Question 1:

Dear Cheap Astronomy – What's the best solution to generate artificial gravity for long-duration space travel?

The best, indeed the only current, solution to generate artificial gravity is to spin the part of your spacecraft that contains the crew. But to identify the ideal combination of engineering parameters such as spin rate, spin radius and the size of the spinning cabin you really want to build a combined medical and engineering laboratory in microgravity, so you can trial all the possibilities. Until that happens we are mostly limited to hypothetical considerations. Fortunately, here at Cheap Astronomy, hypothetical considerations are pretty much what we do.

The general principle behind generating artificial gravity through rotation can be demonstrated on Earth by filling a bucket of water and swinging the bucket around in a circle. Providing you spin it fast enough, even when the bucket is upside down the water doesn't fall out, because the centrifugal force generated by the spin overcomes Earth's gravitation and the water stays in the bucket.

This brings us to the first rule of generating artificial gravity by rotation – you don't want to generate more than 1G at the maximum diameter of rotation or your blood may do what that water in the bucket does. Assuming you are standing with your feet towards the maximum diameter of rotation, which might be the hull of your spacecraft, if you experience much more than 1G will make your blood drain from your head to your feet. A trained fighter pilot can manage up to 9G for short periods before blacking out, but the rest of us would probably black out before we got to 6G.

However, if there is just 1G generated at the maximum diameter of rotation, then blacking out won't be an issue. On the Discovery One spacecraft in the movie 2001 we see astronaut Bowman running laps around its circumference, able to do so by virtue of its spin which generates a radially-directed artificial gravity upon him. This fictional spacecraft was about 16 metres in diameter, so by spinning at about 10 times a minute, it could generate 1 G at Bowman's feet, although his head would only be experiencing only about .75G. Potentially this would confuse his vestibular system, a system within each of your inner ears which helps you know how your body is orientated. Being used to Earth conditions, where the G force at your feet is almost identical to the G force at your head, your vestibular system can tell your feet how to compensate for any acceleratory forces your head is experiencing. But on a 16 metre diameter rotating spacecraft your feet would not be experiencing the same acceleratory forces as your head and so a flailing stumble might eventuate. And if you bent over to pick something up from the floor there'd be a sudden rush of blood to your head. And of course, there's also a problem where if astronaut Bowman runs counter to the spin direction, then he's reducing the angular acceleration, the G force, acting on his body. So, if he ran fast enough, counter to the spacecraft's spin he would eventually lift off the floor.

For these reasons, an ideal artificial gravity environment is generally thought to be a 100 metre spin radius which would ensure the 1G force at your feet is about the same as at your head and the linear speed of the floor is so fast that running in either direction would make no real difference to your net angular acceleration. Nonetheless, it is possible that our sensory and physiological systems could adapt to the smaller Discovery One environment and we could get by just by moving around a bit carefully. Again, until we properly test what's physically and physiologically possible, we just don't know.

All that said, we have actually tested something, at least on a small scale in a short timeframe. A centrifuge designed to spin humans and assess their vestibular responses flew aboard the Space Shuttle Neurolab mission, STS-90, in 1998. This experiment was the first and only proper in-flight evaluation of the effect of artificial gravity on astronauts. The results suggested that a centrifugal force of 0.5 G and 1 G generated for 20 minutes every other day during a 16-day space mission was able to reduce the cardiovascular deconditioning that's commonly seen in zero G spaceflight. So maybe we don't have to spin spacecraft after all, we could just take a human-rated centrifuge along for the ride. But again without testing this properly we just don't know. So, want to land on Mars in the 2030s? Start testing now.

Question 2:

Dear Cheap Astronomy – What is the smell of space?

It's now widely acknowledged that after astronauts have closed the airlock and pulled their helmets off, they experience a faint whiff of something. Whether it's the faint whiff of what space really smells like or just the smell of more earthly materials being rapidly reintroduced to an oxygenated atmosphere is yet to be decided. Being Cheap Astronomy you can probably guess where we sit on this debate spectrum.

Let's start by suggesting that if determining the smell of space had the faintest inkling of economic or scientific significance we would have already positioned some chemical sensors around the astronauts heads, just as they were removing their helmets, to capture some objective data on this phenomenon. The fact that no-one's ever bothered doing this does suggest NASA and other global space agencies don't see a lot of value in confirming that space is an almost-vacuum so whatever astronauts are smelling is mostly about a re-pressurized airlock.

If we did want to investigate the human experience of smelling an almost vacuum we'd have to expose human subjects to an almost vacuum and ask them to take a slow and considered sniff. Unfortunately, those subjects may be too distracted by their sudden inability to breathe to be able collect any useful data – and alas modern-day research ethics committees tend to frown on such experiments anyway.

We also have to acknowledge the possibility of confirmation bias. If Neil Armstrong and Buzz Aldrin reported smelling something, then every astronaut after them is likely to report that heck yeah we smelt something too, since the world's two most iconic astronauts did. This is not to say that Neil and Buzz, or any other astronauts, were wrong about there being a smell, it's just that the apparently common smell reported by everyone might not be quite as common as is assumed.

Neil and Buzz in closing the Eagle's airlock not only brought the almost vacuum lunar atmosphere inside, but also some lunar regolith which apparently smells a bit like gun powder. Subsequent Apollo mission explorers would have bought in a lot more lunar regolith after days of touring around in the lunar rover. Also, Apollo astronauts would have returned to low pressure 100% oxygen atmosphere in the lunar module, while ISS astronauts return to one atmosphere of pressure with a 21% oxygen content. So, it seems unlikely that all astronauts really experience precisely the same smell. In any case, when anything that's been sitting in a cold empty vacuum is suddenly exposed to a warm pressurized atmosphere containing oxygen some degree of ionization and oxygenation will take place on its surfaces – chemical processes which are likely to elicit odors reminiscent of something burnt or of something metallic. So, it seems less likely that astronauts are really smelling space and much more likely they are smelling chemical reactions taking place on the surfaces of their suits or within the airlock itself as various materials are rapidly shifted from an almost vacuum to a breathable atmosphere.

Again all this could be easily confirmed through scientific investigation. The first question to answer is whether our sense of smell is acute enough to detect the few scant atoms and molecules that are present in the almost vacuum of space – and whether we could genuinely distinguish those few scant components from within the dense breathable atmosphere that refills an airlock. We could easily undertake a chemical analysis of a sample recently refilled airlock air, looking for signs of any new components or any new chemistry, which may or may not be in the range of human sensitivity.

Or why not just experiment on us Earth-bound mortals using a method the research ethics committee would agree to – ask people to sniff an Earth-bound airlock after it's been evacuated and refilled – and maybe even put an unflown space suit in there after it's been sitting out in the Sun for a while. If those people report the faint whiff of burnt steak or of something metallic then it's clearly not outer space that they're whiffing.