NAME _____

BEP 210A MIDTERM TEST March 9, 2001

SHORT QUESTIONS: In the spaces provided, answer 12 (**TWELVE**) of the 15 questions given. (5 points for each question, 60 points total) If you need more space, please continue on the back of the page, with a clear indication that you have done so.

1) Give an example of how a large impact has shaped the course of Earth's history.

Two of the major examples of large, important impacts on the Earth are given below:

Proto-moon impact: A large, Mars-sized body hit the Earth, throwing a large amount of the Earth's mantle into space and liquefying most of the Earth. This material remained in orbit around the Earth and eventually combined to form the Moon. The Moon is lacking heavy metals like iron because the impact probably did not have enough energy to throw such heavy substances away from the Earth. Thus, the Earth's core was not affected by the impact much, and any iron in the body that hit the Earth would have sunk into the Earth's core and added to it.

K-T impact: 65 million years ago, an asteroid hit the Earth on what is now the Yucutan Peninsula in Mexico. This likely sent a lot of dust up into the atmosphere and blocked out the sun for months, drastically affecting the climate and causing more than half of the species of life to go extinct, including the dinosaurs. This mass-extinction marks the Cretaceous (K) – Tertiary (T) boundary on the geologic time scale.

2) When looking at all of the planets in our solar system, give an example of how Mars and Earth are similar and an example of how they are dissimilar.

These are some of the possible answers:

Way Similar:

- ~Size (although Mars is smaller than Earth)
- Rock-like (as opposed to gaseous, like the outer planets)
- Evidence of Volcanism, water, and erosion (mostly in the past for Mars)
- Ice caps
- Wind erosion and transport (dunes)

Ways Dissimilar:

- Plate tectonics on Earth (none on Mars)
- Water now on Earth (none on Mars today?)
- Atmosphere (composition and thickness/presssure)
- Temperature (Mars is much colder.)
- Number of impact craters (Mars has many more.)

3) How do Earth's continents grow over time?

The Earth's continents grow by a combination of lateral accretion (adding to continents along edges from collisions) and platform deposition (sedimentary rock deposits on top when submerged under water). Volcanism on continents also adds to continents vertically, but it is minor compared to the other two growth modes.

4) How does paleomagnetism (the history of Earth's magnetic field) provide us with information about the ages of Earth's ocean seafloors?

Ocean crust forms at mid-ocean ridges. When the magma reaches the surface and cools, it freezes with it the direction of magnetic field at that time. Since the Earth's magnetic field reverses randomly over short time scales, the ocean seafloor develops bands of alternating magnetic directions in the rock. These "stripes" of different magnetic "anomalies" can be translated into absolute ages by taking rock samples at places on the ocean floor and dating them. Such paleomagnetic dating can also be done on beds lava beds in places like Hawaii.

5.) Why do earthquakes and volcanoes not occur randomly, but mostly occur along narrow paths around the globe?

Most earthquakes occur at plate boundaries where rock is pulled apart, pushed together, or slid past each other. Most volcanoes occur either at divergent plate boundaries where de-pressurized hot rock melts or at subduction zones where water lowers the melting point of rock in the upper mantle.

6) What is antimatter? Give 2 examples. What happens when matter collides with antimatter? How is Einstein's equation $E=mc^2$ relevant here?

Antimatter consists of particles with opposite properties from ordinary matter; for example, opposite electrical charge. Examples are the antiproton (proton with negative charge), the positron (electron with positive charge), antineutron, (no charge, because neutrons have no charge), and antiquarks (opposite charge of quarks). When a particle collides with its antiparticle, they turn into energy in the form of photons. The energy of the photons comes from the mass of the particles, according to $E=mc^2$ where E=energy, m=mass and c=speed of light.

7) What objects formed for the first time at the period of "decoupling"? Why? What 'decoupled" at that time? Why?

Neutral atoms formed. For the first time, it was cool enough that photons did not have enough energy to break apart atoms; it wasn't hot enough for the electrons to be boiled off from the nucleus. Electromagnetic radiation, decoupled from matter. Electromagnetic radiation interacts with electric charges. When matter is neutral, the + and – charges are close together and almost cancel out, as far as the photons are concerned. The chance of a photon interacting with matter becomes very small.

8) During the period from about 300,000 to 1 billion years after the Big Bang, clumps of matter formed that eventually became galaxies and stars within galaxies. Which fundamental force was responsible for the clumping? Why was that force much more important than each of the other three forces during that period?

Gravity was responsible. First of all, it is a long range force. Once matter was spread out, only long range forces could have any effect – so the strong and weak forces, both short range, were irrelevant. Electromagnetism is also a long range force, but the two kinds of charge, + and -, almost completely cancel when atoms are neutral and are spread apart from each other, (so atoms can't "see" the separate + and – charges of other atoms.) Thus, electromagnetism is irrelevant too. Only gravity, which is long range and attracts everything, is important at this time, even though it is intrinsically much weaker than the other forces.

9) What is Olber's paradox, and what does it tell us about the universe?

Olber's paradox says that if the universe were infinite in space with a homogenous distribution of matter everywhere and had existed for any infinite time, the night sky would be uniformly white – there would be a star in every direction you look. Since that is not the way the sky looks, the universe must not be infinite in space, or in time, or must not be homogeneous. The Big Bang theory says the universe started at a specific time (so it is not infinite in time), which explains why the sky is not uniformly white.

10) What is the "T-Tauri phase" of stellar evolution? Do we observe the sun to be in the T-Tauri phase now? Consider a hypothetical observer in a "galaxy far, far away." Could her observations of our sun show it in the T-Tauri phase even if ours do not or vice versa?

The T-Tauri phase is the early violent phase of stellar evolution, when the star is condensing from gas and dust, but stuff is also bouncing violently back into space. It lasts about 10,000,000 years at the very beginning of a star's life. The sun long since passed its T-Tauri phase, but an observer far enough away could see the sun in its T-Tauri phase if the light took almost the age of the sun to get to her. She would have to be about 4.5 billion light years away.

11) Describe two features of the Precambrian (Ediacaran) fossil record that indicate that life at this time was something rather like a Peaceable Kingdom.

Life in the Precambrian seems to lack any evidence of predator/prey relationships. There are no defensive structures like shells or offensive ones like teeth. Furthermore, most creatures at this time lacked eyes or heads, so they weren't worried about other creatures eating them.

12) Explain what is meant by the following: In the RNA World, RNA molecules perform 2 functions, functions that in modern organisms are carried out by DNA and proteins respectively.

Before modern organisms with DNA-based genmoes evolved, RNA had the job of carrying the information (which DNA does today) and creating shapes to catalyze reactions (which proteins do today).

13) What is meant by saying that a cell expresses a gene? Why does a hair cell express the keratin gene and no the hemoglobin gene whereas a red blood cell expresses the hemoglobin gene but not the keratin gene?

The gene is expressed where its information is transcribed into mRNA and then translated into a protein. The keratin gene is "turned off" by a repressor and/or the hemoglobin gene is "turned on" by an activator interacting with the promoter region, which is upstream of the gene in question.

14) In what form were energy and catalysis thought to be provided to the first forms of life, and in what form are they provided to modern organisms? List two advantages of the modern system over the ancient system.

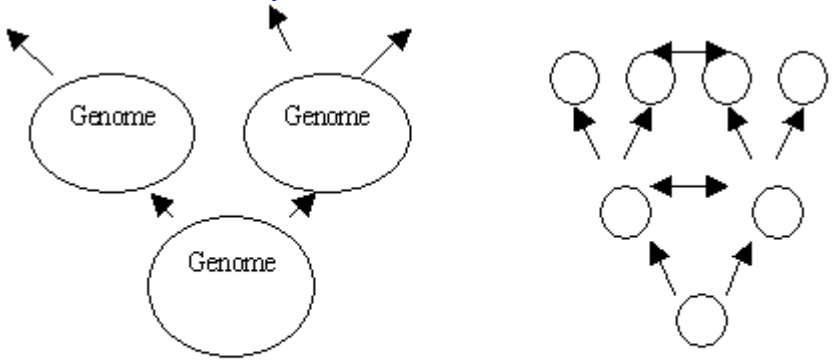
First forms: heat and metals (FeCuS)

Modern: photons and protein enzymes

Advantages: don't need to live in hot environments
Don't need to live near sources of FeS
Photons abundant
Enzymes are versatile catalysts

15) Explain the difference between evolutionary patterns that involve vertical gene transfer only and patterns that involve both vertical and horizontal gene transfer.

Vertical gene transfer is the traditional "tree" view of evolution in which diverging lineages form which cannot share genetic information. This is the case in general for modern multicellular organisms. Horizontal gene transfer involves the branches sharing information between lineages, giving the evolutionary pattern a "bush-like" appearance. It works either by fusing two cells (and therefore combining genomes) or by one cell taking up the genes of another. This is thought to have been important for early forms of life to develop diversity, and it is still common among many forms of bacteria today.



Vertical

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LONG QUESTIONS: In the spaces provided, answer 4 (**FOUR**) of the 6 questions given. (10 points for each question, 40 points total) If you need more space, please continue on the back of the page, with a clear indication that you have done so.

1) Think of a lava lamp, with a light shining at the bottom of a bottle that contains water and wax. What is happening? Why is material moving? In what ways are convection within Earth's mantle similar and dissimilar to that of a lava lamp?

The light shining on the base of the lava lamp is a heat source. It heats up the wax at the bottom, making it buoyant (less dense), so it rises to the top. At the top, it cools down and contracts (becoming denser), so it sinks back down. It can move because it is not too viscous. This process is called thermal convection. It is similar to convection within the Earth's mantle because heat from the core does heat the mantle from the base, contributing to mantle convection and likely causing mantle plumes. The lava lamp is primarily different than the mantle because it is only heated from below. In the Earth, most (about 80%) of the mantle heat is generated internally within the mantle itself from radioactive decay. Only 20% of the mantle heating comes from the core. Thus, the dynamics of convection in the Earth are different than the lava lamp, although the general process is very similar.

2) Review the process by which a nebular cloud of dust and gas became our solar system.

Gravity causes dust and gas to aggregate together, forming a nebular cloud. As gravity pulls the particles closer together, the cloud shrinks and becomes denser. Any slight initial rotation of the particles will become enhanced as the cloud contracts due to the conservation of angular momentum (remember the ice skater analogy). As the cloud shrinks and spins faster, centrifugal forces cause it to take on a disk-like shape with a bulge in the center (like a fried egg). Further contraction in the center of the cloud causes the gas there to heat up. Meanwhile, particles outside the center region are colliding and sometimes sticking together to form planetesimals. Over time, these planetesimals collide to form bigger bodies that eventually will be the planets. When the center is hot enough, nuclear fusion can begin, and a star will be born. An early violent explosion of the star called the T-Tauri phase will blow the lighter elements like gases and other volatiles out away from the inner planets, leaving them rock- and metal-rich. The outer planets will then be more gas- and ice-rich. Over time, the planets will differentiate internally, with the heaviest materials sinking to the middle and the lightest floating to the top.

3) Explain carefully the role of EACH of the four fundamental forces in making the sun shine. What is the ultimate source of the sun's energy? (Note: the phrases "Coulomb barrier" and "$E=mc^2$" should appear in a complete answer, as should an explanation for why the sun's lifetime is so long.)

Gravity pulls the gas together, compressing it and making it very hot. The heat means that the protons move very fast, allowing them to get over the Coulomb barrier caused by the electromagnetic repulsion. The weak interactions allow a proton to turn into a neutron, which is crucial to allowing 4 protons to become ^{4}He (which has 2p and 2n). [The weak interaction plays its role in the initial reaction $p + p \rightarrow D + e^+ + \nu$] The strong interactions are what pulls the protons and neutrons together (to make ultimately ^{4}He) after they get over the Coulomb barrier. The energy for the sun comes from the conversion of some of the 4 protons mass into energy according to $E=mc^2$. (^{4}He has less mass than 4p). [It is the strong interaction, which makes the deep "well" of energy that joins the protons, that does the converting of mass to energy.] The sun's lifetime is long (10 billion yrs) because the process requires a weak interaction, which is weak and hence slow.

4) A key feature of a scientific theory is that it is "falsifiable;" There exit observations of experiments that –if they turned out negatively – would rule out or "falsify" the theory. The following are observations that could have falsified the Big Bang theory (had they turned out differently):

i. Existence and temperature of the Cosmic Microwave Background (CMB).
ii. Abundance of helium and deuterium in regions where no stars have yet formed (primordial abundances).
iii. Dependence of the red shifts of distant galaxies on their distances from us.
iv. Lack of evidence (despite searches) for regions of the universe made out of antimatter, not matter.

Pick two of the above observations and explain why they support the Big Bang theory AND why they would have falsified the Big Bang theory if they had turned out differently. Then give ONE example (presumably not for this course) of a statement or theory that is not falsifiable and therefore not scientific.

i. The Cosmic Microwave Background is the photons left over from the period of decoupling. They have cooled since then because the expansion of the universe has stretched out their wavelengths hence reduced their energy. The Big Bang Theory says they must be around now since they were there at decoupling and haven't interacted with matter since. And they must be a given amount cooler now because the universe has expanded a given amount. If they weren't there, or had the wrong temperature, the Big Bang Theory would be wrong.

ii. In regions where no stars have yet formed, about 75% of the mass is in hydrogen, 25% in helium and a tiny amount (.10%) of deuterium. This is as predicted by Big Bang Theory, which says ^{4}He and D (but no significant amounts of higher elements) are made by nucleosynthesis early on in the Big Bang. If regions where no stars have yet formed had significant amounts of carbon, oxygen, etc., or had too little or too much ^{4}He and D it would mean that the Big Bang Theory is wrong.

iii. The red shifts of distant galaxies are caused by the Doppler effect because they are moving away from us. According to the Big Bang Theory, more distant galaxies should be moving away from us more rapidly, (more space between us and them means more rapid separation as space expands. Or, equivalently, if they're moving away faster, they must have gotten farther away.) If galaxies' red shifts were not proportional to their distances, it would mean that they couldn't have all started at the same place at the same time, hence no Big Bang. The evidence that the red shifts are proportional to distance is crucial support of the Big Bang Theory.

iv. No evidence for patches of antimatter in the universe has been found. The Big Bang Theory says matter and antimatter were mixed and annihilated early on, and only the extra matter exists now. If patches of antimatter were found, it would falsify the Big Bang Theory.

There are many examples of non-falsifiable statements and theories. For example, what if you said that god created the world 6000 years ago but set up everything to make it look exactly like it was created much earlier. How could you falsify that? (Any experiment that said the Earth was older than 6000 years, would be compatible, because the god made it look that way). Basically, most statements that rely on subjective experience are non-falsifiable.

5) An account of the evolution of a bacterial flagellum was presented in *The Sacred Depths of Nature* and also in class as a slide series. Describe what you remember about the postulated sequence of events, starting with a channel and ending with a flagellum, and explain how these illustrate the emergence of a new trait (motility) and the subsequent modification of the trait to produce more adaptive forms. In the course of your answer, explain what is meant by emergence as an evolutionary concept.

1. Existence of a channel
2. Protein A is added to the channel and allows it to work better. The gene encoding this spreads via natural selection because the channel works better.
3. The channel rotates as an unintended consequence of Protein A's presence.
4. Protein B (fibrous) associates with the outside face of the channel. Since the channel is rotating, it acts as a propeller. Thus, creature can now move; the trait motility has emerged (emergent property: something more [motility] from nothing but [the proteins of the channel]).
5. Other proteins (gene encoded) now associate with the neo-flagellum to get it to work better (modification to produce more adaptive forms).

Once you have the emergent trait, natural selection acts on that trait, allowing novel evolutionary ideas to move through time.

6) Consider the following aphorism: There are 3 different kinds of truth:

1) Empirical truth (e.g. continents move)
2) Consensual truth (e.g. it is good to be nice to each other), and
3) Unbidden truth (such as that which comes to us when we create or experience art or understanding).

(a) From the lectures and your readings in biology, describe an empirical truth that particularly interested you, demonstrating your understanding of the underlying processes that are involved.

6 points: Anything will work here, as long as it shows that you understand it (don't just state it).

(b) Describe a consensual and/or unbidden truth that has emerged or become highlighted for you as a consequence of taking the course thus far (you need not restrict yourself to biology here)

4 points: Any answer other than a blow-off one is valid here.