Question 1:

Dear Cheap Astronomy – Please tell us about Dragonfly

Here at Cheap Astronomy, when we heard some murmurs in the background that NASA was launching a new mission to a gas giant moons we instantly thought woo hoo, all aboard for the Europa Clipper. And then we read the memo and, oh right, it's not the Clipper and it's not Europa. We're actually we're going to Titan… again. But, to be brutally honest, the proposed Europa clipper mission is unlikely to do more than further estimate the potential habitability of Europa and it will probably do that from orbit. There's been some suggestions of a lander, but a Europa lander can't do much more than sit on top of the kilometers of ice that lie between it and the potentially life-bearing ocean beneath. The engineering required to bore through twenty kilometres of ice is currently beyond us. So, the next best thing we can do is collect samples of the plumes of steam that we think arise from fissures in the planet's surface. Cassini has already sampled such plumes from Enceladus – with inconclusive results. About all we learned was there's nothing in that water that rules out the possibility of life deep within the Moon, which is kind-of useful, but at the same time, meh.

In fact, the whole back-to-Titan mission plan is kind of nifty. It involves landing a rotocopter, which will fly around on the only moon in the solar system we know to have a dense atmosphere. It's unlikely we'll discover life there, but as we just discussed it's unlikely the Europa Clipper will discover life on Europa either, even though there might really be life on Europa, under twenty kilometres of ice. So, why not do what we can do with 21st century technology and fly something around a distant moon of Saturn - how is that not awesome? Titan is an utterly alien environment and there's no shortage of seriously-extreme engineering challenges that we need to overcome to make that happen.

The physics of flying on Titan will be pretty straightforward since it has 4 times Earth atmosphere's density and just a seventh of Earth's gravity. The bigger challenges are: 1) it's minus -160 degrees Celsius on Titan and it may snow hydrocarbons; 2) it's over one light hour from Earth, so the copter will have to fly and navigate somewhat autonomously and; 3) There's no point doing all this if you can't send the data back to Earth and that data should include a few visuals of our little machine flying around on a freaking moon of Saturn. Ideally, we want some hi-res imagery of the quad copter drone thing lifting of the surface and then buzzing some bizarrely alien outcrops of solid methane and then looking backing to see the source of illumination that's allowing it to see anything, which is of course our Sun, plus some reflected light of the ringed planet Saturn, which presumably occupies a moderate expanse of Titan's sky, but you might not see much of it through the orange haze of Titan's dense atmosphere

The quadcopter will deal with the cold by being nuclear-powered, a radioisotope thermolelectric generator, not only producing electrical power but also warmth. The RTG doesn't itself have enough electrical output to run the rotors, it will instead charge onboard batteries with higher wattage output. So, the idea is the copter will fly during the Titan day – about 8 Earth days and recharge during the night, another 8 Earth days. Final specs of the copter are yet to be worked out, but it will be carrying its own RTG, but all the flight machinery and scientific instruments, including sample collection devices. This all adds up to a whopping 450 kilograms. So, it's a lot of mass, even if it's not a lot of weight to lift against Titan's gravity. The rotocopter design will have four pairs of rotors each about a metre in diameter, two pairs on either side which should deliver a lot of flight stability and the mass of craft should add to its stability, even if it won't be all that maneuverable. It may be able to fly forward at 36 km/h and up to 4k altitude.

The rotocopter will have its own communication dish to transmit and receive directly with Earth. Titan full day night cycle of 15 days and 22 hours is entirely about its orbit around Saturn. Like our Moon – Titan is tidally-locked on Saturn with the same face facing it all the time. So, it's opportunities to communicate with Earth will be mostly in Titan day times, when the part of the moon it's on is facing the Sun. And when does all this happen? Well, in 2034, following a launch in 2026.

Question 2:

Dear Cheap Astronomy – Why don't we fly microscopes to Mars to look for life?

Early microscopy was revolutionary in so far as you could take a drop of pond water and, under magnification, find lots of little swimmy things that no-one had realised were there before. So, of course wouldn't it be great if we could do the same sort of thing on Mars.

The first problem with that is that free liquid water can't persist in Mars' very low atmospheric pressure. Sure, you can still look at dry samples, but dry samples won't spread out flat on a microscope slide. It's difficult looking at chunky three dimensional objects under high magnification, since the higher the magnification the less depth of field you have – so anything with chunky ridges you have to focus on the top of the ridge and then adjust the focus to look at the bottom of the ridge. Indeed, even if you have the patience to keep adjusting the focus, there are other optical issues where a 3d structure will be reflecting light from lots of different directions so you get glare and diffraction problems.

So, if you want really powerful optical microscopy, you need to prepare thin section samples that are flat enough to be virtually 2 dimensional. And there's a further problem with high magnification where having the lens is right up close to the sample, means the lens is shadowing the sample, so it will be too dark to see anything. So, your thin sections also need to be semitransparent so you can shine light through them from beneath. So, that's pretty thin.

And there's another issue. With most biological samples we know about here on Earth once you've prepared a thin section, the material you are looking at is so transparent, it's hard to differentiate cells, let alone different parts of cells. This is where staining comes in – which is pretty much a science in its own right. There's stains for starches, proteins, cell membranes, cell walls, nuclei, chromosomes. The stains create contrast between different structures with different chemical compositions so you can see everything you want to see. Indeed you can use staining to work out what the chemical composition of things are. Most of the useful stains we have at our disposal were found through trial and error, so with a whole different biology that might be on Mars, you'd have to pretty much start from scratch.

Of course there's also electron microscopes, but they also need some intricate sample preparation. Transmission electron microscopes look at thin sections that electrons can pass through – which are stained with heavy metals to create contrast. You also have scanning electron microscopes which magnify 3d structures by scanning their surface to build up a composite image. Those samples have to coated with an electrically conductive covering and earthed, since you are firing electrons at a sample sitting in a vacuum which will build up a big electrostatic charge, so gold for example, works well.

Anyhow, if you want to do microscopy, getting the microscopes to Mars isn't the problem, preparing samples for microscopic observation is the problem – and it's a doozy. Robotic solutions would be a stretch for our current technologies, so it might end up being easier sending people there and setting up a lab, not that there's any level at which that is easy. Or of course, we can just do sample return and look at samples back here on Earth. This is almost certainly what we will end up doing and the upcoming Mars 2020 rover will be collecting samples for a future sample return mission.

We have already sent some impressive magnifying glasses to Mars, including the current Curiosity rover's Mars Hand Lens Imager (MAHLI). It's hardly a microscope, but MAHLI can fully resolve things that are smaller than the width of a human hair and more importantly take pictures of them to send back to Earth.