2017 TVIW Graduate Scholarship Application - Margaret Horton

Essay

The term interstellar travel elicits images of futuristic rocket ships being dreamed, designed, and launched by physicists and engineers in white coats, working to ensure the nuts and bolts of space travel are achieved and maintained. Considered less often, but perhaps just as important as the technical aspects of interstellar travel, are the possible health outcomes associated with the pathway to the stars. In the Disney-Pixar feature film *WALL-E*, humans have abandoned an inhabitable Earth littered with manmade refuse and take refuge in the Axiom, a starliner replete with entertainment, food, technology, and comfort. The Axiom passengers recline their rotund bodies into the starliner version of a motorized grocery store cart, propelling themselves around the ship with the push of a button. Later, the scene shifts and flashes an x-ray of a passenger, depicting tiny bones floating amid a blob of flesh. While the movie is most obviously foreshadowing a depressing future here on earth, one where humans depend on technology for almost every aspect of their lives, not even using their own muscles to get from place to place, the movie poses a very serious question on the long-term health effects of long-term space travel.

The Axiom starliner uses probes to evaluate the habitability of Earth with hopes of returning to repopulate. After WALL-E and EVE, the personable robots at the center of the movie's story, successfully nurture a plant from seed, heralding the successful return of humans to their place of origin, the Axiom passengers disembark. One of the passengers bravely wiggles out of his transportation device, placing his fleshy feet on the ground. One step at a time, the passenger experiences the challenges of re-transitioning to life on earth, using his rotund but atrophied body, and overcoming the health outcomes of space travel.

The movie does not entertain a discussion on microgravity's role in the passengers' languidness and obesity or depict other known health outcomes associated with long-term space travel. Rather, the movie implies that society on Earth reached an unhealthy lifestyle dependent on technology long before the need to evacuate the earth. Regardless of the cause, the movie highlights the importance of the public health prospective when considering interstellar travel. The assumption that hard science alone will take us to the stars is dangerous. When humans overcome the physical limitations of interstellar travel and reach the stars, it is not guaranteed that we will thrive as a species, or even survive. Applying public health practices to interstellar travel will play an important part in a successful interstellar mission.

Public health differs from a traditional understanding of health and medicine in that aims to *prevent* or *reduce* disease among an entire population. The field tackles this issue through a number of approaches: by establishing health education and promotion initiatives; conducting disease surveillance; studying associations between pathogens, environmental toxins, lifestyle factors, and specific health outcomes; emergency preparedness; and promoting preventative health measures across entire societies. In the face of an interstellar mission, the context of public health will change dramatically, but the purpose will remain the same.

Despite the apparent disjointedness of the two fields, public health and space are not strangers. A quick Google search for "public health," "NASA," and "space" results in a number of articles about recent national and global initiatives related to, you guessed it, space technology and public health. The initiatives aim to utilize space technology to improve public health efforts here on Earth. There are projects that utilize remote temperature sensing, air quality data, earth science models, and images of natural disasters and their fall-out in order to inform public policy and respond to disasters. Many of these activities stem from the United Nation's (UN) Committee on Peaceful Use of Outer Space (COPUOS) of 1959 and have established programs in federal agencies and among national governments.

Although the public health and space fields are connected, the new research is mostly steered by improving human health on earth. Take, for example, the collaboration between the (NASA) and the Centers for Disease Control and Prevention (CDC), the Earth Science Enterprise. The program aims to improve predictions in weather, climate, and natural hazards through space technology and decision support systems used for public health. Many chronic and infectious disease are related to environmental conditions. Another example of utilizing space research to improve human health on earth has implications for interstellar space travel as well, but was driven and funded by interests in human health on earth. Researchers at the Arizona State University collaborated with International Space Station (ISS) crews to study the behavior of *Salmonella* bacteria in space. The study contributes to improving pneumococcal vaccine effectiveness through the creation of a new recombinant formulation. In the process of observing the bacteria on the ISS, researchers learned that at microgravity, the bacteria behave as if in the human gut, multiplying rapidly. This finding, although specific to one type of bacteria, could have implications for increased virulence of bacteria that are manageable on earth. As if the unpredictable behavior of bacteria in space were not enough of a complication, researchers have also studied antibiotic resistance among bacteria cultures on the ISS. These studies, although propelled by earth-based medicine and technology industries, are providing valuable insight into the likelihood of interstellar travel.

Although the interaction between the public health and space fields is a bit lopsided today, public health can provide important insights into the space industry as well. When considering interstellar public health, there are two important categories: the known and the unknown. Over 50 years of space travel has resulted in a body of research describing the effects of space travel on the human body and psyche. The latest research on the topic today is being conducted aboard the ISS. Scientists have already evaluated the most efficient position for performing CPR at microgravity (the headstand position, in case anyone was wondering). Others have addressed issues relating to water recycling on the ISS: the original disinfection procedure led to unintended results associated with the unanticipated iodine build up among astronauts (increased thyroid stimulating hormone levels). The scientists behind this project were able to implement a system to remove the extraneous iodine from the drinking water, a process that is also used in earth-based water processing. Researchers have also observed the reactivation of latent viruses, such as the ubiquitous Epstein-Barr Virus, which is estimated to be present in 90% of the adult population, which could lead to a resurgence of symptoms and infectiousness, putting a strain on the existing medical treatments in space. The stability of pharmaceutical products in space is starting to be evaluated: do drugs interact differently with the human body in space? If so, how can they be optimized for effectiveness among space travelers? Another set of researchers, the IntraVenous Fluid GENeration for Exploration Missions (IVGEN) team, has undertaken the project of producing sterile intravenous solution for inflight surgeries. These discoveries not only inform the future of interstellar travel, but also provide new perspectives on the way things are done on earth.

Getting to another galaxy is not like driving to the lake for the weekend. Stephen Hawking and Yuri Milner's recent interstellar probe plan suggests the shortest timeline yet—decades. However, the proposition involves the launch of hundreds of small "spacechips," which are about the size of a postage stamp. Knowing what we know now about long-term spaceflight, the decades of space travel would take a toll on human health, even if a spacecraft carrying a batch of interstellar colonists could travel as efficiently as a smaller, stamp-sized device. Assuming the biologists, chemists, and physicists figure out how to turn astronaut Mae Jemison's elegant, ecology-driven solutions into reality, which would provide a sustainable source of food, clean water, and other organic materials, the known health outcomes of long-term space travel could compound over time. Current research indicates that long-term space flight impacts the human body in a number of ways: a weakened immune system, loss of bone density, decreased heart rate, and increased mental stress, among other sequalae. It is important to note, however, that the research is based on the long-term space flights to date. No one has exceeded 438 consecutive days in space, so the effects of multiple years, let alone decades, is unknown.

During interstellar travel, a successful public health infrastructure will facilitate health promotion, disease reporting, risk mitigation, and disaster response during the journey as well as at the final destination. Much of the existing public health infrastructure is designed to address situations and conditions that, theoretically, are unique to Earth dwellers, and won't be an issue in interstellar travel. Adverse health outcomes associated with tobacco use or other substance abuse, for example, would be virtually eliminated if tobacco is left behind. Vector-borne infectious disease, such as malaria, Zika, Chagas disease, dengue fever, and chikungunya, cannot be borne if the vectors are not brought along on the ark, so to speak. Public health ethics can inform these types of decisions: is it better to artificially select the types of life that will brought along, or try to maintain entire ecosystems for replication at the final destination?

Ensuring the cohort of colonists is as healthy as possible prior to lift-off, although such screening brings implications of eugenics, could lessen the burden placed on the fledgling space-based medical system. Nevertheless, new diseases and conditions are discovered on a regular basis here on Earth. Despite the colonists' best efforts to eliminate disease threats from their environment and health conditions within their population, negative health events will be inevitable. A robust interstellar public health infrastructure won't be able to anticipate new diseases or provide immediate solutions, but it will play an integral part in maintaining human health and adapting to new health obstacles.

The current global public health infrastructure relies heavily on channels of communication between local, national, and international health agencies. Local groups monitor disease incidence and notable health events, communicating the observations to the next tier.

These carefully constructed pathways of observation, documentation, and communication structures allow those involved at higher tiers to identify, analyze, and assess new health events. On an interstellar mission, this kind of structure would be imperative to assess the health of the voyagers. The system not only allows for surveillance, reporting and response of known issues, but also allows for the identification of new trends and patterns. The closed-loop environment of a ship would simplify some aspects of disease surveillance, as previously mentioned, but it would also create a new set of problems: remaining infectious diseases could bear a greater burden on the traveling population and the exposure to toxins and radiation could cause unanticipated illness. Conditions associated with radiation exposure on earth are likely to be similar during long-term spaceflight, but due to the unprecedented duration of exposure, the effects could take new forms.

The closed-loop environment is a breeze to manage when compared to the final destination. If the planet is hospitable to human life, it is surely hospitable to other forms of life as well. An interstellar mission must consider this possibility and plan for the unknown. The new planet could be home to pathogens that impact human sapiens, so the robust surveillance and reporting network must be maintained upon colonization. What's more, the colony ought to have basic medical provisions to sustain human life. Although the medicines may not function the same way in space, the World Health Organization (WHO) has established a list of essential medicines necessary for a basic health-care system, which includes broad-spectrum antibiotics, analgesics, antihistamines, and so on. A list of essential medicines and devices should be developed for interstellar travel as well.

Assuming the colonists safely arrive to the new planet, successfully readjust to life outside the ship, and are not affronted with some kind of lethal pathogen, there are other aspects to consider when evaluating the long-term survival of humankind. Research based off animal breeding data indicates that a population of at least 10,000 individuals is necessary to ensure adequate genetic diversity over time. Unless the interstellar ship could carry 10,000 passengers, it is unlikely that the colonists would be able to maintain the desired levels of genetic diversity on the new planet. The lack of diversity could result in birth defects and other health conditions. Perhaps advances in genome science will provide a solution to this problem. Regardless of the degree of genetic diversity, reproductive health is an important concentration in the public health field that should not be ignored on an interstellar mission. Female astronauts have returned to earth and have successfully given birth to healthy children after spaceflight, but once again the question of spaceflight duration remains. Research indicates that the human reproductive organs are especially sensitive to space radiation, and lower levels of spermatogenesis has been observed in male astronauts upon return to earth. If an interstellar mission lasts decades, travelers will not only be concerned with the reproductive consequences upon colonization, but also during flight. A reptilian egg was successfully fertilized aboard the ISS, but lab mice have not been able to conceive viable offspring at this point in time. Before any sort of interstellar mission is planned, additional research is needed to address this issue.

WALL-E's Axiom passengers were lucky, all things considered. Despite the musculoskeletal atrophy, the passengers returned to earth adequately nourished, hydrated, mentally stable, and otherwise in good health. A bustling nursery full of Axiom-born children were brought to the planet as well. Even in a fictional world full of possibilities, the Axiom could have benefitted from a more rigorous public health perspective during its design and development process. For example, the starliner could have incorporated exercise programs to offset the effects of microgravity and improve overall well-being. However, even in a world free of realistic limitations, the nature of interstellar travel today means that the application of public health practices in space are speculative at best. There is value in considering the known, the unknown, and realizing that what we understand today may transform into something unknown tomorrow. Public health tackles these issues on a regular basis: acute infectious diseases emerge without warning, researchers discover new associations between chronic health conditions and past infections, viruses mutate, bacteria become resistant to antibiotics, and so on. The public health lessons that have been learned on earth can provide insight as we move beyond our atmosphere and beyond our galaxy.