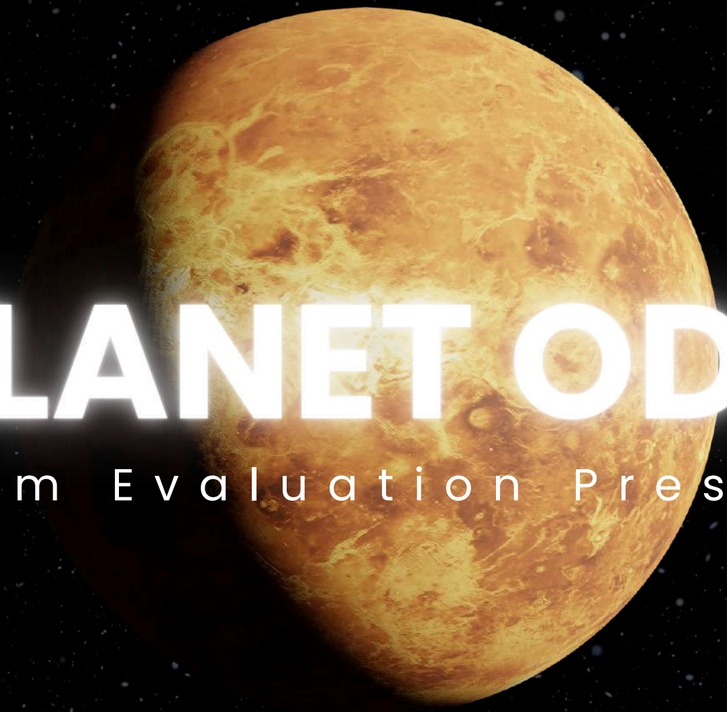
MENTORS : Astitva Roy Srisha Singh Paaritosh Jain Ayush Bokad



RED PLANET ODYSSEY

End Term Evaluation Presentation

Summer Project

Astro Biology

ASTROBIOLOGY IS ABOUT STUDYING LIFE IN THE UNIVERSE. IT LOOKS FOR PLACES WHERE LIFE COULD EXIST BEYOND EARTH, CHECKS FOR SIGNS OF LIFE ON OTHER PLANETS, AND STUDIES HOW LIFE CAN SURVIVE IN TOUGH CONDITIONS. IT ALSO EXPLORES HOW LIFE BEGAN ON EARTH AND HOW IT MIGHT EVOLVE IN THE FUTURE.

Summer Project

Classifications of biological sciences in space

- HUMAN AND ANIMAL
- MICROBIAL
- PLANT

Summer Project

Human and Animal Biology

ENVIRONMENTAL CUES FOR DEVELOPMENTAL PROCESS

1. **Microgravity:** Causes muscle and bone loss.
2. **Radiation**: Increases cancer and genetic damage risk.
3. **Psychological Stress:** Isolation and confinement affect mental health.
4. **Immune System**: Weakens, increasing infection risk.
5. **Medical Facilities**: Limited emergency care options.
6. **Nutrition**: Difficult to maintain balanced diet.
7. **Circadian Rhythms:** Disrupted sleep patterns.
8. **Reproduction:** Unknown effects on development and reproductions.

Ways to study

1. **ISS Experiments**: Study rodents and cell cultures in microgravity.
2. **Simulated Microgravity**: Use Earth-based tools like RWVs.
3. **Parabolic Flights:** Conduct brief experiments in short bursts of microgravity.
4. **Physiology Studies**: Monitor astronaut health and rodent habitats.
5. **Genetic Research**: Analyze gene expression changes.
6. **Radiation Tests**: Examine DNA damage.
7. **Behavioral Studies**: Monitor mental health effects.

Plant Biology

ISOLATION AND STUDY OF MECHANICAL EFFECTS ON PLANT CELLS (WATER DELIVERY IN MICRO GRAVITY)

ENVIRONMENTAL CUES FOR DEVELOPMENTAL PROCESS

1. Radiation
2. Pressure
3. Light
4. Temperature

Summer Project

Microbial Biology

Microbial biology studies in space have become an important area of research, particularly with the rise of long-duration space missions and the potential for future human exploration of Mars and other celestial bodies. These studies focus on understanding how the unique conditions of space—such as microgravity, radiation, and isolation—affect microbial life. Key aspects include microbial growth, gene expression, mutation rates, antibiotic resistance, and interactions with human hosts and the spacecraft environment.

Microbial Biology

Ways to study

1. ISS Experiments: Lab studies in microgravity.
2. Sample Return: Analyze returned space samples.
3. Remote Monitoring: Track microbes with sensors.
4. Genomics: Study DNA changes in space.
5. Biofilms: Examine growth in microgravity.
6. Ecology: Explore microbial interactions.
7. Radiation: Test survival under space radiation.
8. Simulations: Ground-based space condition tests.
9. Life Support: Develop microbial recycling systems.

NASA’s commercial LEO destination

- Northrop Grumman
- Nanoracks “Starlab”
- Orbital Reef (blue origins, sierra space and boeing)

Summer Project

REPORT

THIS REPORT IS ABOUT EXPLORATION OF LIFE IN EXTREME ENVIRONMENTS, BOTH ON EARTH AND IN SPACE.

1. **DEEP MARINE LIFE ON EARTH**: MICROBES LIVE IN THE OCEAN'S DEEP SUBSURFACE, USING CHEMICALS FOR ENERGY, DESPITE HIGH PRESSURE AND EXTREME CONDITIONS.
2. **UNDERGROUND LIFE ON EARTH**: MICROORGANISMS THRIVE DEEP UNDERGROUND, USING CHEMICALS LIKE HYDROGEN, ADAPTING TO EXTREME CONDITIONS.
3. **EXTREME SURFACE HABITATS ON EARTH**: EXTREMOPHILES LIVE IN HARSH PLACES LIKE HOT SPRINGS AND POLAR REGIONS, USING CHEMICALS FOR ENERGY INSTEAD OF SUNLIGHT.
4. **LIFE ON VENUS**: POTENTIAL MICROBES MIGHT LIVE IN VENUS' UPPER CLOUDS, SURVIVING IN ACIDIC WATER DROPLETS.
5. **LIFE ON MARS:** SCIENTISTS SEARCH FOR MICROSCOPIC LIFE UNDERGROUND ON MARS, WHERE CONDITIONS MIGHT BE MORE FAVORABLE.
6. **WATER ON THE MOON:** DISCOVERING WATER ON THE MOON IS IMPORTANT FOR FUTURE EXPLORATION AND THE POSSIBILITY OF LIFE.
7. **ICY MOONS:** MOONS LIKE EUROPA AND ENCELADUS MIGHT HAVE OCEANS BENEATH THEIR ICE, WHERE LIFE COULD EXIST.

Extreme marine subsurface life on Earth

DEEP UNDERGROUND, EARTH HOSTS A VAST COMMUNITY OF TINY ORGANISMS LIVING IN HARSH CONDITIONS. THIS AREA, CALLED THE DEEP BIOSPHERE, INCLUDES BACTERIA, ARCHAEA, AND EUKARYOTES, AND IS VAST, COVERING 2 TO 2.3 BILLION CUBIC KILOMETERS. THEY USE CHEMICALS FROM THE EARTH'S CRUST FOR ENERGY INSTEAD OF SUNLIGHT, THRIVING IN EXTREME HEAT, COLD, SALINITY, AND PH LEVELS. DESPITE THE CHALLENGES, THESE MICROBES MAKE UP 15% OF EARTH'S TOTAL LIFE AND SHOW SIGNIFICANT GENETIC DIVERSITY. SCIENTISTS STUDY THEM TO LEARN HOW LIFE CAN SURVIVE IN TOUGH ENVIRONMENTS, PROVIDING CLUES ABOUT POTENTIAL LIFE ON OTHER PLANETS.

Life under the terrestrial subsurface

UNDERNEATH THE EARTH'S SURFACE LIES A HUGE WORLD OF TINY LIFE FORMS, INCLUDING BACTERIA, ARCHAEA, AND EUKARYOTES. THESE MICROBES LIVE IN EXTREME CONDITIONS WITHOUT SUNLIGHT, USING CHEMICALS LIKE HYDROGEN FOR ENERGY. THEY MAKE UP 60% OF EARTH'S MICROORGANISMS AND HELP US LEARN ABOUT EARLY EARTH CONDITIONS AND LIFE ON OTHER PLANETS. STUDYING THEM IS TRICKY BECAUSE THEY GROW SLOWLY, BUT IT'S IMPORTANT FOR UNDERSTANDING MICROBIAL DIVERSITY AND HOW CARBON MOVES AROUND. THESE EXTREME ENVIRONMENTS ARE SIMILAR TO THOSE IN SPACE, GIVING US HINTS ABOUT HOW LIFE CAN SURVIVE IN TOUGH PLACES.

Extreme habitats on the surface of the Earth

ON EARTH, SOME PLACES ARE SUPER TOUGH FOR LIFE, LIKE HOT SPRINGS, ICY POLAR REGIONS, AND SALTY LAKES. BUT TINY ORGANISMS CALLED EXTREMOPHILES LOVE THESE EXTREME CONDITIONS. THEY SURVIVE IN PLACES WITH HIGH HEAT, FREEZING COLD, LOW OXYGEN, OR CRAZY PH LEVELS. INSTEAD OF SUNLIGHT, THEY USE CHEMICALS LIKE HYDROGEN AND METHANE FOR ENERGY. SCIENTISTS STUDY THEM TO LEARN ABOUT LIFE'S LIMITS AND HOW IT MIGHT SURVIVE ON OTHER PLANETS. THESE ORGANISMS, INCLUDING BACTERIA AND FUNGI, ADAPT IN COOL WAYS, LIKE MAKING ANTIFREEZE MOLECULES OR CHANGING THEIR MEMBRANES. EVEN IN HARSH PLACES, LIFE FINDS A WAY TO THRIVE!

Habitability on Venus

VENUS IS A TOUGH PLACE TO LIVE ON ITS SURFACE BECAUSE IT'S SUPER HOT, DRY, AND HAS THICK AIR. BUT SCIENTISTS ARE INTERESTED IN THE POSSIBILITY OF LIFE IN ITS UPPER CLOUDS, WHERE IT'S MORE LIKE EARTH. THERE, TINY WATER DROPLETS IN SULFURIC ACID COULD SUPPORT MICROBES. EVEN THOUGH VENUS IS HARSH, THERE ARE HINTS OF UNKNOWN STUFF THAT MIGHT BE FROM LIVING THINGS. RECENT VOLCANIC ACTIVITY MIGHT ALSO GIVE NUTRIENTS FOR LIFE. EVEN THOUGH VENUS IS TOUGH, SCIENTISTS ARE CURIOUS ABOUT LIFE IN ITS UPPER CLOUDS, ESPECIALLY SINCE THEY FOUND SOMETHING CALLED PHOSPHINE, WHICH COULD MEAN LIFE.

Extant Life on Mars

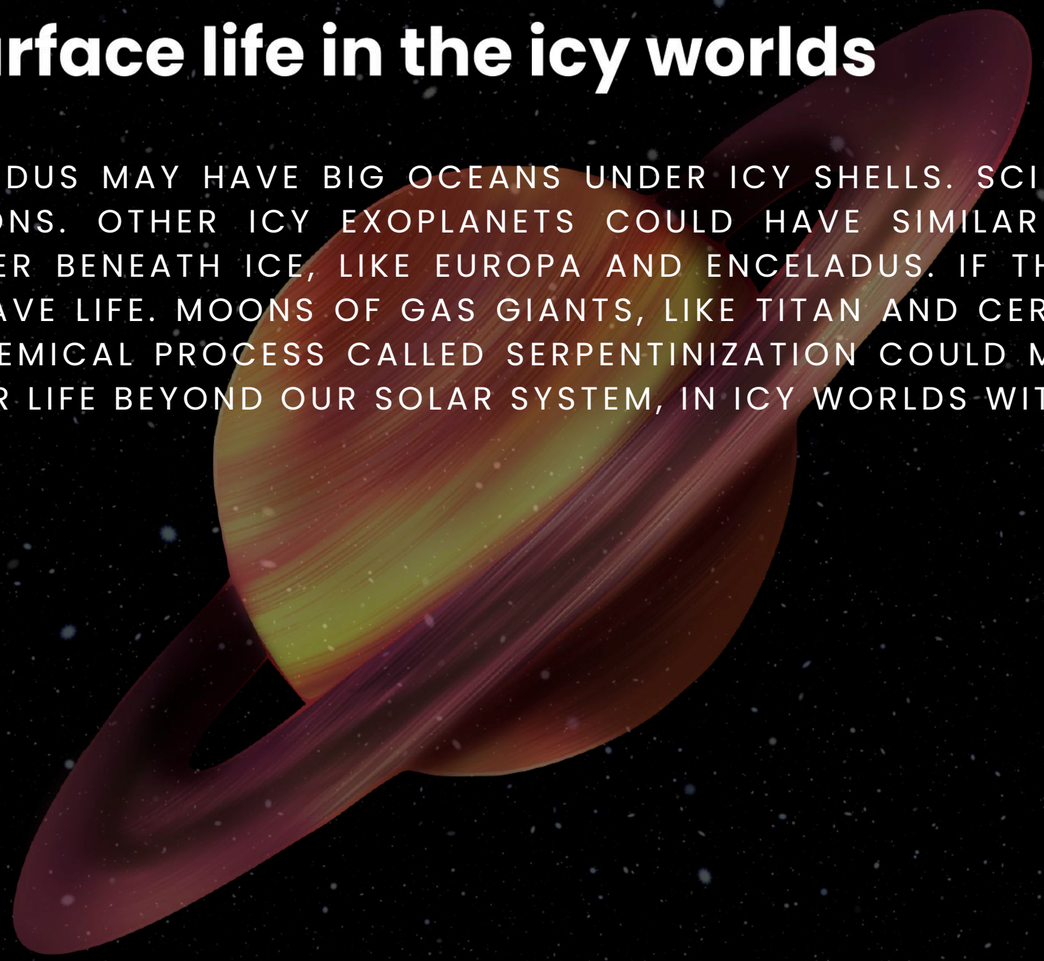
SCIENTISTS ARE CURIOUS ABOUT MARS BECAUSE IT MIGHT HAVE HAD LIFE. WHILE WE HAVEN'T FOUND PROOF YET, WE THINK ANCIENT MARS HAD WATER AND COULD SUPPORT LIFE. NASA'S ROVERS ARE LOOKING FOR SIGNS OF PAST LIFE, ESPECIALLY NEAR OLD RIVERS OR LAKES. IF THERE'S LIFE ON MARS, IT MIGHT BE TINY AND UNDERGROUND, USING MINERALS FOR ENERGY. EVEN THOUGH MARS HAS A THIN ATMOSPHERE AND TOUGH CONDITIONS, WE'RE STILL LOOKING FOR LIFE. RECENT DISCOVERIES OF ORGANIC STUFF AND PAST WATER MAKE US THINK MARS COULD HAVE SUPPORTED LIFE. WE HAVEN'T FOUND DIRECT PROOF YET, BUT WE'RE HOPEFUL OUR EXPLORATION WILL UNCOVER MARTIAN SECRETS.

Search for water on Moon

SINCE 1645, PEOPLE WANTED TO FIND WATER ON THE MOON. EARLY IDEAS BY MICHAEL VAN LANGREN THOUGHT LUNAR CRATERS WERE "OCEANS." WILLIAM PICKERING IN THE 1800S SAID THE MOON HAD NO AIR, SO WATER WOULD EVAPORATE. KENNETH WATSON IN 1961 SAID ICY WATER MIGHT BE IN DARK CRATERS. APOLLO MISSIONS AT FIRST FOUND NO WATER, BUT LATER SAW SIGNS OF IT IN VOLCANIC GLASS. IN THE LATE 2000S, CHANDRAYAAN-1 AND CASSINI FOUND WATER ON THE MOON. NASA'S SOFIA CONFIRMED WATER IN SUNNY AREAS. RECENT DISCOVERIES SHOW WATER IN SUNNY PLACES TOO. MORE RESEARCH IS NEEDED TO KNOW WHERE LUNAR WATER COMES FROM, IMPORTANT FOR FUTURE MOON EXPLORATION.

Search for subsurface life in the icy worlds

MOONS LIKE EUROPA AND ENCELADUS MAY HAVE BIG OCEANS UNDER ICY SHELLS. SCIENTISTS EXPLORE THEM FOR LIFE SIGNS, LIKE WATER ERUPTIONS. OTHER ICY EXOPLANETS COULD HAVE SIMILAR OCEANS. NASA FOUND 17 EXOPLANETS WITH POSSIBLE WATER BENEATH ICE, LIKE EUROPA AND ENCELADUS. IF THESE OCEANS HAVE ENERGY AND RIGHT STUFF, THEY COULD HAVE LIFE. MOONS OF GAS GIANTS, LIKE TITAN AND CERES (DWARF PLANET), MIGHT ALSO HAVE LIFE UNDER ICE. A CHEMICAL PROCESS CALLED SERPENTINIZATION COULD MAKE STUFF FOR LIFE THERE. THESE FINDINGS HELP US LOOK FOR LIFE BEYOND OUR SOLAR SYSTEM, IN ICY WORLDS WITH HIDDEN OCEANS.



BACTERIAL GROWTH SIMULATION

Bacterial growth is a type of **population dyamics**, which is the study of population size (number of individuals) over time. Bacterial growth can be studied both by analyzing data from a real experiment or by creating a virtual experiment. So,we will **simulate bacterial growth** on the computer via using Python and its libraries.

We will first create a Mathematical model of bacterial growth and then create a computational model of it via programming !!

We will study **Exponential** & **Logistic growth** models with some assumptions and will also study bacterial phases, effects of temperature, death rate and other terms.

Reference :

https://gist.github.com/dragly/b6c8c5a163585ebda95c4d45946025cd

BACTERIAL GROWTH CURVE

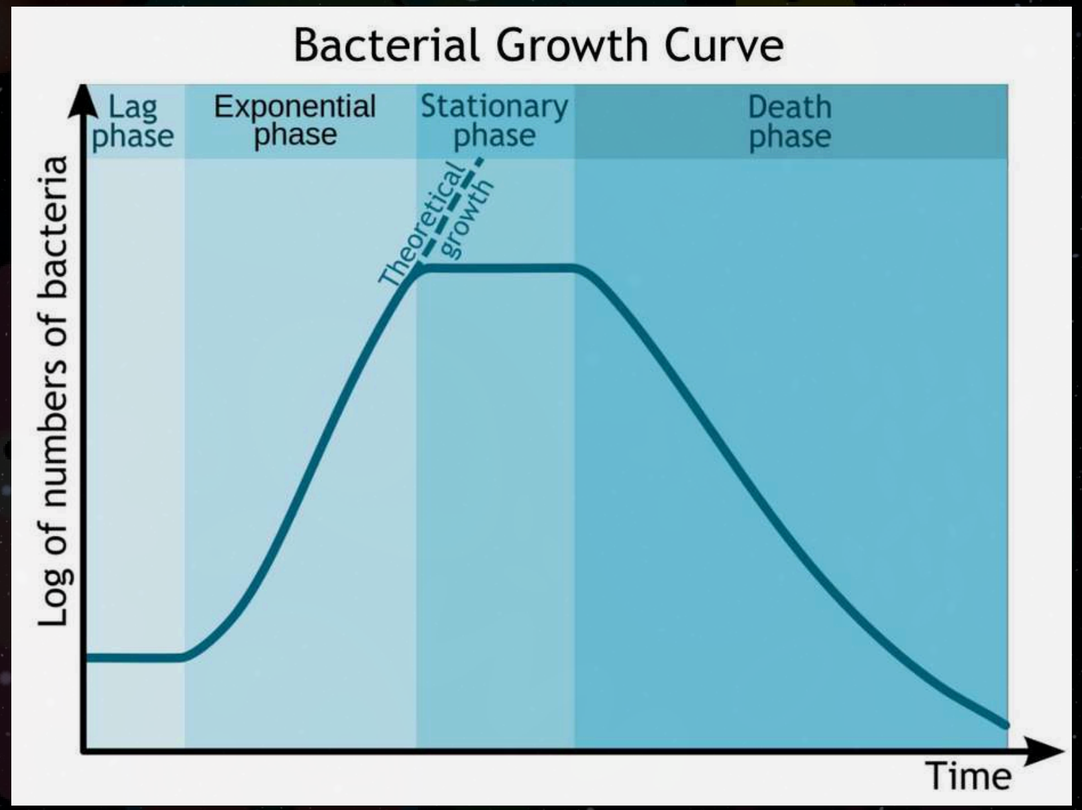
Bacteria are unicellular organisms that tend to reproduce asexually by the means of binary fission. The time taken for a bacterial cell to double is called **generation time**. In a closed system with enough nutrients, a bacteria shows a predictable growth pattern that is the bacterial growth curve :-

Lag Phase : The bacteria upon introduction into the nutrient medium take some time to adapt to the new environment. In this phase, the bacteria does not reproduce but prepares itself for reproduction.

Log \exponential Phase : During this phase, there is an exponential increase in the number indicated by a section of the growth curve. This is reproduction phase.

Stationary Phase : In the stationary phase, the rate of growth of the cells becomes equal to its rate of death. The bacterial population remain constant.

Death Phase : This is the last phase of the bacterial growth. At this stage, the rate of death is greater than the rate of formation of new cells.



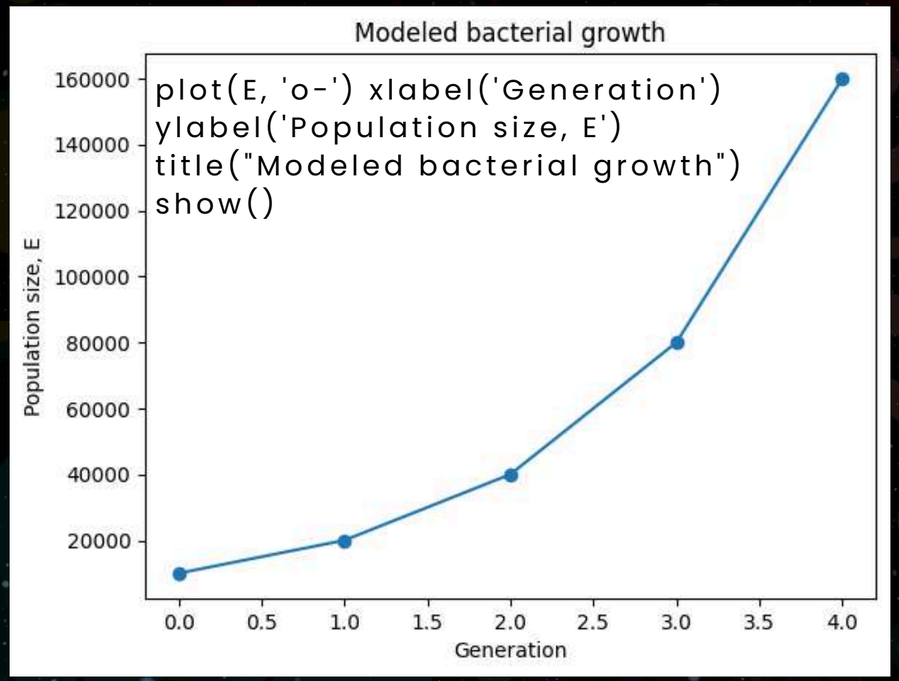
EXPONENTIAL GROWTH

Assumptions:

- no factors limiting growth
- no death
- same generation time

As the Population doubles after each geneation time :-

$$E_n = E_{n-1} + \Delta E = 2E_{n-1}$$



Let E_n be the number of bacteria at a given time step n.

t_n be the time after n steps.

Δt be the generation time.

E_0 be the initial population.

ΔE is the change in Number of bacteria per time stamp

all functions and modules from the pylab module are imported

declaring timesteps and initializing number of bacteria at time t array as a zero array.

declaring E_0

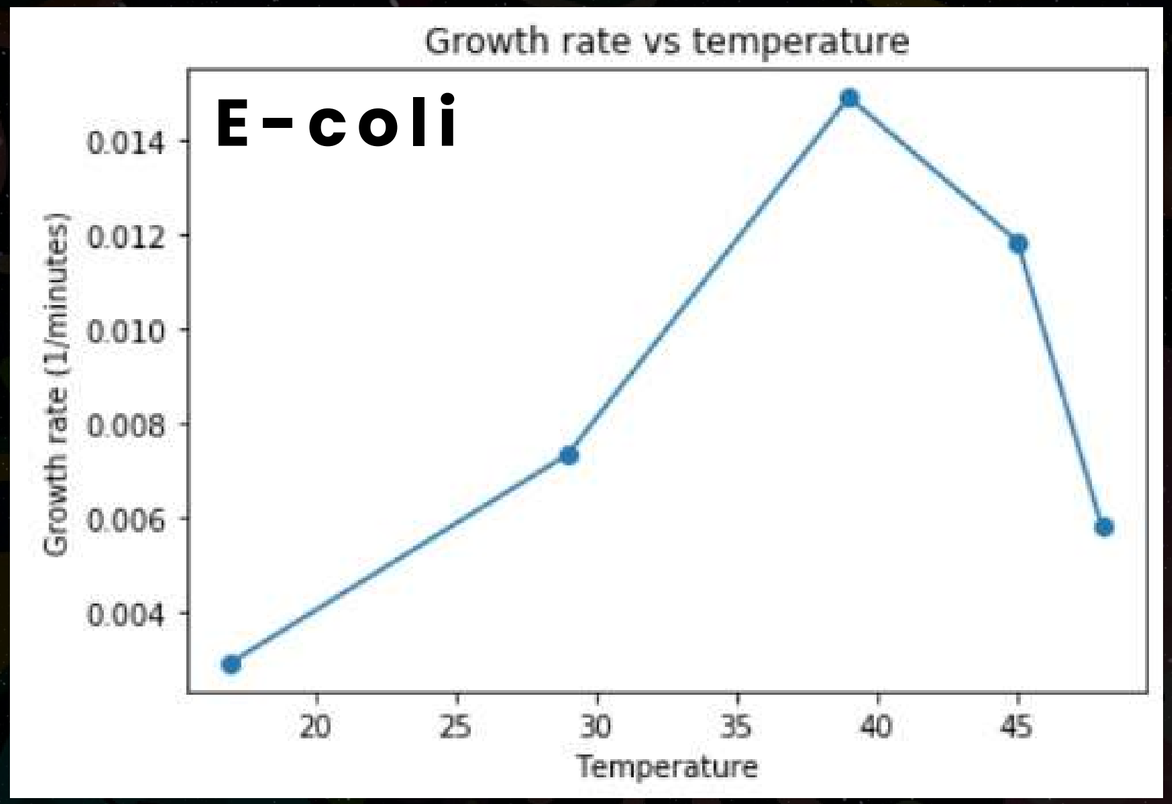
loop to calculate E_n at each timestep

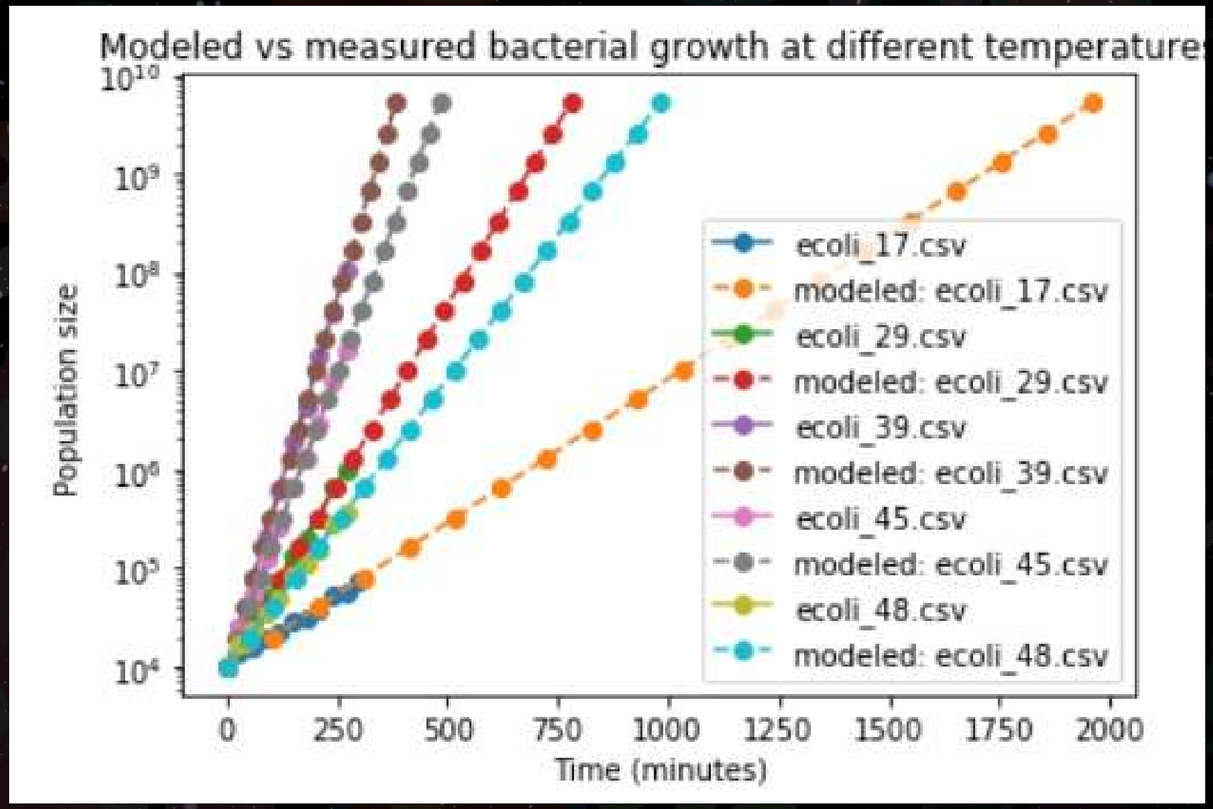
Will print the whole list of number of bacteria at each timestep.

```
from pylab import *

N = 5
E = zeros(N)

E[0] = 10000.

for n in range(1, N):
    E[n] = 2*E[n-1]

print("Number of bacteria: ", E)
```

EXAMINING THE EFFECT OF TEMPERATURE ON GROWTH

The relationship between temperature and bacterial growth rate is typically non-linear and can vary significantly among different bacterial species. Generally, each bacterial species has an optimal temperature range where it grows most rapidly.





Growth Rate- Its just the slope of the population size v/s time graph denoted as a

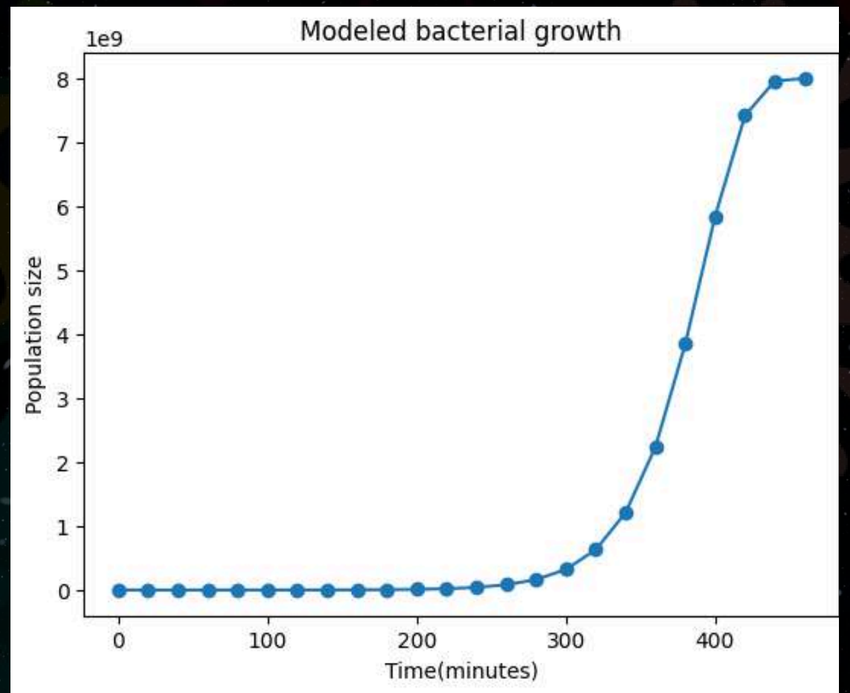
```
a = (log10(E[-1]) - log10(E[0])) / (t[-1] - t[0])
generation_time = log10(2)/a
```

LOGISTIC GROWTH

Assumptions:

- If there is no limitation in resources available, the population doubles each generation.
- There is a finite and constant supply of resources available each generation.
- same generation time

$$E_n = E_{n-1} + (1 - E_{n-1}/K)E_{n-1}$$



where K is the **maximum sustainable population**

$$K = 8 \times 10^9$$

```
from pylab import *

N = 24
dt = 20  # min
K = 8e9

E = zeros(N)
t = zeros(N)

E[0] = 10000.

for n in range(1, N):
    E[n] = E[n-1] + (1 - E[n-1]/K)*E[n-1]
    t[n] = t[n-1] + dt

plot(t, E, 'o-')
xlabel('Time(minutes)')
ylabel('Population size')
title("Modeled bacterial growth")
show()
```

loop that will iterate from timestep 1 to N to calculate the number of bacteria at each timestep logistically

DEATH RATE

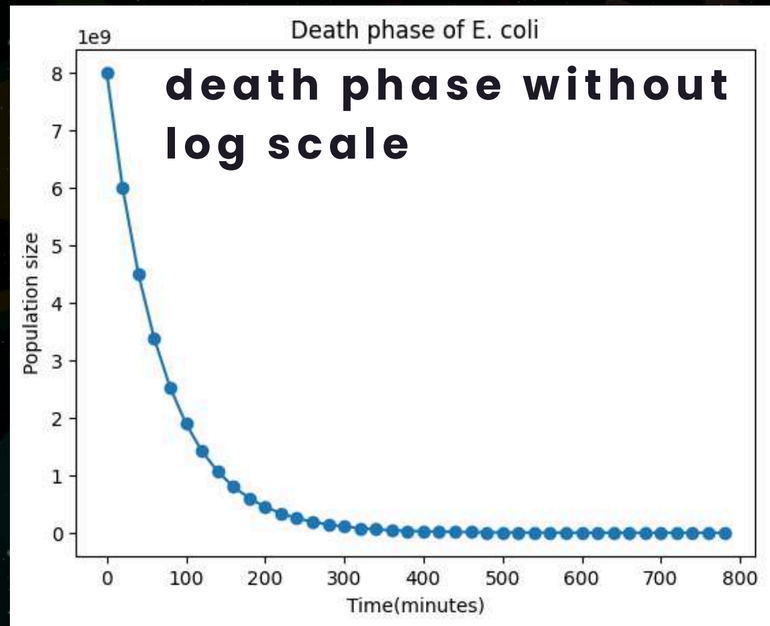
Assumptions:

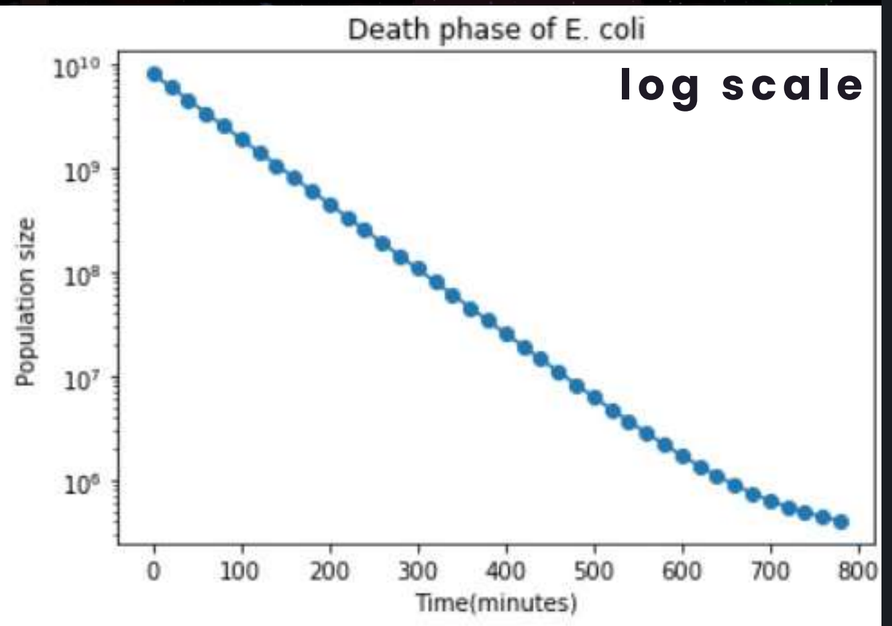
- The bacteria do not reproduce.
- The rate of bacteria that dies in each time step, is proportional to the difference between the number of bacteria and the long-term sustainable number of bacteria.

D :- the fraction by which bacteria die each generation.

F :- equilibrium population (3e5 for E-Coli)

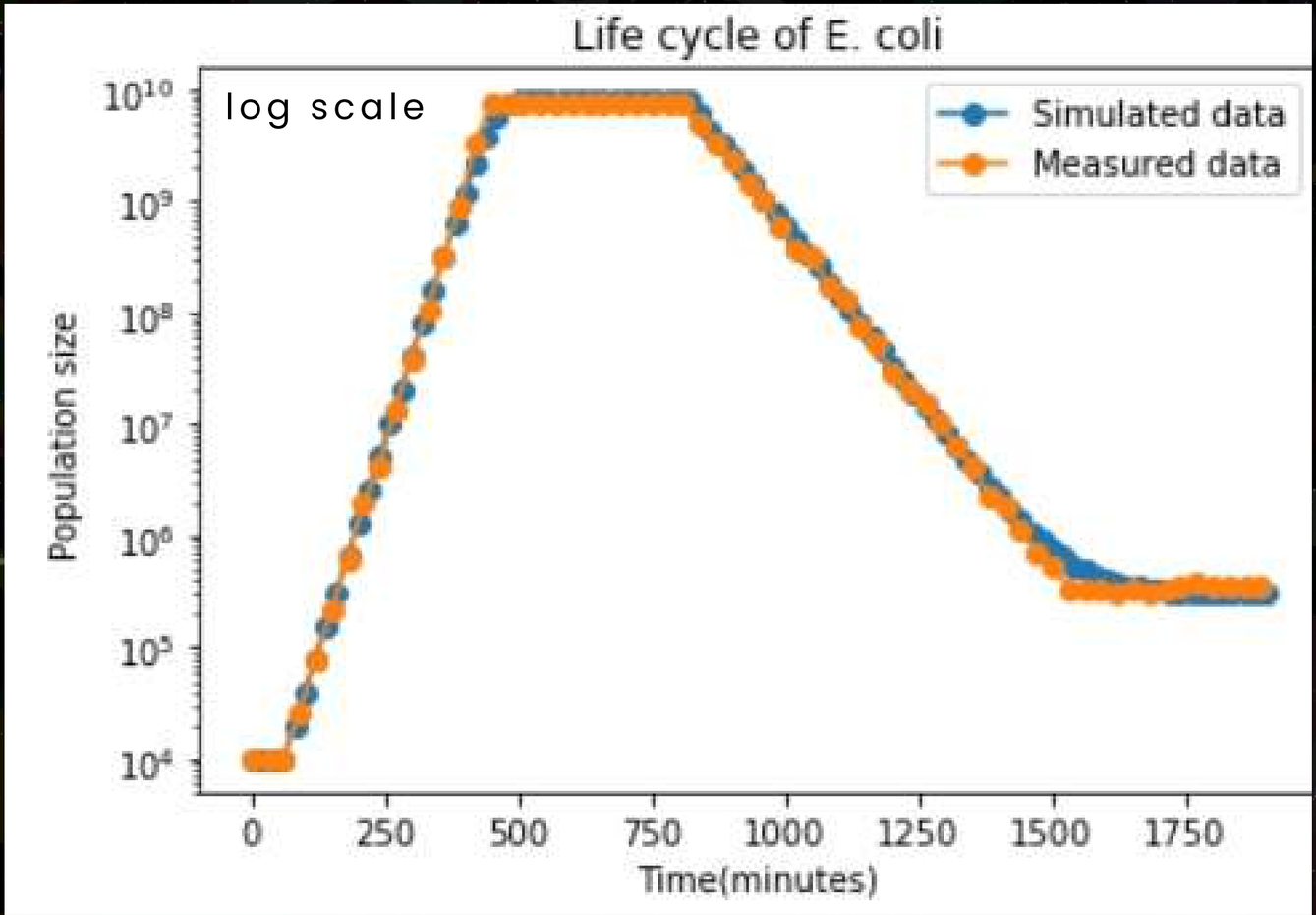
$$E_n = E_{n-1} + D(E_{n-1} - F)$$






```
from pylab import *

N = 40
dt = 20  # min
D = 0.25
F = 3e5

E = zeros(N)
t = zeros(N)

E[0] = 8e9

for n in range(1, N):
    E[n] = E[n-1] - D*(E[n-1] - F)
    t[n] = t[n-1] + dt

plot(t, E, 'o-')
xlabel('Time(minutes)')
ylabel('Population size')
title('Death phase of E. coli')
yscale('log')
show()
```

MODELING ALL PHASES



SO, AS WE CAN SEE VIA USING 3 MODELS IN LOOPS FOR DIFFERENT GROUPS OF GENERATIONS WE CAN SIMULATE THE LIFE CYCLE OF BACTERIA !!!

```python
from pylab import *

N_lag = 4     # Generations in the lag phase
N_log = 38    # Generations in the logarithmic growth phase
N_death = 54  # Generations in the death phase

# Total number of generations
N = N_lag + N_log + N_death

dt = 20  # min
K = 8e9
D = 0.25
F = 3e5

E = zeros(N)
t = zeros(N)

E[0] = 10000

# perform lag phase modeling
for n in range(1, N_lag):
    E[n] = E[n-1]
    t[n] = t[n-1] + dt

# perform logistic growth modeling
for n in range(N_lag, N_lag + N_log):
    E[n] = E[n-1] + (1 - E[n-1]/K) * E[n-1]
    t[n] = t[n-1] + dt

# perform death phase modeling
for n in range(N_lag + N_log, N):
    E[n] = E[n-1] - D*(E[n-1] - F)
    t[n] = t[n-1] + dt
```

dividing generations to all phases

constant population

logistic growth till it reaches K

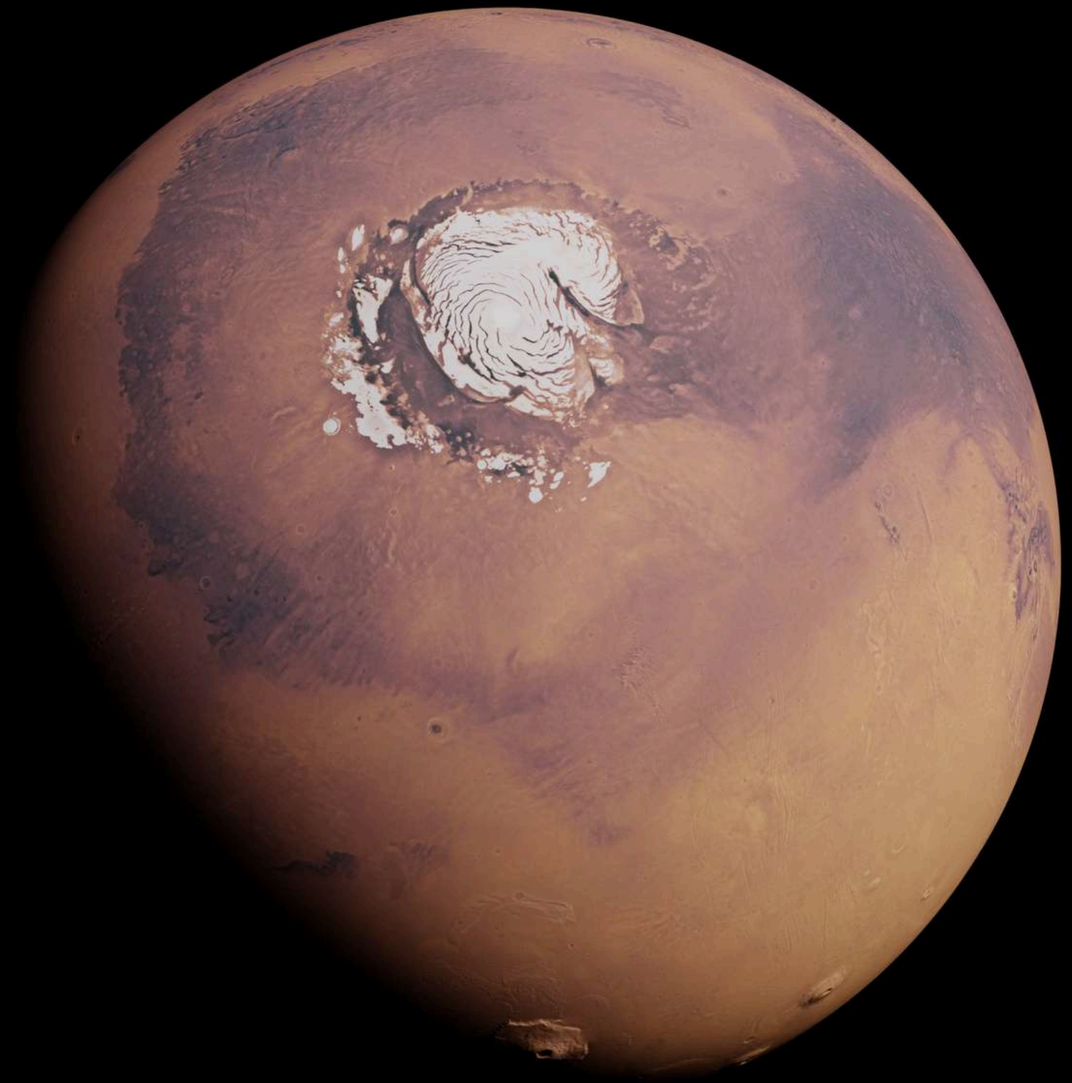
Death rate

Martian Test Chamber

In order to test the survivability of plants on Mars, a sealed chamber with controlled conditions to replicate the Martian environment shall be prepared. By simulating the chamber's temperature, pressure, atmosphere, etc- the conditions that could possibly affect plant survival and growth on the planet- we can expand our knowledge about plants' resistance to such extreme conditions beyond the theoretical aspect. Such experiments have been conducted (or still under progress) by organisations like NASA (the SAM instrument on the Curiosity Rover), etc with future prospects including the inhabitation of Mars.

Conditions that Need to be Monitored

1. Insulation of the chamber
2. Sterlisation of the chamber
3. Temperature
4. Pressure
5. Atmospheric composition
6. Gravity
7. Radiation
8. Regolith composition



Insulation and Sterlisation

The chamber needs to be sealed and insulated from the surrounding environment. We plan on using **acrylic** for the inner and outer walls of the chamber, the gap in between being filled with **resin**. These materials are **strong, transparent as well as good insulators**, hence suitable for our purpose. Sterlisation of the chamber is also necessary in order to eliminate any possibility of contamination by terrestrial life.

Temperature

Temperature on Mars varies between 143 K to 293 K during the day-night cycle. Therefore we will need to vary temperature largely in a short time in the chamber. Hence, we plan on using **liquid nitrogen pipelines** and **nichrome resistors**, uniformly attached across the inner walls, for cooling and heating respectively.

Atmospheric Composition, Pressure

Atmospheric pressure will need to be nearly constant at **around 600 Pa,** which can be managed by employing automated **inlet and outlet valves** attached to the gas source and vacuum pump respectively. The gas source will release a gaseous mixture with composition nearly identical to the Martian atmosphere (around 95% CO_2, 2.7% N_2, 1.3% Ar and rest O_2). The valves will function based on **pressure sensors** placed inside the chamber.

Radiation / Illumination

Lack of a dense atmosphere on Mars and its **distance from the Sun** affect the intensity of radiation of various wavelengths reaching the surface of the planet. To accommodate for it, a source of UV light, such as a **Xenon or Mercury discharge lamp** could be put to use. The intensity of heat and light energy falling on the planet (max 589 W/m²) conveniently falls under the energy range that such a lamp can generate (200 to 600 W/m²).

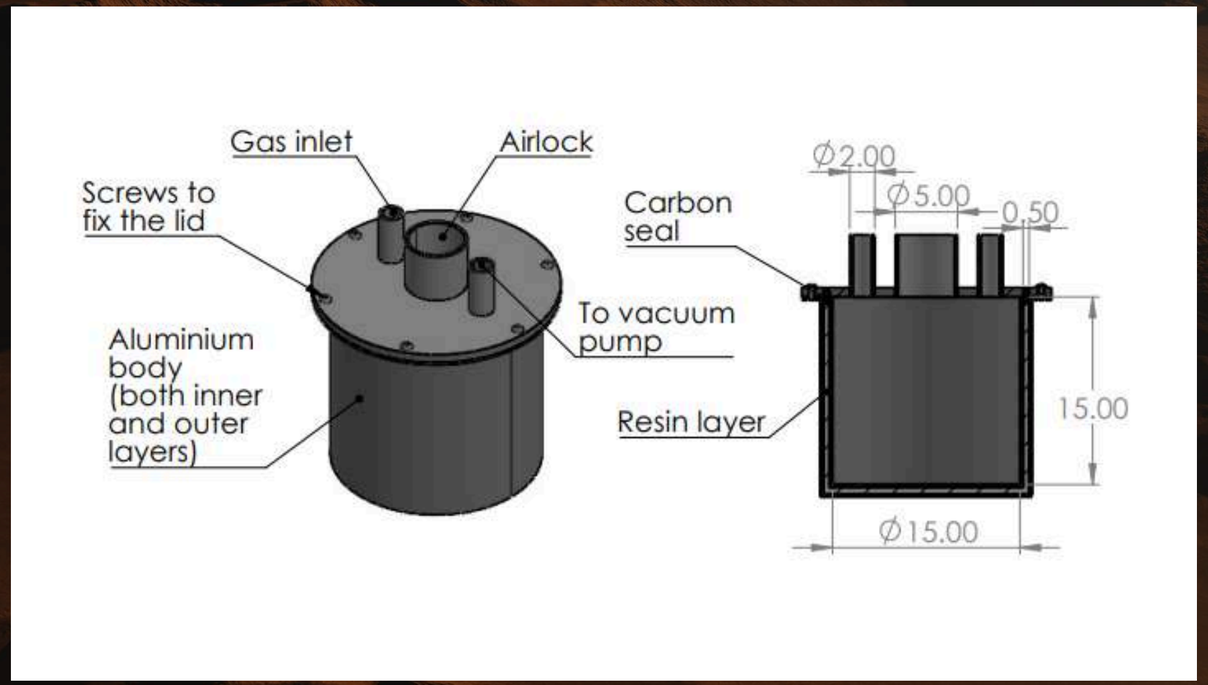
Regolith Composition and Gravity

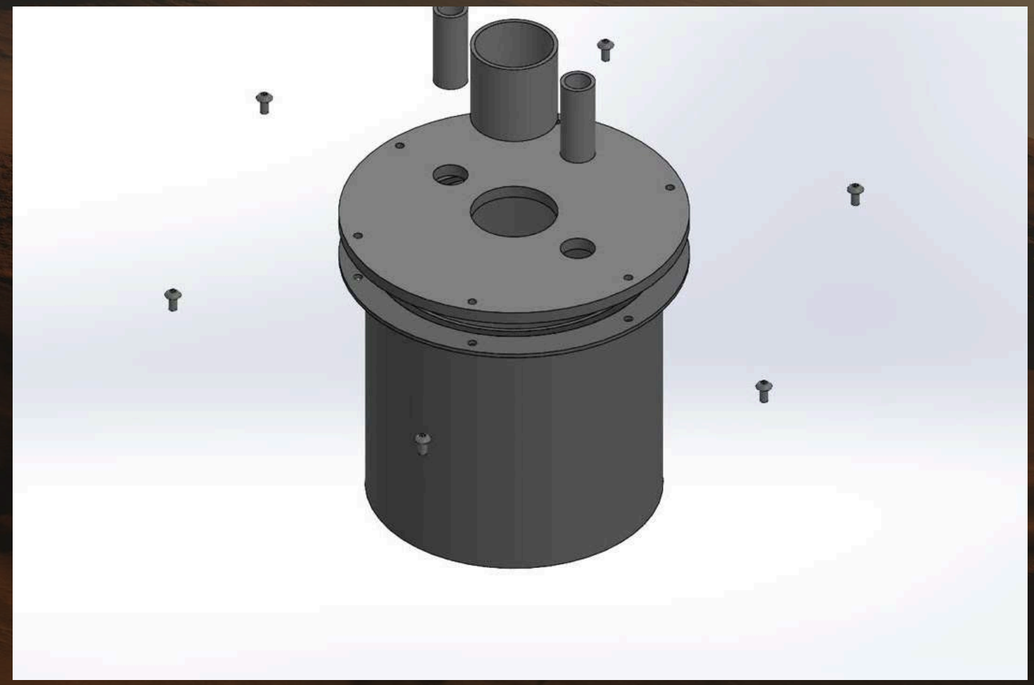
- Martian surface is primarily composed of **weathered basalt, sulphates, oxides, perchlorates**, etc.
- The major and minor elements essential for life as we know it are present, however not in the form of nutrients.
- **Water and air retention** of Martian regolith is also very poor.
- **Carbon** in its organic form is absent.
- By incorporating these fundamental properties, regolith simulants are prepared to replicate Martian soil as closely as possible.

- However, this does pose challenges in gravity simulation. Low water retentivity implies that the regolith would be **prone to disturbance** if we intend to use centrifugation to reduce effective gravity to 0.38 g (as it is on Mars). We need the regolith to be **static** for the experiment to be conducted properly.

The Chamber Design

Taking into consideration the feasibility, resource limitations, etc; and keeping in mind our requirement of mimicking the Martian environment as closely as possible, we deigned a 15x15 (cm) chamber with valved inlets/outlets, an airtight lid, vacuum insulation, etc, as shown below.





ESTIMATED GROWTH RATE FOR USTILAGO MAYDIS

1. LAG PHASE:

- Under harsh conditions, such as those simulating Mars, the lag phase might be prolonged as the organism adapts to the stress.
- Estimated Duration: 24 to 48 hours.

2. EXPONENTIAL PHASE:

- Growth during this phase is usually rapid under optimal conditions. But, under Martian conditions, growth might be slower due to low temperature and reduced pressure.
- Estimated Doubling Time: 24 to 36 hours (compared to 8-12 hours under Earth-like conditions).

3. STATIONARY PHASE:

- The stationary phase would occur once the growth rate slows down due to resource limitations or accumulation of waste products.
- Estimated Duration: This phase could extend for several days as the organism shifts to a survival mode under stress.

4. DECLINE PHASE:

- Eventually, the growth rate may decline as the stressors overwhelm the organism's capacity to survive.
- Estimated Duration: 48 to 72 hours after the stationary phase begins, leading to a gradual decline in viable cells.

OVERALL GROWTH RATE:

Growth Rate (μ) Estimate: Due to the harsh conditions, the specific growth rate (μ) might be around 0.02 to 0.04 per hour. This is lower than typical growth rates under optimal conditions, where μ could be closer to 0.1 to 0.2 per hour.

COMPARISON TO EARTH-LIKE CONDITIONS:

Under Earth-like conditions, Ustilago maydis might show a much faster growth rate, with a doubling time of around 8 to 12 hours and a μ closer to 0.1 to 0.2 per hour during the exponential phase

MONOD KINETICS

It relates the specific growth rate of an organism to imiting growth substrate

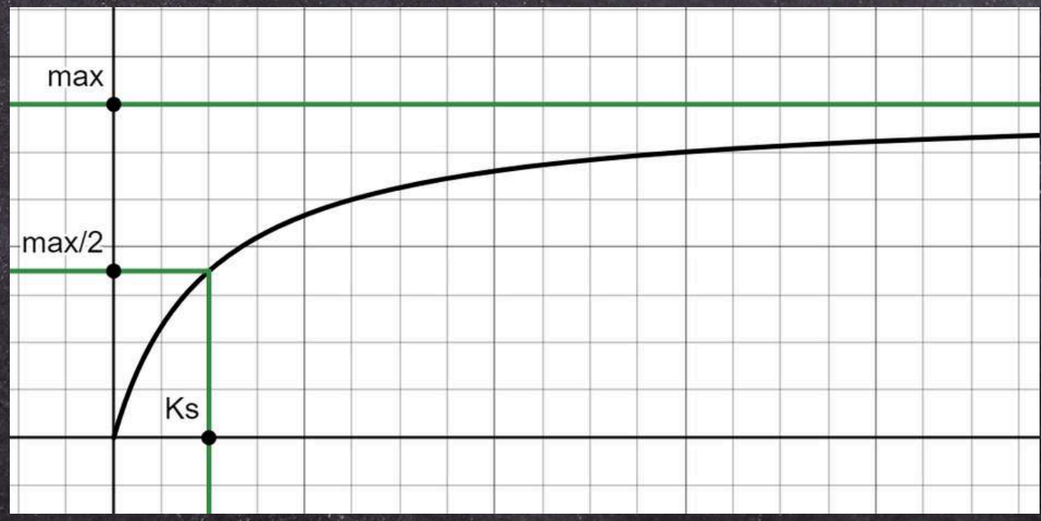
$\mu =$ Specific growth rate defined as $\frac{1}{x} \cdot [\frac{dx}{dt}]$

$S =$ limiting substrate Concentration

$K =$ Substrate saturation constant when $\mu = \mu_{max}/2$ then $K_s = S$

$$\mu = \mu_{max} \cdot \frac{[S]}{K_s + [S]}$$

Maximum growth rate of the oragnism



SPORE FORMATION DATA FOR USTILAGO MAYDIS UNDER MARTIAN CONDITIONS

1. INDUCTION OF SPORE FORMATION:

- **Spore formation might be triggered more rapidly under stress conditions. The onset of spore formation could begin soon after the organism enters the stationary phase as a response to the environmental stressors like low temperature, high UV radiation, and low atmospheric pressure.**
- **Estimated Onset Time: 48 t**o 72 hours after exposure to Martian conditions.

2. RATE OF SPORE FORMATION:

- **Under optimal conditions, Ustilago maydis may not prioritize spore formation unless in response to nutrient deprivation or environmental stress. In Martian conditions, the spore formation rate could be significantly higher due to the extreme environment.**
- **Estimated Rate: Approximately 10-20% of the cells may undergo spore formation per day during the stationary phase. This is a rough estimate as the rate can vary significantly based on the severity of the conditions.**

SPORE FORMATION DATA FOR USTILAGO MAYDIS UNDER MARTIAN CONDITIONS

COMPARISON TO EARTH-LIKE CONDITIONS:

• Under Earth-like conditions, spore formation in Ustilago maydis might be less frequent and slower, with only 5-10% of cells forming spores over the same timeframe under non-stressful conditions.

SUMMARY OF SPORE FORMATION:

• Onset Time: 48-72 hours post-exposure.
• Rate: 10-20% of cells/day during the stationary phase.
• Frequency: 60-80% of the surviving population forming spores by the end of the stationary phase.
• Viability Duration: Weeks to months under simulated Martian conditions

BIOMASS PRODUCTION FOR USTILAGO MAYDIS FOR MARTIAN CONDITIONS:

COMPARISON TO EARTH-LIKE CONDITIONS:

- Under Earth-like conditions, biomass production would likely be higher, with peak biomass reaching 70-100 mg/L during the exponential phase and maintaining higher levels during the stationary phase.

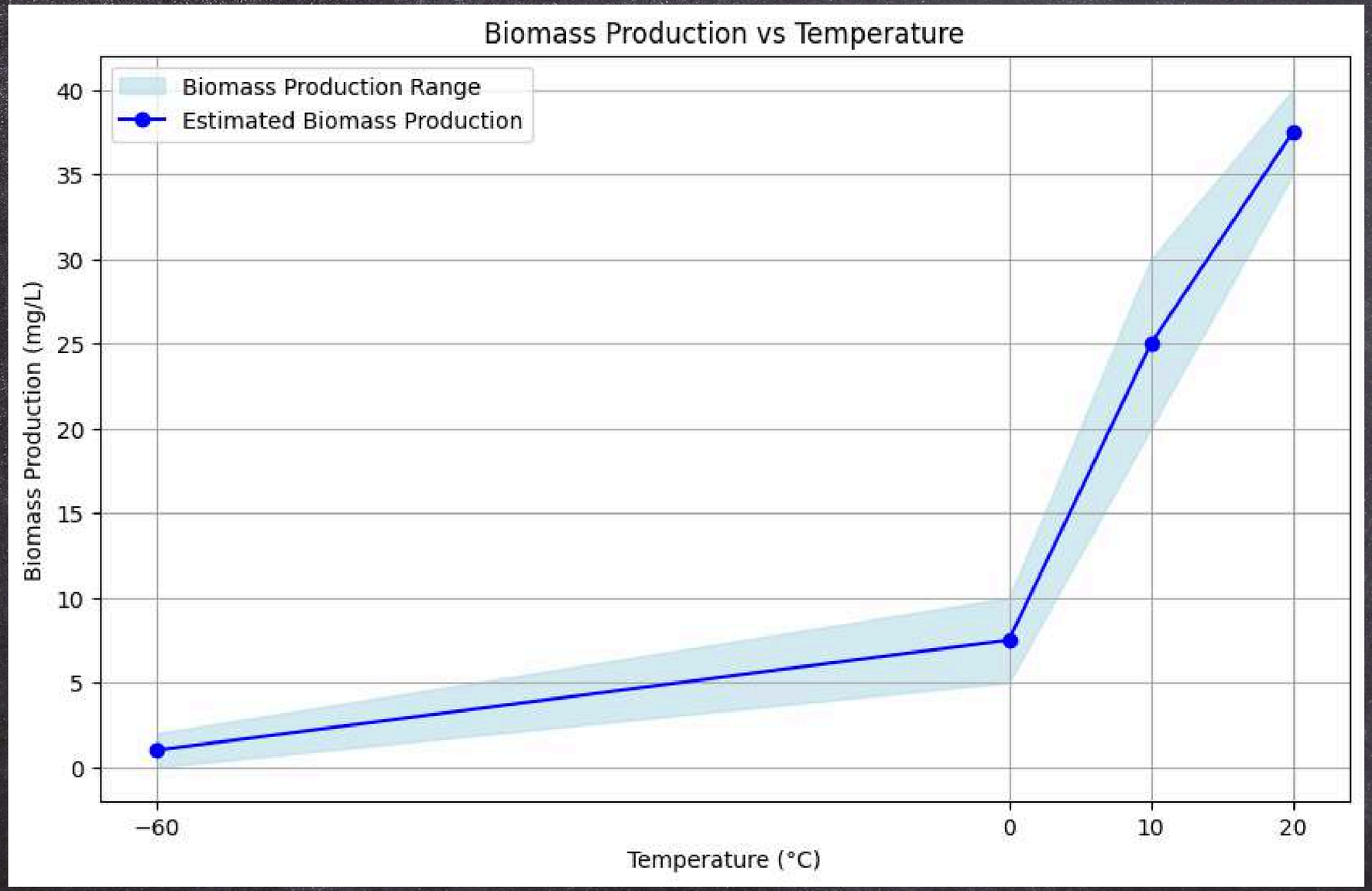
SUMMARY OF BIOMASS PRODUCTION:

- Lag Phase Biomass: 5-10 mg/L
- Exponential Phase Peak Biomass: 40-50 mg/L
- Stationary Phase Biomass: 50-55 mg/L
- Decline Phase Biomass: 40-50 mg/L

FACTORS AFFECTING GROWTH

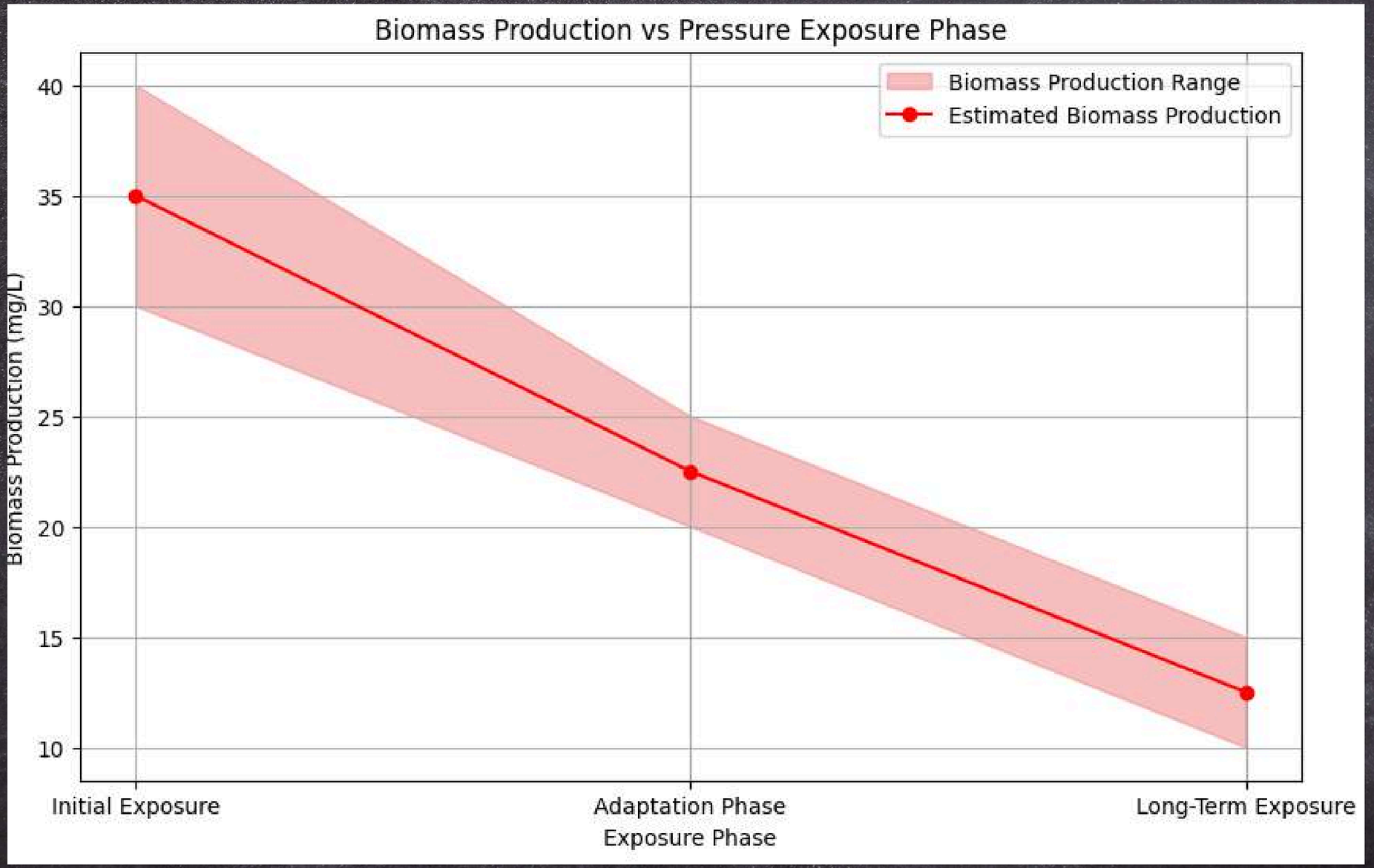
TEMPERATURE

- **TEMPERATURE RANGE:**
  - -60°C to 20°C (typical Martian surface temperature fluctuations)
- **GROWTH DYNAMICS:**
  - Low Temperatures (-60°C to 0°C): Minimal growth observed, with metabolic activities significantly slowed down. The fungus might enter a dormant state, with no noticeable biomass increase.
  - Moderate Temperatures (0°C to 10°C): Slow growth observed, with limited metabolic activity. Some biomass production occurs, but growth rates are reduced by 50-70% compared to Earth-like conditions.
  - Higher Temperatures (10°C to 20°C): Increased metabolic activity and growth, with biomass production closer to Earth-like conditions, though still reduced by approximately 30%.


Biomass Production vs Temperature
Biomass Production Range
Estimated Biomass Production
Biomass Production (mg/L)
0
5
10
15
20
25
30
35
40
−60
0
10
20
Temperature (°C)

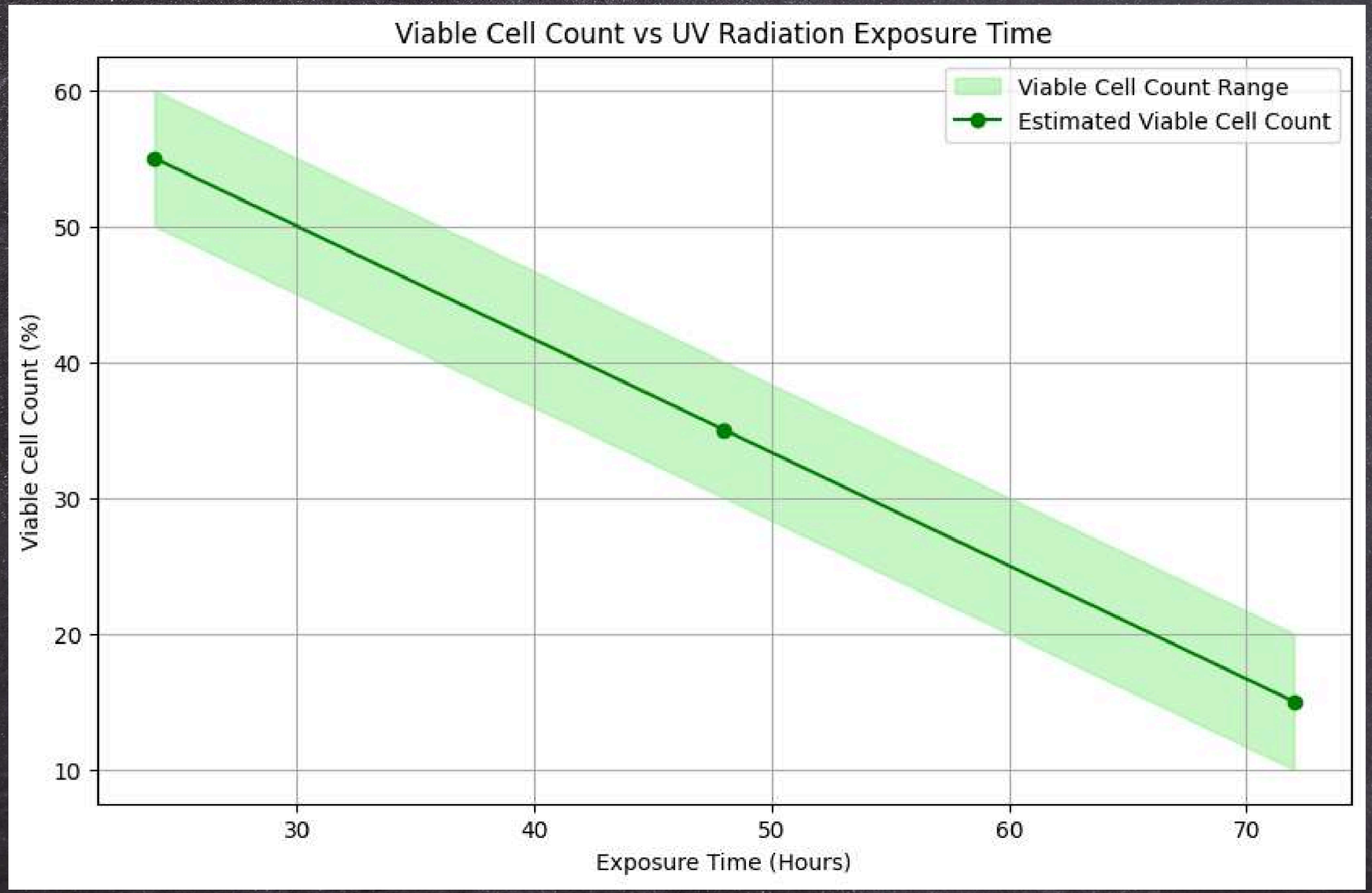
PRESSURE:

- Simulated Martian Atmospheric Pressure: ~600 Pa (0.6% of Earth's atmosphere)
- Effects on Cellular Integrity:
- Initial Exposure: Immediate stress response, with potential cell membrane deformation and reduced cellular integrity. Some cells may lyse or become Non-viable.
- Adaptation Phase: Cells may exhibit stress-induced metabolic changes, including increased production of protective proteins and metabolites. Growth is slow, with a high percentage of cells entering a dormant or spore state.
- Long-Term Exposure: Overall growth rates decrease by 70-80%, with significant cellular stress markers observed. Viable cell count may drop to 30-40% of initial population.


Biomass Production vs Pressure Exposure Phase
Biomass Production Range
Estimated Biomass Production
Biomass Production (mg/L)
40
35
30
25
20
15
10
Initial Exposure
Adaptation Phase
Long-Term Exposure
Exposure Phase

Radiation Exposure:

- Simulated UV Radiation: Equivalent to Martian surface levels (~250 nm wavelength UV-B and UV-C)
- Impact on DNA Integrity:
  - Short-Term Exposure: DNA damage observed, including double-strand breaks and pyrimidine dimers. Increased mutation rates in surviving cells. Some cells initiate DNA repair mechanisms, but efficiency is reduced due to stress.
  - Spore Viability: Spore formation increases as a survival mechanism, but overall spore viability is reduced by 30-40% due to radiation damage.
  - Overall Survival: Survival rates drop by 50-60% after extended UV exposure, with significant loss of cellular function in surviving cells.


Viable Cell Count vs UV Radiation Exposure Time
Viable Cell Count Range
Estimated Viable Cell Count
Viable Cell Count (%)
60
50
40
30
20
10
30
40
50
60
70
Exposure Time (Hours)

Summary of Data for Simulated Martian Conditions:

- **Temperature Impact: Biomass production varies significantly with temperature, peaking at 35-40 mg/L at higher temperatures.**
- **Pressure Impact: Severe reduction in growth, with long-term viable biomass stabilizing at 10-15 mg/L.**
- **Radiation Impact: High levels of DNA damage and reduced spore viability, with survival rates dropping to 10-20% after extended exposure.**

THANK YOU

For Your Attention

Summer Project