Question 1:

Dear Cheap Astronomy – How big can rocky planets and how small can gas giants get?

Well there is some data, so we don't have to talk in hypotheticals. There's a rocky planet with about 40 times Earth mass and about 3 and a half times Earth's diameter, which is about 85% of Neptune's diameter. So, it's a mighty big rocky planet that's approaching gas giant scale.

The planet, TOI 849 b, discovered in 2020, orbits very close to a Sun-like star, completing each orbit in about 18 hours. It is presumably tidally locked and the surface that's facing its star is estimated to have a surface temperature of 1500 degrees Celsius.

The general view is that this is one bizarre planet. Our admittedly limited understanding of planet formation has it that anything in a protoplanetary disk that's more than about ten Earth masses will start a kind of runaway accretion process where it should inevitably end up as a gas giant. For example, Jupiter's core is about fifteen Earth masses and probably composed of rocks and metal.

It's possible that TOI 849 b was a gas giant but lost its surrounding gas leaving only its bare core behind. This could be the result of an earlier collision or maybe just prolonged exposure to the stellar wind of its star could have blown it all away – although there are other gas giant exoplanets in close proximity to their star that are still hanging to their gas envelope. So perhaps TOI 849 b suffered both, first a collision and then close-proximity photon-blasting from its star.

Anyhow, it's there and if we find ten more TOI 849 bs in the next ten years we'll probably stop saying it's bizarre and just add it to the growing list of possible planetary outcomes found across the cosmos.

As we often point out at Cheap Astronomy the known population of exoplanets is a biased sample – we just detect what we are able to detect. So, it's easy to detect large planets orbiting close to small stars and hard to detect small planets orbiting far away from large stars.

As for small gas giants, these are plentiful enough to have to be granted their own category – gas dwarfs. A gas dwarf is any gas planet smaller than Neptune. In the current population of known gas giant exoplanets, there are actually a lot more gas dwarves than gas giants. Indeed, it seems Neptune size is the dividing line, also sometimes called the radius cliff. So, there's lots and lots of sub-Neptune planets while planets bigger than Neptune seem comparatively rare – and that includes Jupiter and Saturn. We just got lucky with two big ones in our Solar System – well three if you count Uranus, which is very slightly bigger than Neptune, though with less mass.

The theory behind the Neptune radius cliff is that any Neptune sized body that accumulates more gas generates enough internal gravity that the gas starts working into the rocky iron core so there's quite a long phase where such a planet can accumulate more gas without growing in size, the gas just keeps mixing in to the solid core – so it accumulates mass without growing in size. It's only when the core material is fully saturated with gas (which is mostly hydrogen) that the surrounding gas envelope starts growing further – that is, its radius gets bigger. And at least from the data we have available it seems that it’s quite rare that there’s ever enough free gas to build up a gas giant to a size that’s much larger than Neptune.

It's worth repeating this is just current thinking based on our possibly biased sample of observable exoplanets. Thinking may shift again as our resolving power improves and we start spotting more of them.

Question 2:

Dear Cheap Astronomy – Will we grow crops in Martian regolith.

So, firstly you can’t really grow any plants from Earth on Mars since Earth plants need oxygen. While photosynthesis can make oxygen, plants don’t have vascular system that can move the oxygen around. So if there isn’t enough oxygen in the atmosphere to start with, then the roots die and the plant dies. You might have more luck with single-cell algae, but they need a lot more water and warmth than they will ever get on Mars. And sure it might be warmer and wetter underground on Mars, but then you can’t have photosynthesis.

So really the only way to grow plants on Mars is to first land astronauts or robots and build a sealed, oxygenated and warmed greenhouse. With that in place, we can then talk about the growth potential of Martian regolith. Unlike lunar regolith, which is composed of sharp and spiky particles, mostly fractured shrapnel from small and large meteorite collisions, Martian regolith particles have undergone weathering so are smoother and rounder – some components have been shaped by water, from way back when water flowed on the planet, but otherwise the Martian winds have done most of the work.

Speaking of the winds, there also some exchange between Martian regolith and Martian dust, where dust may stay aloft in the atmosphere for long periods, remembering that although the atmosphere is less dense than Earth, there’s also less gravity. There’s always some dust in the atmosphere, which is what makes the Martian sky red, but also when dust storms arise during Martian spring and summer, because there’s more gas from polar ice melts and more energy from solar heating, what might otherwise be considered regolith becomes dust lofted upwards for a temporary period. And this cycling of regolith to dust to regolith also adds to the weathering.

But anyway, once the regolith is back on the ground and in a greenhouse, could we actually grow Earth plants in it? Well, not easily. Our landers and rovers have found a lot of perchlorate in soil samples. Although we have only tested a few sites, its consistent finding at all those sites suggests it may be a planet-wide phenomenon. And unfortunately perchlorate, is pretty toxic stuff, not only to plants but also to people. So, while you might be able to grow some slow-growing perchlorate-resistant plants, they will still absorb that perchlorate so you couldn’t eat them anyway.

Optimists have suggested we could first seed the land with bacteria that can metabolise perchlorates, which might work if those bacteria didn't need water and weren't bothered by the high UV radiation on the Martian surface. Unfortunately, neither of those things are true. And sure you could bring the soil into a protected environment and grow the bacteria there – but if you are going to go to that sort of trouble you might as well just build a processing plant and chemically leach the perchlorate out. Indeed if you are going to go to that sort of trouble, you might consider it would be a whole lot easier just to grow everything hydroponically.

So, as always, anything is possible, but whether it's worth it, economically or existentially, remains to be seen. If we ever do decide it's really worthwhile to colonise such a harsh environment as Mars, then we yes could have industrial scale greenhouses and industrial scale soil leaching refineries. Then we could add organic nutrients in the usual way – which is the one part of all this that might be cheap. On the bright side the leached perchlorates could be converted into oxygen and rocket fuel, so at least you can take some holidays from your smelly old greenhouse – probably to somewhere that isn't red.