of CO_2 gas in the atmosphere, caused by human activities, what will happen to the reef-building activity of coral polyps, which extract calcium and carbonate ions from the seawater around them to build their homes? Also, does global warming destroy coral reefs?

Answer Question 6 and then check your answer by researching at the web site whose Internet Address (URL) is listed below.

http://www.earthinstitute.columbia.edu/news/story6_3.html

The Greenhouse effect is the natural mechanism by which a planet's surface is warmed by infrared absorbing gases in its atmosphere.

Natural and anthropogenic greenhouse gases such as carbon dioxide, methane, nitrous oxide, and water vapour in the Earth's atmosphere absorb infrared radiation, and then reradiate some of it back towards the Earth's surface causing it to become warmer.

Global warming is a warming of the Earth's atmosphere owing to the anthropogenic enhancement of the greenhouse effect.

7. Can you explain, at the molecular level, why CO₂ gas is transparent to visible light and ultraviolet radiation but is opaque to infrared radiation, as it absorbs and re-radiates infrared radiation to produce the greenhouse effect?

To successfully answer this Question, you must **demonstrate an understanding** of the mechanisms of absorption of photons of infrared radiation by individual molecules of CO₂ gas. Before you can fully understand the greenhouse effect, you must understand how CO₂ molecules absorb photons of infrared radiation.

Lower secondary science textbooks usually do not explain how CO₂ gas molecules absorb infrared radiation. Consequently, lower secondary science textbooks do not fully explain the basic processes involved in the greenhouse effect.

Students in each Learning Group should now research the answer to Question 7 by visiting the web sites whose Internet Addresses (URL's) are listed below.

1. <http://www.chem.arizona.edu/courses/chem242/movies/ir.html>

2. <http://www.shu.ac.uk/schools/sci/chem/tutorials/molspec/irspec1.htm>

3. <http://www.chemguide.co.uk/analysis/ir/background.html>

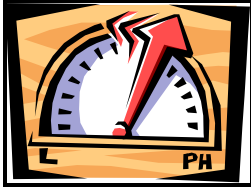


Students in each Learning Group now collaborate to produce an electronic group report on all aspects of the greenhouse effect.

They confine their research to the web sites whose Internet Addresses (URL's) are listed below. **Please note that any images you use are subject to copyright**

1. <http://www.pbs.org/wgbh/nova/ice/greenhouse.html>
2. http://www.greenhouse.gov.au/pubs/factsheets/fs_effect.html
3. <http://www.ngdc.noaa.gov/paleo/globalwarming/greeneffect.html>
4. http://das.ee.unsw.edu.au/~solar/classrooms/1_1.html
5. <http://www.glassworks.org/contest/greenhouse.html>
6. <http://www.science.org.au/nova/016/016key.htm>
7. http://www.dar.csiro.au/info/material/info98_2.htm
8. <http://www.geog.ouc.bc.ca/physgeog/contents/7h.html>
9. <http://www.dar.csiro.au/cc/>
10. http://www.epa.nsw.gov.au/soe/97/ch1/4_4.htm
11. <http://www.abc.net.au/science/earth/climate/uncertain.htm>
12. <http://www.greenhouse.gov.au/>

8. Is global warming the same as the greenhouse effect? Explain.

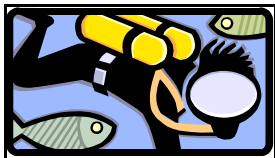


Students in each Learning Group now collaborate to produce an electronic group report on all aspects of global warming.

They confine their research to the web sites whose Internet Addresses (URL's) are listed below. Please note that any images you use are subject to copyright.

1. <http://www.columbia.edu/cu/21stC/issue-1.3/warmmain.html>
2. <http://library.thinkquest.org/17471/index.shtml>
3. <http://www.letus.nwu.edu/projects/gw/index.html>
4. <http://www.chooseclimate.org/>
5. <http://www.ngdc.noaa.gov/paleo/globalwarming/what.html>
6. <http://www.ncdc.noaa.gov/ol/climate/globalwarming.html>
7. <http://www.epa.gov/globalwarming/index.html>
8. <http://www.ucsusa.org/globalresources/0warming.html>
9. <http://www.llnl.gov/str/Duffy.html>
10. <http://cdiac.esd.ornl.gov/pns/faq.html>

9. Can you **list** the consequences of global warming?

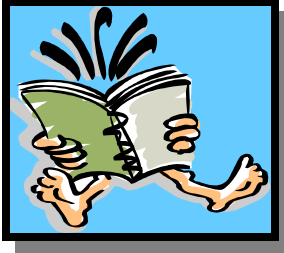


Students in each Learning Group, firstly write an electronic report into the consequences of global warming. Secondly, they debate at class or year or whole-of-school level whether or not global warming is actually happening?

Their report and debate should include questions like: Is global warming happening as a direct result of human-induced global change? Is the mean global sea level rising? Does global warming destroy coral reefs? Plus any other related questions of mutual interest.

They confine their research to the web sites whose Internet Addresses (URL's) are listed below. **Please note that any images you use are subject to copyright.**

1. <http://www.ncpa.org/ba/ba299.html>
2. http://science.msfc.nasa.gov/newhome/headlines/essd06oct97_1.htm
3. <http://earth.agu.org/revgeophys/dou gla01/dou gla01.html>
4. <http://www.maui.net/~jstark/fingerpr.html>
5. <http://www.newscientist.com/ns/19991127/itnstory199911274.html>
6. <http://www.gbrmpa.gov.au/>
7. <http://www.photolib.noaa.gov/reef/>
8. http://www.seaworld.org/coral_reefs/introcr.html
9. http://www.canoe.ca/CNEWSScience0011/01_suzuki-can.html
10. <http://www.aims.gov.au/pages/research/coral-bleaching/scr1998/scr-00.html>
11. <http://www.marinebiology.org/coralbleaching.htm>
12. <http://www.co2science.org/subject/c/summaries/bleachingtemp.htm>



REFLECT AND RE-LEARN

Students in each Learning Group are to firstly identify and list, as a dot-point summary, all those key science concepts (ideas) that they have come to understand by studying this Earth & Beyond Science Instructional Module.

Secondly, they are to identify and list those words and concepts (ideas) that are unclear to them. They then seek help from other students in their Learning Group, and then from other Learning Groups.

Your teacher will assist you, only after your science class has expended every effort to clarify the difficult content on their own.