

Astronomy 5 Midterm Answers

Tuesday, May 5, 2015, 9:30–10:45 AM

Part I: Multiple Choice

Use the scantron to answer the questions from this section. In each case, choose only the single best answer.

1. The age of the Earth is approximately what fraction of the age of the universe?
 - A. 1/540
 - B. The Earth is three times as old as the Universe
 - C. **1/3**
 - D. 1/9
 - E. 9/10
2. The main chemical building blocks of life besides hydrogen are carbon, oxygen, and nitrogen. Where were they formed?
 - A. in the Big Bang that created the universe
 - B. in the protostellar nebula during star formation
 - C. in the Sun, and they are transported to Earth by the solar wind
 - D. **in the nuclear burning cores of stars and then ejected into space when those stars died**
 - E. in the center of the Earth and then ejected onto the surface via volcanism
3. What is the heaviest element (i.e., the one with the largest atomic mass) created by nuclear fusion in stars?
 - A. silicon, Si
 - B. carbon, C
 - C. helium, He
 - D. uranium, U
 - E. **iron, Fe**
4. Considering the hallmarks of the scientific method, why is anecdotal evidence of little value in science?
 - A. **anecdotal evidence is, by definition, not verifiable or repeatable**
 - B. anecdotal evidence is seldom logical
 - C. anecdotal evidence is accompanied by a large uncertainty
 - D. people who recount the anecdotes simply can't be trusted to be truthful
 - E. anecdotal evidence is based on prejudice and superstition

5. Which of the following statements does **NOT** automatically follow from the observation that the universe is undergoing uniform expansion?
- A. the universe is cooling down
 - B. the universe is continuously becoming more rarified
 - C. there must be a special moment when the expansion of the universe started
 - D. the universe must be dominated by dark matter**
 - E. the universe once consisted of a hot, dense plasma
6. Stars form predominantly out of
- A. electromagnetic radiation
 - B. cosmic dust
 - C. the gas provided by stars via their stellar winds
 - D. dark matter in the Galaxy
 - E. the gas in interstellar molecular clouds**
7. The first galaxies formed in the gravitational “wells” (centers of attraction) provided by
- A. the leftover debris from exceptionally large supernovae
 - B. photons from the cosmic microwave background.
 - C. the non-zero curvature of the universe.
 - D. super-massive black holes.
 - E. large concentrations of dark matter.**
8. The “RNA World” hypothesis posits that:
- A. self-replicating RNA molecules preceded and gave rise to the DNA-based life that is now universal on Earth**
 - B. RNA-based organisms from another world seeded life on Earth
 - C. there was once a branch of life in which the genetic code was based on RNA, but it was outcompeted and disappeared when DNA-based life independently arose
 - D. ribonucleic acid – RNA – offers a plausible alternative to carbon-based chemistry for life
 - E. during the Hadean era when the Earth was particularly hot, RNA-based life was the only kind that could survive
9. By applying Occam’s Razor, which of these responses would you use to counter the claim that global catastrophes such as floods and volcanoes were solely caused by alien visitors?
- A. There was no one present to objectively observe these catastrophes
 - B. There is no good reason why aliens would do such a thing
 - C. Aliens probably don’t have the technology to cause such events
 - D. References to these catastrophes are found in historical writings
 - E. There already exist plausible geological mechanisms to explain these phenomena**

10. The s- and r-processes produce isotopes that are usually:
- A. proton-heavy
 - B. neutron-heavy**
 - C. electron-heavy
 - D. equally heavy in protons as in neutrons
 - E. equally heavy in electrons as in neutrons
11. The interior structure of Earth can be studied with p- and s-waves (pressure and shear waves, also known as longitudinal and transverse waves). What is true about these seismic waves?
- A. They travel at the same speed and through all media.
 - B. They travel at different speeds and travel through all media.
 - C. They travel at the same speed but p-waves can't go through liquids.
 - D. They travel at different speeds and s-waves can't go through liquids.**
 - E. They travel at different speeds and p-waves can't go through solids.
12. After the formation of helium by hydrogen burning, what nuclear reaction in stars is the key stepping stone to the formation of all elements in the periodic table other than the few light elements that were produced in the Big Bang?
- A. the triple-alpha reaction**
 - B. oxygen burning
 - C. the proton-proton chain
 - D. neutron addition
 - E. nuclear fission
13. What is widely regarded by scientists to be the source of the water in the Earth's oceans?
- A. Comets.**
 - B. The giant impacting object that created the Moon.
 - C. The planetesimals that initially formed the Earth.
 - D. Diffuse water vapor captured from the gas disk during the formation of the Solar System.
 - E. Solar winds.
14. Which of the following is NOT a greenhouse gas:
- A. water vapor, H_2O
 - B. nitrogen, N_2**
 - C. carbon dioxide, CO_2
 - D. methane, CH_4
 - E. nitrous oxide, N_2O
15. Light traveling from the nearest star (not including our own sun) was emitted roughly
- A. 25,000 years ago
 - B. 2.5 million years ago
 - C. 4 years ago**
 - D. 2 centuries ago
 - E. 8 minutes ago

16. What can you conclude from the observation that the most primitive meteorites have an age of about 4.567 billion years, when they are dated using radioactive nuclides?
- A. that this is the age of the Sun, and the Solar wind is transporting small solid bodies that condensed in the Sun into the Earth's atmosphere
 - B. that another star passed by the Solar System at this time, leaving debris in its wake that continues to rain down upon the solar system
 - C. that this is the time when the Moon formed in a collision between the Earth and another large body, and that the fragments created in that collision are still raining down upon the Earth
 - D. that this is the time of the formation of the solar system, and these meteorites are part of the debris left behind from the formation process**
 - E. that this is the time when a planet underwent a catastrophic collision, sending fragments throughout the solar system that are now falling onto planets as meteorites
17. The earliest evidence for life on Earth is
- A. skeletal remains of bizarre Cambrian creatures in the Burgess Shale.
 - B. stromatolites
 - C. microfossils of cyanobacteria
 - D. isotope abundance ratios in ancient carbon deposits that differ from the global average in just the way that metabolic processes would produce.**
 - E. fossil imprints of prokaryote cells near mid-ocean ridges
18. What process internal to the Earth supplies most of the heat that makes volcanism and plate tectonics possible?
- A. the diffusion of solar heat into the Earth's interior
 - B. geochemical reactions
 - C. the decay of radioactive elements created in supernovae**
 - D. compression of the Earth by its own gravity
 - E. friction caused by lunar tides
19. In science, conceptual representations of observed phenomena are referred to as
- A. predictions
 - B. beliefs
 - C. facts
 - D. paradigm shifts
 - E. hypotheses or models**

20. Which of the following is NOT one of the premises of Darwin's Theory of Evolution?
- A. Those features that favor some individuals over others are heritable.
 - B. Individuals can influence the heritable features that give them and their offspring a survival advantage via their behavior.**
 - C. There is a struggle for existence
 - D. More individuals are produced than can survive
 - E. Individuals vary in features that influence their survival and their reproduction (no two individuals are exactly the same, and some will do better than others – i.e. natural selection)
21. Which of the following facts could lead you to conclude that life is capable of arising at a vast number of locations throughout the Universe?
- A. The abundances of elements as heavy as carbon and above is as large throughout most of the Galaxy as it is in the solar system.
 - B. The nebular theory is a generic theory that should apply to a large fraction of all forming planetary systems, and this is consistent with the direct observation of numerous protoplanetary disks.
 - C. The increasing pace of discovery of planets outside our solar system is showing that planetary systems are a common phenomenon.
 - D. The laws of physics & chemistry are the same throughout the universe.
 - E. All of the above**
22. How do scientists know the interior structure of the Earth, in spite of the fact that they have not been able to tunnel directly into it?
- A. Subterranean water flowing through the Earth dissolves some of the minerals it encounters, so when it reaches the surface, it can be used to piece together the composition, density and temperature of the Earth's interior.
 - B. Scientist's inferences about the Earth's interior are drawn entirely from theoretical modeling.
 - C. They use the Moon's orbit to draw inferences about how matter is distributed throughout the interior of the Earth.
 - D. The content of upwelling convection cells in the Earth's mantle reveal what is going on below.
 - E. They use the timing and the reflections of seismic waves generated by earthquakes around the globe.**
23. The two most abundant elements in the universe are ...
- A. iron and hydrogen
 - B. carbon and oxygen
 - C. helium and hydrogen**
 - D. hydrogen and carbon
 - E. helium and carbon

24. All living organisms are made of cells. The fact that all cells in life on Earth are based on the *same* fundamental biochemistry suggests that
- A. there must be only one way for life to arise and evolve.
 - B. life originated from a variety of sources.
 - C. the biochemistry of life on Earth will apply throughout the universe.
 - D. all life on Earth shares a common ancestor.**
 - E. self-replication could not start happening until cells appeared.
25. How does the structure of DNA allow for its replication?
- A. The bases in the pairs that join opposite strands of the double helix must always pair up with their complementary partners, so when DNA is split into two separate strands, each strand can reform copies of the original double helix by matching complementary base pairs.**
 - B. DNA can be unwound by twisting until it is linear, and then it can be copied by the cell machinery.
 - C. DNA can roll across a cell membrane, leaving an imprint that the cell can then refill to produce an exact copy of the original DNA molecule.
 - D. The protein subunits that make up DNA are individually self-replicating.
 - E. DNA is a coiled spring that generates copies of itself as it vibrates back and forth along its length, snatching base pairs from the medium around it.
26. What process most succinctly describes the likely growth of our entire Milky Way Galaxy over cosmic time?
- A. The slow buildup of matter as gas is continuously pulled into the Galaxy by its gravity and that gas is transformed into stars
 - B. The Galaxy formed very early on in the history of the universe, and the only evolutionary change it has undergone has been its continual formation of new stars
 - C. It has continuously been built up by the production of new elements in dying stars, which then form the next generation of stars.
 - D. The Galaxy originally started out as a large diffuse nebula that has been slowly shrinking and spinning faster as it forms more and more stars.
 - E. The Galaxy has been built up by a succession of mergers of smaller stellar systems**
27. How can we date rocks and thereby determine a time scale for the geological history, and eventually the biological history, of the Earth?
- A. measure the size of the zircons in the rocks, since zircons get bigger with time.
 - B. measure the depth of the rocks, since sediments pile up uniformly with time
 - C. measure the age of fossils embedded in the rocks using carbon-14 dating.
 - D. measure the abundances of a long-lived radioisotope and its daughter product, and use the age equation to deduce how long it has been since the rocks formed.**
 - E. measure how much the rocks have oxidized, since they progressively combine chemically with atmospheric or oceanic oxygen over time

28. Most life on Earth uses only 20 amino acids to build proteins. A common ancestry for all life forms on Earth is evidenced by the fact that amino acids found in living cells ...
- A. are an equal mixture of left-handed and right-handed molecules.
 - B. are all left-handed molecules.**
 - C. are all right-handed molecules
 - D. uses a different set of 20 amino acids, depending on what branch of the tree of life they are on.
 - E. are an unequal mixture of left-handed and right-handed molecules, left-handed being most abundant.
29. All living cells use the molecule adenosine triphosphate (ATP) ...
- A. to constitute the lipid bilayer that forms the cell wall
 - B. as a building block for the backbone of nucleic acids
 - C. to store and release energy for biochemical processes**
 - D. to carry oxygen into cells
 - E. to catalyze biochemical reactions
30. In order to have a global magnetic field, a planet must have ...
- A. an electrically conducting fluid in its interior that is undergoing convection, plus a reasonably rapid rotation**
 - B. magnetic rocks throughout most of its interior
 - C. magnetized rocks on its surface
 - D. a large core of solid magnetized iron
 - E. active plate tectonics
31. The carbon dioxide cycle provides a terrestrial thermostat, because if the atmosphere gets too cool, then ...
- A. more ice forms near the poles and causes sunlight to be reflected back into space.
 - B. it rains less, so rainwater does not dissolve so much CO₂ from the atmosphere as it falls, and CO₂ therefore builds up and heats the Earth by the greenhouse effect.**
 - C. it rains more, causing CO₂ to become dissolved in the oceans and to produce a greenhouse effect in the ocean.
 - D. there are fewer clouds in the sky, so more sunlight can reach the Earth and be absorbed by photosynthesizing plants that absorb the CO₂.
 - E. plants don't grow as much, so they don't absorb carbon dioxide from the atmosphere, and the CO₂ then builds up and heats the Earth by the greenhouse effect.

32. What is the currently favored hypothesis for the main source of the Earth's oceans?
- A. melting and sublimation of polar ice caps
 - B. differentiation of the primitive planetary material, whereby the lightest substances floated to the top
 - C. icy material directly accreted from the solar nebula
 - D. impacts by icy planetesimals, or comets after the Earth formed**
 - E. chemical reactions on the hot, Hadean Earth that combined hydrogen and oxygen to form water, and hydrogen and nitrogen to form ammonia.
33. The energy radiated by the Sun comes ultimately from ...
- A. Fission reactions in the core of the Sun
 - B. The triple-alpha reaction
 - C. The conversion of the Sun's gravitational energy to heat, followed by the emission of that thermal energy in the form of electromagnetic radiation
 - D. The conversion of a small amount of mass to energy in the course of the fusion of 4 protons to produce helium**
 - E. Matter-antimatter annihilation in the core of the Sun
34. According to the nebular theory for the formation of the solar system, why were the Jovian planets (that is, the gas giants) formed at distances from the Sun well beyond the realm of the terrestrial, rocky planets?
- A. because that is the only place where gas was in the solar nebula
 - B. because the abundance of dark matter is greater out there, and it boosted the formation process of planets
 - C. because that is beyond the snow line, where the abundant ices could be solid, and thereby contribute to planet formation by being incorporated into planetesimals**
 - D. because the early solar wind blew away all the gas from the inner solar system
 - E. because most of the mass of the solar nebula was out there
35. Which of the following processes is believed to have been an important source of the Earth's present atmosphere?
- A. gas pulled in by the Earth's gravity from the solar nebula
 - B. matter blasted from the surface of the Moon
 - C. it was carried in by the Mars-sized body that hit the Earth and created the Moon.
 - D. outgassing by volcanoes on the Earth's surface**
 - E. charged particles trapped from the solar wind

36. Most of the carbon dioxide that was originally present in the Earth's atmosphere ...
- A. is presently dissolved in the oceans
 - B. has frozen out in the polar regions
 - C. has escaped into space
 - D. is still present in the atmosphere
 - E. **has formed carbonate rocks by combining with minerals like calcium in the ocean and then precipitating out onto the ocean floor.**
37. As the Sun runs out of hydrogen in its core and expands to become a red giant,
- A. the Earth's oceans will freeze solid
 - B. **the Earth will experience a runaway greenhouse effect followed by the total loss of its atmosphere**
 - C. the Earth will be swallowed
 - D. the Earth will be ejected from the solar system
 - E. the Earth will be vaporized and blown out in the intense solar wind
38. Silicon has a chemistry similar to that of carbon, so why is it disfavored as a possible basis for life elsewhere?
- A. **silicon dioxide is a rock (quartz), so its mobility is extremely limited, while carbon dioxide is a mobile gas.**
 - B. it is rare compared to carbon
 - C. silicon is a larger atom than carbon, so it takes up too much space inside the cell
 - D. silicon is extremely reactive chemically, so it cannot form stable compounds easily
 - E. because humans use most of it for computer chips
39. According to the definition of life given in this class, what is the reason why a virus isn't considered to be a real life form?
- A. a virus does not have its own machinery for self-replication
 - B. a virus does not engage in metabolism
 - C. a virus is not composed of cells
 - D. after being replicated, a virus does not grow
 - E. **all of the above**
40. What is the ultimate fate of the Sun?
- A. over time, the weak but steady solar wind will finally carry away most of the Sun, leaving behind a dark cinder.
 - B. it will eventually explode as a supernova
 - C. **it will swell up to become a red giant, then expel its atmosphere in a strong wind, and finally become a white dwarf star**
 - D. it will get smaller and smaller until it transforms into a black hole at the end of its life.
 - E. it will expand with the expanding universe until it becomes so rarified that even gravity cannot hold it together.

Part II: Short answers. Fill in the blanks *on this test sheet* with the word, number, or short phrase that provides the correct meaning to the sentence or answers the question best. You're welcome to do any figuring you want on the back of the page. *Write legibly!*

1. There are 4 stable isotopes of the element calcium (Ca), which has an atomic number of 20. Its second most common isotope has an atomic mass of 44 (constituting 2% of the calcium in your bones and teeth). Assuming the atom is neutral, this means that it has

___20___ protons, ___20___ electrons, and ___24___ neutrons (give a number).

2. What is the heaviest element created by nuclear fusion in stars? ___**iron, or Fe**___

3. The three domains of life, based on cell structure and DNA distinctions, are:

___**bacteria**___, ___**archaea**___, and ___**eukarya (or eukaryotes)**___

4. The process of "reading" a DNA molecule to produce a segment of RNA is called

___**transcription**___. The process of generating a protein molecule using the information contained in an RNA molecule is called ___**translation**___.

5. All early life must have been ___**anaerobic**___ organisms, because the Earth's atmosphere was oxygen-free during its early years.

6. A ___**prokayote**___ is a single-celled organism with no nucleus, while a ___**eukaryote**___ has a nucleus and other organelles such as mitochondria.

7. A set of 3 base pairs, which is called a codon, contains the genetic code for a specific

___**amino acid, or peptide**___.

8. What is the dominant *matter* constituent of our universe? ___**dark matter**___

9. The idea of a “molecular clock” to determine how long it has been since two species diverged from being members of a single species is based on the assumption that the rate of mutations in their DNA has been constant.

10. DNA consists of two helical “backbones” consisting of sugars and phosphates. These backbones are held together by base pairs that are joined by hydrogen bonds. There are 4 (give a number) different bases in DNA.

Part III: Short answers. Answer the following questions *on this test sheet* with one or two sentences (please, not more). Use the back of the sheet, if necessary. *Write legibly!*

1. Give an example of a positive feedback that could lead to a runaway heating or cooling of the climate if no competitive negative feedbacks were operating.

Here are some positive feedbacks (there are others besides these):

- **When the climate cools, ice forms. Ice reflects sunlight, so when it forms, the earth absorbs less heat, and the earth cools down, forming more ice**
- **When the earth heats up, ice melts at the polar ice caps, so more sunlight is absorbed there because seawater absorbs sunlight instead of reflecting it. Therefore, the temperature rises more and even more polar ice melts.**
- **When it gets warm, there is more rainfall, and more plants grow. Plants absorb more sunlight than barren land, so that raises the temperature. A higher temperature leads to more rainfall, and thus more plant growth, and therefore even higher temperatures.**

2. What physical process drives plate tectonics and how does it work?

Convection in the Earth's mantle: the overturning convection cells move laterally beneath the Earth's crust, exerting a lateral force on the crustal tectonic plates (via frictional forces conveyed through the asthenosphere).

3. Explain why evolutionary adaptation must apply to a species rather than to an individual.

In order for a species to benefit from a useful evolutionary adaptation, that adaptation must be present throughout the gene pool for that species. A beneficial trait might originally arise in a single individual, but the survival advantage then enjoyed by that individual progressively enters the gene pool in successive generations as its offspring inherit the trait and consequently become more fit for survival than those who do not possess the trait.

Otherwise stated, an individual will live and die, but any evolutionary adaptation it might have had will only have a long-term evolutionary consequence if the adaptation gets passed on into the gene pool of the species.

4. What does a greenhouse gas actually do, physically, to contribute to global warming?

A greenhouse gas absorbs infrared radiation. The Earth cools itself by emitting thermal infrared radiation into space, but if greenhouse gases are present, they absorb that infrared radiation and thereby prevent the energy from escaping into space. That heats the atmosphere. Greenhouse gases are transparent to sunlight, so the Sun's energy is not impeded from reaching the ground and heating the Earth.

5. The half life of some radioactive substances produced in nuclear fission reactors is a few thousand years – say, 2000 years. If the level of radioactivity in the nuclear waste from a reactor exceeds the acceptable irradiation limits for humans established by the EPA and AEC by a factor of 64, how long will that waste have to be buried before it can be deemed safe?

If we need to wait for the radioactivity to decline by a factor of 64, then we need to wait for 6 half lives because half of the radioactive substances decay every half-life:

$$1/64 = (1/2)^6$$

One half-life is 2000 years, so 6 half-lives is 12,000 years.

6. What suggests that the first life forms on Earth may have been extremophiles? What kind of extremophiles?

The most primitive single-celled organisms that can be found on Earth today, prokaryotes – both archaea and bacteria – are themselves extremophiles. We expect that the most primitive organisms are the ones most closely related to the first life forms, since evolution leads to increased complexity. We therefore conclude that the first life forms are likely to have been extremophiles.

In particular, the most primitive organisms known are largely thermophiles. This is consistent with the earliest life forms having arisen in or near hydrothermal vents.