Question 1:

Dear Cheap Astronomy – What's the big deal about hydrogen on Enceladus?

Hearing that we've discovered the most abundant element in the Universe in a water plume from Saturn's moon Enceladus might seem a bit ho-hum. But the key point is it's molecular hydrogen, or H2.

Apparently, it's quite unusual to find molecular hydrogen H2 mixed in with fresh or sea water anywhere on Earth, except around hydrothermal vents. The abundance of H2 around these vents forms the basis of the ecosystems that are found there, which is all based on microorganisms from the Archaea kingdom being able to combine the H2 with CO2 to form methane.

Up on the Earth's surface, in sunlight, photosynthetic organisms combine H2O and CO2 to form glucose – using a biochemical pathway that produces oxygen as a by-product. The now-abundant presence of oxygen in our atmosphere essentially blocks methanogenesis, which can only take place under anaerobic conditions, like in a cow's gut or deep under the ocean near a hydrothermal vent.

Out at Saturn, there's not enough solar flux – not enough sunlight – to drive photosynthesis as we know it. So finding H2 in Enceladus' subsurface water ocean strengthens the case for its habilitability, at least for a certain type of life that doesn't depend on photosynthesis. Now, finding H2 in Enceladus water plumes is in no way evidence of life – but NASA can now claim they've identified three key foundations which could support life on Enceladus – liquid water, organic compounds (that they've found in previous investigations) and now an energy source, H2.

What's more speculative, but certainly plausible, is that the H2 originates from something on Enceladus that's equivalent to Earth's hydrothermal vents. This is plausible because H2 is one of those things that has to be produced continuously to persist in any substantial quantity. H2 is highly volatile as a gas and otherwise very chemically reactive in a solution – in other words, it's just not going to last long as pure H2. It's also plausible that the detected H2 came from the hot vents on Enceladus' ocean floor – since there's clearly something that's heating Enceladus' oceans, keeping them fluid and making them expand, which then drives the geysers of water that spurt out from its icy surface.

Now, back on Earth, you'd struggle to find any trace of H2 in any body of water, other than nearby hydrothermal vents. H2 is such as biologically-useful molecule that all the H2 produced from Earth's hydrothermal vents is quickly gobbled up by existing life-forms before it gets anywhere near the surface of our oceans.

So, as some scientists have acknowledged, the relative abundance of H2 in the Enceladus water plumes, could be equally taken as evidence that there's no life, that's anything like Earth's life, in Enceladus' sub-surface oceans. Life, as we know it, would not have let such a valuable energy resource pass it by.

So, as usual, we are stuck trying to imagine the possibility of life in another place, when we only know about life in one place, Earth. All we can really say is that we've found something on Enceladus that supports life on Earth. And that life on Earth is a fairly restricted form of life that only proliferates in darkness around deep ocean hydrothermal vents. So, the H2 finding is sort of encouraging, but there's a whole string of assumptions required before you could suggest anything faintly conclusive about it.

Going forward from this, the other famous and potentially-life-bearing solar system moon Europa, which orbits Jupiter, has a similar morphology to Enceladus and recent Hubble telescope observations suggests that it also pumps out water geysers on a regular basis. We are planning to launch the Europa Clipper mission sometime in the 2020s – and no doubt mission planners are already thinking about how they might go one step further than the Enceladus findings. As is usual in this area – stay tuned.

Question 2:

Dear Cheap Astronomy – Will we ever send a probe down beneath the icy crust of Enceladus?

Will we ever send a probe? We'll ever is a long time, so sure – maybe. It's even feasible we could manage such a feat with today's technology. But it's inconceivable we would go to trouble of shipping all the infrastructure that's needed out to a moon of Saturn since this would probably deplete all the resources of the world's major economies.

On either Europa or Enceladus, drilling down to the sub-surface ocean means drilling through at least 15 kilometres of solid water ice. On Earth, the deepest we've ever drilled is about 12 kilometres down through solid rock. That particular job took about twenty years to accomplish, although that's partly because no-one was in a huge rush to complete the project.

And on Earth, 12 kilometres is the deepest we are likely to go in the near future, since the temperature at that depth approaches 200 degrees Celsius – which tends to disrupt the operation of any drilling technologies we currently have at our disposal. It's likely we will develop the technologies to go further down at some point in the future, but for now there's no real economic imperative to mine down to these depths when there's plenty of shallower material available. The deepest we've ever drilled into ice is about 3.5 kilometres – and about the deepest we could ever go is around 4.5 kilometres, because that's the deepest depth of ice that there is on Earth.

It's been suggested that if you wanted to drill a hole into Enceladus' icy crust on the cheap, you could try flying a sizable chunk of plutonium 238 there and just drop it on the surface. A sizable chunk of plutonium 238 can generate heat of about one thousand degrees Celsius at its surface, so the plutonium chunk might be able to melt a hole all the way down that's just slightly wider than itself. But the physics of the situation is complex – while the plutonium's radioactive decay will maintain a heat output for decades – its passage through very cold ice will expose it to very rapid convective heat loss as the surrounding ice melts to liquid water and that water carries the heat away. It's possible that this convection loss would be so rapid that the hot plutonium chunk will just sit on the surface in a shallow pond of its own creation – never sinking further than the distance beyond which the liquid water it thaws freezes back into ice again. And remember Enceladus is a small moon, so there's not much gravity to drive a rapid descent.

And even if a hot object does actually bore down into the solid ice, the water it thaws has to go somewhere – and most of it will refreeze into the space the descending object leaves in its wake. So the only way this process might create an open channel is if the descending object is followed by an apparatus that sucks out melted water as it goes. But of course, this means sucking liquid water up through kilometre lengths of tubing – notwithstanding that water would refreeze long before it reaches the surface.

We could send down a robot probe that melts its way through the ice and just lets the hole close behind it, but then it has no way to communicate whatever data it collects back to the surface unless it can somehow manage to claw its way back out through 15 kilometres of ice.

So, really, there not much advantage gained by trying to melt a hole through ice. You might as well just use standard drilling techniques, treating the ice as though it's just another kind of rock. So, this just brings you back to the issue of needing to ship a crazy amount of infrastructure out to a moon of Saturn in order to undertake an enormously ambitious engineering project.

So, in fact, our current option of sampling the water that spurts out from cracks in Enceladus' surface is not only the best option now, but may well be the best option we ever have to assess whether life exists below the surface. It's possible that these cracks might offer a route down, but it's more than likely that the cracks are actually grinding surfaces between shifting tectonic plates of ice – which would eventually destroy anything that tried to go down them.

In any case, future environmental protection agencies are unlikely to grant anyone a permit to undertake drilling operations that might pollute the underlying oceans of Enceladus, or otherwise infect the moon with Earth bugs. Such environmental protection agencies probably won't be keen on you dropping chunks of hot plutonium on the surface either.