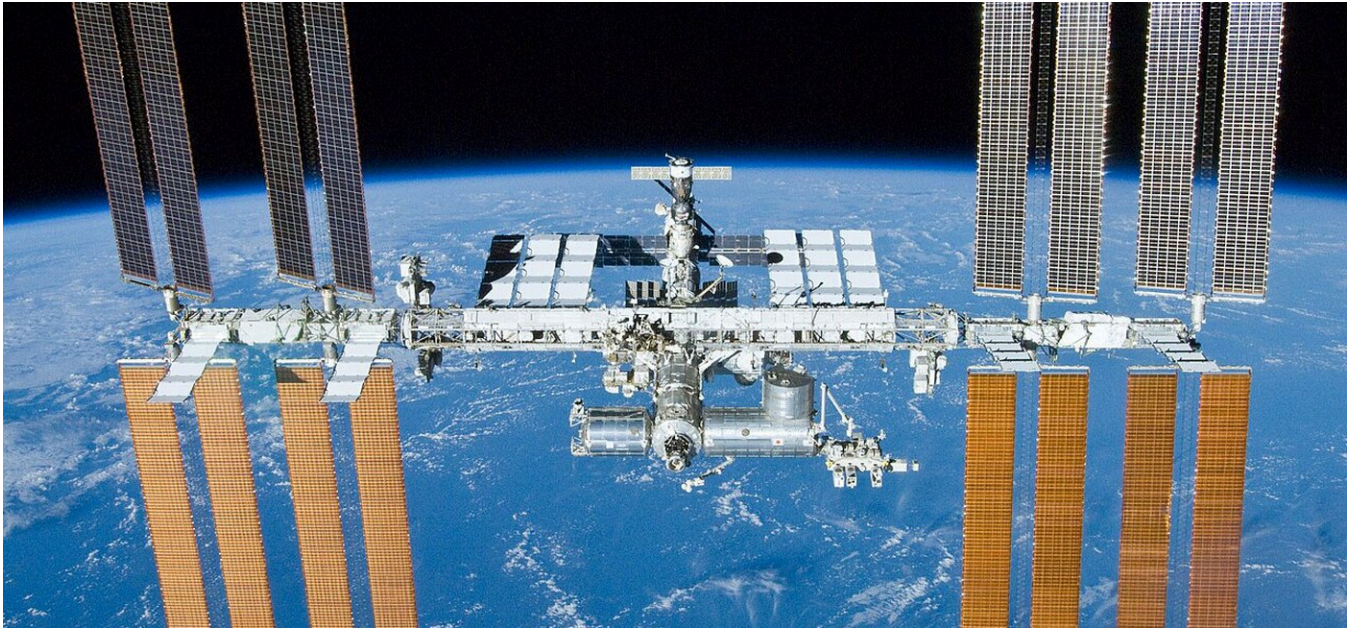


Living in Space

Survival, Adaptation, and What It Means to Leave Earth Behind

Name _____ Class _____ Date _____

PART 1: THE HUMAN BODY IN SPACE



The International Space Station, continuously occupied since November 2000 and humanity's only long-term home beyond Earth

Photo: NASA (public domain)

The human body evolved over millions of years to function in one specific environment: Earth, with its particular gravity, atmosphere, temperature and magnetic field. Take a human being off this planet, and things start to go wrong almost immediately. In microgravity, astronauts lose roughly 1 to 1.5% of their bone density per month. Their muscles atrophy without the constant resistance of gravity. Fluids shift upward toward the head, causing puffy faces, increased intracranial pressure, and vision problems that scientists call Spaceflight Associated Neuro-Ocular Syndrome, or SANS.

The problems go deeper than bones and muscles. Space is full of radiation: energetic particles from the sun and from distant supernovae that can damage DNA, increase cancer risk and possibly harm the brain. The International Space Station (ISS) orbits inside Earth's protective magnetic field, yet an astronaut on a six-month stay still receives roughly 80 to 160 millisieverts. A person on the ground receives only 2 or 3 in a year. A mission to Mars would leave that protection behind completely. Instruments on NASA's Curiosity rover measured the radiation during its journey, and the result suggests that the round trip alone would deliver about 660 millisieverts. That is more than the 600 that NASA now allows an astronaut over an entire career.

PART 2: THE PSYCHOLOGY OF ISOLATION



Astronauts at work outside the International Space Station, with the coast of New Zealand far below

Photo: NASA (public domain)

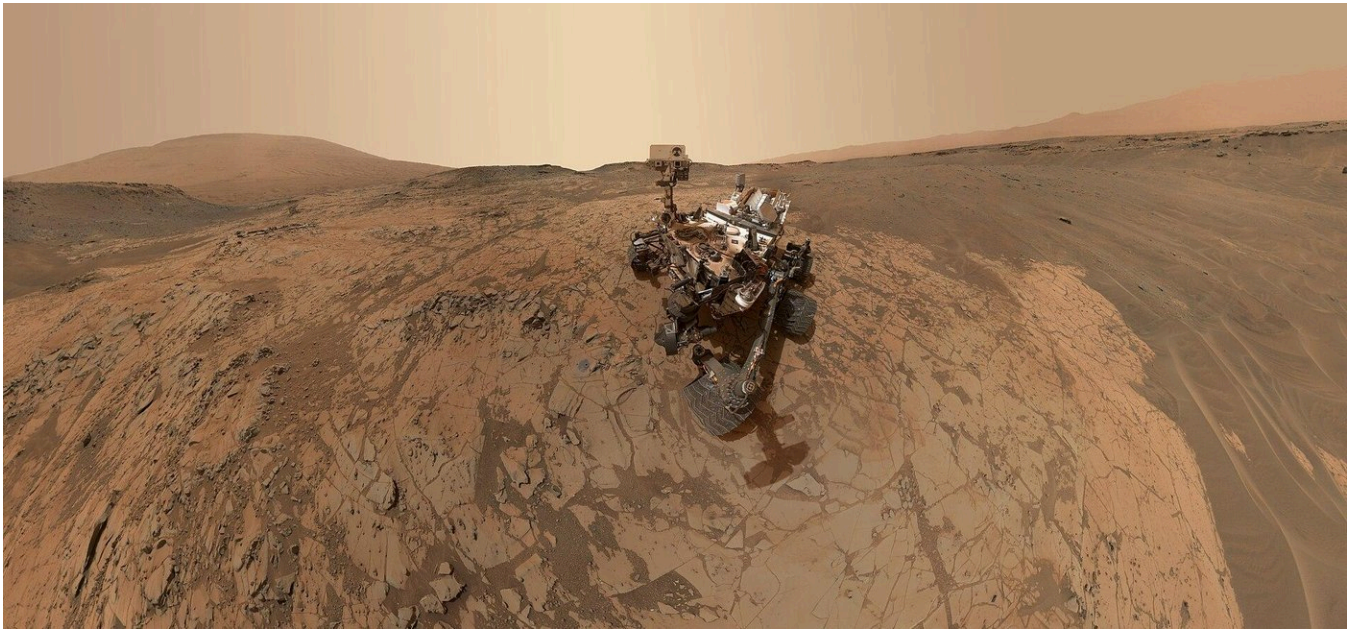
Physical challenges may actually be easier to solve than psychological ones. Imagine living in a space the size of a small apartment with the same three to six people for years. There is no weather, no fresh air, and no open sky, and you cannot step outside for a walk. Communication with Earth is delayed: on Mars, a message takes roughly 4 to 24 minutes to arrive, depending on where the two planets are, which makes real-time conversation impossible.

Astronauts say the same thing in plainer words. Shortly before the end of his 340 consecutive days aboard the ISS, the American astronaut Scott Kelly was asked what the hardest part had been. "The hardest part," he said, "is being isolated from people on the ground who are important to you."

Studies from analogous environments on Earth, such as Antarctic research stations, submarines and isolated research habitats like HI-SEAS in Hawaii, show consistent patterns. After several months of confinement, crews report more conflict, low mood, sleep problems and monotony. Researchers have also described a third-quarter effect: a psychological low point roughly three-quarters of the way through a mission, when the initial excitement has faded and the end still feels far away. Managing crew psychology may be one of the most important factors in a successful Mars mission.

PART 3: BUILDING A HOME BEYOND EARTH

If humanity is to become a multi-planetary species, we need more than rockets; we need habitats. On Mars, the average temperature is about minus 60 degrees Celsius, and the atmosphere is about 95% carbon dioxide, with almost no oxygen. Atmospheric pressure is less than 1% of Earth's, so low that liquid water cannot survive on the surface and an unprotected human would lose consciousness in about 15 seconds. Any Mars habitat must provide breathable air, stable pressure, warmth, radiation shielding, water recycling and food production, all with minimal resupply from Earth.



NASA's Curiosity rover on the slopes of Mount Sharp, Mars, in a self-portrait assembled from images taken by the camera on its arm

Image: NASA/JPL-Caltech/MSSS (public domain)

Current proposals range from the practical to the audacious. SpaceX has talked about pressurized domes and underground shelters. NASA studies in-situ resource utilization (ISRU): using Martian soil, ice and air to produce building materials, fuel and breathable oxygen. This is no longer only theory: between 2021 and 2023, the MOXIE experiment on the Perseverance rover made oxygen from the Martian atmosphere 16 times. The total was just 122 grams, about what a small dog breathes in ten hours, but it proved the principle. Other ideas include inflatable habitats, structures 3D-printed from regolith (Martian soil), and even terraforming, the centuries-long process of changing the planet's atmosphere to make it more like Earth's.

Life Support: Earth vs. Space

98%

On Earth, the biosphere provides air, water, food and waste recycling for free. In space, every one of these systems must be engineered. In 2023 the ISS reached 98% water recovery for the first time, turning the crew's sweat, breath and urine back into drinking water. That figure is the target engineers set for long missions far from Earth, where no supply ship can arrive.

PART 4: WHO GETS TO GO?

Perhaps the most profound question about living in space is not how but who. Early Mars missions will carry only a handful of people. If we are selecting the founders of a new society, what criteria should we use: physical fitness, scientific expertise, or psychological resilience? The first settlers will make decisions that shape a community for generations. What language will they speak? What laws will govern them? Will they be employees of a corporation, citizens of a nation, or something entirely new?

Elon Musk has said he wants to see a city of a million people on Mars, but who can afford the ticket? If space settlement is driven by private companies, it risks becoming a privilege of the wealthy: a new world built by and for those who could pay to leave the old one. Others argue that it should be a public project, funded by governments and open to all.

There is an older objection too. Writing in 1958, just after the first satellite was launched, the philosopher Hannah Arendt noticed that people were greeting the event as a first step in escaping from the Earth. She found this troubling, and described the attitude as a form of alienation from the only world that makes human life possible. Are we building a backup for humanity, or running away from our problems?

KEY VOCABULARY

Term	Meaning	Term	Meaning
<i>microgravity</i>	very weak apparent gravity, as experienced on the ISS (not truly zero gravity)	<i>atrophy</i>	to waste away or weaken from lack of use
<i>intracranial</i>	inside the skull	<i>radiation</i>	high-energy particles or waves that can damage living tissue
<i>monotony</i>	a tedious lack of variety; the same thing over and over	<i>analogous</i>	similar enough in certain respects to be useful for comparison
<i>multi-planetary</i>	existing on more than one planet	<i>audacious</i>	showing a willingness to take bold risks
<i>terraforming</i>	transforming a planet's environment to resemble Earth's	<i>resilience</i>	the ability to recover quickly from difficulties
<i>privilege</i>	a special advantage available only to certain people	<i>in-situ</i>	in the original place; using materials found on location
<i>habitat</i>	a place built or suited for living in	<i>third-quarter effect</i>	a psychological low point about 75% of the way through a long mission

Discussion & Analysis

Living in Space · Lesson Activities

A. COMPREHENSION

1. Name three physical effects of living in microgravity.

2. Why is radiation a bigger concern for Mars travelers than for ISS astronauts? Use figures from the reading.

3. What did Scott Kelly say was the hardest part of his mission?

4. What is the third-quarter effect, and why does it matter for long missions?

5. Why can't liquid water survive on the surface of Mars?

6. What is ISRU, and what did the MOXIE experiment demonstrate?

7. What did the ISS achieve in 2023, and why does it matter for missions to Mars?

8. What two different concerns does Part 4 raise about leaving Earth?

B. VOCABULARY IN CONTEXT

Complete each sentence with a term from the vocabulary list. Use each term once.

analogous · atrophy · audacious · habitat · microgravity · monotony · multi-planetary · privilege ·
radiation · resilience

1. After three months in a hospital bed, the patient's leg muscles began to _____ from disuse.
2. Antarctic research stations provide _____ environments for studying the isolation of space travel.
3. The plan to build a city on Mars within 20 years was criticized as overly _____.
4. Cosmic _____ can damage DNA and increase the risk of cancer in astronauts.
5. The _____ of submarine life (the same routines, the same faces, the same walls) is psychologically exhausting.
6. Access to a good education should not be a _____ reserved for wealthy families.
7. Becoming a _____ species is often described as humanity's insurance policy against extinction.
8. In _____, objects and people float because they are in continuous free fall around the Earth.
9. Crew members are chosen partly for their _____, since things will certainly go wrong.
10. Any Mars _____ would have to supply its own air, water and warmth.

C. CRITICAL THINKING

1. If you were selecting six people for the first permanent Mars settlement, what five qualities or skills would you prioritize? Explain why.

2. Hannah Arendt saw the wish to leave Earth as a kind of alienation from our own world. Do you agree, or is it the opposite: a sign of ambition and the instinct to survive?

3. The ISS now turns 98% of its waste water, including urine, back into drinking water. How does this change your idea of what normal life on Mars would look like?

4. Should Mars settlers be governed by Earth's laws, or should they create their own? What are the risks of each approach?

D. THE GREAT DEBATE: SHOULD WE SETTLE MARS?

Scenario: The United Nations is voting on whether to fund a \$500 billion international program to build a permanent settlement on Mars. Earth faces climate change, poverty and shrinking resources. Should humanity invest in becoming multi-planetary, or fix Earth first?

Position A: Yes, go to Mars

Earth will not last forever. An asteroid, a pandemic, nuclear war or climate collapse could end civilization. Mars is a backup for the human species. The technology developed for it (recycling, energy, food production) will benefit Earth too. Waiting until Earth is fixed means waiting forever.

Position B: No, fix Earth first

That money could do enormous good against poverty, disease and environmental damage here. Mars is a frozen desert with no breathable air. Why build a worse version of Earth instead of saving the real one? This is escapism for billionaires while billions suffer.

Position C: Both, Earth first

Continue Mars research at current levels. Send robots. Develop the technology. But most resources should go to Earth's urgent problems. Settlement can wait until we have shown we can look after one planet before we attempt two.

After the debate, write your own position in three or four sentences.

E. COLONY DESIGN CHALLENGE

You are the chief planner for the first Mars settlement of 50 people. Make a decision in each category and be prepared to defend every choice.

1. Location

Near the equator (warmer, more sunlight) or near the poles (water ice)? On the surface, underground, or in lava tubes?

2. Energy

Solar panels (light, but dust is a problem), a nuclear reactor (reliable, but heavy to transport), or both?

3. Food

Hydroponic greenhouses? Insect protein? Lab-grown meat? How much should come from Earth as a backup?

4. Governance

Democracy, appointed leadership, or a rotating council? Who resolves disputes? Whose laws apply?

5. Communication

Messages take 4 to 24 minutes each way, so no live calls. How do you maintain relationships with Earth?

6. Mental health

How do you prevent the third-quarter effect? What recreation do you include? How do you handle conflict?

Notes on your three most important decisions:

F. ESSAY PROMPT

Choose ONE of the following and write a well-organized essay of 300 to 500 words on a separate sheet of paper.

- Option A: "Humanity has no future if it stays on one planet." Do you agree or disagree? Use evidence from the reading and your own knowledge.
- Option B: You have been selected for the first Mars settlement. Write a letter to your family explaining why you chose to go, what you expect life to be like, and what you will miss most.
- Option C: Compare the challenges of living on Mars with those faced by polar explorers, submarine crews or early settlers on Earth. What can history teach us about surviving in extreme environments?



The Blue Marble, photographed by the crew of Apollo 17 on December 7, 1972. Should we protect it, leave it, or both?

Photo: NASA (public domain)

Teacher's Notes & Answer Key

Living in Space · Instructor Guide

LESSON OVERVIEW

LEVEL

Advanced (CEFR B2 to C1)

DURATION

60 to 90 minutes

FOCUS

Reading, debate, colony design

Source material: NASA human spaceflight research; Mars rover missions; Hannah Arendt, *The Human Condition*

Series: Humans & The Universe, Lesson 4 of 8. Works as a standalone lesson.

SUGGESTED LESSON FLOW

Warm-up (5 min)	Ask: would you go to Mars if you could never come back? Quick poll and discussion.
Pre-reading (5 min)	Review key vocabulary. Prioritize microgravity, atrophy, radiation, terraforming and resilience.
Reading (15 to 20 min)	Parts 1 to 4. Students can read in pairs, alternating paragraphs.
Comprehension (10 min)	Section A, oral or written.
Vocabulary (10 min)	Section B. Ten gaps, word bank supplied.
Debate (10 to 15 min)	Section D. Assign positions or let students choose. Push for evidence from the reading.
Colony design (15 to 20 min)	Section E in pairs or small groups. Each team presents its plan and the class votes on the best design.
Homework	Section F essay. Section C questions can be used for a second discussion lesson.

ANSWER KEY: SECTION A (COMPREHENSION)

- Any three of: loss of bone density (about 1 to 1.5% per month), muscle atrophy, fluid shifting toward the head, puffy face, increased intracranial pressure, vision problems (SANS).
- The ISS orbits inside Earth's magnetic field, which gives some protection; even so, a six-month stay delivers about 80 to 160 millisieverts. A Mars mission leaves that protection behind, and the round trip alone would deliver about 660 millisieverts, more than NASA's career limit of 600.
- Being isolated from the people on the ground who were important to him.
- A psychological low point about three-quarters of the way through a mission, when the excitement has gone and the end still feels far away. A Mars mission would last two to three years, so the low point would come when the crew is far from help.
- Because atmospheric pressure on Mars is less than 1% of Earth's. At such low pressure liquid water is not stable; it boils away or freezes.

6. In-situ resource utilization: using materials already on Mars (soil, ice, the carbon dioxide in the air) to make building materials, fuel and oxygen, which reduces what must be shipped from Earth. MOXIE, on the Perseverance rover, made oxygen from the Martian atmosphere 16 times, 122 grams in total, proving that it can be done.
7. It recovered 98% of its water for the first time. That is the level engineers consider necessary for long missions far from Earth, where resupply is not possible.
8. First, that settlement led by private companies could become a privilege of the wealthy. Second, Arendt's worry that the wish to escape Earth reflects alienation from the world that makes human life possible.

ANSWER KEY: SECTION B (VOCABULARY)

1. atrophy 2. analogous 3. audacious 4. radiation 5. monotony 6. privilege 7. multi-planetary
8. microgravity 9. resilience 10. habitat

DISCUSSION EXTENSIONS

Film connection: Compare The Martian (2015) with the real challenges described in the reading. What did the film get right, and what did it simplify?

Ethics: If settlers have children on Mars, those children never chose to live there. Is that ethical? What rights should people born on Mars have?

Link to Lesson 3: Torpor could ease some of the psychological problems described here. How would it change the case for going?

Current events: Have students research SpaceX's Starship, NASA's Artemis program or China's Tiangong space station. How close are we to a permanent human presence beyond Earth orbit?

Section E: There is no correct design. Reward teams that notice trade-offs, for example that the poles offer water but less sunlight for solar power.

KEY DISCUSSION LANGUAGE

Prioritizing

"The most critical factor is..." /
"Above all, we need..."

Trade-offs

"The advantage of X is... but the cost is..."

Feasibility

"In theory this works, but in practice..."

Ethics

"Is it right to...?" / "Who benefits and who suffers?"

Comparing

"Unlike Earth, Mars..."

Defending

"I chose this because..." / "The evidence suggests..."

Sources & Further Reading

Bone loss, fluid shift and SANS: NASA Human Research Program.

Radiation: Zeitlin et al., Science (2013), measurements by the Radiation Assessment Detector on the Mars Science Laboratory; NASA career limit of 600 millisieverts.

Scott Kelly: news conference from the International Space Station, February 2016.

MOXIE: 16 oxygen-production runs and 122 grams in total, NASA Jet Propulsion Laboratory (2023). ISS 98% water recovery: NASA (June 2023).

Hannah Arendt, The Human Condition (1958), Prologue.

Humans & The Universe

An eight-lesson advanced reading and discussion series

This lesson is part of a connected series for advanced learners. Each lesson pairs a science fiction premise with the real science, history and ethics behind it, and each works as a standalone class or as part of the full sequence.

1	The Dark Forest: game theory, deterrence and the fate of civilizations	
2	Should We Answer? SETI, the Fermi Paradox and the risk of saying hello	
3	Waking Up in the Future: hibernation, time and the cost of survival	
4	Living in Space: survival, adaptation and leaving Earth behind	<i>you are here</i>
5	Scarcity and Survival: resources, rationing and who gets to live	
6	First Contact Protocols: diplomacy, danger and speaking for humanity	
7	The Ethics of Technology: power, responsibility and dangerous tools	
8	Endings and Legacy: extinction, memory and what we leave behind	

Lesson 1, The Dark Forest, is a free download from Tahrir Teaches on Teachers Pay Teachers.