Question 1:

Dear Cheap Astronomy – How will we find the first evidence of extra-terrestrial life?

Well of course, we don't know – the question is more invitation to review the various options and rank the relative likelihood of those options based on the information we have to hand.

So - it's possible that we'll first find evidence of intelligent life in the form of an electromagnetic signal of technological origin coming from another star system. However, signal attenuation over light year distances means it's not likely our current technology could detect signs of Earth's civilisation from more than five light years away – and there aren't that many star systems with a five light year radius of ours. It's also been our experience on Earth that as technology advances we become more radio quiet – favouring cable and fibre optics over open air broadcasting. Indeed, a civilisation that developed underground or underwater wouldn't find much use for electromagnetic transmissions at all, at least not until they started space exploration. In any case, we've detected nothing to date and we may well continue finding nothing for a long time to come – but the absence of evidence is not evidence of absence. Fermi's paradox is based on some naïve assumptions.

Another option is that we find evidence of fossilised life on a meteor arising from somewhere else in the solar system – like the 1996 claim of fossilised life found on ALH84001, a Mars meteorite with microscopic structures allegedly resembling bacteria, though it's a claim that never gained wide acceptance. We might even find fossils on a extrasolar object that's transiting through our system one day. All this is possible, but has a low probability of success. After all Earth would be a rich source of space-transiting rocks that have been thrown up by meteor impacts and the like, but they would be an exceedingly tiny proportion of all the rocks that are to be found floating around the solar system – let alone outside it. So, just on that basis we should assume that you are vastly more likely to find a space rock with no evidence of life than one with evidence of life.

Of course we have other options for finding life in the solar system. For example, we now had several rovers on the surface on Mars. These are yet to find evidence of either fossilised or living life, but it's certainly worth pursuing further surface exploration and to do sample returns. Given the extent of the search already, no-one's expecting we'll find more than microbial scale life but that would still be quite something.

The other major search frontiers in the solar system include the oceans of gas giant moons, notably Europa and Enceladus, which have confirmed liquid water oceans beneath an icy crust. After that there's Venus' cloud tops, which have a life-friendly temperature and pressure zones, although no water. The recent discovery of phosphine in Venus' atmosphere represents little more than weak circumstantial evidence, where life might be one explanation for its presence, notwithstanding there's still much debate about whether or how much phosphine we've really detected there.

Anyhow, to date we taken an appropriate probability-based approach to searching for extraterrestrial life. SETI the astronomical search for life kicked off in the early 60s and is still going strong. And as soon as we could get to Mars we started looking for life there and that is still going strong. The next best options of the gas giant moons and Venus's cloud tops have already been briefly investigated with missions and there are plans to go back for a closer look in the next decade or two. Indeed, anywhere we go in space, we'll always keep an eye out for life just in case.

Of course, with life on Earth being the only life we know of we have a natural bias to look for the same kind of life elsewhere. Genuinely alien life may be of a form that we haven't considered yet and hence we could be looking in the wrong places, but at the same time alien life should share some common principles of chemistry and structure, at least to the extent of enabling growth and reproduction and also evolution, which may be a mandatory factor if lifeforms are to become capable of making and wielding technology.

Question 2:

Dear Cheap Astronomy – Are we safe from asteroid impacts now?

No, but we are safer. The recent DART mission showed that you can divert the trajectory of an asteroid by impacting it with a fast moving spacecraft. The 2022 DART mission demonstrated that the DART spacecraft's kamikaze crash moved the asteroid Dimorphous by some tens of metres. Tens of metres won't save Earth from a collision with an object that's already closing in – but from sufficient distance such fractional shift could very well modify its trajectory so that it misses. Of course you'd then have to recalculate the parameters of its new trajectory and hope it won't just come back around for another approach, but that's exceedingly unlikely since space is big, I mean really big. Indeed it's very, very unlikely that any we know from Earth's history that very unlikely isn't zero.

We also know that right now, there are over 29,000 near-Earth asteroids and over 100 near-Earth comets – 2, 270 are considered potentially hazardous objects because they cross Earth's orbit and have a diameter of more than 140 metres. Around 150 of these known PHAs are over 1 kilometre in diameter, which is getting into the global catastrophe range. Over 5 kilometres then gets into the mass-extinction range and there's only two of those we know of, with neither on anything like a collision course with Earth.

You may also hear that just in the last year or so we have now positively identified 97% of all near-Earth asteroids over 1 kilometre in diameter – not all of which are Earth-orbit crossing, they are just in the general proximity for now. This knowledge arises from the Spaceguard initiative where back in the 1990s NASA was set the goal of identifying over 90% of NEO's greater than 1 km in diameter. This goal was achieved in around 10 years, since then the name has become a more generalised term to cover similar efforts both in and outside of NASA. Our current coverage of 97% means we've identified 891 of an estimated 920 NEOs of that size. But from the perspective of scary unlikelihoods, we are just estimating there's a total of 920, it might be 921 or two. Or to put it another way, we think there's still another 29 we haven't found yet, but it might be another 30 or 31.

The total estimate is based on mathematical modelling and is probably about right, but there's still a scary unlikelihood ithat there may be some long period NEOs with highly elliptical orbits that just shoot in for a brief perihelion around the Sun and are then not seen again for hundreds or thousands of years. These will generally be icy objects, originating from outside the asteroid belt – and hence become comets as they get closer to the Sun, with a tail of volatiles blown out in the solar wind. Most NEO's originate from within the asteroid belt and so are more rocky and have less eccentric orbits.

Probability-wise we are much more likely to get hit by one of these asteroids in nearby orbits – since there's so many more of them with so many more potentially intersecting trajectories. The mass-extinction 10 kilometre diameter Chizcalub object that hit 66 million years was probably a rocky asteroid similar to known objects in the asteroid belt, based on its iridium content.

But in any case, constant vigilance is always the best policy, since the possibility of a previously unknown object appearing out of nowhere is not zero – and with our current technologies we'll still need at least 10 years advanced warning to manage a DART-like asteroid deflection, so we do want the current and future trajectories of all big NEOs calculated and tracked fairly exactly

So we could still all die tomorrow – or more likely die within months of seeing something tomorrow that's coming right for us and already too close or too fast to do much about. But at least we know for a fact that that is a very unlikely scenario – and we have most of the more likely scenarios pretty-much covered now. Well, as long as we keep at it anyway.