50 summary questions for Life in the Universe (end-FS2019)

1. We identified three key things about the Universe that makes Life possible:
   (a) atomic diversity, as produced by stars
   (b) temperature gradients and a lack of thermal equilibrium
   (c) intermediate temperature environments that are stable over long periods of time, as in planetary systems.

   Make sure you understand the overall significance of these in the big picture.
2. What are the basic features of the Solar System in terms of the orbits of the planets etc. and what do they suggest for how the Solar System formed around the Sun?
3. What are the different phases in the development of a planetary system out of a proto-stellar nebula?
4. Roughly how long does this process take and how do we estimate this observationally?
5. What produces the radial variation in chemical composition of planets/moons within the Solar System and why must this be a non-gravitational process?
6. Why are asteroids and comets of interest in understanding the early Solar System?
7. How can we estimate the "ages" of rocks, and what does the "age" actually mean here?
8. What is thought to be the primary origin of the atmospheres of rocky planets like the Earth?
9. Why is the mass of a planet important for the evolution of its solid rocky material and of its atmosphere, and what other factors may be important?
10. What role(s) can tidal forces play in planets and moons?
11. What determines whether a moon or planet can retain an atmosphere?
12. What is the "greenhouse effect" in an atmosphere?
13. Make sure you are broadly familiar with the molecular basis for DNA, RNA and proteins, and also with the basic idea of photo-synthesis and aerobic and anaerobic respiration (but the details of these latter processes is not important).
14. What was the Miller-Urey experiment?
15. What are some of the milestones in going from primitive life to complex organisms?
16. What is the evidence that astronomical impacts have shaped life on Earth?
17. Why is our carbon and water based Life likely to be preferred over other elements/solvents?
18. What is thought to have been the geological and atmospheric history of Mars, and of Venus, and why were these different from that of the Earth?
19. What is special about Europa and Enceladus, and where are these two moons?
20. What is special about Titan, and where is it?
21. When were exo-solar planet systems discovered, and how?
22. What are the different methods by which we can detect exosolar planets, both indirectly and directly, and what are some of the relative pros and cons of each?
23. What can be learnt from observations of transiting planets in terms of their densities, and also their atmospheres?
24. What is meant by "adaptive optics"?
25. Why is interferometry of interest in observations?
26. Very roughly, how many exosolar planets are now known?

27. How do the known exoplanets broadly compare with the planets in our own Solar System, and what, if anything, can we learn from this?
28. What is "the habitable zone" defined, and why might we want to modify this definition?
29. How could we possibly detect remotely the presence of Life on exoplanets?
30. What is the Drake equation and what is SETI?
31. What are some of the main difficulties in having meaningful two-way communications with other civilizations?
32. Why does the fusion of atomic nuclei release energy, but only up to iron (Fe)?
33. What is the Gamow Peak, and why is it relevant for determining the reaction rates for different fusion reactions.
34. Why are all fusion reactions strongly temperature dependent?
35. What is the significance of the negative heat capacity of any self-gravitating body (such as a star) in controlling fusion reactions?
36. Why is there a minimum mass to the stars that can support fusion, and how, roughly, does the lifetime of a star depend on its mass?
37. What are the possible end-points of stellar evolution (neutron stars, white dwarfs etc) and why are these very compact objects?
38. What happens in a supernova?
39. How do supernovae produce heavy elements beyond Iron, and how else are such elements produced?
40. Why is the fusion of Carbon problematical, but why is the formation of Carbon in stars actually less difficult than you might have expected given this problem?
41. What is the evidence for the Big Bang, and how can we estimate when it occurred?
42. What is the evidence that the Universe started off in a very homogeneous and uniform state?
43. Why do we think that most of the matter in the Universe is actually "non-baryonic" (i.e. not comprised of protons, neutrons and electrons)?
44. What is Ω and why does our observation that $\Omega \sim 1$ today suggest that something must have set Ω very close to unity at early times?
45. Why does "Inflation" set Ω very close to unity?
46. What is meant by "Baryogenesis"? Why do we know that the early Universe had a small imbalance of matter over anti-matter?
47. What is a dark matter halo, and why do they have densities of order 1000 times higher than the Universe as a whole?
48. What caused the baryonic matter to separate from the dark matter in some haloes, and to form concentrated rotating galaxies (about 1000 denser again) at the centers of the dark haloes?
49. What would have happened if Q had been much larger, or much smaller, then the $Q \sim 10^{-5}$ of our Universe?
50. Make sure you know roughly the order of magnitude sizes of quantities like
    (a) masses of atoms, cells, humans, planets, stars and galaxies
    (b) length scales of atoms, cells, humans, planets, stars, galaxies and the horizon
    (c) ages of the Solar System, main sequence lifetime of stars, age of the Universe etc.