Science & technology 2021

To Edit a Planet

Introductory Questions (Xavier and Stav)

- **What would a perfect Earth look like?**
    - What a way to start the curriculum! A deeply philosophical question that doesn't have a concrete answer! However, I think that all humans (or at least most of them) can agree on the fact that a 'perfect Earth' would be one in which every person and animal has the resources they need to live safe, happy lives without the threat of danger, whilst also providing as little damage to the planet as possible.
- **What is the ideal climate for the Earth?**
    - The ideal climate for the Earth is very different to the ideal climate for humanity. Humans have evolved to only live at specific temperatures, and though we do live in places which are incredibly hot or incredibly cold (looking at you Oymyakon), many parts of the Earth would be uninhabitable. Technology made it possible for humans to survive in the sort of weather that we are not made for. The optimal temperature for humans is agreed to be about 27°C with a tropical climate. The reason is that this is the temperatures that allowed humans to evolve in the first place. However, the optimal climate for the Earth is its natural climate, as if it was undisturbed by humanity. You could argue that the ideal climate for the Earth would be one with the highest possible amounts of biodiversity, but this isn't really possible without huge amounts of terraforming. The necessary temperatures for life to exist on Earth are not yet clearly defined (because of the numerous exceptions which include tardigrades). However, we do know that the window for life on Earth is incredibly slim.
- **Do we have a responsibility to restore the Earth to what it was like before humans began to change it?**
    - Once again, another very difficult question. Humans cannot coexist with the Earth without altering it in some way, so I feel that it is impossible for us to restore the Earth to its original state, as we will simply destroy it again. What we should do is try and reduce the negative impacts that we have on the Earth so that we can coexist with it. On the other hand, it is important to think about what it means to "restore" Earth to its original state. When did humans "begin" changing the planet? The first hunt or perhaps the first fire? The easiest answer is after a major ice age, and this is not what we first think of when we say

"restoring" the planet. What we surely have a responsibility to do is to control to the best of our ability that the planet is most habitable and safest to all its habitants (humans, animals, plants etc).

- **Many philosophers have distinguished between the natural and the good. When it comes to the Earth, should we make such a distinction?**
    - This is giving humans a ridiculous amount of power, as our 'good' is very different to what 'the Earth' would consider 'good'. Humanity would consider 'good' to be things that would benefit us as a species, whilst the Earth would consider the preservation of itself to be 'good' (assuming that the Earth could be sentient). I think that the distinction must be made, so that we are able to recognise that we must change our ways to prevent climate change, by eliminating some 'good' to assist the natural.
- **When, if ever, is it okay for humans to change the weather?**
    - We have already begun to change the weather. The most common form of this is cloud seeding, used to increase the amounts of rain or snow within a region. The only reason that we have recently begun to change the weather is because we need to for our own survival, and it will only get more drastic in the future. However, we have also changed the weather through climate change, such as how it's increasing rates of rainfall. The question of whether we should be changing the weather is one you must decide for yourself, but with the way our planet is going, it seems very likely we will have to.
- **When, if ever, is it okay for humans to change the physical landscape?**
    - Due to how we inhabit the Earth, it is impossible for us to not change the physical landscape without living incredibly nomadic lifestyles. Personally, I believe that it is okay to change the physical landscape of the Earth, provided that it does not provide negative impacts on the Earth itself. Additionally, anything that ever touched the Earth changed it and contributed to its story. The landscape of Earth is not a painting in a museum, but more of a statue in the making. However, it is important that by changing the landscape we do not destroy it or forget what was there beforehand. Where do we draw the line? That is a great question with no universal solution; a paradox in the making.
- **If technology is used to preserve something natural, is it still natural?**
    - I would argue that it is natural if it is preserving, rather than recreating, as we are simply assisting what is natural to try and keep it in a natural state. The use of technology for preservation is absolutely fine, as long as nature itself doesn't begin to depend on technology.
- **Do we owe future generations an Earth similar to the one we live in today? Or does every generation need to make the best of the planet it inherits?**
    - We would hope that our parents would attempt to preserve the Earth for us, and so we must do the same for our children. Due to the fact that Climate Change is irreversible if we do not take action within the next 8 - 10 years, the next generation may not have a planet to make the most of.
- **Is changing the climate equally bad if it is done by accident or on purpose? Is it necessarily bad in the first place?**

    - What we must realise is that we can change the climate in a positive or a negative way. If we are changing the climate in a positive way (e.g. reversing the effects of climate change) it is better to do so purposefully, as it may inspire others to do the same. The inverse is true if we change the climate in a negative way. Changing the climate by accident does not do as much harm in the long term, however each generation must be held accountable regardless if the change happened accidentally or purposefully.
- **If we discover a planet just like the Earth but with no people on it, would it be all right to colonize it?**
    - When the Europeans began to colonise the world, they often considered the inhabitants to be inhuman or subhuman, due to their cultural beliefs. If we encounter planets filled with life that isn't human, and decide to colonise it, we are simply repeating the mistakes of the past. Proceed with caution.
- **If we discover a planet that is not Earth-like but we can use technology to terraform it so that we can live there, would it be all right to do so?**
    - We have, over a long period of time, altered our own planet to make it inhabitable for us through using land to graze crops and similar activities. Terraforming a non-Earth-like planet is the same, but on a much larger scale. The question that we must ask is how will terraforming impact the planet as a whole. Again, it is fine as long as the history of that planet is not wiped out. Planets are more like a masterpiece in the making than a finished artwork in a museum.
- **Do your answers to the above questions depend on whether these planets have life on them? If so, does it matter whether that life is intelligent?**
    - The answers to these questions do depend on whether these planets have life on them. Destroying / altering a planet's ecosystem after the damage we have caused to our own would be a terrible thing to do. Instead, whether the life is intelligent or not, I think it would be much more important to study it and see what we could learn. It also depends on the lifespan of the evolution of the species on the planet. Let me explain: certain species have developed to the point that evolution has specified the species too much. A notable example of this is pandas, as if areas such as bamboo forests were destroyed, they would struggle to survive. The same may be true for some alien species.
- **Suppose we were to discover a vast new empty island on the Earth. Would your answer be the same for the island as they were for another planet?**
    - I think that our answers would change if the issue appeared on Earth due to the issue of proximity. If it is close to us and we can easily use it with little effort, then humanity likely would not dependent on whether there was life on it or not. The island would still be impacted by the decisions of the other nations regarding climate, so it may be more ideal if this empty island was on another planet, as we could then try and protect the rest of that planet whilst using the island.
- **Would the world be better with more technology or with less**
    - If we removed technology, we would be getting rid of many controversial things (such as TikTok), but to improve the world, we need more technology. To solve many of the problems caused by technology, we now require new technology, and so we must build on

the mistakes of the past to create solutions for the future. Simply removing these problem technologies is not enough, as the issues will persist. For example, even if we completely stopped producing Carbon Dioxide and all greenhouse gases today, the temperature would continue to rise. Therefore, we need technology to help us in the future.

This is an unexpectedly deeply philosophical debate. Technology, in short, is progress that our species has created: progress that is not objectively good or bad, but rather a sign of greater control and power from humans. The real question, are we trusted to run the world for the sake of the good?

If It's Broke, Fix It: Geoengineering (Xavier)

- **The Earth is warming rapidly; human activity is responsible. Consequences will include rising sea levels, extreme weather phenomena, and mass extinctions.**
- **As it becomes clear that we can't stop global climate change in time to prevent all of these consequences–at best we can slow it down–the idea that we need to take active measures to mitigate (or even reverse) climate change has grown more mainstream**
    - **This podcast is a good introduction to the scientific principles and controversies related to this new field of geoengineering. There are many other sources available to research online, though nearly all reflect significant bias for or against geoengineering, in part or in full. Discuss with your team: do scientists have a responsibility to remain unbiased? How about policymakers?**
        - Firstly, what is geoengineering? Geoengineering involves large scale efforts to change the Earth in an attempt to decouple the effect of carbon emissions on our climate. In other words, it tries to make carbon emissions not affect the climate as drastically. I would recommend that you listen to this podcast, as it covers a lot of interesting information hard to condense onto this website.
        - Scientists definitely have a responsibility to remain unbiased, as science aims to explain and understand. If the analysis that scientists provides contains aspects of a specific opinion or belief without explicitly stating so, then it is not a completely unbiased explanation. However, it can be difficult for scientists to remain unbiased, as they sometimes prefer the explanation that is able to receive the most funding for research or the one they have researched the most. In contrast, policymakers do not have a responsibility to remain unbiased, as they represent the people who elected them. We would hope that these policymakers would consider the facts before making decisions.
- **One main branch of geoengineering focuses on removing carbon dioxide from the atmosphere. Consider this overview of different CO2-removal strategies in the context of who will "govern" their implementation. Discuss with your team: who should be in charge of such geoengineering efforts? If a country independently begins building facilities to remove carbon dioxide from the atmosphere, should it be stopped—and, if so, by whom?**
    - Within this document are a range of geoengineering efforts to remove CO2 from the atmosphere, and the challenges that accompany them. These efforts range from planting

more trees (#TeamTrees) to fertilising oceans and even capturing CO2 from the air using chemical processes (I would recommend that you read through them all).

- Though there are specific issues that each of these strategies may face, the general issues faced include land use, scalability, a lack of incentives to adopt the strategies and of course, governance. For this to work, the above study recommends governance on every level, from local to international. I believe that you need international governance for CO2 removal to be successful in a successful and ethical way. Of course, this will require cooperation at national, regional and local levels for it to work.
- If a country decides they want to build some of these commercially available CDR technologies, there is no reason why it should be stopped, as long as it is done so in an ethical manner, as it would assist the whole world. In fact, the economic benefits that nations may gain by removing CO2 from the atmosphere may incentivise other nations to begin using CDR technology as well. The only reason that intervention should occur is if the country is disadvantage workers or is removing CO2 from their economy and releasing it in others (as CO2 can be transported once removed from the air).

- **Be sure to research the following terms and concepts related to carbon dioxide removal:**
  - **carbon sequestration | land use management | biochar | biomass**
    - **Carbon Sequestration:** Carbon Dioxide is incredibly harmful to the planet due to its property to trap heat in the atmosphere. Carbon Sequestration attempts to solve this by capturing and storing carbon. This process occurs naturally in plants (#TeamTrees), soils and the ocean, with large areas of this captured CO2 being known as a Carbon Sink (basically underground). By storing this carbon, it prevents it from entering the atmosphere and trapping heat.
    - **Land Use Management:** Though generally, this means managing the land and the resources on it in whichever way individuals and governments determine to be necessary, in the context of carbon dioxide removal, land use management can include reforestation (restoring forests), afforestation (converting non-forested land to forest) and optimising forestry and agricultural practices (truly riveting).
    - **Biochar:** Biochar is a form of charcoal that is created by burning biomass with little access to Oxygen in a process known as pyrolisation. It is able to sequester (store) a large amount of Carbon from the biomass, which would normally be released as greenhouse gasses if the biomass was simply burnt. Biochar also is able to improve water quality, soil fertility, agricultural production, making them incredibly useful!
    - **Biomass:** Biomass is a plant or animal material that is used for energy production. The most common of these are forms of wood, but it also includes many crops, food processing and manure. Biomass has been defined as Carbon Neutral by the UN and EU, as the energy released by burning it is equivalent to the amount that it is able to absorb when replanted. This has generated some controversy in the scientific community, as though all biomass crops are able to sequester carbon, they may not be carbon neutral depending on changes in land use, such as deforestation.
- **enhanced weathering | carbon dioxide capture | ocean fertilization**

    - **Enhanced Weathering:** The natural process of weathering begins by silicate and carbonate minerals dissolving in rainwater, absorbing CO2 as they form bicarbonate ions. These then end up in the ocean and become stable, storing a higher amount of CO2 than they release. Weathering is currently responsible for storing 0.3% of CO2. Enhanced Weathering involves doing weathering on a much larger scale. Terrestrial Enhanced Weathering involves dispersing silicate minerals on land, likely in areas of crop production, in high amounts. This speeds up the reaction and results in high levels of CO2 absorption whilst also acting as a fertiliser and increasing crop production. Oceanic Enhanced Weathering is a much more direct approach, placing the silicate minerals along coastlines or within the ocean to increase the amount of carbon absorbed, whilst also have the lovely side-effect of decreasing ocean acidity (how convenient!). However, it's unknown how Oceanic Enhanced Weathering would affect the biodiversity and ecosystem of the ocean.
    - **Carbon Dioxide Capture:** This attempts to remove Carbon Dioxide at its sources, most commonly fossil fuel based power plants or other areas which emit high amounts of CO2. The CO2 which is dispersed is then separated from the air, most commonly through carbon scrubbing (also known as absorption) using amines. This CO2 would then be transported by pipeline and to a point where it can be sequestered. The most common suggestions include injecting it into exhausted oil and gas fields or reacted with carbonates (specifically olivine).
    - **Ocean Fertilisation:** Ocean Fertilisation involves dumping Iron Sulphates or other nutrients into the ocean to increase populations of phytoplankton. These plankton will absorb CO2 and then die, storing carbon. However, there have been high amounts of opposition towards this approach, as the impacts of ocean fertilisation are still unknown, as well as the vague laws surrounding it.
- **ocean upwelling | removal of other GHGs**
    - **Ocean Upwelling:** Natural Upwelling occurs when surface winds over the ocean push warm water away from an area. Cool water then rises to fill this area. This cooler water is generally more nutrient rich, and has higher populations of phytoplankton. This process occurs naturally, but in the context of geoengineering, it is suggested that a series of pipes are used to pump cold water up to the surface of the ocean, increasing phytoplankton populations which will then absorb CO2. However, there has been a limited amount of research into this, and it is unknown whether it would be practical or not.
    - **Removal of other GHGs:** Though Carbon Dioxide is one of the most common Greenhouse Gases in the atmosphere, there are many others that we must remove if we wish to reverse climate change. These include Methane, Nitrous Oxide, HCFCs, CFCs and Ozone. The processes range from the relatively normal, such as the reaction of Methane with a byproduct of Ozone's reactions with light, to the fantastical, such as using lasers to break up CFCs. However, the focus remains on removing CO2 from the atmosphere, as it makes up more than 75% of greenhouse gases in the atmosphere.
- **If the less controversial approach to geoengineering focuses on removing carbon from the atmosphere, the other focuses on reducing the amount of sunlight that reaches the Earth.**

Explore these six geoengineering strategies for reducing the warming impact of solar radiation. Discuss with your team: if you had to invest in one of them, which would you select?

- **Aerosol Injection:** If you'd listened to the above podcast (which I would highly recommend) you would have already heard about this geoengineering strategy. It's based off of the idea of volcanoes, and how when they erupt, they release Sulphuric Acid which, when it forms aerosols within the atmosphere, is able to reflect sunlight. By artificially introducing aerosols into the atmosphere, we would be able to induce cooling. This is the most commonly proposed form of solar-geoengineering, as we currently have most of the necessary technology. However, there are still many unknowns, such as the impact of releasing Sulphur into the atmosphere, including acid rain (though no meat showers), and the difficulty of getting the heavy technology necessary to spray it up into the stratosphere.
- **Marine Cloud Brightening:** Clouds are full of water (as we learn in school), but what if we added more? Marine Cloud Brightening suggests this, with it involving ships spraying saltwater into clouds above the sea. This would brighten the clouds and reflect more sunlight, decreasing heat. This could be much more localised than Aerosol Injection, but may have unintended effects on weather patterns if only certain regions are 'brightened'
- **Space Sunshades:** Have you ever looked up at the sun and thought 'I need to go and put my sunglasses on.' That's what scientists believe they should do with space sunshades. This involves placing one large mirror, or multiple small mirrors, into space to reflect sunlight away from Earth. For it to be offset climate change, the mirror would need to reflect back approximately 2% of all sunlight that comes towards Earth. This is the least environmentally disruptive solar geoengineering solution, but is also the most technologically difficult.
- **Cloud Thinning:** Though previously, we said that it was a good idea to increase the reflectivity of the clouds, not all clouds are created equal. Cirrus clouds are thin wispy clouds that actually absorb more energy than they release, and they absorb a lot. Estimates say that the heat trapping effect of cirrus clouds is greater than all human created CO2! Because of this, drones could inject aerosol particles into these clouds, resulting in them dissipating faster. However, if this is done incorrectly, the cirrus clouds could come back thicker, and increase the heat trapping effect.
- **Ocean Mirror:** A less well-known solution, this involves using sea vessels to create tiny microbubbles at the ocean's surface. This sea foam would then reflect sunlight. Though there are major advantages to this, such as the large amount of the Earth's surface covered in water, the main disadvantage is the economic cost in constantly using boats and other sea vessels to create these microbubbles and have them remain there, with large amounts of energy being required.
- **High-albedo Crops and Buildings:** Albedo is a measure of how reflective a surface is of light without the light being absorbed. The highest albedo colour is white, so basically this involves painting buildings white. Whilst it would have limited use in cities, as many buildings are already white, the main amount of reflectivity would come from genetically

engineering plants to be more reflective, either in colour or due to a waxy consistency. Though they may be less appealing to eat, it might be worth it to save the planet.

- If I had to invest in one of these technologies, I would likely invest in either high-albedo crops and buildings or aerosol injection, as they seem to be the ones with the most research behind them, and would be the most likely to attract funding and become a reality. I have to admit though, a giant mirror in space would be pretty awesome.

- **Be sure to research the following terms and concepts related to sunlight management:**
  - **solar radiation | albedo | ice-albedo feedback | radiative forcing**
    - **Solar Radiation:** Radiant energy emitted by the sun comes from a nuclear fusion reaction. Approximately half of this energy is visible, shortwave light whilst the other half is infrared/ultraviolet. This energy heats up the Earth.
    - **Albedo:** Have you ever touched a black car on a hot day and found that it was much warmer than you expected? That's because of albedo. Albedo is a measure of how much light that hits a surface is reflected rather than absorbed. Darker colours (such as black) have a low albedo, meaning that they reflect less light and absorb most of it, whilst lighter colours (such as white) have a high albedo, and reflect more light and absorb less.
    - **Ice-albedo feedback:** Ice-albedo feedback is what we call a positive feedback loop, which means that effect A creates more of effect B and consequently B creates more of A and so on. Ice-albedo feedback follows the same cycle. Existing ice reflects light coming from the sun, which prevents it from getting absorbed by the Earth. When ice melts, the total surface area of ice decreases, which means there is less ice to reflect sunlight and therefore more sunlight is absorbed by the earth. This warms up the Earth even more and causes more ice to melt. Ice-albedo feedback is a phenomenon that has a severe effect on global warming and dramatically accelerates the melting of ice caps, glaciers and sea ice.
    - **Radiative Forcing:** Radiative Forcing is the difference between the solar energy absorbed by the Earth and the energy radiated back into space. Changes to this result in changes to the temperature of the Earth. It's caused by varying amounts of, you guessed it, greenhouse gases!
  - **marine cloud brightening | desert reflectors | cool roof | sunshield**
    - **Marine Cloud Brightening:** A process by which the albedo of clouds is increased by spraying salt water particles into low lying clouds above oceans, increasing their reflectivity. This solar-geoengineering strategy was first proposed by John Latham in 1990.
    - **Desert Reflectors:** Not to be confused with Dessert Reflectors, a new dieting program, desert reflectors were theorised by Takyuki Toyama and Alan Stainer, and at first glance seem absolutely crazy. The idea involves placing 60,000 square kilometres worth of mirrors, or some form of reflective sheet on the surface of the Earth. This area is equivalent to the size of Sri Lanka! The estimated cost would be a mere $280 billion, a much lower amount than the proposed amounts to reverse climate change.

        - **Cool Roof:** A cool roof is a roof on a building that is designed to reflect more sunlight and absorb less heat than a regular roof, due to having a lower albedo. They can be made by using a reflective paint, a sheet covering or reflective tiles. The coolest possible roof is one made of stainless steel, but costs result in this not being very common.
        - **Sunshield:** The Sunshield is a component of the James Webb Space Telescope that shields the main optics from the Sun's heat and light, allowing it to take photos of far away stars and galaxies without interference, as the heat signals of these far away stars / galaxies are incredibly low. There are five layers of the sunshield, with each being the size of a tennis court whilst also being as thin as a human hair. The sunshield is made out of Kapton, with each layer being coated in aluminium.
    - **stratospheric aerosols | Mt. Pinatubo | Arctic methane release**
        - **Stratospheric Aerosols:** Stratospheric Aerosols are a collection of particles suspended in the stratosphere. When talking about Stratospheric Aerosols, the most common one is Sulphuric Acid. One proposed use of Stratospheric Aerosols is to inject high amounts of them into the atmosphere, reflecting the Sun's rays and decreasing the amount of energy absorbed by the Earth.
        - **Mt. Pinatubo:** In 1991, one of the largest volcanic eruptions of the 20th Century occurred in the Zambales Mountains, a mountain range bordering the provinces: Zambales, Tarlac, and Pampanga. On June 15th, 5 cubic kilometres of ash and sulphuric acid haze was ejected into the atmosphere, reaching up to 35km high. Due to the high amount of ash ejected, 10% less sunlight hit the Earth's surface, decreasing global temperatures by 0.4OC, showing that Stratospheric Aerosols can decrease global temperature.
        - **Arctic Methane Release:** The Arctic region is a store of a lot of the world's methane, through natural gas deposits, permafrost and solid compounds. However, as the Arctic melts, much of this stored methane is released, increasing the amount of Greenhouse Gasses in the atmosphere and making the effects of climate change even worse.
- **When exploring methods of geoengineering, be sure to consider:**
    - **effectiveness | time scale | externalities | costs**
        - **Effectiveness:** With the rapid pace of climate change, less effective solutions simply make less impact, and therefore have less benefit.
        - **Time Scale:** Climate Change is rapid and ever increasing, and so we have a rather short time scale. Geoengineering solutions which may take 100 years to research and gradually decrease the effects of climate change may be less desirable than those which only take 15 years to enact.
        - **Externalities:** Defined as "A consequence of an industrial or commercial activity which affects other parties without this being reflected in market prices." Basically, the unforeseen effects of something which is not reflected by economic impact. For example, an externality of burning fossil fuels for power is climate change. There

may be externalities of many geoengineering solutions, and more research is required in an attempt to determine them.
        - **Costs:** Even though climate change is a life threatening event, money must still be considered, as governments only have so much funding they can provide towards it. More expensive solutions, though they may be more effective and have less impact on the environment, might be vetoed by governments in favour of cheaper solutions.
    - **trade-offs | termination effect | reversibility | encapsulation**
        - **Trade-Offs:** A trade off is where you give up one thing that you desire in order to receive another desirable thing. Within the context of geoengineering, this may be decreasing cost to increase effectiveness, or decreasing time scale whilst also decreasing the reversibility.
        - **Termination Effect:** This is the risk of the geoengineering solution suddenly stopped working. For example, if we had used Aerosol Injection but continued to release CO2 into the atmosphere, if we were unable to continue distributing Sulfuric Acid particles into the atmosphere, then the global temperature would rise at an incredibly rapid rate. Decreasing the termination effect is essential so that we do not become dependent on a geoengineering solution.
        - **Reversibility:** The ability for a solution to be reversed. Most geoengineering solutions are reversible, but that's not necessarily a good thing, as that means that anti climate-change terrorists or those who are against using geoengineering may be able to stop the deployment of the geoengineering solutions and reverse its effects.
        - **Encapsulation:** To encapsulate something means to enclose it, so encapsulation (in the context of geoengineering) means whether it will enclose around, or affect the entire world. Certain geoengineering solutions will only affect a certain area of the globe, such as high-albedo crops and buildings whilst solutions such as aerosol injection will have a global effect. Some nations may not wish to carry out geoengineering or have it affect them, and would therefore be opposed to any encapsulative geoengineering.
- **One common criticism of geoengineering is that, if people believe new technologies could "solve" climate change, they will lose the political will to reduce carbon emissions and take other preventative measures. Some refer to this problem as "moral hazard". Discuss with your team: do you think people would react in this way? If so, should we stop research into geoengineering, or would the solution be for governments to implement it secretly?**
    - I personally do not believe that this would occur. Most people who have the political will to reduce carbon emissions would also believe in geoengineering, as they understand the severe impacts that climate change will have on the planet and will be willing to take actions to prevent a rise in temperature. However, there would likely be three groups of people who are against geoengineering; climate change deniers, conspiracy theorists and those who believe we should not alter the earth. If any of these groups negatively reacted against governments, the solution would not be to stop research, nor would it be for

governments to implement it secretly (conspiracy theorists would have a field day). Instead, we would need to persuade these individuals that geoengineering is necessary through science education.

- **Suppose a geoengineer came to you with the perfect technology for adjusting the climate of the Earth: it could create any climate desired with zero side effects. Discuss with your team: what would you do with this power? Would you look to restore the climate from a certain point in the past—and, if so, what point?**
    - The ideal climate, as discussed in the introductory questions, is not a question that we can easily answer. However, I (as would many climate change protesters) would restore the climate to pre-industrial revolution levels, as having a second chance would be rather nice (though it would be rather entertaining to take us back to the Ice Age).
- **Will Antarctica become habitable in the near future? If so, who should decide who lives there? Discuss with your team: should nations threatened by rising sea levels be given Antarctic territory for relocation?**
    - Currently, the primary reason that Antarctica is uninhabitable due to our inability to grow food there, which is caused by both its lack of precipitation and incredibly cold temperatures. However, climate change could both increase precipitation and temperature, resulting in Antarctica becoming inhabitable for humans! If we did decide to allow humans to live there, the obvious group to decide would be the United Nations. However, the purpose of Antarctica, as written in the Antarctic Treaty is to be 'a scientific preserve.' Even if Antarctica did become inhabitable, there would still be incredible research that could be done in this undisturbed territory. However, those nations with high populations of climate refugees may have no place else to go, and so the Antarctic Treaty may have to be amended to allow those individuals a new home.
- **While geoengineering aims to tackle issues that impact the world on a large scale, there are other technologies that also aim to affect the environment, but on a smaller level. If had the power to change one thing about the climate of your city, what would you change to make it more comfortable or habitable? Are there changes you would make to the landscape?**
    - My city (Christchurch) is luckily very inhabitable and comfortable. However, I know that many others are not. If I could change the climate of one of these cities, I would increase the rain level in a city experiencing heavy amounts of smog, as it would assist in washing out water-soluble pollutants and particulate matter. One change I would definitely make to the landscape of my city however, is raising it up. As a relatively coastal city, many inhabitants are threatened by rising sea levels, and so by raising us further above sea level, we can decrease the risk that they will lose their homes.
- **Explore the following techniques used to manipulate, take advantage of, or otherwise utilize elements of the environment in a "non-natural" way. How well do these methods work? What are the arguments against using them more often?**
    - **cloud seeding (glaciogenic and hygroscopic) | fog harps**
        - **Cloud Seeding (glaciogenic and hygroscopic):** Cloud Seeding changes the amount or form of precipitation that falls from clouds by dispersing substances into

the clouds themselves. The two forms of cloud seeding are glaciogenic cloud seeding and hygroscopic cloud seeding. Hygroscopic cloud seeding involves dispersing water drawing particles, such as forms of salt, into low-lying, warmer clouds. This results in water droplets condensing and swelling, increasing the weight of the clouds and resulting in rain. Glaciogenic cloud seeding is carried out on colder clouds, with the particles instead acting as points around which ice can accumulate, causing snow. There is currently no definite proof that cloud seeding works, and if it does the effects are negligible. The main arguments against cloud seeding include its high expense, the negative effects that the particulates used often have and the lack of research into the field.

    - **Fog Harps:** Fog is simply a large collection of water droplets, and so when fog passes over regions, fog collectors are often used to collect this water. However, these are highly ineffective, collecting only about 3 litres per square meter of mesh, 1% - 3% of the possible amount. Enter the fog harp, an improvement on the design which removed the horizontal lines of the mesh, only having vertical wires. This is because the horizontal wires prevented the water from dripping down, eventually clogging up the collector and causing the fog to flow around. Fog Harps, though currently only in a prototype phase, are able to collect up to 9 litres per square meter of mesh, a 3x improvement over a traditional fog collector.
- **bioprecipitation | cloudbuster | hail cannon**
    - **Bioprecipitation:** This is the nucleation of ice in bacteria in clouds, causing rain / snow. Basically, ice particles form around bacteria within clouds, which is then dispersed through rain / snow. These biological nuclei are capable of allowing freezing at much warmer temperatures than cloud seeding provides, allowing snow at warmer temperatures. However, these bacteria can cause freezing injury and frost to plants if they come in contact with them, resulting in these bacteria damaging crops.
    - **Cloudbuster:** This device, designed by Wilhelm Reich (a psychoanalyst) in 1877 could supposedly cause rain by manipulating ‘Orgone Energy’ present in the atmosphere. The cloudbuster was made of a series of parallel metal pipe, followed by a collection of flexible metal tubes coming out of each one that were then placed into a pool of water, as it was a ‘natural orgone absorber’. This supposedly acted as a lightning rod, drawing the water to the ground when it was pointed at clouds. There has been no proof that this energy actually exists, or that the device worked in any way, so take Reich’s findings with a grain of salt.
    - **Hail Cannon:** If there’s one form of weather that farmers find annoying, it’s hail, as hail destroys the crops that they’ve been growing. Therefore, someone began to manufacture hail cannons. These are large metal cones that create shockwaves every 1 - 10 seconds, supposedly turning the forming hailstones within a 100m square around the cone into rain / slush. However, there has been no proof that Hail Cannons actually work, as thunder provides a much larger shockwave yet doesn’t

destroy hail. It seems that the only use of a hail cannon is to annoy nearby neighbours.

- **The ability to modify the weather isn't just coveted by climatologists and policy-makers—it has also found military applications. Look into the tenets of the UN's Environmental Modification Convention and discuss with your team: why was this treaty written in the first place? What risk (if any) is posed by countries not signing it?**
    - From 1967 - 1972, the U.S. military attempted to extend the monsoon season in Vietnam, a nation it was currently at war with, to cause damage to their supply trails through flooding. How did they aim to do this? Cloud seeding. The task force, codenamed Operation Popeye / Operation Motorpool, flew over 2000 runs throughout the five year programme. There is no proof, however, that this ever worked. This then caused the formation of the UN Environmental Modification Convention in 1977, which bans nations who have signed or acceded to it from modifying the dynamics, composition or structure of the Earth for military purposes. Countries that have not signed it definitely pose a military risk, as if they were able to develop technologies that could create hurricanes, or manipulate tsunamis, or cause droughts, they could cause more damage than any army.

House Hunters 3000: A User's Guide to Settling the Stars (Xavier and Stav)

- **You can't get there from here. One argument against colonizing other planets that it would be very difficult for humans to reach them. Look into the following forms of faster-than-light (FTL) travel found in science fiction. Are any of them at all plausible in the real world?**
    - **FTL | hyperspace | warp speed | wormholes**
        - **FTL:** Faster-than-light (FTL) travel is the diffusion of matter faster than the speed of light. According to Einstein's special relativity theory, only particles with a mass of 0 may travel at the speed of light. Particles with a larger mass may not reach this speed. Thus, FTL travel is a purely fictional concept unless scientists effectively debunk Einstein's theories. Despite this, there have been theories of particles named Tachyons that exceed the speed of light, but they seem highly improbable. If faster-than-light speed travel does exist, it has to be what physicists call "apparent" FTL travel, which is based on the idea that some contorted regions of space might permit matter to travel faster than light could in "normal" circumstances. The theory of "apparent" FTLs can be co-existent with Einstein's theories. Commuting on planet Earth is slow enough, so many tend to think that even if we find a habitable planet, reaching and colonising it would take too long for it to be worth it. It took 3 days and 4 hours for Apollo 11 to reach the moon. A trip to mars would take 150 - 300 days! In contrast, paying a visit to Pluto would take 9.5 years… By this scale, traveling outside our solar system would probably last longer than a lifetime and even colonising another planet seems impossible with today's technologies. If scientists will be able to develop spaceships that come close to traveling at the speed of light, the challenge of colonising a faraway planet seems more achievable.

However, FTL goes faster than the speed of light, so that raises another question: Why would we potentially need to be able to travel at a faster-than-light speed? In order to understand why, we need to put the speed of light in perspective. When we think of the speed of light, we think it as something instant and unnoticeable, almost like teleportation of light. In reality, it takes 7 minutes from light to travel from the Sun to the Earth, this time is not nothing. When we look at how big and wide the known universe is, the speed of light just does not seem fast enough (hence the unit "light year", a unit used to describe how far away planets are from each other).

A habitable planet, as seen before, has a very strict set of rules in order to exist (even though we do not know to what extent yet…), so it is highly unlikely we have a habitable planet close to us in under a light year. Suddenly, the speed of light seems too slow for the imagination and certainly slower when we look at the bigger picture.

- **Hyperspace:** As the name suggests, hyperspace is the concept of going above four dimensions of the universe where the laws of general and special relativity do not apply. Because of these special properties, matter in hyperspace can travel faster than the speed of light. As hyperspace is not directly a transportation method, the authors has to then find a way to utilise this area of the cosmos, such as wormholes, warp drive, and others as we will see later on. Hyperspace is a very popular way among science fiction writers to explain why spaceships (and other weird forms of transportation found in science fiction) can exceed the speed of light. Famous writers such as John Campbell, Arthur C. Clarke and Isaac Asimov have used this concept in their stories. Even Michio Kaku has written a book called Hyperspace, which you can read here.
- **Warp Speed:** Star Trek, here we go again! Within the Star Trek universe, warp speed works by bringing matter and antimatter into collision. This reaction allows for spaceships to travel faster than the speed of light. Such a strong reaction is regulated by a scarce mineral called dilithium, which is really just two lithium atoms bonded to form this super molecule which cannot be replicated. The motor which allows a spacecraft to travel at warp speed is called a warp core, and is where all the reactions take place. What is special about warp speed in contrast to other impossible travel systems is that it has a measurable, limited speed. In contrast to hyperspace, warp speed is possible in the "normal" side of the universe, which makes it possible to go above the speed of light under Einstein's laws. In order to do that, space is "warped up" to conform to the spaceship using FTL travel as shown below. Warp speed could not be entirely fantasy, however, as NASA is working on a project with the same idea of warping space named the Alcubierre Warp Drive.

- **Wormholes:** Also known as Einstein-Rosen Bridges, these are a theoretical method of FTL travel that doesn't break Special Relativity. Imagine if the universe was a flat piece of paper, and there were two dots on it. One of these dots represents Earth, whilst the other represents a solar system light-years away from us. Normally, this would take decades of travel, even if we had technology that could travel near the speed of light. However, the idea of a wormhole is that we fold the piece of paper over so that the two points touch, allowing you to travel through a wormhole connecting the two points. This only appears to be faster than light travel (assuming that the distance through the wormhole is less than the distance if you directly travelled there), but you are not travelling at a speed faster than light, as you're simply finding a shortcut. Wormholes have been used in books, such as 'A Wrinkle in Time' and 'Dune'. T.V. Shows such as Star Trek (once again…) and Doctor Who. The most well known example of wormholes in films is Interstellar (go watch it, the music in it is amazing!). Wormholes are currently being researched, and it's entirely possible that they may actually exist!

- **Given that faster-than-light travel is more likely to be science fantasy than science fiction, colonization of other solar systems would likely require traveling to them very slowly. It might take decades or centuries. Look into the idea of generation ships, in which those setting off to the stars would do so knowing they'd never reach their destinations. The hope would be for their children or grandchildren to complete the journey. Discuss with your team: would you sign up for such a mission? Would it be fair to the children of the original travellers to find themselves born in space?**
    - Generation ships are based on the idea that space journeys are long. Like, really long. Because of this, generation ships travel for hundreds, possibly thousands of years, with the descendants of the original travellers being the ones who will land on a new planet. Studies have shown that you would need approximately 100 people to have a large enough population pool, as well as a cylindrical ship (to generate artificial gravity) that would need at least 0.45km2 of space for growing food alone! There would of course be unknown social and psychological impacts of humans living in space for their entire lives. Many other difficulties make generation ships a challenge for humanity to reach using our current technology. The ethical dilemma of generation ships is what to do if the children of the original travelers wish to turn around, and return to Earth. This likely would be impossible, but is it fair to bring these children into the world with a set destiny?

- **In lieu of generation ships, one could imagine people on missions to other planets somehow frozen or suspended for a period of time, then revived at the end—spending the actual travel time in a condition NASA calls "human stasis". Discuss with your team: if human stasis were possible, should we also implement it on Earth to reduce resource usage?**
    - The human stasis that NASA is researching isn't quite as science fiction as it sounds. It involves lowering the temperature of the astronauts by 5 - 10OC, reducing metabolism and decreasing the amount of food that has to be bought aboard the ship. This in turn then decreases the travel time due to reduced weight. Human stasis on Earth would be much more controversial. The main issue that comes with it would be the high expense, as we

would have to use energy to keep these people in 'human stasis,' as well as the resources to build the machines that would do so.

- **Sunlight can be used to propel objects; solar energy can be harnessed and converted into kinetic energy. Are solar sails the solution to interstellar travel?**
    - The Breakthrough Starshot Initiative is an initiative that would aim to get a satellite to Alpha Centauri in 20 years, using the technology of Solar Sails. Alpha Centauri is the closest star to our Solar System (besides the Sun) but is still 41 trillion km away, so solar sails are currently the only reasonable option. Solar sails work in a similar way to regular sails; they're slowly accelerated by the force of light from the sun, but are able to reach very high speeds. Breakthrough Starshot are aiming to attach a tiny microchip to a solar sail and send it off towards Alpha Centauri. However, both dust and radiation may interfere with it along the way, so it's not certain that this solar sail will be successful. However, it's the best technology that we currently have for interstellar travel.
- **Even if we could travel through space, where would we go? Look into the efforts to find Earth-like planets around other stars, and be sure to explore the following terms:**
    - **Goldilocks zone | exoplanets | exomoons**
        - **Exomoons:** Exomoons are, rather simply, moons that orbit exoplanets. However, they are much harder to identify and locate than exoplanets. So hard in fact, that we are yet to find a single exomoon! This is because radiational velocity is unable to identify exomoons, leaving only the transit method, gravitational lensing and a few other techniques, such as pulsar timing and direct imaging. Pulsar timing involves looking at specific stars known as pulsars, which emit regular radio waves which almost never vary. Small differences in these radio waves can show the existence of an exoplanet, and even smaller differences could possibly show the existence of an exomoon. Direct Imaging is rather intuitive, and involves using infrared to take photos of stars. Occasionally, an exoplanet will also be visible. However, all of these techniques are incredibly difficult, and it is unlikely that we will discover an exomoon without either new technology or a lot of luck.
        - **Exoplanets:** Exoplanets are any planets found outside of the solar system. For a long time, until 1992 in fact, exoplanets only existed in science fiction and theory. This is because it took until 1992 to discover a planet from a different solar system. Until this date, it was nearly impossible to detect planets from light years away because they appeared much fainter than stars. Since then, 4104 exoplanets have been proven to exist as of December 4th! There are currently three main methods to discovering exoplanets. The first method is called radiational velocity, otherwise called the Doppler wobble. I won't go too much on detail, but it basically measures how much a star "wobbles". If a star moves towards the Earth at a certain speed but has measurable abnormalities in its travel, it is likely that a planet orbits this star. To make it clearer, it is the phenomenon shown below. It has been the most useful method of finding new exoplanets. The second method is gravitational lensing, which occurs when a star comes next to another star which results in a change of the stars' magnetic field. Last but not least, the transit method is the most logical. It

analyses how much light a star emits, and if there are regular times when the light input seems to decrease, a planet is probably the reason behind that. This method also helps calculate the planet's surface temperature.

- **Goldilocks zone:** This concept is very easy to define. A Goldilocks zone (or in more scientific terms, the circumstellar habitable zone) is an area around a star where the temperature is just right to have a planet that could potentially be habitable. More specifically, the temperature needs to be around the temperature where liquid water can exist at a certain pressure (boiling and freezing points vary depending on pressure), because where you can find (liquid) water you can probably find life. It is important to note that a planet does not have to necessarily contain water in order to belong to the Goldilocks zone. Where the Goldilocks zone is situated around a star depends on how big and hot a star is; bigger stars have a Goldilocks zone more faraway than a smaller star. Fun fact: the Goldilocks zone is actually named after a fairy tale called "Goldilocks and the Three Bears" where a girl chooses from a set of items and settles for the one that is "just right".

- **Kepler 168-F | super-habitable & super-Earth**
  - **Kepler 168-F:** I recommend reading the article linked on this one; it contains many insightful quotes. Kepler 168-F is an exoplanet known to be "the cousin of planet Earth", because not only is it in the Goldilocks zone of its star, but it is also pretty Earth-size (only 10% larger than Earth). If you have connected the dots, that means either that 1) it could have liquid water on it and 2) it could be habitable! Kepler 168-F is the first planet to be discovered that resembles Earth and it is the main reason it is famous among scientists and astrologists. It was discovered in 2014. Research has told us that it takes this planet about 130 days to orbit its star and that it is probably colder than the Earth, as its star is less hot and because it orbits on the outer ring of the star's habitable zone. Because of its slight differences with the Earth, it is not a sibling planet but more like a cousin (hence the name). Despite the research, we still do not know what the atmosphere consists of. This video made by NASA is also very informative.
  - **Super-Habitable & Super-Earth:** These two terms describe two different types of planets. Firstly, super-habitable planets are planets that are more inhabitable than Earth, and could therefore support a wider range of biodiversity. Generally, it is expected that they would be about the same size as Earth, with possibly higher temperatures, higher concentrations of Oxygen in the atmosphere and that they would be a further distance from their sun (e.g. further into the habitable zone). Super-Earth planets, however, are exoplanets that have a larger mass than Earth but a lower mass than our solar system's smallest gas giants, Uranus and Neptune. This does not mean they are inhabitable, but many scientists believe that a Super-Earth is more likely to be inhabitable than the average planet.

- **Just because we're still a Type I civilization on the Kardashev scale doesn't mean we can't look into off-Earth living arrangements. Consider this strategy for terraforming the moon. Assuming we could maneuver comets into action as described, would there be any strong**

arguments against it? Do we prefer the moon to be in its natural state, even if that means it is inhospitable to life?

- Before answering the question, let us first define the Kardashev scale. The goal of this scale is to answer two main questions: 1) What is the status of a given civilisation based on its technological advancements? 2) How much can this given society advance before self destruction or else?
    - The Kardashev scale compares how much energy a civilisation uses to how much space they occupy (a planet, a solar system, a galaxy etc). According to Kardashev (1964), the technological advancements and how much energy is used run parallel to each other. In other terms, how much energy a society is able to harness defines its technological status. Civilisations are classed in 6 boxes: type O, type I, type II, type III, type IV and type V (basically 0 to 5). I won't go too much in detail, but type 0 is least advanced and type 5 is a superpower civilisation controlling multiple universe! According to this article, we are not quite a type I civilisation as the WSC suggests, but we will be in a few hundred years.
    - In terms of terraforming the Earth using comets, this idea does seem interesting, but would require a high amount of resources to be dedicated towards it. In the article it says that approximately 100 comets the size of Hayley's Comet would need to be taken to the moon from areas past Pluto. Considering we haven't recovered a single comet from anywhere in the solar system, this seems like a task which will require more technological advancement before it can be carried out. The question of whether we prefer the moon to be in its natural state or a habitable one isn't the relevant question. The question is, with rising populations worldwide, do we have a choice besides making it habitable?

- **Comets are not the only way to radically alter a planet or moon. How likely is it that the following proposed approaches could be used in our own lifetimes, and what sorts of celestial bodies would be best suited for each?**
    - **interplanetary contamination | space mirrors | shell worlds**
        - **Interplanetary contamination:** This refers to the biological contamination of a planetary body, in either direction. Either forward contamination (Earth -> Elsewhere) or backward contamination (elsewhere to Earth). Generally, we are more concerned about destroying alien ecosystems ourselves, but the threat of being destroyed also remains. However, it has been suggested that we could purposely bring plants to contaminate locations, particularly to the moon once it has an atmosphere, allowing them to develop. However, we must ensure that we do not damage these foreign environments if we do so.
        - **Space Mirrors:** This theoretical technology allows terraforming of specific locations on planets such as Mars by focussing sunlight onto a particular area, heating it up and making it more habitable. The current suggestion is to create a 1.5km wide mirror out of reflective balloons, suspended in Martian orbit. This would then focus sunlight onto one area, heating it up to 20OC, much more reasonable than the -140OC to -60OC that is normal on Mars! The main criticism

of this idea is that it could possibly focus forms of dangerous radiation, but if done properly, this could be an easier way to terraform limited parts of Mars.

    - **Shell Worlds:** Terraforming is difficult, particularly if you don't have an atmosphere to work in. Enter Shell Worlds, planets encased by a shell of kevlar, dirt and steel. An atmosphere can then be created on the inside of this shell world, and terraforming can begin. The atmosphere will also be easily contained by the shell, with the shell providing other benefits such as radiation protection, near limitless design and access to the vacuum of space (useful for many industries). The only major issue is the creation of the atmosphere on Mars (the likeliest nearby candidate to become a shell world), as the atmosphere would need to be 6.6% the mass of Earth's atmosphere (a lot!).
- **artificial magnetospheres | atmosphere thickening/removal**
    - **Artificial Magnetospheres:** Mars once had a very similar magnetic field to Earth, but it degraded over time. The lack of magnetic field on Mars resulted in a lack of protection to its atmosphere, reducing the atmosphere's size and dropping temperatures on Mars. However, it's been proposed that by placing a giant magnetic shield at one of the Lagrange points (see below), Mars' would be protected. It's expected that this would result in an increase of 4C per year, allowing liquid water and easier Mars exploration.
    - **Atmosphere Thickening / Removal:** If we wanted to inhabit a planet without an atmosphere for a long period of time, we'd need to manufacture our own. There are three major ways that we could thicken the atmosphere. Firstly, we could use orbital mirrors (like the space mirrors above) but on a much larger scale. To terraform Mars, we'd need a mirror roughly 250km in diameter! Other options include creating greenhouse gas factories on Mars (they're finally good!) and crashing asteroids rich in ammonia onto the Martian surface. Atmosphere removal, on the other hand, would more likely be applied to our own planet, though it could be applied to other habitable planets, as well as Venus. Likely, geoengineering techniques involving CO2 removal would be used, such as Carbon Dioxide Capture and Carbon Sequestration (see If it's Broke, Fix it for more detail on these).
- **nitrogen importation | extremophiles & modified bacteria**
    - **Nitrogen Importation:** Our atmosphere on Earth is roughly 78% Nitrogen, so if we wanted to create an Earth-like atmosphere, we would likely need to import nitrogen from somewhere. The easiest way would be to use ammonia (NH3) stored inside asteroids, which we could crash into the planet. The ammonia would then degrade into Nitrogen and Hydrogen, beginning to make a more liveable atmosphere. However, the atmosphere would have had to be thickened before this process could begin, or the Nitrogen gas would dissipate into space.
    - **Extremophiles & Modified Bacteria:** Extremophiles are bacteria that are able to survive in what would normally be deadly conditions, whether it be in temperature, acidity or ability to survive high levels of radiation and UV sunlight. These

conditions are particularly useful to study, as they are likely to be replicated in space travel and on other planets. For example, bacteria in Antarctica are subject to UV radiation, high salinity and low temperatures, likely very similar conditions to Mars. Scientists have also been able to do cross species DNA transfer with some extremophile bacteria, which may allow us to alter helpful bacteria in the future for what would normally be inhospitable environments.

- **Consider these finalists in a competition to design 3D-printed habitats for Mars. Learn the fundamental engineering principles behind each of them. Then, discuss with your team: would you want to live in such a habitat? Does the American origin of all these designs hint at a future in which certain countries try to dominate outer space?**
    - There are five finalists in the competition. Some of the fundamental engineering principles behind them include, access to resources (solved by 3D printing / using materials gathered on Mars), shape to maximise floor space (cylindrical), air filtration (gardens) and radiation shielding. The habitats all are created to be appealing to live in, and the habitat created by Team AI SpaceFactory focuses on separating individuals so they have their own space, to increase morale. The fact that all of the designs are American definitely shows that some countries will try and dominate outer space. The main issue with space colonisation is the economic barrier that comes with it, resulting in richer and more developed nations being able to pursue it more easily and therefore dominate it.
    - **Space colonization and transformation:**
        - **Outer Space Treaty | MarsOne | Lagrange point | biocentrism**
            - **Outer Space Treaty:** The Outer Space Treaty forms the basis of space law, and was written in 1967 by the United Nations. It prevents the weaponization of space and the placement of nuclear weapons within it. It also states that no nation may claim sovereignty over any part of space, and planet, any moon or any other celestial body. It does, however, allow for the placement of Weapons of Mass Destruction in space.
            - **MarsOne:** At first glance, MarsOne seemed like one of the first attempts to get humans to Mars. However, upon closer inspection, we can see that it wasn't as successful as it seemed. MarsOne was created with the purpose of landing the first humans on Mars, and was not run by a specific nation, instead being a private company. They allowed anyone to apply, and received expressions of interest from over 200,000 people. This was narrowed down to a pool of 100, who would eventually be narrowed down to 24, after a series of group challenges. The plan was to televise these challenges, and use that money to help fund Mars One. However, after their mission deadlines were pushed back up to nine years (!) MarsOne declared bankruptcy in 2019, resulting in their mission never going ahead.
            - **Lagrange Point:** Lagrange Points are positions in space between two celestial bodies (such as the Sun and the Earth) where a small object can orbit in an exact pattern, because the forces of gravity and the centripetal force cancels out. There are five Lagrange Points around each celestial body

in relation to another. This results in the object staying in a constant position relative to the celestial bodies. This is particularly useful for objects such as telescopes, with two of the Earth / Sun Lagrange Points currently being occupied by telescopes.

- **Biocentrism:** Biocentrism is a Theory of Everything created by Robert Lanza, an American Scientist. It is built off of the idea that consciousness created the universe, rather than the universe creating consciousness. It hypothesis that the first defined event in the universe was the appearance of 'the property of life,' which was then demonstrated in matter. This is rather complicated, so I will leave the in-depth research to you. More information can be found here and here.

- **planetary protection | Artemis Project | space tourism | Dyson Sphere**
  - **Planetary Protection:** We often take precautions to prevent the spread of disease, and when we're exploring planets, that's no different, except that it extends to any unwanted biological organisms. Planetary Protection is the idea that we want to prevent both forward transmission (Earth -> another celestial body) and backward transmission (another celestial body -> Earth). Generally, it involves using dry heat sterilisation, or making things very hot.
  - **Artemis Project:** The Artemis Project, more often called the Artemis Programme, is a moon landing project that aims to put 'the first woman and the next man' on the moon by 2024. It's primarily run by NASA, but also is partnered with European Space Agency (ESA) Japanese Aerospace eXpolration Agency (JAXA) and the Canadian Space Agency (CSA). The general purpose of this is to set up a semi-permanent presence on the moon, eventually leading to a sustainable colony and a Lunar Economy! The key part of this is the Lunar Gateway, an international space station allowing the exploration of the Lunar South Pole. Definitely keep an eye on the Artemis Project!
  - **Space Tourism:** Dictionary definition, 'Human Space Travel for recreational purposes.' However, Space Tourism is going to likely become much more than that, becoming a full industry within its own right. Companies such as Space X, Blue Origin and Virgin Galactic. Space X is, in fact, planning to send people around the Moon! Even National Space Agencies are beginning to offer Space Tourism, with NASA offering trips to the International Space Station for $35,000 a day starting this year! Space Tourism will continue to expand, and one day taking a holiday in space may be as normal as going overseas
  - **Dyson Sphere:** Solar panels are a wonderful source of renewable energy, but they are rather inefficient, as almost none of the energy released from the sun hits the Earth. Enter the Dyson Sphere, a hypothetical megastructure with the purpose of harvesting all of the energy from the sun. The idea is that a series of structures orbiting the sun would absorb the energy of the

sun and then take it to the Earth, allowing the optimal amount of energy to be absorbed in a sustainable manner. It is suspected that this is one way to identify more developed species, as Dyson Spheres would give off an unusual form of Infrared Radiation. A Type II Civilisation on the Kardashev scale would likely be using technology similar to a Dyson Sphere. However, we are still a long way from using these, and there are many problems we would have to solve before we began to build them

What Would Noah Do? Coping with the Next Great Flood (Blaithan and Xavier)

- **Over the next century, rising sea levels will gradually flood coastal communities around the world—and will present an existential crisis for many island nations. Consider this forecast and others like it. Discuss with your team: should policymakers be doing more to spread awareness of this looming crisis, or is it too early to panic?**
    - The first article shows how a more accurate way of calculating land elevation based on satellite readings has been developed, showing that by 2050, around 150 million people's homes will be submerged. We can see many maps comparing the new and old projections of the rising tides. The differences in these are extreme and anyone seeing them may not believe it. Take Vietnam for example: The old projection shows floods in patches across the bottom of the country, however, the new projection shows that the area of Vietnam below Cambodia may be completely submerged, putting the lives of around 20 million people at risk.

      The second article tells us 11 sinking cities that could disappear by 2100. The main causes of this are rising sea levels and excessive groundwater pumping which changes the pressure and volume in the land, causing it to sink. Some of these places are already taking action to try and protect the people. The Indonesian government plans to move Jakarta 100 miles from its current location, which would take around 10 years and cost 33 billion USD. An architectural firm in Bangkok constructed an 11-acre park called Chulalongkorn University Centenary Park which can hold 1 million gallons of water and people in the Netherlands have built water parks that double as reservoirs that can be used to hold water. The awareness of this crisis is high in many areas, however many cities will not be as aware as other until it is too late for them. Policymakers should be doing more to spread awareness so people can build defenses such as seawalls, levees, etc to protect themselves from the high tides or migrate to other areas if it is too late to do so.
- **The Netherlands is investing in a dike meant to help protect its people from rising sea levels. What technological approaches are Dutch engineers taking to make it an effective long-term solution? Should Venice and other low-lying cities be following their lead, or are they merely staving off the inevitable?**
    - The Afsluitdijk is a dike (basically a dam to the sea) that was built in 1927, and has helped to protect the low-lying nation of the Netherlands from rising sea levels. It has also doubled, however, as a motorway, connecting Noord-Holland and Friesland. In an effort to

increase the protection it provides, as climate change results in rising sea levels, they have begun to update the design. Firstly, they are adding 75,000 concrete blocks on the flanks of the dike. This disrupts approaching storms that may threaten the Netherlands. Each of these blocks will also be GPS chipped, making them easy to maintain and inspect.

Other additions include a fish migration river and increased pumping technology, as well as the use of architectural artworks along the dike in an effort to encourage citizens' interest in it. Other cities should definitely follow the lead of the Netherlands, though they may struggle with the high economic cost of building a dike. Often, the simplest solution is the best one, and there's nothing simpler than blocking the water with a large wall. In terms of 'staving off the inevitable,' having more time to solve climate change and begin to reverse it using Carbon Dioxide Removal is always worth it, and so it is worth building barriers to protect these historic cities. There are of course some cities and villages where it is inevitable that they will disappear underwater, such as the Alaskan island of Kivalina, and we must try and make progress so that no more of these people's homes end up underwater.

- **Over the last century and longer, many cities have radically transformed the environment around them in order to survive and grow. How much of Singapore didn't exist a generation ago? Discuss with your team: are these cities already terraforming the Earth?**
    - In the past 20 years, Singapore has increased its population by two million people and tripled its GDP, becoming a centre for global business. With this spike of growth, the city has grown as well. This may seem rather difficult, considering that Singapore is a city state trapped between Malaysia and the ocean. However, Singapore practices Land Reclamation, during which sand, rocks or cement are added to an area of water until that area can be built on, allowing the city to expand. More recently, Singapore has begun to build dikes and then drain water from within them, allowing them to expand out more easily. This could count as terraforming, as Singapore is altering the topography of the Earth, but the question is whether this is major enough to count as terraforming. I will leave that question to you, kind scholars.
- **Does the world need to invest in wildlife connectivity corridors to allow species to migrate in the face of climate change—or do we need to take more drastic measures to preserve biodiversity?**
    - Wildlife Corridors connect together two significant habitats, enabling migration and breeding opportunities. Wildlife Connectivity Corridors are now being used in an attempt to connect together currently inhabited areas that may become uninhabitable due to rising temperatures to new, inhabitable areas. However, there are many issues to this. Many areas may have a similar temperature but a completely different environmental characteristics, such as a humid / arid area. Also, current wildlife corridors' climates may be altered, making it near impossible for animals to migrate. We may need to take more drastic measures in the future to preserve biodiversity, such as geoengineering or forced migration of species.

In 2006, Dubai was declared the city with the largest ecological footprint per person in the world. Since then, Sheikh Mohammed, the ruler of Dubai, has begun their goal of transitioning to 75% renewable energy by 2050. This desire to transition was caused by the creation of a 'zero carbon city' in 2006, Dubai needing to reduce its dependence on natural gas and the rise of solar power. Since then, the public transport sector of Dubai has drastically grown, energy negative neighbourhoods have been developed, energy regulations on buildings have been put in place and Dubai is now in the process of building a giant solar power plant. Dubai now have an ecological footprint per person similar to the United States, showing a massive improvement in 12 years and giving us hope for the future. However, the economic investments that they have made are incredibly high, and considering that most nations do not have a GDP per capita comparable to the UAE ($68,000 = 8th in the world), they may struggle to invest as much money. This is why global cooperation is so crucial to prevent climate change issues from spiraling out of control.

    - **NOTE BY SHAURYA:** LOOK AT MASDAR CITY IT'S REALLY COOL (lowkey a scam tho)

- **Is the solution underwater cities? Interest in such settlements has sunk over the last several decades, even as the seas themselves have risen; can you identify reasons why? Discuss with your team: would you rather live underwater or on another planet - or underwater on another planet?**
    - Currently, there are only three inhabitable underwater areas. Generally, they are used for research, education or commercial purposes. Creating more of these, and permanently inhabiting them would assist greatly in scientific research. Our existing technology would allow us to house up to 100 people in an underwater habitat, but there are many risks that come with this. We do not currently have sufficient evacuation procedures or environment control that would allow these areas to be safely, permanently inhabitable. There would of course be benefits that would come from putting people underwater, such as scientific research, a possibly tourism sector and easier access for deep sea minors and underwater archeologists. However, there simply isn't enough interest, as humans find heading out towards the stars and the unknown a much more interesting adventure than heading down beneath our feet. I would prefer to live underwater, but that's because it seems slightly less risky than travelling to another planet, at least with our current technology...
- **Rising sea levels are a slow-moving crisis; though some scientists speculate that there could be possible tipping points leading to abrupt accelerations, by and large they are expected to increase slowly but steadily. Discuss with your team: would it be better if this crisis were unfolding more quickly?**
    - A world in which the climate crisis was unfolding quickly would be one in which action would be taken more quickly. Because the climate crisis is occurring at such a slow rate, every nation is waiting for others to act. If the crisis was occuring more quickly, then having the crisis unfold more quickly would institute international co-operation for our collective survival, and result in action finally being taken against climate change.

Concluding Questions (Xavier)

- **Consider this author's eloquent declaration of "The Concession to Climate Change [He] Won't Make." Discuss with your team: in a time when the Earth seems burdened by every person on it and every choice they make—including the choice to make more people—should children be protected from learning about the climate change crisis until they are older? Should new children's literature be written to protect them from the truth—or to motivate the next generation to action?**
    - The article outlines Jedediah Britton-Purdy's, a professor in environmental law, concerns of raising a child in a world that seems to be doomed to climate change. He expresses that he wants his son to first learn to love the environment, its ecosystems and the organisms inhabit it, before learning that the lives they, humans, lead is slowly destroying the natural world. He wants his son to know that it's fine to love imperfect and damaged things. Appreciate the environment, learn to love it, and use that passion as incentive to help preserve it. Just because we might be powerless as an individual, it doesn't mean that we are powerless as a whole.

      Jedediah also affirms the fear reluctant parents have with bringing children in our world today. We can't ensure that our children will be safe and happy with our current foreseen future but that should serve as even more reason to help build a sustainable world and to teach the youth that the earth is worth saving. He says, "The only alternative to giving up on humanity is to have children whom we cannot keep as safe as we would wish, or as safe as some of us were raised to imagine we could." Furthering his opinion that the only way to make sure that the future generation is safe is by working towards more sustainable civilisations.
    - In terms of teaching children about climate change, it is important to be aware that it's quite easy to teach them to be indifferent and pessimistic if we educate them in a way that portrays climate change as something we cannot overcome. Schools and parents need to keep a delicate balance between helping them understand the world and forever scarring them. Children shouldn't be shielded from the truth; it's not as simple as protecting them from the outside world because withholding information from them will be the same thing as having them walk around a cliff in blindfolds. Ignorance is not bliss in this scenario. Works of literature, media, and education should aim to educate in a way that motivates and encourages sustainability, not teach despondency. It's a difficult needle to thread but it's necessary for our youth today.
      ~Jutin
- **It never rains on Vulcan. Endor contains only forests and fan service. In science fiction, planets often have very uniform climates; an entire planet is a desert, or a jungle, or a frozen wasteland. If the entire Earth had to be a single biome, what would you want that biome to be?**
    - Ideally, we would want a slightly more habitable biome than Vulcan or Hoth, but having a biome similar to Endor would be rather nice. In my opinion, a temperate biome, such as forest or grasslands would be ideal. We also have to remember that the amount of sunlight that the biome gets will vary, resulting in more snowy forests as we approach the poles and

tropical forests at the equator. This allows for biodiversity, and also gives humans lots of trees to climb (a wonderful pastime).

- **If you were designing a new planet from scratch, what kind of climate would you want it to have? How varied would it be from place to place, and would all parts of this planet be equally comfortable for habitation? If not, how would you decide who lives where?**
    - Your definition of an ideal climate will depend on your opinion on biodiversity. If we wanted to simply have a planet optimal for humans to inhabit, we would likely live in a tropical world. However, if we wish to protect the biodiversity of this planet and allow multiple, diverse species to inhabit it, we should create more of a jigsaw puzzles of climates, separating the different groups of animals that live in each climate. Humanity's ability to colonize the planet also seems to have proven that we are able to inhabit almost anywhere (assuming that we do not have any climates hotter / colder than we currently have). In terms of deciding who lives where, I would say that we leave that up to the people, as each of us have preferences for the climate that we like.
- **How many people do you think should live on the Earth, in an ideal world? Would this number be the same as its "carrying capacity"? If you think population should be reduced or further growth limited, how would your team go about controlling the population? Would any of these methods be ethical and/or feasible enough to implement in real life today?**
    - In an ideal world, everyone on Earth will have the resources that they need to live long, fulfilling lives. Because of how the Earth itself has limited resources, resulting in it having a limited population. With current rates, the population is expected to reach 10 billion by 2100, and I expect that would likely be the maximum amount that we could have on the Earth, and our average living quality may be lower than many developed parts of the world. In terms of limiting further growth, we have seen in the past that actions such as the One Child Policy have not been incredibly successful, and so the best method would probably be space colonisation. Both Mars and the Moon provide habitats where we could move millions, possibly billions of people. This is obviously not feasible now, but in the future, hopefully it will be.
- **Harvard sociobiology professor E.O. Wilson has said "the constraints of the biosphere are fixed". Are they? Will we be able to renew our supply of resources on Earth by mining asteroids? In what other ways might we be able to expand the constraints of the biosphere, and are any of them realistic?**
    - If right now, we wanted to magically move everyone in the world to an ecological footprint (the amount of land required to fill all of their needs) equivalent to the average U.S. citizen , we would need another four Earth's worth of land. Though we know how to theoretically drive forward economic progress, that depends on an infinite Earth with infinite resources, which we obviously do not have. With our current food production rates, we would be able to support between 2.5 billion and 10 billion humans, depending on how much of the diet was made of grain and how much was made of meat, with a fully vegetarian diet able to support 10 billion people.

      The constraints that Earth places upon us are definitely semi-fixed, in that it only provides

a limited amount of natural resources, but we are able to leave the biosphere and explore space for resources. This is where asteroid mining comes in. Currently, more than 500 asteroids that we have discovered are valued at more than $100 trillion! From these asteroids and comets, we would also be able to recover water, which could then be either taken back to Earth or converted into rocket fuel. We would (hopefully) be able to stabilise the Earth's economy using this. The main issue is that the resources on asteroids are slightly limited, and do not represent many other resources that we need on Earth. I believe that the best way for us to expand the biosphere would be colonising both the moon and Mars, though both of these remain unrealistic goals right now.

- **Consider the manifesto of the eco-modernist movement, whose leaders believe economic growth, technological progress, and environmental preservation can all coexist. Are these writers too optimistic?**
    - Eco-modernists hold the belief that 'humanity must shrink its impact on the environment to make room for nature' but rejects the idea that 'human societies must harmonise with nature to avoid economic and ecological collapse.' They believe that by substituting the ecosystems that we depend upon (energy, food, water, waste) for technology solutions will allow us to become more efficient, creating more space for nature to be undisturbed. Proposed solutions by eco-modernists include genetically modified / synthetic food, using aquafarming to farm fish, desalination and agriculture intensification.

      They are also in favour of supporters of CDR. These technologies, according to eco-modernists, will allow us to use less space, yet still allow the economy to grow and our species to progress. The main criticism that I would make is that our land is still finite, and we can only become so efficient before we run out of land to use. Also, everything is interconnected, and so this alteration of environment in an effort to increase our efficiency will have a knock on effect across the rest of the planet.
- **Discuss with your team: would you agree to build an emissions-generating power plant in an impoverished community, if the alternative is lack of access for that population to reliable electricity?**
    - This is an often discussed issue regarding the climate debate, as many developing nations want to reap the benefits of emissions-generating power before they transition over to renewables, as many of the most powerful nations in the world today built their economies off of emissions-generating energy. Therefore, I believe that you must begin with some form of emissions generating power before you transition over, though you should aim to transition as soon as possible. Climate Change legislation such as the Copenhagen Accord asked developed nations to reduce their emissions whilst developing nations would instead have to slow the growth of their emissions. This is the approach that we should take to have a united world fighting climate change.
- **Read about the Kim Stanley Robinson novel New York 2140. Does the author's description of how he went about "flooding" New York City offer any insights into how people in general should think about the impacts of climate change on future living situations?**

    - When Kim Stanley Robinson chose to flood New York City in his novel, he flooded it by 50ft (15.25m). This is quite a bit larger than the estimated flooding by 2140, with an expected 3ft - 15ft (0.9m - 5m) rise. The fact that this is such a drastic flooding is an attempt to scare humanity into taking action against climate change. Though it is not fully factual, it is based on fact, and there would still be drastic impacts on living situations if we had a 5m rise in sea level. He also chooses not to focus on how we got to this situation, but how people have adapted, showing that even though it is inevitable that we will be affected by climate change, we will be able to continue on.
- **As a radical solution to a warming climate, some futurists have suggested moving the Earth to a new orbit further away from the sun. Discuss with your team: is it worth even imagining such dramatic measures? What extreme solutions would you propose if you had the power to ignore the laws of physics?**
    - It's been proposed that we move the Earth into a Mars like orbit. There have been three main propositions of how to do so, each of which has its own flaws. Firstly, using an electric thruster, also known as an ion drive. This would, however, uses roughly 85% (!) of the Earth's mass to create the thrusters and fuel. The second solution is a Solar Sail, a method of propulsion that uses light to propel an object.

      However, the solar sail required to move Earth would have to be 19x its diameter, and would take over 1 billion years to move the Earth into a Mars like orbit. Finally, gravitational slingshots could be used, using asteroids to give us a slight push. Once again, we have a major problem though. Nearly one million asteroids would need to pass near the Earth in order to slingshot us into a far enough way orbit.

      If we could ignore the laws of physics, hopefully with no ill effects, I would likely just move us further away from the Sun. Other possibilities include decreasing the size of the sun, magically removing CO2 from our atmosphere or putting a giant mirror into space (as previously seen, this is an actually proposed solution!). I'm sure that you scholars will be able to think of much more creative ideas than I can, and I wish you the best of luck breaking the laws of physics to fix the planet

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