1. A deep sea rig drills beneath the sedimentary cover, and recovers a sample of unaltered basalt that can be used for reliably* dating the rock. The location of the sample is 70 km from an actively spreading ridge crest, where the full rate of spreading is known to be 5 cm/yr (full rate means rate of one plate relative to the other plate).
   a. What method of dating would likely be used?
   b. What would the age of the basalt sample likely to be?
   c. What was the polarity of the geomagnetic dipole at that time relative to the modern dipole?

   *This is really very hard to achieve for submarine basalts, but for the sake of this problem assume that it can be done.

2. Most scientists now believe that variations atmospheric CO$_2$ concentrations have played a key role in climate regulation throughout Earth’s history. Explain the role that CO$_2$ plays in the Shrag and Hoffman’s hypothesis of late Proterozoic glaciations. Explain in particular the various processes that, according to them, acted to raise and lower atmospheric CO$_2$ concentrations and how these processes interacted with or were affected by other geological processes or factors. (Hint: you might want to read their Scientific American article).

3. In what ways was the Cretaceous period unique? What geologic factors contributed to this uniqueness? Among other things, explain how events and processes in the Earth’s deep interior might have played a role in creating a unique environment at the surface of the Earth.

4. Contrast and compare volcanism at divergent and convergent plate boundaries. Be comprehensive, and include, among other things, causes of melting, volcanic products, eruptive style, and climatic impacts.
5. For each of the following events in Earth history, give the most widely accepted date of occurrence (in millions of years ago), briefly explain how we think we know that date, and briefly describe the probable role of contingency in the event. Be as specific as you can.

   a. origin of life
   b. origin of eukaryotic cell
   c. Cambrian explosion
   d. origin of mammals
   e. early Cenozoic diversification of mammals
   f. origin of Homo sapiens

6. Draw a geological time scale of the Phanerozoic indicating the eras, periods, and epochs. On this time scale, draw general curves showing our currently most widely accepted views of the history of the following throughout the Phanerozoic:

   a. eustatic sea level
   b. diversity of marine life
   c. global average temperature
   d. atmospheric CO$_2$
   e. diversity of terrestrial vascular plants

For each of the above curves, a-e, briefly describe the geological evidence for it, and briefly describe one specific reason for significant uncertainty in the curve. Be as specific as you can.

7. A. In 1910, the prominent paleontologist Henry Fairfield Osborn of the American Museum of Natural History in New York published a version of the geological time scale in his popular book *The Origin and Evolution of Life*. The time scale included all of the Phanerozoic periods familiar in the modern time scale, but it gave the date of the Cambrian-Precambrian boundary as 30 million years ago, and the age of the Earth at 60 million years ago. Explain how Osborn could use essentially a "modern" time scale with numerical dates that were so different from dates accepted today.

   B. Give the approximate dates that are most widely accepted today for the Cambrian-Precambrian boundary and the age of the Earth, and briefly explain how these dates have been derived.
8. The diagram below shows relationships among elements of the Earth system. For each of the lettered connections: describe a specific example from a particular point in Earth history, briefly explain the nature and magnitude of the connection, and give a brief but specific physical explanation of the connection.