OUTCOMES SCIENCE 4

EARTH & BEYOND

INSTRUCTIONAL MODULE 1: INTRODUCTION

TARGET YEAR GROUPS: 10 / 11 / 12

Student Name:

Tutorial Group:

What is Earth System Science (ESS)?

Earth System Science analyses the dynamic interactions within and between the various subsystems: Geosphere, Biosphere (including humans), Hydrosphere and Atmosphere of System Earth, which resides within its suprasystem, the Solar System. Earth System Science emphasises how these interactions may bring about global environmental change, especially the sustainability of human life on planet Earth.

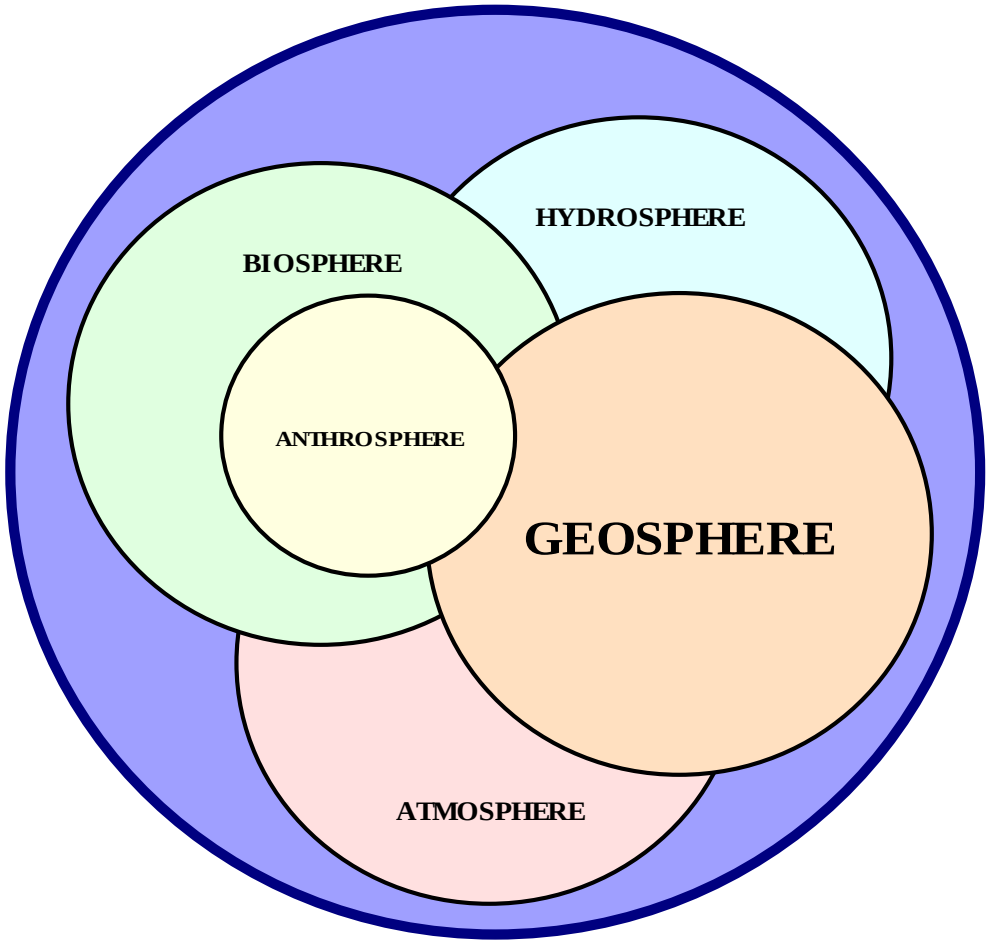


FIGURE 1: SYSTEM EARTH WITH GEOSPHERE AS A FOCUS

A system may be considered as an arrangement of interdependent subsystems. The system is separated from its surroundings by a specified boundary. The subsystems act together, each contributing to the overall operation of the total system.

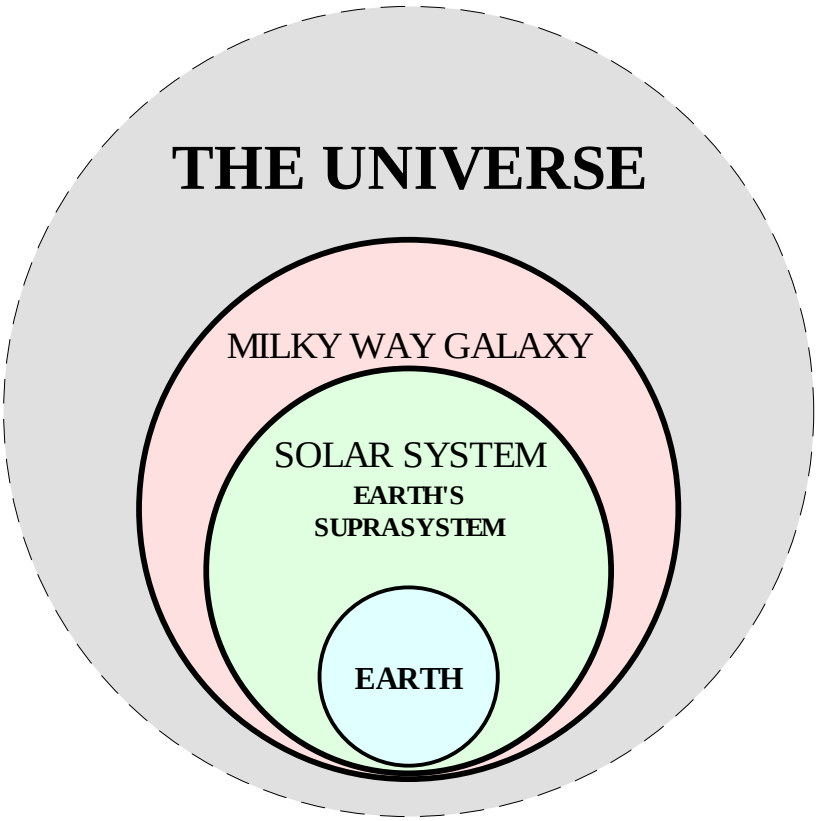


FIGURE 2: THE EARTH WITHIN IT'S SUPRASYSTEM

In defining Earth System Science, I stated that Earth resides within its suprasystem, the Solar System, as shown in FIGURE 2 given above.

What do you think is the suprasystem of our Solar System? Can you now explain in a general way what a suprasystem is?

In FIGURE 2 given above, why is the boundary of the Universe shown with a dashed line? Do you agree that it is meaningless to talk of the Universe having a boundary? If the Universe had a boundary, then there would be a finite limit to the size of the Universe? Who knows where the Universe ends? Can the Universe have an end? What do you think?

On a global scale, System Earth comprises the following subsystems: the Geosphere, the Biosphere (including the Anthrosphere), the Hydrosphere (including the Cryosphere) and the Atmosphere as shown in FIGURE 1 given on page one.

That's a lot of spheres. Can you think of some more 'earth science' words that include the word…**sphere**? List and define as many as you can. You may like to visit the Earth's Spheres web site at the following Internet Address (URL).

http://www.cotf.edu/ete/modules/msese/earthsysflr/spheres.html

Can you broadly define each of the subsystems of System Earth as shown in FIGURE 1, given on page one?

Most probably, the names of each of Earth's subsystems will be new words to you, except possibly for the word, Atmosphere? How can you make meaning of these new words? Perhaps you could start with the prefix of each word, Geo-, Bio-, Anthro-, Hydro-, and Cryo-? Each prefix should give you a clue as to the meaning of each relevant word.

Students in each Learning Group should now brainstorm as many ideas as they can about each of the Earth's subsystems as shown in FIGURE 1. They should then try to broadly define each subsystem.

Students in each Learning Group should now self-check the correctness of their definitions by referring to those provided below.

- **The Geosphere is the solid Earth that includes continental and oceanic crust as well as the various layers of the Earth's interior. Three recognised seismic discontinuities, Mohorovicic, Gutenberg and Lemann, separate solid Earth into four distinct layers: CRUST, MANTLE, OUTER CORE and INNER CORE.**

- **The Biosphere is the life zone of the Earth and includes all living organisms, including humans (The Anthrosphere), and all organic matter that has not yet decomposed.**

- **The Hydrosphere includes all 'water' (H_2O) on Earth in the gaseous state (water vapour), in the liquid state (water) and in the frozen state (The Cryosphere).**

- **The Atmosphere is the gaseous envelope that surrounds the Earth and constitutes the transition between the surface of the Earth and the vacuum of space.**

There I go again, using difficult words like **seismic discontinuity**. What is a discontinuity? Its just another name for the word, boundary.

In subsequent Instructional Modules, you will broadly examine each of the Earth's subsystems. At the same time, you will analyse selected interactions between them that produce global environmental change. You will be required to study selected interactions between the various subsystems so as to achieve a holistic understanding of System Earth.

What does the word **holistic** mean? Holistic means that the whole system, for example, System Earth, is greater than the sum of its component subsystems, because it includes in addition to each subsystem, all of the interactions between each subsystem.

How do we define global environmental change?

Global environmental change embodies the nature and consequences of natural and human induced changes to the interacting physical, chemical, geological, biological and social processes that regulate the environment supporting human life and influence the quality of that life on planet Earth.

That's a mega-mouthful of a definition! Although, most probably, at this stage, you may not completely understand this definition, I am confident that you can give some examples of global environmental change?

Students in each Learning Group now brainstorm some examples of global environmental change, with teacher input as is necessary. How many examples did you identify and list?

Students in each Learning Group now broadly analyse, under the following headings, one (1) example of global environmental change that they have identified and listed:

- **What are its main features?**
- **What processes caused it?**
- **What are its effects?**
- **How can it be rectified?**

You will apply a Systems approach in your study of 'Earth and Beyond', as such an approach, emphasises interconnections between the various component subsystems. This is achieved by analysing the interconnecting exchanges of both matter and energy between each of the respective subsystems of System Earth.

Before we commence our analysis of System Earth, students in each Learning Group should discover the complexity of our analytical task. You are to identify and list some of the ways that we interact with only one selected subsystem, the Atmosphere and the ways our atmosphere interacts with us.

System Earth as a holistic system is extremely complex, involving many interacting physical, chemical, geological, biological and social processes. A single Systems diagram that captures all of this complexity would be impossible to draw. We can however, draw a series of increasingly complex diagrams depending upon the required level of complexity of our focus.

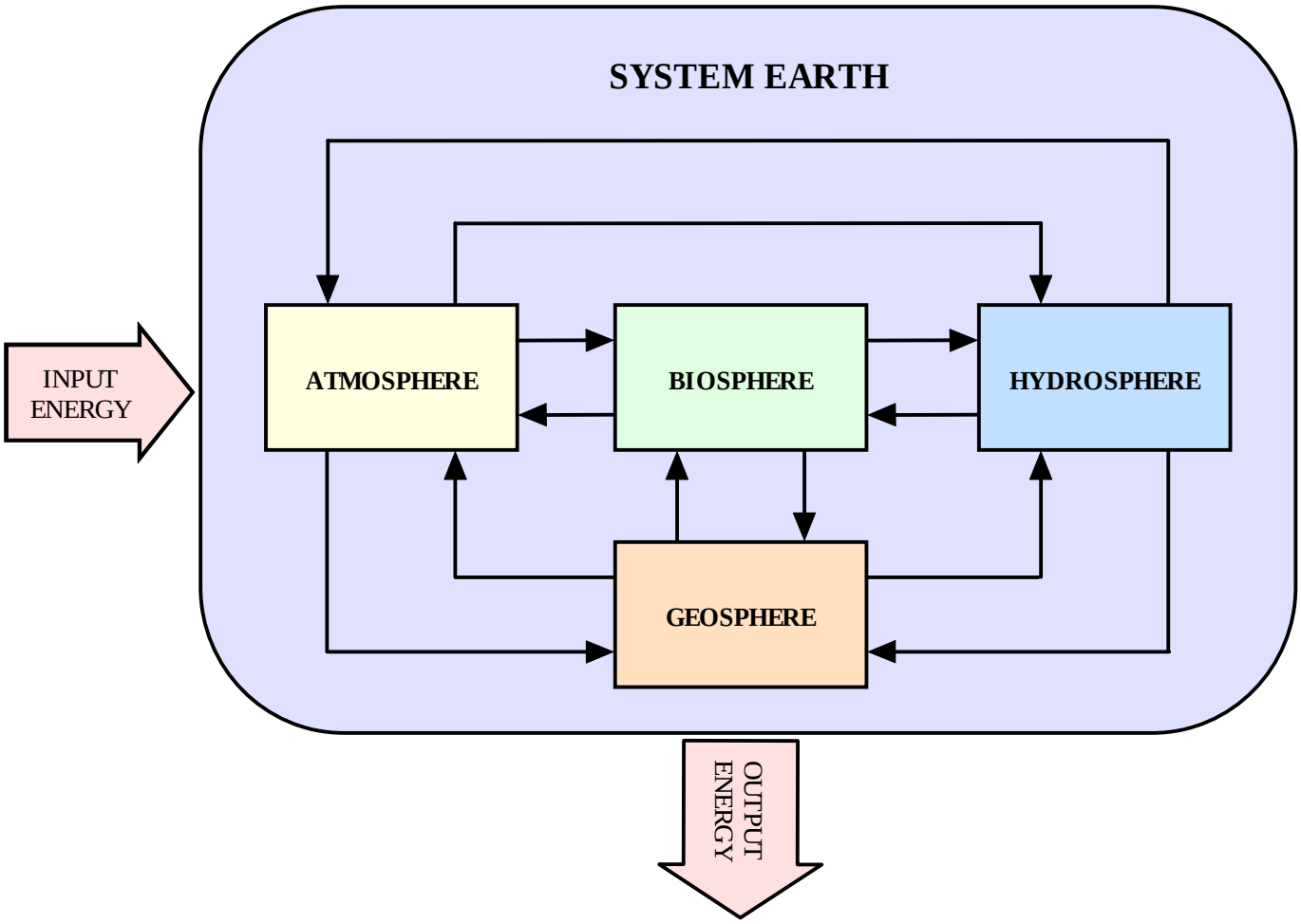


FIGURE 3: SYSTEM EARTH WITH INTERACTING SUBSYSTEMS

System Earth is essentially a closed system. What do we mean by a closed system? A **closed system** is closed with respect to the exchange of matter, but energy may be transferred between the system and it's suprasystem.

Why do we say that Earth is essentially a closed system? Can you think of some of the ways System Earth exchanges matter with its suprasystem, the Solar System?

Can you think of some of the ways System Earth exchanges energy with its suprasystem, the Solar System?

In contrast, the subsystems of System Earth are **open systems** as both matter and energy can flow across the boundaries between each of the subsystems. Can you think of some of the ways matter and energy flow across the boundaries between the Atmosphere and the Hydrosphere?

Many systems are **self-regulating**. They have the ability to maintain a steady state through positive and negative feedback.

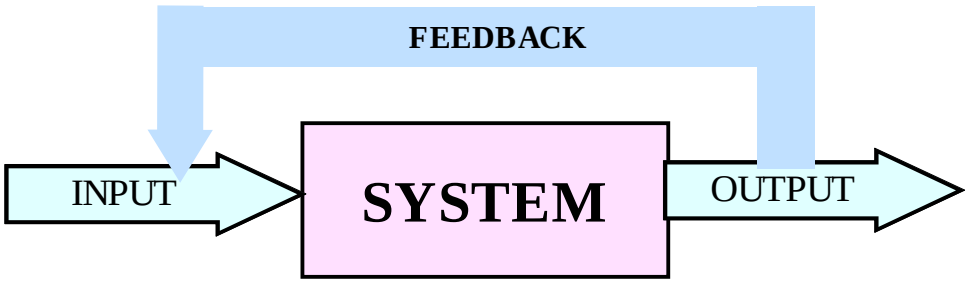


FIGURE 4: SYSTEM WITH FEEDBACK LOOP

A **steady-state system** is an open system in which the rates at which matter and energy leave the system are equal to the rates at which they enter.

Feedback is that portion of the output of a system that is fed back to the input and affects succeeding outputs.

Positive feedback is a change in the state of a system that enhances the quantitative effect of the initial imposed change and results in increasing output.

Negative feedback is a change in the state of a system that counteracts the quantitative effect of the initial imposed change and results in decreasing output.

Students in each Learning Group may like to **further explore** the concept of feedback by visiting web sites whose Internet Addresses (URL's) are listed below.

1. http://www.indiana.edu/~geol105/G105L1.html
2. http://www.meto.umd.edu/~owen/CHPI/LOGIX/lxinx123.htm
3. http://www.nrdc.org/nrdc/nrdcpro/analys/feedbk.html
4. http://www.usra.edu/esse/essonline/whatis.html
5. http://www.usra.edu/esse/BrethColor.GIF

Unfortunately, the authors of some earth science web sites when applying systems theory to System Earth use the word… "***Equilibrium***", when they should be using the words… "***Steady state***". Equilibrium can only be achieved within a closed system, whereas a steady state is achieved in an open system when the rate of output equals the rate of input.

Students in each Learning Group should visit Web site #1 from Indiana University. They should then carefully read the text and then discuss and debate whether or not they should 'mentally' replace the word "equilibrium" given on page 3, with the words "steady state".

In G105 Lecture 1, the first in a series of Geology 105 Lectures at a University of Indiana Web site (Under construction), Dr Paul Blanchon provides introductory lecture notes on a Systems Approach to Earth Study. Although Dr Blanchon has since left Indiana University, I hope that work will continue at this excellent web site.

At Web site #2, Professor Owen E. Thompson, from the Department of Meteorology at the University of Maryland, provides logical argument in applying the concept of feedback to explain enhanced greenhouse warming.

Students in each Learning Group should access Web site #2. They should then analyse Professor Thompson's arguments and finally self-test their understanding of feedback by accessing the self-test provided in the Positive and Negative Feedback pages.

Web site #3 from the Natural Resources Defence Council Inc provides on page 3 a global warming and climatic change diagram, which identifies five (5) examples of feedback loops relating to global warming.

Students in each Learning Group should print a copy of the diagram and then number each feedback loop. They should then carefully analyse each numbered feedback loop and write brief notes, in the text box provided below, explaining the operation of each numbered feedback loop.

Web site #4 includes a somewhat simplified black and white Earth System Science Diagram, which I have reproduced as FIGURE 5, below.

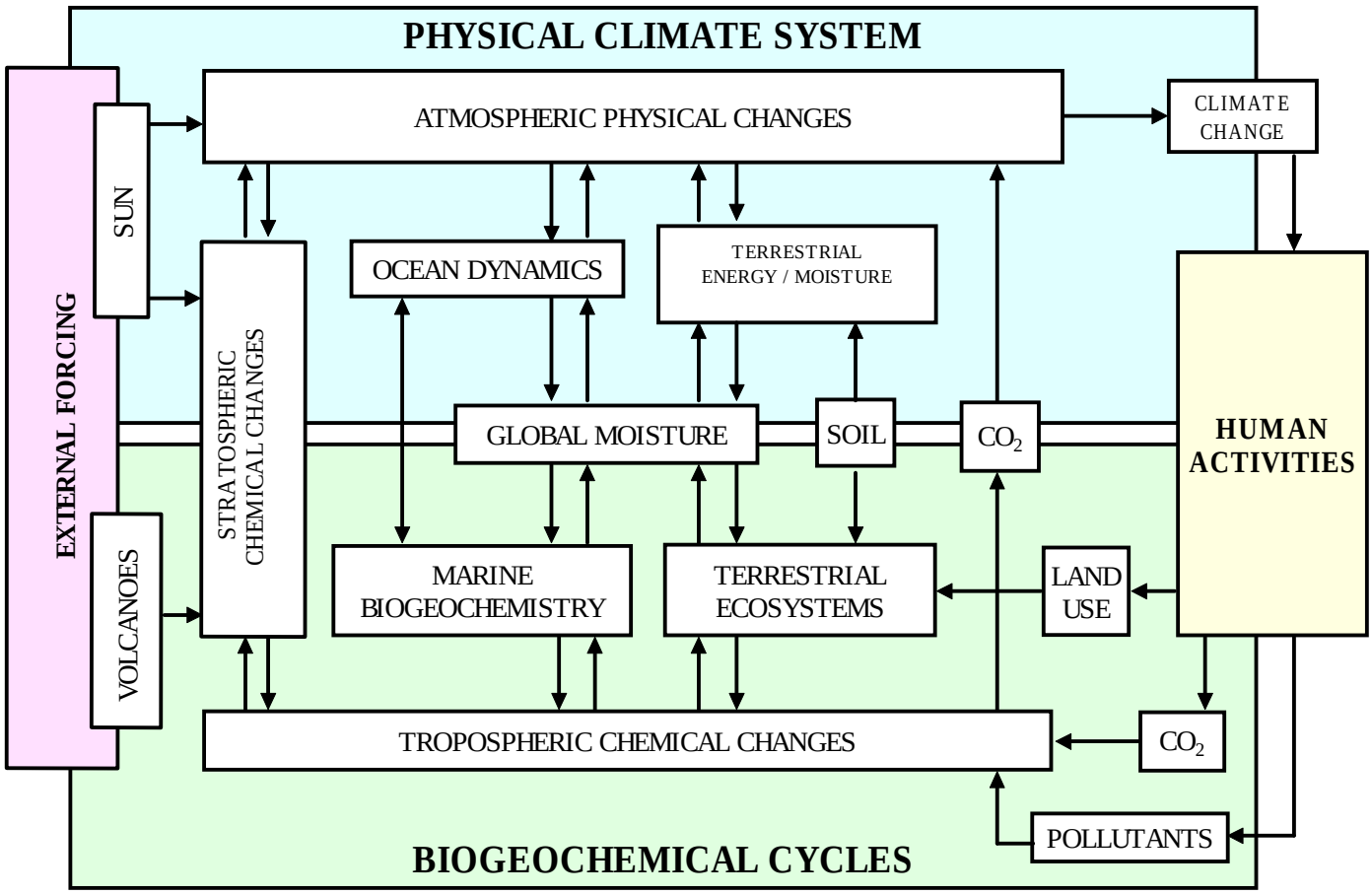


FIGURE 5: AN EARTH SYSTEM SCIENCE DIAGRAM
(Adapted from ESS-Overview NASA 1986)

At Web site #3, you broadly studied how the release into the atmosphere of carbon dioxide gas [CO_2 (g)] from human activity, may enhance global warming.

Students in each Learning Group should now identify, trace and discuss the CO_2 cycle shown in FIGURE 5, given above.

Also, each student should explain, referring to FIGURE 5, how land use can lead to global climate change.

Web site #5 provides a very complex full detail colour Bretherton Earth System Science Diagram.

Students in each Learning Group should print a 'landscape orientation' of the Bretherton Diagram. They should then carefully analyse their printed copy to try to explain in more detail, how land use can lead to global climate change.

At this point of time, your teacher does NOT expect that you will be able to demonstrate detailed understanding of how CO_2 emissions produced by human activity, and land use by humans, can produce global climate change.

You will study in detail the impact of selected human activities on System Earth in subsequent Instructional Modules.

The purpose of asking you to complete the previous two assigned tasks is to show once again, to a limited extent, the complexity of the interacting processes occurring within and linking the various component subsystems of System Earth.

We humans should reflect upon how our lifestyles impact on System Earth.

Would you agree that each of us is a custodian of System Earth for future generations of living things, which will share the Biosphere with our descendants?

Some scientists say that this comment demonstrates the arrogance of *Homo sapiens sapiens*. They say that System Earth survived long before our ancestors first walked upright. They say that rather than practising self-delusion by assuming responsibility for the welfare of System Earth, we should protect us from ourselves.

I humbly suggest that these scientists are missing the point. We humans are a component subsystem of System Earth (The Anthrosphere). If we as a species managed to curb our population growth, are we not, as a subsystem, then demonstrating self-regulation, using negative feedback?

What do you think?

Would you agree that our population growth would inevitably lead to population collapse as no organism can feed upon its own wastes?

http://metalab.unc.edu/lunarbin/worldpop

Will we as a species ever have the intelligence and discipline to curb our population growth?

What do you think?

Students in each Learning Group should now discuss and debate my comments given above. They should then record their opinions in the text box provided below.

Earth System Science seeks to understand the nature of the dynamic processes that produce matter and energy flows between the interacting subsystems of System Earth: Geosphere, Hydrosphere, Atmosphere and Biosphere (and Anthrosphere); and how these dynamic processes impact on the sustainability of life, especially human life, on planet Earth.

We now come to the BIG question that continues to perplex the minds of very many people, including mine, and hopefully now, yours.

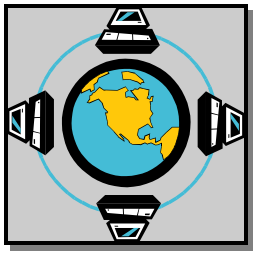
How has the interplay of these interacting Earth system processes been maintained so as to provide environmental conditions necessary for sustaining life on Earth, for over 3.5 billion years?

Is it just a matter of luck, or is System Earth self-regulating, or can we see the hands of a Creator at work in our corner of the Universe? What do you think?

James Lovelock in his controversial Gaia hypothesis suggests that the biota of planet Earth operate dynamic feedback processes that regulate the amounts of certain physical environmental factors, like atmospheric oxygen concentration, so that they remain within precise ranges over geological periods of time.

Biota refers to all living organisms in an ecosystem. An **ecosystem** is an interaction between a group of organisms and their environment that produces a self-sustaining system. The **environment** of a living organism is all those factors in its surroundings that have an effect on that living organism.

Some advocates of the Gaia hypothesis have even gone so far as to suggest that Earth is in fact, a vast living system that consciously manipulates its own environment, so as to sustain itself as a living organism. What do you think of this idea?



Students in each Learning Group should now **research**, using the Internet, currently held scientific opinion on the scientific status of the Gaia hypothesis.

- Before commencing your Internet search, please be aware that the authors of some web sites unfortunately misstate the Gaia Hypothesis. Also, some refer to the Gaia Hypothesis as the Gaia Theory.

- In the discipline of science, what is the difference between a hypothesis and a theory? Is there a difference? Explain.

- Most unfortunately, some web site authors unintentionally misuse the Gaia hypothesis in debating environmental matters by presenting arguments that blur the boundaries between science, philosophy and theology.

- Students in each Learning Group should now, with their supervising teacher, **evaluate** the web sites whose Internet Addresses (URL's) are listed below.

http://ess.geology.ufl.edu/ess/Introduction/GAIA_hypothesis.html

http://www.geog.ouc.bc.ca/conted/onlinecourses/geog_111/3d.html

http://www.sprl.umich.edu/GCL/paper_to_html/gaia.html

http://www.oceansonline.com/gaia.htm

http://www.newscientist.com/ns/980530/features.html

http://www.magna.com.au/~prfbrown/gaia_jim.html

http://www.gaiasociety.org/

Lynn Margulis in her fascinating little book The Symbiotic Planet, A New Look at Evolution, (The Science Masters Series), Phoenix, Orion Books Ltd, London, 1999, on page 150 states that:

"Gaia is a series of interacting ecosystems that compose a single huge ecosystem at the Earth's surface."

Also on page 133 she defines an **"…ecosystem as a set of communities of different species of organisms, living in the same place at the same time, enjoying an influx of external energy and matter."**
On the same page, she claims**"… that an ecosystem is a volume of the Earth surface where organisms recycle energy and matter at a faster rate inside the system than between it and other systems."**

Students in each Learning group should now label the preliminary systems diagram, given below as FIGURE 6, which tries to shows the relationship between System Earth, it's Biosphere, Gaia and three generic ecosystems.

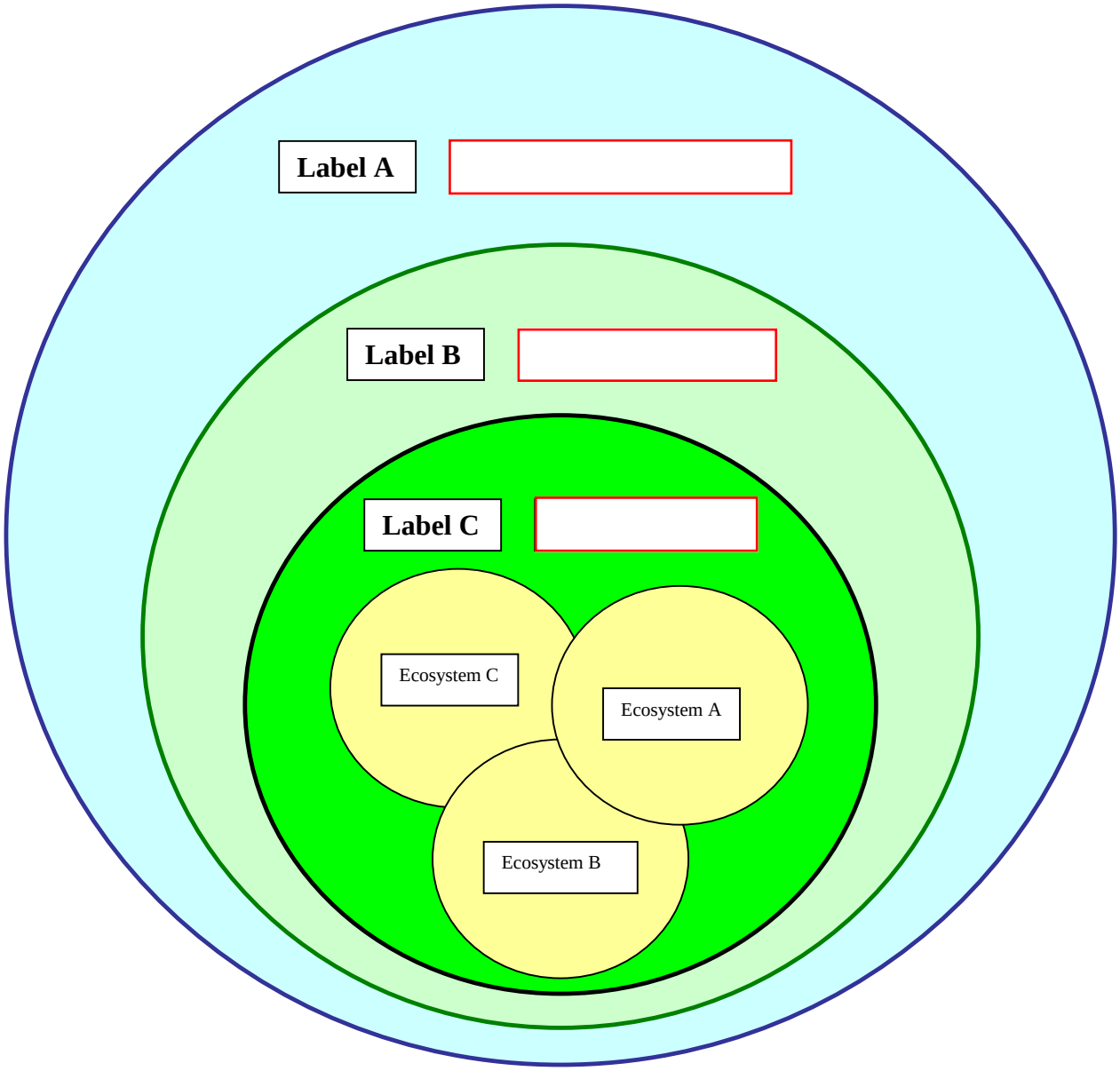


FIGURE 6: SYSTEM EARTH AND GAIA: A PRELIMINARY DIAGRAM

What actually is the relationship between Gaia and the Biosphere? Is it possible to show the relationship using a systems diagram? What do you think? You would be aware that the systems diagram, given as FIGURE 6 above, neglects to show three major interacting component subsystems of System Earth.

I consider that because FIGURE 6 does not include the Geosphere, the Hydrosphere and the Atmosphere, it is unable to show the true relationship between the Biosphere and Gaia.

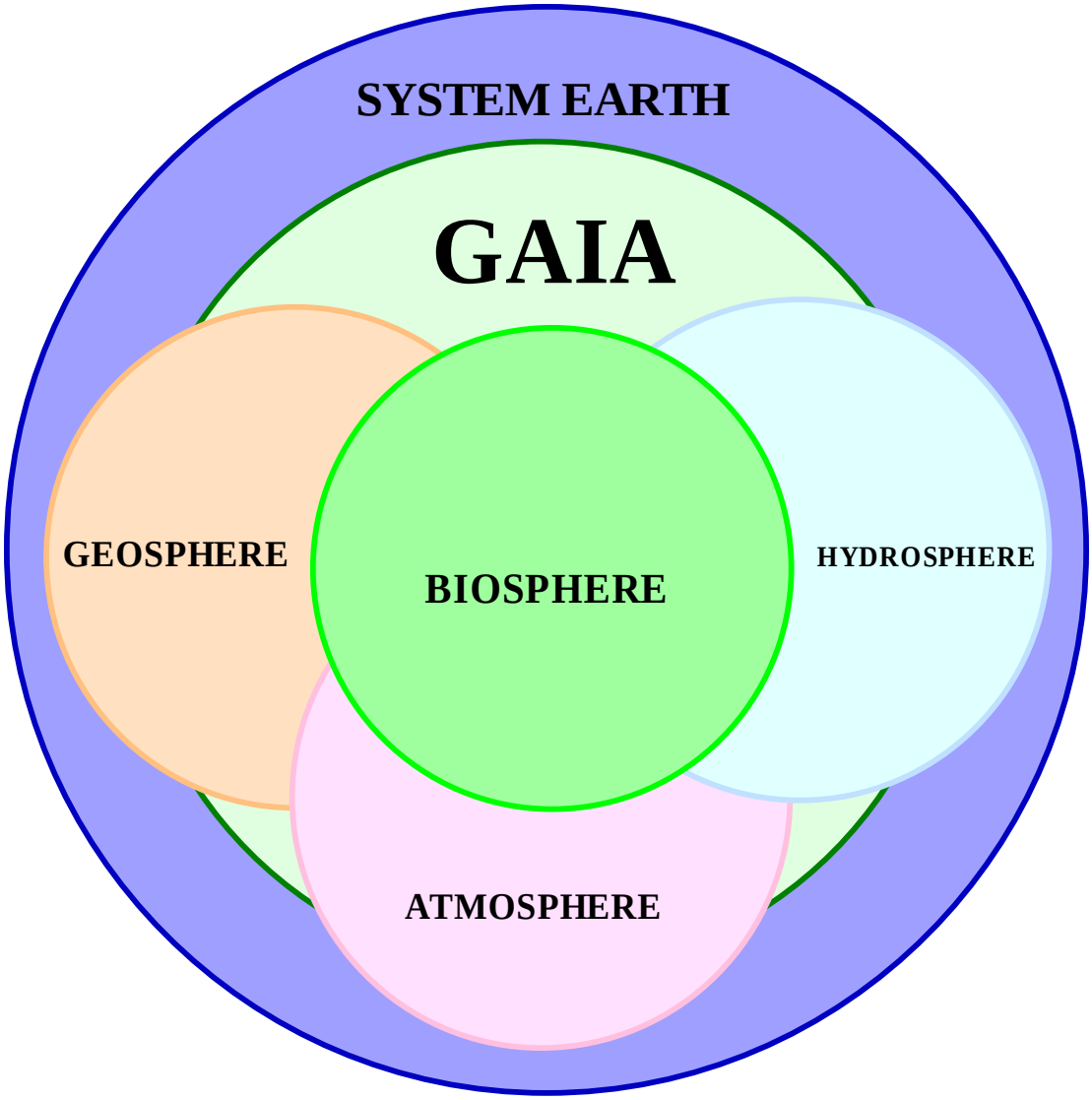


FIGURE 7: SYSTEM EARTH AND GAIA

Thus far, I have presented only one definition of Gaia as stated by Lynn Margulis, co-author of the Gaia hypothesis. Lynn Margulis defines Gaia as a planetary sized ecosystem, which many scientists would simply refer to as Biosphere-1.

Can I humbly propose that Gaia may be conceived as much more than merely Earth's Biosphere? Would it be possible to redefine Gaia so as to make it a more universal concept in our study of Earth System Science?

Gaia is the sum total of all processes interacting within and between the Biosphere and the other subsystems of System Earth, together with those physical parts of the Geosphere, the Hydrosphere and the Atmosphere that interact with the Biosphere, allowing System Earth to sustain it's evolving biota over geologic time.

I consider that my definition, by defining Gaia from a systems viewpoint, reflects the holistic nature of Earth System Science. What do you think? Do you agree with me?

I also believe that an analysis of System Earth, from a Gaian viewpoint, should generate new insights into our understanding of how System Earth evolved from interaction within and between its component subsystems, over geologic time.

My belief has been confirmed by recent work at the University of Indiana, Geology 105-web site, which I first mentioned on page 8 of this Lesson.

http://www.indiana.edu/~geol105/G105L23jj.html

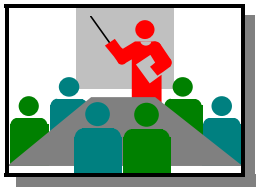
At this excellent web site, the authors provide lectures in Earth System Science that analyse, from a Gaian viewpoint, the interacting subsystems of System Earth as they evolved over geologic time.

In Geology 105 Lecture 23: Gaia: A self-regulating Earth System through Time? we are presented with four (4) postulates of the Gaia hypothesis.

1. "Once life developed it must have regulated Earth's climate and preserved an environment comfortable for it to evolve in."
2. "One life has started it quickly gains control over the entire system and regulates it and continues to regulate in the face of environmental change."
3. "The Earth system is self-regulating and can recover from major catastrophes such as asteroid impacts."
4. "If life and the environment are closely coupled they should show evidence of evolving together."

Reference will be made to relevant Geology 105 Lectures when we analyse, in a greater depth, each component subsystem of System Earth, in subsequent Instructional Modules.

Unfortunately, the recent Geology 105 Lectures added to the University of Indiana web site do not stand-alone. This is evident in that throughout each Lecture, reference is made to diagrams from various cited reference sources. These diagrams are not reproduced in the online lectures, most probably because of copyright.



We still need to clarify the relationship between the Biosphere and Gaia. Are they in actual fact, different names for the same entity?

Perhaps a student from your science class may volunteer to E-mail the Gaia Secretariat at the following E-mail Address:

mailto:Gaia@uel.ac.uk

The purpose of your class E-mail is to ask the Gaia Society for clarification of the relationship between the Biosphere of System Earth referred to as Biosphere-1, and Gaia.

You may also like to post a collaborative article to the Gaia Society's web site by visiting the following Internet Address (URL).

http://www.gaiasociety.org/

Then access the Post facility by clicking on the Discussion & Notice Board hot spot on the Gaia Society's home page.

Your article could be a very brief précis of your Internet research into the relevance of the Gaia hypothesis to the study of Earth System Science.

Students in each Learning Group should now reflect upon what they have learned in this Introductory Lesson, by compiling a glossary of key words / concepts (ideas), identified by them during discussion and debate.

To research the difference between a theory and a hypothesis, you should conduct research at the Miami University web site, whose Internet Address (URL) is given below.

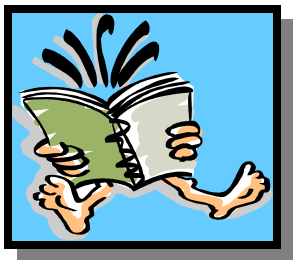
http://www.carleton.ca/~tpatters/teaching/climatechange/sciencemethod.html

YOUR GLOSSARY:

Students in each Learning Group should add to the glossary, which I have started by defining, for example, the term Biosphere.

- **Biosphere** is all life forms and the environments they interact with.

YOUR GLOSSARY (continued):



REFLECT AND RE-LEARN

Students in each Learning Group 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.