Day 8 - Diagnostic Tools & Ready Medicine

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Although it is likely that doctors will be among the first set of people to come to Mars, bringing their lighter weight tools with them, doctors need more than just knowledge to diagnose and treat patients who might be sick. Because it is infeasible transport a complete set of diagnostic tools and medicine to treat various illnesses and many medicines degrade over time (many are predicted to degrade more quickly in space conditions). Currently astronauts are sent up with an ultrasound (portable) defibrillator, a device for looking deep into the eye, and two litres of saline. There is a 20 minute delay in telecommunication between earth and the red planet. Robo-surgeons are in the works but not yet ready.
We will be transporting predominantly healthy people, which should remove most viral diseases (as they will have no secondary host or reservoir unless we are dealing with something like HIV with long latent periods). Fungal and bacterial illnesses (potentially yeast infections) are our threats.

Diagnostic tools
For bacterial infections, synthetically produced bacteria phage are excellent biosensors and can output bioluminescence when they are activated, indicating the presence of a target bacteria (and thusly a potential infection). They can work rapidly (hours), and can double as antibiotics as phage can push bacteria into a lytic cycle. **This works in vitro but we don't think we can use phage as an anti-biotic in vivo because they are highly immunogenic.** Paper-based diagnostics can be frozen and used later - these work for viral illnesses as well - which target specific RNA sequences as indicators.
In vivo diagnostics can be done with engineered E. coli which have been used to monitor exposure of the gut microbiome to drugs and mammalian cells have been used as in vivo biosensors as well. However, targeting in vivo sensors in incredibly difficult.
https://phys.org/news/2015-12-diagnostic-tools-synthetic-biology.html

Synthetic biology would allow us to create novel diagnostic biosensors as new illnesses mutated and developed.
http://embomolmed.embopress.org/content/early/2016/07/11/emmm.201606541

Nanopore sequencing has been done successfully in space, it can quickly sequence the genetic material in a sample (even novel samples). It can be used as a diagnostic tool and has been used to test for emerging outbreaks like Ebola and Zika without needing to come up with a custom diagnostic test. You do have to know what you are searching for in the sequence and program the nanopore accordingly, but the method can take as few as 10 minutes. It has plans of being used to keep tabs on the travelers environment in space.
https://phys.org/news/2016-08-nasa-dna-sequencing-space-success.html
https://www.nasa.gov/mission_pages/station/research/news/dna_sequencing

The last important challenge we will cover is maintaining a strong microbiota and managing the diversity necessary to process our food and keep us health. If an astronaut had an imbalance in their gut biome, or had to take antibiotics and wipe out their gut flora, they would need to borrow a "starter" either from a constantly growing plate of gut bacteria (co-culturing at its finest) or from a fellow healthy astronaut - poop soup see *C. Diff*

CANCER is going to provide a challenge we are not yet equipped to diagnose or treat without methods used on Earth. Due to increased radiation the likelihood of developing cancer might be elevated, but traditional treatment methods which often rely on a holistically treatment plan (change in diet, change in habits, regular treatment that results in change in physical ability - currently able bodied becoming frail).
AUTOIMMUNE ILLNESSES will also present a challenge.

Treatment Tools
Pain killers - Morphine grown with yeast http://www.synbiosmart.com/brewing-morphine-from-glucose-in-yeast/

Antibiotics - produced by bacteria or by using lantibiotics...http://synbioproject.org/cpi/applications/synbio-lantibiotics/
http://www.sybhel.org/?p=730

Ruder *et al* discuss the potential to engineer human cells which can be used to produce helpful enzymes.

Activities

K-5
Elephant toothpaste in a closed container to represent the lysis of a cell that is infected with a bacteria phage.
If you want to try something less messy, you can use balloons and fill them with marbles, but it doesn't show the same self replication that you get with the toothpaste. It more resembles repeated infection.
Note Elephant toothpaste traditionally uses yeast (yay) and 10% hydrogen peroxide, but has a more dramatic reaction with reaction with 20% hydrogen peroxide and potassium iodide. Note - this second one tends to get hot.

6-8
Carrying over the elephant toothpaste activity, but incorporating specificity by creating containers which have specific "binding sites" for the phage. This could be replicated by having specific syringe tops for buckets which only screw into specific syringes to inject the .
Talk about creating a diverse and strong microbiome and the protective components of a strong gut bacteria, and a skin biome against opportunistic bacteria.
Do a hand print onto an agar plate, taking swabs of that and characterizing it using acid fast test, gram staining, growing on selective media, looking through microscopes when available.

9-12
Can we get kids working with phage? Can we create a bacteria lawn and then let students attempt to take it out with bacteria phage?
Supplies

- Fully grown plates with lawns of bacteria
- Specific phage set for one type of bacteria (likely unedited E. coli)
- Phages that are not set for E. Coli
- Incubators would be helpful

Grow the lawns of bacteria and talk with students about phage and their role in diagnostics and antibiotic potential. Be sure to outline the current struggle with in vivo use of phage.
Once lawns have grown talk about the specificity of phage. Inoculate several plates with your phage. Allow lawn plaques to form and discuss the indication of a positive result.

Letting students collect their own phage and bring them into our lab is always so fun.

Generating a diverse microbiome on a plate.