

Endings, Spring 2006

Questions for study III

(be prepared to discuss and turn in these questions Tuesday, April 18)

Ward and Brownlee, *The Life and Death of the Planet Earth*

1. (page 26) What is an **atom**? Give at least **five** ways in which an atom of hydrogen differs from an atom of carbon.

An atom is the smallest unit of matter that still has recognizable chemical properties.

	Atom of hydrogen	Atom of carbon
Number of protons	1	6
Number of neutrons	0	6
Number of electrons	1	6
Mass	1 amu	12 amu
Chemical state at room temperature	Gas	Solid

There are other differences in chemical behavior as well.

2. (pages 27 and 28) What evidence is there for the theory that a large body the size of Mars (but not Mars itself) slammed into the Earth to break off pieces that would become the **moon**?

The composition of the moon is similar to the composition of the Earth's crust in certain elements. Moreover, the chemical signature of the lighter elements of the moon is similar to that of the Earth's crust.

3. (page 28) What evidence exists that the **Earth's rotation** has slowed ten percent over the last 500 million years?

"growth rings in ancient corals about 400 hundred million years old show that the day was only 22 hours long so that there were over 400 days in a year. In July 1996 a research study reported evidence, from several sedimentary rock records providing an indicator of tidal periods, that the day was only 18 hours long 900 million years ago." according to Nick Strobel at <http://www.astronomynotes.com/gravappl/s10.htm> (last updated March 2001).

4. (pages 31 and 32) They keep speaking of "**density**" or "denser" or "less dense", whether they are discussing rocks or the atmospheres of various planets. What is density, and how does it differ from **weight**?

Density is a measure of the efficiency of packing material in a given volume. Thus, mathematically, density is the mass of a material divided by the volume it

occupies. Note that “weight” is used interchangeably with “mass” in everyday language (though technically they are not the same) so weight and density are indeed two different quantities. Something can be dense but not heavy. like a gold ring.

5. (pages 30 and 54) What is **plate tectonics** (yes, we all know it’s a theory, but a theory of what?)? How is plate tectonics related to the **second law of thermodynamics**?

Plate tectonics is the theory of the Earth’s origin and continued behavior, related to geological phenomena like earthquakes, volcanoes and mountain building. The main point of plate tectonics is that the crust (technically, the lithosphere) of the Earth is broken up into many tectonic plates, both oceanic and continental, which move independently at different speeds and directions. The plates move due to a mechanism that is directly related to the second law — the hot interior of the Earth is trying to move heat to cold, cold space. Because the heat must flow through dense materials, the mechanism of the second law is called **convection**.

6. (page 53) James Lovelock’s **Gaia hypothesis** postulates that the Earth itself is a living organism. Ward and Brownlee disagree with this hypothesis. What characteristics define something as “alive”? Are viruses alive? Are computer viruses alive?

Broadly speaking, there is not a great deal of agreement on what constitutes “alive”. The terms I have seen in common among most definitions is that the object must **metabolize** (use energy to maintain itself) and **reproduce** (make the next generation). By this broad definition, both viruses and computer viruses are alive.

7. (page 59) In the diagram, two plates (the gray layers) are shown: one to the left with the volcanoes on top of it, and one to the right that is sinking under the one to the left. Why is the plate to the right sinking under the plate to the left? How do we know this really happens?

The plate to the right is denser than the plate to the left; because they were moving toward each other, the plate to the left overrides the plate to the right in an action called **subduction**. We “know” this happens because we can “see” the earthquakes occurring at depth in these subduction zones, by the use of seismology.

8. (page 61) Why is the weathering of the mineral **wollastonite** important to the biogeochemical cycles described in this section?

Wollastonite is a calcium silicate mineral that weathers in the presence of water and carbon dioxide into calcium carbonate, which is limestone. Therefore, wollastonite can “fix” carbon by turning carbon dioxide into limestone, which would remove more or less permanently carbon dioxide from the atmosphere. However, limestone if buried deeply enough (like at a subduction zone) can react with the mineral quartz to generate wollastonite and carbon dioxide. Thus, the

rate at which wollastonite weathers and the rate at which subduction occurs determine to a large degree the amount of carbon dioxide there is in the atmosphere.

9. (page 102) The authors perpetuate a common oversimplification: "...[the Sun's] light powers photosynthesis, which converts sunlight into food sugars by plants..." Plants don't make food sugars out of sunlight *only*; what **materials** are necessary for plants to carry out photosynthesis?

Carbon dioxide and water are the necessary materials to build into food sugars; the energy to bond the simpler molecules into the more complex is supplied by sunlight.

10. (page 102) "In fact, our Milky Way galaxy makes dozens of new stars each year." Really? Find a good photo of a so-called "**stellar nursery**" where such stars are born (web page, book or magazine), and give the complete citation.

A good set of photos of different stellar nurseries exists at the NASA site (http://antwrp.gsfc.nasa.gov/apod/stellar_nurseries.html, last updated February 2, 2005) titled "Astronomy Picture of the Day". Another good source is space.com.

11. (pages 104 and 105) The authors don't explain this somewhat cryptic statement: "...if all the hydrogen was converted to helium, the Sun would only have **one-fourth** the number of atoms it started with..." On page 103, the authors state that the first critical step in nuclear fusion is to fuse two protons (hydrogen nuclei) into a single deuterium nucleus. This cuts the number of atoms in half, from two to one. How do the authors arrive at the "one-fourth" figure?

It turns out that it takes four protons (hydrogen nuclei) to fuse to make one helium nucleus. Thus the number of atoms is quartered because four hydrogen atoms are required to make one helium atom.

12. (page 106) The graph shows the "age of animals", a period in Earth's history where multicellular life forms flourish. The graph is spoiled a bit by the cryptic y-axis (the vertical axis) with its "1" and "2" and no other labels. Be the editor of this book and supply the correct label for the quantity this axis represents, **including the units**. Hint: note the point representing "now" and the y-value it corresponds to.

The vertical axis is a measure of the Sun's solar output, or brightness (luminosity) – literally the amount of light energy we get from the Sun, measured in current solar luminosities (i.e., "1" = the current solar luminosity). We have established in the last set of questions that sunlight is the source of nearly all energy on the surface of the Earth and thus changing the brightness will have a direct impact on surface temperatures.

13. (page 109) Fill in the reasoning from "the problem of the life span of the biosphere [of Earth]" and "the probability of finding biologically active planets

in our galactic neighborhood.” In other words, what’s the **connection** between how long life exists on this planet with the likelihood of meeting (or even detecting) an ET (extra-terrestrial)?

The connection is the assumption that technological civilizations around the universe will last just about as long as we will. In other words, we’re an average technological civilization. We are limited by the extinction of complex life, so prior to a few years ago, we thought we had another 5 billion years (until the sun reached its red giant stage) to communicate with someone else. Note that it seems quite likely that we’ll find someone to talk to in 5 billion years, especially if they’re going to be around 5 billion years. However, if they and we are only going to be around 100 million years because of extinctions caused by the supercontinent cycle or 500 million years because the oceans start evaporating off, then the likelihood that our 500 million year window overlapping with their 500 million years window seems less likely.

14. (page 113) What is **reduced carbon**? For that matter, what is **oxidized carbon**? Give an example of a molecule with reduced carbon. Give an example of a molecule with oxidized carbon? Finally, why is reduced carbon necessary for life to exist?

Reduced carbon is carbon that bonds only to hydrogens (or other carbons). Oxidized carbon as the name implies is attached to at least one oxygen. Methane (CH_4) is a good example of reduced carbon; carbon dioxide (CO_2) is a good example of oxidized carbon. Reduced carbon is necessary for life because molecules with reduced carbon have chemical bonds that will provide energy for organisms (i.e., they are food molecules).

15. (whole chapter) The Gaia hypothesis is an example of a **feedback mechanism**; in other words, when a change in the biosphere occurs, the consequence of that change “feeds back” into the biosphere to either accelerate the change (**positive** feedback) or slow down the change (**negative** feedback). Which type of feedback (**positive** or **negative**) in any system tends to allow the system to continue? Is the **loss of carbon dioxide** from the biosphere an example of positive or negative feedback? In either case, explain your answer.

Negative feedback tends to damp out the change imposed on the system, and therefore allows the system to continue its status quo. The loss of carbon dioxide, as outlined by Ward and Brownlee, will lead to cooler temperatures at the surface, which will in turn slow down the rate of wollastonite weathering, so not as much carbon dioxide will be turned into limestone. This allows volcanic carbon dioxide to be pumped into the air, increasing the amount of carbon dioxide, which negates the original loss of carbon dioxide and so this is an example of negative feedback.