

# Tutorial Questions

## Are We Alone?

### PHYS2170

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## Tutorial 1. Stars – Energy for Life

1. What do we mean when we say stars liberate energy?
2. Explain the key processes taking place in a stellar core: nuclear fusion and the proton-proton cycle.
3. Why can a star be considered a balancing act?
4. Why would the regions close to stars (planets) be most likely to harbour life? Assuming this is true what are the most important characteristics of a star so far as life is concerned and why?
5. Explain why core temperature is important in protostars and newborn stars.
6. What is the relationship between a stars mass and its lifetime? Explain how that affects what stars are likely to encourage life.
7. How does a star liberate energy as its hydrogen fuel becomes depleted? How does this affect the star and its ultimate end?

## Tutorial 2. Stars – Big ones, little ones, exploding ones.

1. What are the differences in the way massive stars and less massive stars end their lives?
2. How is a white dwarf different from a normal star? Could such a star support life?
3. Why can't a low mass star produce many elements heavier than carbon?
4. Why can massive stars go on fuse elements up to Iron in their daily lives?
5. What happens to massive stars when they exhaust all of their fuel and has fused most of the nuclei in its core into iron? Explain.
6. If iron marks the end of the fusion chain liberating energy how do massive stars synthesise heavier elements so important to life?
7. Why are supernovae very necessary for the development and evolution of life?
8. Why may supernovae ultimately limit the ability of life to survive?

## Tutorial 3. The early Earth

1. What was the source of the Earth' s oceans and early atmosphere and was it probably composed of? Why did the early Earth have a much smaller amount of free oxygen gas than is now the case? Why was the formation of this early oxygen important?
2. How does our present atmosphere differ from the primordial atmosphere? What changed it and how?
3. What processes tend to remove nitrogen from the atmosphere? What processes replenish it?
4. Why can' t we determine what the Earth was like soon after it formed 4.5 billion years ago?
5. What is the leading theory on how life arose on Earth 3.5 billion years ago? What were the essential ingredients for this process to occur?
6. What can laboratory simulations of the conditions that may have existed on the primitive Earth tell us about the formation of organic molecules? What difficulties stand in the way of making an accurate experiment that duplicates the primitive Earth?

## Tutorial 4. Astrobiology 1.

1. Why might clays be important in making complex molecules?
2. Is it possible that organic molecules from outer space played an important role in the formation of life on Earth?
3. Why are cells important to living organisms? Why can we say that the first cell was a small pond, full of organic molecules and water?
4. Where might the ancestors of the modern cells have come from? What environmental hazards did they have to overcome?
5. What is the key difference between prokaryotes and eukaryotes?
6. Why has water been so important to life on Earth? Should we expect life on other planets to require liquid water?
7. Why does carbon appear to be the best element for building complex life throughout the universe?
8. Would silicon serve as well as carbon in giving structure to large molecules? Could life be built from silicon? Why or why not?
9. Why does water's high heat of vapourisation and large heat capacity give water an advantage for use as a solvent in living organisms?
10. What are the advantages of a solvent that expands when frozen?

## Tutorial 5. The nature of life on Earth

1. What would you say is the difference between living matter and inanimate matter? Illustrate with examples.
2. Why do we say that the composition of living organisms resembles the composition of the stars? What does this imply for theories of how life might have originated throughout the Universe?
3. Why are carbon and nitrogen such important elements in all living creatures when they are comparatively rare in the Earth?
4. What fact is strongly suggestive that life began in the seas on Earth as oppose to arriving from space?
5. Do elements heavier than iron produced in supernova explosions play an important role in living creatures? Give examples.

## Tutorial 6. Astrobiology 2

1. Many biologically important molecules are said to be chiral. What does this mean? Given that all proteins in Earth life are chiral -L suggest one way in which this came to be.
2. What are proteins and how are they related to amino acids? Statistically what does the number of amino acids used by life tell us?
3. What is DNA? Describe the basic parts of DNA. Why are the monomers in DNA so special?
4. How do DNA molecules replicate or reproduce themselves? What other key functions besides reproduction do DNA molecules regulate?
5. What exactly does the term mutation mean? Are mutations necessarily helpful or hurtful? What role does mutation play in evolution?
6. Thermodynamics states that entropy must always increase i.e. in a closed system the total disorder must increase. Life on the other hand has moved from disorder to increasing order as evolution has progressed. Does life then contradict thermodynamics?
7. Would we expect another form of life, in some other planetary system, to be made of the same elements of life on Earth? Would we expect such life to use the same kinds of amino acids as we do? Should we expect life to have developed DNA molecules like living organisms on Earth? Why or why not?

## Tutorial 7. Mars

1. What sort of observation made before spacecraft visited Mars encouraged people to believe Mars might have vegetation and even intelligent life.
2. How was that view of “Lush Mars” slowly eroded? Why is it impossible for any liquid water to exist on the surface of Mars?
3. On Earth the atmospheric pressure decreases by a factor of 2 every time we gain 6 km altitude. The surface pressure on Mars is 1/50 that of Earths at sea level. What altitude is this equivalent to on earth?
4. How would you boil an egg on Mars?
5. What evidence suggests that water has not been flowing on Mars for billions of years?
6. Why might the regions at the edge of the polar cap be more favourable to life than the equator?
7. Why would Mars have a thicker atmosphere if it were a larger planet? How would a thicker atmosphere affect the chances of life on Mars?
8. Imagine for a moment there were technological eukaryote life on Mars. How could an intelligent Martian detect life on Earth? (Examine the cases of Earth in the stone age i.e. no technology, and Earth before the emergence of multi-cellular life forms.)

## Tutorial 8. The arrival of life on Earth

You need to carry out the following preparatory work before the tutorial.

1. The origin of life on Earth may be one of the most important questions we can ask. We have fossil and isotopic evidence for life on Earth 3.5 and 3.8 billion years ago. By researching, either on the web or otherwise, find out what this best recent evidence is. How precise are the dating techniques?
2. There are several ideas about where life on Earth came from. It originated in a primordial soup or in hydrothermal vents or inside rocks 5 km below the surface of the Earth by some sort of pre-biotic chemical evolution. The possible discovery of life on a meteorite that came from Mars has brought more credibility to the idea that life could have originated on Mars 4 billion years ago when there was water on Mars and then have been transported to the Earth inside a meteorite. If this is correct then we could call ourselves Martians. By researching, either on the web or otherwise, make a summary of the evidence for and against the Martian origin theory. Formulate your own view on the likelihood of a Martian origin and be prepared to argue your case.

## Tutorial 9. How many intelligent extraterrestrial civilisations are there?

1. State the Drake equation. What do each of the terms in the equation mean?
2. Why can we approximate the number of intelligent civilisations in our galaxy,  $N$  by the lifetime of an average civilisation,  $L$ ?
3. What is the average distance between stars in our part of the Milky Way. State your answer in parsecs and light- years.
4. How does our estimate for the average distance between civilisations in the Milky Way affect our chances for communication with any of these civilisations? Compare the distances we expect for civilisations *closest* to our own in the two cases of  $N = 20,000$  and  $N = 15$  million.

## Tutorial 10. Communicating with ETs

1. If the average lifetime of a civilisation in the Milky Way turns out to be less than 3500 years we may be unable to establish two-way communication with other civilisations. Why is this so?
2. Use the approximation  $N = L$  to estimate how many round trip radio messages neighbouring civilisations could exchange if  $L = 15$  million years. (Fig 1)
3. Why do we think the parent stars of some advanced civilisations might be invisible? How would you detect such a civilisation?
4. Why do radio waves seem far superior to spacecraft for interstellar communication?
5. What do radio astronomers mean by the water hole? Why do some astronomers think that the water hole may include some strong interstellar transmissions?
6. Light waves and radio waves travel at  $c$ ,  $2.988E^8$  m s<sup>-1</sup>. How long did it take the message sent from the Arecibo radio telescope in 1974 to overtake the Pioneer spacecraft, which had then been travelling for two years at a speed of 10 km s<sup>-1</sup>?

## Tutorial 11. Interstellar travel

1. What difficulties stand in the way of an interstellar spacecraft that scoops up fuel from interstellar gas and dust as it travels through space at 99% of the speed of light?
2. What is time dilation? How could this benefit a crew on a spacecraft travelling at a significant fraction of the speed of light?
3. For velocities,  $v$ , that are nearly equal to  $c$ , the energy needed to reach a given velocity varies in proportion to the ratio  $c/(c-v)$ . How much energy is needed to accelerate to a velocity of  $v = 0.99c$  compared with  $v = 0.90c$ ?
4. What advantages could we design into an automated message probe that would render it far superior to the Pioneer plaque or the Voyager record?

## Tutorial 12. UFOs and making contact

1. Discuss the clues that enable you to judge the distance to: (a) a familiar object, (b) an unfamiliar object. Using ray-tracing, work out a rule-of-thumb estimate of the "depth of field" or "depth of focus" of an optical system. Apply this analysis to both the human eye and to a domestic camcorder.
2. What is the angular resolution of the human eye? Assuming you can "steer" your eyes to this resolution, what would be the accuracy of a distance estimate made using binocular vision (i.e. triangulation using the distance between your eyes as the baseline)?
3. Your next-door neighbour bangs on your door late one night, holding a small saucer-shaped object she says just crashed in her back-yard. What would convince you that the object was of extraterrestrial origin?
4. Which of the laws of Physics are you most willing to allow might be proven wrong by an advanced civilisation?
5. How far advanced is current (human) military technology? Which of James Bond's gadgets are plausible, and which are not?
6. Someday, somebody might invent a material stronger than steel (actually, they already have). Can you imagine a material stronger than the intermolecular bonds of its component molecules?

## Tutorial 13. Artificial life and artificial intelligence

1. Do you believe that it will be possible in the future for computers to think? To feel emotion? To have “intuition”? To make scientific discoveries?
2. If you answered yes to any part of the first question, how many years do you think it will be before a computer with “human-level” capabilities in this area is developed?
3. If you answered no, what is the strongest argument you can think of against computer intelligence?
4. Using an internet search engine, track down Thomas Ray' s “Tierra” program and read about it. If you have access to a PC, download the software and try running it.
5. Do the same for Life32. Life32 is easier than Tierra and more fun, so if you have limited time, try Life32 first.