ASTROBIOLOGY IN THE CLASSROOM

Lesson plans for science in UK Secondary Schools

The UK Centre for Astrobiology

UK Centre for Astrobiology

THE UNIVERSITY of EDINBURGH

ASTROBIOLOGY IN THE CLASSROOM

THE ASTROBIOLOGY LESSON PLAN COLLECTION

Written for teachers by teachers at the Astrobiology Summer Academy

Funded by the UK Space Agency and the Science and Technology Facilities Council (STFC) and with assistance from the National Space Academy.

Description of the Collection and Scheme of Work

Astrobiology is the study of the origin, evolution and distribution of life in the Universe. The lesson plans in this Astrobiology Collection are designed to cover a wide diversity of topics in biology, chemistry and physics that encompass some of the most fascinating questions in science such as: How did life originate? Is there life beyond Earth? Will humans explore and settle other worlds?

These lesson plans are designed with the flexibility so that you can create customised modules to fit different stages of the curriculum and different science focuses. Lesson plans include theoretical activities, practical examples and basic scientific principles that align with key curriculum learning outcomes. Many of the lesson plans have material that can be used over multiple lessons.

The astrobiology lesson plans can also be used to augment existing modules in science. In particular, they offer a way to achieve interdisciplinary science learning and bridge learning outcomes across traditional science areas.

Below is a list of the lesson plans available, their objectives and their required resources.

Table of Lesson Plans in the Collection

Lesson title	Context	Objectives	Activities/Resource
Choc Rock Cycle	11-16 Earth Science	Identify rock types. Understand the rock cycle.	Various chocolate bars. Cheese grater, Large clear mixing bowl, Gloves
Detecting life on exoplanets	13-16 Physics	Absorption/emission spectra & chemical composition. How spectrometers work. Know that we can probe the atmospheric composition of exoplanets (or stars) using spectroscopy.	Old CDs, boxes, tubes, well cut card, spectroscopes (if available), cutting equipment, card-sorting exercise.
The Habitability of Mars	11-13 Biology, Chemistry	pH tests Filtration and evaporation Requirements for growing plants. Humans and plant resources.	Soil samples. Basic sand plus: salt, citric acid, bicarbonate of soda, tea, ground up Rennie etc. to create acid, alkali or saline extremes, pH testing materials, filtering and evaporation basins.
Impactors, photosynthesis and food webs	11-13 Biology, Space	Meteorites Impact events How meteorite impacts affect the environment. Factors affecting photosynthesis. Food webs and primary producers.	Cabomba weed, microsyringes or boiling tubes and racks, light source, neutral density filter set, access to YouTube video for starter. Access to IT suite for Impact:Earth follow up activity.
Life in Extreme Environments	11-16 Biology	Organisms adaptation to their specific habitat/environment. Biological experimental skills. Bacterial growth. Conditions on exoplanets.	Agar plates set, solutions of specific factors – acidity, alkalinity, salinity, water for temp tests. Cotton Buds. Powerpoint on extremophiles
Photosynthesis on Mars	13-16 Biology	Factors affecting photosynthesis. Inverse square rule and solar radiation. The martian environment.	Information source for comparison of parameters with Mars / Earth, Immobilised Scenedesmus Quadracoda, alginate (made ahead) see SERCC for instructions. Day lamp, metre stick.
Dinosaurs, Materials and their preservation	11-13 Chemistry, Earth Science	Know about extinction and evidence for it in the rock record. Material properties and preservation.	Impact demonstration: Fish tank/glass tank. Flour, tennis ball, small plastic

		Environmental impact of society. Be able to discuss and predict the fate of human waste in the environment/how long-lived it will be.	dinosaurs or other animals. Materials Preservation Activity: Bread (or other food), pieces of paper, metal objects, plastic cups, mobile phone. Acid Demonstration: Bread, chicken bones, concentrated acid.
A Frozen World	11-16 Biology	Respiration. Osmosis and water potential. Enzymes and rates of reaction.	Conical flasks, Ice cubes – made with saltwater and fresh water Food colouring. Tardigrades, Hydrogen carbonate indicator solution, Yeast and glucose solution (pre-prepared), Water at different temperatures – hot, warm and cold, Marker pen, Salt, Digital microscope (optional), Petri dishes & pipettes
The Effect of Radiation on Life - ExoMars	11-16 Physics, Biology	Understand how radiation can affect life. Know how to look for evidence for life.	UV beads, UV light UV pens for marking banknotes / paper, Banknotes / paper, Soil samples, Tests for protein, starch, fats.
Meteorites from Mars	14-18 Physics	Energy transfer. Kinetic and potential energy calculations, Measurement of instantaneous velocity, Use of software to analyse video and extract kinematic data. Escape velocity	Impact simulator fish tank. Fixed video camera, Tracker software package (or just pupils' smartphones) Small grains such as rice (too cohesive?), hama beads, polystyrene balls, (powder like flour may be too slow, billowing). Sufficient to fill container to depth of 20 mm. A wooden lattice.
Designing a spacesuit	13-16 Physics	Ultraviolet light. The space environment. Dangers of UV light. UV protection.	UV light source, UV beads, various materials with different UV absorption factors (e.g. clingfilm, polarising filters,

			paper, glass, tissue paper etc.), various thickness of material with best UV resistance.
Extremophiles and the search for life in space	11-16 Biology	Extremophiles & the environments they live in. How adaptations help organisms survive. Exoplanets.	Cards matching organisms to different environments
Mars Science Laboratory and Chromatography	13-16 Chemistry	Life processes and chemicals associated with them. Chemical tests. Chromatography.	Chromatography practical, plus separate solvent specifically chosen **not** to work for teacher demo, pictures of MSL, video on SAM instrument on MSL, pre made chromatogram on board with (2+) measurements shown
Bugs in Space!	11-16 Physics, Chemistry, Biology	Microgravity, Tim Peake, Solids/Liquids/Gases, Buoyancy, UV	Closed plastic containers, water, food colouring, golden syrup, solids of different sizes, some of which float and some of which sink, rulers, timers.

“ASTROBIOLOGY IN THE CLASSROOM”

Written by the Astrobiology Summer Academy
Katherine Barker

LESSON PLAN

Level: Age 11-16

TITLE: THE CHOC ROCK CYCLE

SUBJECT AREA: CHEMISTRY

Context of lesson:

The Choc Rock Cycle

Resources needed:

Crunchie bar, Marble effect chocolate, Lion bar, Large bars of; milk chocolate and white chocolate, Cheese grater, Large clear mixing bowl, Gloves, Bunsen burner, Tomato soup, baking tray

Learning Objectives: Knowledge, Understanding, Subject Specific Skills

Identify the types of rocks in relation to the chocolate bar modelled

Predict the rock cycle on Mars based on picture evidence.

Critique the issues within the rock cycle.

Key Words/Language/Spellings to display

Igneous, Sedimentary, Metamorphic, Tectonics.

Spoken Communication

Discussion based lesson

Reading

Writing

Numeracy

Learning Outcomes / Success Criteria

All pupils will;

State the different types of rock and know why the chocolate bars were chosen to represent these rock types.

Most pupils will;

Be able to describe the processes that cause certain types of rock to form, e.g. hot lava cooling to form rock that contains bubbles and crystals (like a crunchie)

Be able to explain the importance of models in science

Some pupils will;

Understand the process of rock weathering and be able to demonstrate this in discussions

<table>
<tr><td colspan="3">Be able to describe what the images from curiosity can tell us about rock cycle events on Mars</td></tr>
<tr><td>Teaching and Learning Strategies</td><td>Differentiation/Key Questions</td><td>Timing</td></tr>
<tr><td>Starter Engagement SMSC Clarifying purpose of lesson

Start with the bars. Get pupils to think about what they represent:

Lion bar = Sedimentary -Layered rock which sometimes contains fossils.

Marble effect chocolate = Metamorphic - Mixture of the other rock types that have been put though intense heat and pressure deep under the ground

Crunchie bar = Igneous - Rock that has cooled from molten lave that contains crystals and often air bubbles.

Remind higher ability pupils that quick cooling lava = small crystals and slow cooling lava = large crystals. Magma cooling underground = large.</td><td>What rock type is this? Why do you think so? Can you give me an example rock to represent this?</td><td></td></tr>
<tr><td>“Prepare”

Explain the importance of models.

Before the lesson (Pre-grate some milk and some white chocolate (keep them separate!) Cut up the crunchie and lion bars into small blocks so you can see inside them. Set up a Bunsen, gauze, tripod and safety mat).</td><td></td><td></td></tr>
<tr><td>“Do”
Grate some chocolate and ask pupils what it’s supposed to represent (weathering).

Sprinkle a layer of milk chocolate followed by a layer of white chocolate and ask pupils what it is supposed to represent (erosion and transport).

Repeat layering of milk then white chocolate.

Apply pressure with gloved hands or utensil.</td><td>Ask pupils what needs to happen in order to turn the sediment into rock (Burial and pressure)
Ask pupils what rock type this is (sedimentary) and what features does it have? (layers and sometimes fossils)
Ask what rock type comes next (metamorphic) and what needs to</td><td></td></tr>
</table>

Apply heat by putting the bowl on top of the tripod with gentle heat from the Bunsen. Here you can ask pupils to identify issues with this stage of the model (no pressure and not extreme heat). DO NOT let it melt! Otherwise you have made igneous when it cools! Show pupils the marble effect and ask about the features of metamorphic rock and how it comes to be that way (it is subject to heat and pressure so the layers mix and look 'marbled' and it cools because it is pushed towards the earth's surface due to uplift) Remind pupils that this rock is then weathered erodes, and then turned into sediment rock again. It may then be melted and turned into lava –so put the bowl back over the Bunsen to melt the chocolate. Ask what happens next (it cools – becoming rock)	happen to make metamorphic? (extreme heat and pressure underground) • What rock type is this? (Igneous) what features does it have? (crystals and air bubbles).	
Review Remind pupils that this rock is then weathered erodes, and then turned into sediment rock again. Potential Issues with the rock cycle? Does every cycle happen as such? Sedimentary to Igneous?	*What are the issues with the rock cycle?*	
Prepare Question the pupils on plate tectonics –	*What happened? Any ideas on 'old Earth'*	
"Do" Demonstrate plate tectonics with a metal baking tray and add tomato soup. Have a template for The Pangea Region – separate continents. Heat from the bottom and allow the continents to drift apart.		
Review		

Video ? demonstrating Plate Tectonics – Youtube.		
Prepare Relate to Mars – rock cycle events. Show pictures of Mars from Curiosity.	*Would this cycle happen on Mars?*	
“Do” Discuss why there is not so much metamorphic rock on Mars? Pupils given a few minutes to talk about possible reasons.	*Think about – Plate tectonics and Carbon cycle.*	
Review Create a class discussion based upon group responses.	*Pupils to lead discussion.*	
Lesson End Show picture of Olympus Mons and provide facts. Relate similarity and differences to Everest. Home Learning: Produce a glossary on the words – Meteor, Meteorite, Asteroid, Comet, Planet.		

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"ASTROBIOLOGY IN THE CLASSROOM"

Written by the Astrobiology Summer Academy

LESSON PLAN

Level: Age 13-15

TITLE: DETECTING LIFE ON EXOPLANETS

EXOPLANET SPECTROSCOPY

SUBJECT AREA: PHYSICS

Context of lesson: How we investigate exoplanets. Presumably will come near the start of a space topic, or in a topic on the EM spectrum. Can be linked to chemistry lessons on electronic levels if appropriate.
Resources needed: Old CDs, boxes, tubes, well cut card, spectroscopes (if available), cutting equipment, salt-collars for Bunsen burners, pre-made slits, lamps . You can build your own spectroscopes. Details are provided at this link: http://www.cs.cmu.edu/~zhuxj/astro/html/spectrometer.html Recently picked leaves (enough for whole class).
Learning Objectives: Know that the absorption or emission lines you can see in a spectrum tell us about the chemical composition of an object. Understand the difference between an absorption and emission spectrum. Understand how a spectrometer works by splitting light. Know that we can probe the atmospheric composition of exoplanets (or stars) using spectroscopy. Know that particular signs of life cannot be seen by spectroscopy (e.g. oxygen).
Key Words/Language/Spellings to display Emission, Absorption **Spoken Communication** Class discussions **Reading** Instructions for building spectroscopes
Learning Outcomes / Success Criteria **All pupils will;** Have constructed a spectroscope using basic materials Have observed an emission/absorption spectrum using a spectroscope **Most pupils will;** Have matched real spectra with the emission lines for given elements **Some pupils will;** Have observed the spectrum of one or more plant leaves

Teaching and Learning Strategies	**Differentiation/Key Questions**	**Timing**
Starter Pictures of the sun in different parts of the EM spectrum on the board.	*What is the sun made of?* *How do we know?* *(if no one can answer)* *What colour is the sun?*	5
"Prepare" Show pupils an example of a home-made spectroscope Give instructions how to make them – stress importance of the slit Provide materials	*What are the features of a good spectroscope (light tight, thin slit)* *Provide ready made versions to those having trouble*	5
"Do" Build spectroscopes Look at various light sources (tubes if available, salt collars, other lamps if necessary) Take photos with their phones, if it'll work NEVER LOOK DIRECTLY AT THE SUN	*Some examples in the URL. Get students to come up with their own interesting ones.*	15
Review Ask the pupils what they observed through their spectroscope. Discuss what they think that means. Show them a picture of some elemental spectra. Can they identify any of these in their images (or pre-loaded images if need be)?	*Ask if the pupils can identify any of the elements they might have seen – some may be aware of noble gases in fluorescent tubes etc.*	10
Prepare Ask what we would look for on other planets if we wanted to observe life. Tease out answers about oxygen, etc. Show a picture of earth – what colour is it? Why?		5
"Do" Observe different plant leaves with the spectroscopes. (With a bright light shining on them) Do they have a specific signature? Can the pupils describe it.	*When finished get pupils to draw the features of the spectrum in their book.*	15
Review What signatures can we observe on exoplanets? What are the elements or molecules that life produces? What about looking beyond visible wavelengths.		5
Lesson End Pupils to write out different biosignatures and why they are good/bad for observing in exoplanets.		5

"ASTROBIOLOGY IN THE CLASSROOM"

Written by the Astrobiology Summer Academy
Janey Irving

UK Centre for Astrobiology

LESSON PLAN

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Level: Age 11-13

TITLE: THE HABITABILITY OF MARS
SUBJECT AREA: BIOLOGY

Context of lesson:
Habitability of Mars Investigation which can be used to assess knowledge of pH scale and skills of testing soils, carrying out filtration and evaporation. Links in to the requirements for growing plants and could be used to introduce soil science and fertilisers.

Resources needed:
Soil samples from different locations on Mars being investigated. These can be a basic sand plus any of the following: salt, citric acid, bicarbonate of soda, tea, ground up Rennies etc to create acid, alkali or saline extremes. Control = basic sand to compare (it is expected that cress/mustard will be able to grow in wet sand though not well, allowing discussion of nutrients)
pH testing materials, filtering and evaporation basins.

Learning Objectives: Knowledge, Understanding, Subject Specific Skills
Skills - To be able to carry out pH testing, filtration and evaporation
KU - To be able to specify the requirements for growing plants. To apply this to the design of a biodome to support people living on Mars.

Key Words/Language/Spellings to display - evaporation, filtration, biodome

Spoken Communication - discussion of how to carry out the experiment and results. Group discussion of creation of biodomes prior to written task (optional).

Writing - experimental writeup, design a biodome

Starter Engagement SMSC Clarifying purpose of lesson **Mission statement alongside picture of Curiosity Rover Scoop on board:** You have been given soil samples collected by the Curiosity rover visiting Mars. The mission is to see if the Mars soil is able to support plant life.	*What do seeds need to be able to germinate? What do plants need to grow?*	5 min

"Prepare" Show pupils the soil samples and examine them in dimple tiles using hand lens. Question: What could we test? (assuming done acids/alkalis)	*If pupils have not done acids/alkalis this will need to be introduced and taught first.*	5 min
"Do" Test pH of all. Pupils mix samples with water and test with pH paper or take samples of the water and test with Universal Indicator.		10-15 min
Review Two samples are neutral, discuss what other test could be done to see if there are any dissolved substances within the soil.	*How can we separate solids? Allow discussion of methods. What if one dissolves and the other does not?*	2 min
Prepare Show/tell how to separate by filtration and evaporation. As you are not making crystals quick evaporation using evaporating basins and bunsen burner/tripod method.	*Have a diagram of the set up or example for pupils to see if they need reminding how to set this up.*	2 min
"Do" Complete this test on the two samples		15 min
Review What have they learned about the soil samples? You may wish to write this up as part of a report back on the mission.	*Differentiation using a simple table of results with questions to help pupils form conclusions.*	2-15 mins if write up done

Prepare How well will each sample sustain plant life?	*What do plants need to grow? Linking in to aspects of soil science and the fact that*	2 min
"Do" Either have pre prepared cress or mustard seeds grown in wet sand versions of your samples or if time allows set these up with pupils. Discuss which have grown. Have a dry sand control to show too. Pupils to write up their observations as part of their mission report.		5-15 min if pupils set up seed sample
Review Lead into discussion of what had to be added to all samples to allow plants to grow. Mars has dry and salty conditions as well as areas with acidic and alkali conditions if water were added. How could we grow things to sustain life on Mars?		10 min-30 min if full design done
Lesson End Get pupils to start designing a biodome to grow food for astronauts living on Mars. What would we need to take with us to make Mars soil like our soil? What is the difference between our soil and sand? Potential longer term project linking aspects of all these lessons or potential homework task. This could then link in to growing plants and thinking about oxygen and water needs for germination and light, macromolecules needed for growth.		

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"ASTROBIOLOGY IN THE CLASSROOM"

Written by the Astrobiology Summer Academy
Chris McGinlay

LESSON PLAN

Level: Age 11-13

TITLE: IMPACTORS, PHOTOSYNTHESIS AND FOOD WEBS

SUBJECT AREA: BIOLOGY

Context of lesson:
Photosynthesis
Impacts & the history of life on earth
Extinction events & how they happened

Resources needed:

Impact diorama set up in a tray
Access to YouTube video for starter.
Cabomba weed,
microsyringes or boiling tubes and racks,
light source,
neutral density filter set,
Access to IT suite for follow up activity.

Learning Objectives: Knowledge, Understanding, Subject Specific Skills
This list needs to be cut down. Not all of this is going to end up in the final plan, UNLESS this turns into a block of work.

Know that Earth gets struck regularly with objects from space, and understand the effect different sized impactors have (from small ones that burn up to big extinction level events).
Know that plants need light to photosynthesise, producing sugar(food) and oxygen and understand the effect of reduced light availability on rate of photosynthesis.
Be able to predict effect on food webs of preventing photosynthesis for months or years
Skills:
Experimental procedures with cabomba weed
Controlling variables, fairness in experiments, repeated measurements.
Producing a suitable graph from data.

Key Words/Language/Spellings to display
Asteroid, meteor, meteorite, photosynthesis, extinction
Spoken Communication
Class and group discussion with peers and teacher.
Reading
Experiment guide
Writing

Recording results, answering questions, construction of simple report (effects on food webs) **Numeracy** Measurement of volume, production of graph, calculation of averages
Learning Outcomes / Success Criteria **All pupils;** Can state that objects from space strike the Earth regularly, but large impacts rarely happen. Can state the chemical word equation for photosynthesis Can state that smaller impacts occur more frequently than large impacts. **Most pupils;** Describe some of the effects of a large meteorite strike on the Earth. State the effect of a large impactor preventing photosynthesis for months or years on food webs **Some pupils;** Can give an example of a large impact structure on the Earth Can state the chemical equation for photosynthesis using chemical symbols.

Teaching and Learning Strategies	**Differentiation/Key Questions**	Timing
Starter Engagement SMSC Clarifying purpose of lesson What killed all the dinosaurs? Drop an object into a tray of flour, stratified with chocolate powder, icing sugar etc, with a light source, two lego dinosaurs and a fern leaf. Ensure object is sufficiently large to create a cloud of debris suspended in the air. **Alternate Starter or Activity Changers** Watch the 2 minutes B612 Foundation video on Impact Frequency: http://vimeo.com/92478179 Watch the 2 minute video on the effects of the KT impact: http://goo.gl/Q9nji1 Highlight the second video around 1:40 where dust obscures the sun for months.	*How often do small objects strike the Earth?* *What happens to most small objects in the atmosphere?* *Would a big impactor (10km) at 11+ km/s plus have time to burn up in a ~200km of atmosphere?* *What happens to grass covered by a rock or a tent for a few days or weeks?* *Could plants grow or survive for months without light? Could some survive? Could animals survive?* *Why do plants need light? What chemical reaction is driven by light energy?*	4 mins videos + 5 mins question s
"Prepare" Groups of 3 or 4 students. Collect cabomba samples (see SAPS reference)		5 mins
"Do"	*Should we run each experiment for 1 minute or two minutes.*	20-30 mins

<table>
<tr><td>Use hint on SAPS site to add sodium hydrogencarbonate to the water to prevent availability of dissolved carbon dioxide being a rate limiting factor.

Students measure volume of gas produced in syringes using variety of neutral density filters 0% 20% 40% 60% 80% 100%.

Observe and make qualitative notes of bubbling rate alongside volume produced in given time.</td><td>
How can we keep this fair? What variables do we need to control?

Are there any variables which are hard to control?</td><td></td></tr>
<tr><td>Review</td><td>*Which product of reaction is the 'food'?*
What would happen to plants and the animals which eat them in an extended absence of light?
What organisms might be able to survive?</td><td>5 mins</td></tr>
<tr><td>Prepare

Distribute a different food web to each group.</td><td></td><td>1 min</td></tr>
<tr><td>“Do”
Get each group to estimate how a lack of primary production would affect the food web, how long effects would start to appear at each node.</td><td></td><td>5-10 min</td></tr>
<tr><td>Review

Group or class discussion of webs.</td><td></td><td>1 -2 mins</td></tr>
<tr><td colspan="3">**Lesson End**

This could be a follow on lesson, or could be a plenary: use the Impact:Earth! Simulator from Purdue to find the minimum devastating impactor. Could be teacher exposition or pupils working in groups on tablets if sufficient time.
http://www.purdue.edu/impactearth/
http://www.open.edu/openlearn/science-maths-technology/science/physics-and-astronomy/meteoric</td></tr>
<tr><td colspan="3">**Possible Follow Up Activities**
1. Impact:Earth! Students explore impact parameters, nature and extent of effects.
2. Complete a story board illustrating sequence of events, before, during and after a large meteorite impact.
3. Produce a piece of creative writing based on survivors in the aftermath of a major impact event.</td></tr>
</table>

4. Students research history of impacts on Earth and produce a display of some type.
5. Collect the gas in sufficient volume for oxygen test.
6. Show some pictures of plants kept in dark for various periods of time.

Main article for using Cabomba
http://www.saps.org.uk/secondary/teaching-resources/190-using-pondweed-to-experiment-with-photosynthesis-

Direct link to the teachers guide:
http://www.saps.org.uk/attachments/article/190/SAPS%20-%20Bubbling%20Cabomba%20pondweed%20-%20teaching%20notes.doc

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"ASTROBIOLOGY IN THE CLASSROOM"

Written by the Astrobiology Summer Academy
Katharine Barker

LESSON PLAN

Level: Age 11-16

TITLE: LIFE IN EXTREME ENVIRONMENTS

SUBJECT AREA: BIOLOGY

Context of lesson:
Adaptation / Intolerance to specific environments

Resources needed: Agar plates set, solutions of specific factors – acidity, alkalinity, salinity, water for temp tests. Cotton Buds. Powerpoint on extremophiles

Learning Objectives: Knowledge, Understanding, Subject Specific Skills

- Recognise the need for organisms to adapt to their specific habitat/environment
- Conduct a practical using skills based on microorganisms and sterile environment
- Predict the presence or absence of bacterial growth on specific conditions
- Justify reasons for choice of exoplanet based upon results obtained and previous scientific knowledge.

Key Words/Language/Spellings to display
Extremophile, adaptation, exoplanet
Spoken Communication
Discussion based within numerous tasks
Reading
Writing
Writing section for chosen exoplanet with suggestions using existing scientific knowledge and evidence from investigation.

Learning Outcomes / Success Criteria

All pupils will; Identify adaptations on Earth and attempt to state possible environments on other planets. Provide a basic explanation of reasons for voting for specific exoplanet.

Most pupils will; Correctly predict the presence/absence of bacteria from their chosen condition. Obtained results demonstrating accurate microbiology practical skills. Justify reasons for the choice of vote for exoplanet with reasoning touching upon other hostile conditions and some relation to previous scientific knowledge.

Some pupils will; Incorporate ideas of planets having multiple hostile conditions and relate to the chosen exoplanet with a detailed explanation justified of choice. Attempting to relate extremophile evidence to choice. Evidence of relating to previous science modules.

Teaching and Learning Strategies	Differentiation/Key Questions	Timing
Starter Engagement SMSC Clarifying purpose of lesson		5

Plant and Animal pictures on the board. Pupils in groups/pairs to state the specific adaptations that each organism has to survive in their given habitat.	*'What characteristics allow them to survive in that specific environment'?*	
"Prepare" Introduce (continue) the subject of exoplanets, pictures (no information shown).	 *What is an exoplanet?* *Why are Scientists interested in exoplanets?*	5
"Do" Can the pupils' state possible environmental factors/conditions that may be present. Jot down conditions – relate to previous topics – *soil samples*		5
Review Discuss Show the specific conditions each exoplanet 'has' – relate to conditions to be investigated	 *Why do you think this?* *Is there any relationship to distance and hostility? Atmospheric links*	5
Prepare Groups/pairs to choose/given a specific factor to investigate. Areas to mention are skill based – sterile environments when using microbes.		5
"Do" Pupils collect swab of an area (bacteria) and add cotton bud to a small solution of chosen factor – alkaline, acidic,salt soln, water for the temp and UV (if applicable) Add a small control section to the dish to allow for observation of cross contamination. Tape side and add factor tested. For the factor of temperature add to cold, warm and hot conditions. Teacher to produce a control with just a small solution of water – room temp?		10

Prepare Pupils to predict what they think they will observe – presence or absence of bacterial growth in the plates. Suggestion to their prediction.		5
"Do" Draw around plate and draw in possible prediction of growth in relation to the control sample. Second plate drawn for comparison with results. Suggestions for prediction using previous scientific knowledge of chemical reactions and temperature.	*Pupils to state suggestions.*	10
Review Use a ppt which demonstrates the extreme conditions organisms can survive in – which scientific names for specific types of extremophiles.		5
Following Lesson		
Prepare Remind pupils of how specific microorganisms can survive in hostile environments.	*Can anyone name or jot down the names of the types of microbes able to survive in specific hostile conditions*	5
"Do" 2 minutes to discuss – jot down		2
Review Review ppt from previous lesson with scientific names and predictions of bacterial growth for the specific conditions investigate.	*Any additions/ changes people wish to make to their predictions last lesson based on the ppt shown and discussions?*	5
Prepare Collect plate and draw your observations onto the plate drawn in your books. Conclude reasons for the presence/absence of bacterial growth. Analyse the plates of other factors completed around the class		0
"Do" Pupils to complete task with relation to previous knowledge of organisms and sustaining life.	*What conditional solutions demonstrated best bacterial growth? Was this supported by predictions?*	10

Travel around the class observing growth under specific conditions. Pupils to produce a piece of writing based upon their own and the class findings on which exoplanet we should plan to further investigate.	*Which planet should we focus on for further investigations in relation to being able to sustain life?*	
Review Vote for specific exoplanet. A few pupils chosen to read their piece out with reasons for vote and why humans should want to investigate further.	*Pupils asked for their chosen exoplanet to investigate – reasons?* *Peer comments given to readers*	5
Discussion: We have focused on one specific condition. Question pupils on the validity of this. Suggest ideas on how does this apply to Earth and how does Earth compare to the exoplanets.	*Will these planets only have one specific hostile condition?* *What else is needed for organism survival?* *Does the chosen planet support this?* *What does the agar contain and is this a possibility on the planet?*	10
Lesson End Explain NASA findings of microorganisms being found on spacecraft/ lunar probe.		5

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LESSON PLAN

Level: Age 14-16

TITLE: PHOTOSYNTHESIS ON MARS

SUBJECT AREA: BIOLOGY

Context of lesson:
The light levels on Mars are about 56% less than on the Earth because it is further away from the Sun. If all other requirements for life were met, would this be enough for photosynthesis? What other conditions would life need on Mars for photosynthesis, of life in general, to be viable?

Likelihood of life elsewhere – learning through experiment which factors affect photosynthesis. Using findings to examine conditions for photosynthesis on mars, and likelihood of life on mars.

Resources needed:

Information source for comparison of parameters with mars / earth (Nasa, Celestia, TWIG, Eyes on the solar system, Planet Trump cards),
Immobilised Scenedesmus Quadracoda alginate (made ahead) see SERCC for instructions.
Day lamp
Metre stick
Bicarbonate indicator

Learning Objectives:

Differences between planets and how solar irradiance varies in the solar system.
How photosynthesis works and what affects it.

Key Words/Language/Spellings to display
Photosynthesis, algae, respiration.
Spoken Communication
Class discussion of photosynthesis and relevance to life on earth and elsewhere! (possible discussion of food webs)
Reading
Interpreting data on different planets
Writing
Forming conclusions, presenting results.
Numeracy
Tabularising relation of colour of indicator to distance from light source. Measuring distance

Learning Outcomes / Success Criteria

All pupils will; have completed experiment safely with valid results. State that plants use photosynthesis to generate sugars from carbon dioxide and water using light.

Most pupils will; State which factors affect the rate of photosynthesis.

<table>
<tr><td colspan="3">Some pupils will; Describe why photosynthesis would occur at a lower rate on Mars</td></tr>
<tr><td>Teaching and Learning Strategies</td><td>Differentiation/Key Questions</td><td>Timing</td></tr>
<tr><td>LESSON 1</td><td></td><td></td></tr>
<tr><td>Starter
Show picture of Earth vs Mars & question “what’s the difference?”

Show picture of greenhouses on Mars. Could this happen? What do plants need to grow?</td><td>What are the differences between Earth and Mars?

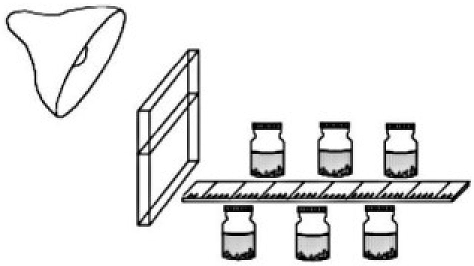
Could plants grow on Mars? What do plants need? Do these things exist on Mars?</td><td>5</td></tr>
<tr><td>Review
Photosynthesis & what factors affect it.

Write down word equation for photosynthesis.

The main difference between Earth and Mars is the distance from the Sun. That’s what you’re going to test.

Introduce the indicator and how it works. Shows drop in carbon dioxide in the water.</td><td>Can you think of how we can test these parameters? Draw and plan some tests.</td><td>15</td></tr>
<tr><td>“Do”
Add algae balls & indicator solution to bottles.

Set up 6 Bijou bottles along 10 cm lengths of metre stick. Put lamp to just in front of first bottle.

Students should monitor the bottles for colour changes as CO_2 is used up by photosynthesis.</td><td>Ensure equal amounts of algae (25 balls) and indicator in each. Leave for 20 mins
</td><td>20</td></tr>
<tr><td>Review
Compare results of the class. What does the experiment show?</td><td>Does rate of photosynthesis decrease linearly with distance?

Would plants be able to grow on, say, Pluto?</td><td>5</td></tr>
<tr><td colspan="3">Lesson End
Relate findings from the experiment and factfiles to the likelihood of finding photosynthesising organisms on Mars.
Extension/ Homework: Write an account of how an area of land on Mars could be made suitable for planting.</td></tr>
</table>

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"ASTROBIOLOGY IN THE CLASSROOM"

Written by the Astrobiology Summer Academy
Charles Cockell

LESSON PLAN

Level: Age 11-14

TITLE: DINOSAURS, MATERIALS AND THEIR PRESERVATION

SUBJECT AREA: CHEMISTRY/BIOLOGY

Context of lessons
The dinosaurs went extinct 65 million years ago. What is the evidence for this extinction and the evidence for an asteroid impact in the rock record? What evidence for our presence would exist in the rock record 65 million years from now?
Section 1 – Introduction to extinction. Discussion of dinosaur extinction. Evidence for an asteroid impact.
Section 2 – Examine different objects, discuss what they are made of and discuss how quickly they are degraded in the environment. These objects will degrade at different rates (sandwich faster than paper faster than plastic faster than mobile phone).
Section 3 – The rock cycle and the likelihood of human waste lasting millions of years.
Area of curriculum
Materials/Evolution/Chemistry

Resources needed:
Impact demonstration: Fish tank/glass tank. Flour, tennis ball, small plastic dinosaurs or other animals.

Materials Preservation Activity: Suggestions for objects needed: Bread (or other food), pieces of paper, metal object (such as a spanner), plastic cups, mobile phone. You will need to write an information sheet for each of these describing what they are made and a brief summary of ways they might be destroyed naturally in the environment.

Acid Demonstration: Bread, chicken bones, concentrated acid.

Learning Objectives:
Extinction and evidence for it in the rock record.
Degradation of materials
The fate of human waste in the environment/how long lived it will be.

Key Words/Language/Spellings to display
Rock cycle, biodegradation, waste, extinction, metamorphic, metamorphism, igneous, sedimentary.
Spoken Communication
Class discussion of the rock cycle and the fate of different types of materials in the rock cycle
Reading
Read about waste and how long it survives for in the environment/the main ways it is degraded.

Writing Forming conclusions, presenting results. **Numeracy** Timelines and rates of degradation
Learning Outcomes / Success Criteria **All pupils will;** State that materials are degraded by natural processes. State that living things leave behind evidence for the existence in the past. **Most pupils will;** Give an example of a process that would degrade evidence for living things. Give an example of a human made item that may become fossil evidence for our existence. **Some pupils will;** State that different materials degrade at different rates. Give an example of a variable that will affect the rate of degredation. Predict what might happen to a given item over hundreds, thousands and millions of years.

Teaching and Learning Strategies	**Differentiation/Key Questions**	**Timing**
LESSON		
Starter *Impact Demonstration:* Tennis ball is hurled with vigour into a glass fish tank (or other transparent container) that contains flour and small plastic dinosaurs/other animals. The dust fills the container and then the students are asked what effect this has had on the visibility in the tank (it has been reduced). This illustrates that dust lofted into the atmosphere cuts out light and thereby photosynthesis (to be discussed later). Outline this week's activities. Introduce the concept of extinction.	*What affect has the impact of the tennis ball into the flour had on the atmosphere in the tank and the visibility of the plastic animals?*	5
Review Concept of extinction. Discussion of when dinosaurs died and evidence for an impact in the rock record (iridium layer, quartz)	*What is extinction? What evidence can we find for an impact in the rock record*	5
Class questioning on what an asteroid impact would have done to the environment and why it would have killed dinosaurs. Note these down on the board.	*What would a large amount of dust in the atmosphere do to sunlight? How would the shut-down of photosynthesis affect life?*	10
Introduce the objects to be discussed in the lesson.		5
"Do" *Materials Preservation Activity:* Each group picks an object and write down what it is	*What are the objects made of? In what ways might they be degraded in the*	10

made of and how long, if the object was placed into the natural environment, it would last for. Effects of environmental conditions e.g. temperature, acid should be considered (see Grid below). It is useful for the students to have a short information sheet (see *Resources needed*), that describes the objects and what they are made of. This will help them think about how things will degrade and therefore how long they might last. Each group writes their information into a grid and then all of the information is added into one grid to make a complete set of information. Crucial points for them to understand is that hot conditions will generally accelerate degradation and low temperatures will make things last longer (there can be a discussion here about rates of chemical reactions and how higher temperatures accelerate them and lower temperatures slow them down). Acid will tend to destroy objects faster. This part of the grid can be discussed alongside the *Acid Demonstration* during the review discussion. The mobile phone contains a variety of substances such as plastic, metal. This object can be given to higher level pupils who would be able to consider the different rates of deterioration of materials and so predict that different parts of it will degrade at different rates (note that a mobile phone contains many materials, so the discussion needs to be kept simple to thinking about just one or two of its constituent materials).	*environment? How quickly will they degrade? What affect will different physical conditions in the environment have on their degradation?* *Higher ability pupils to have mobile phone.*	
Acid Demonstration. At this point a demonstration can be made of the effects of acid (e.g. sulfuric acid) on organic material (e.g. bread, which is organic material) and bones (e.g. chicken bones) to show how environmental conditions (here pH), can influence the preservation	*What types of materials degrade fastest? What processes might be involved in their degradation (e.g. microbes or chemical processes or both?)*	5

of materials such as an animal in the fossil record. Class questions on other processes that would degrade materials faster (e.g. rock cycling, volcanoes, erosion).		
Review A short summary in jotters comparing what evidence there is of the dinosaurs versus what evidence there might be of human civilisation.	*Ask students to discuss the fate of their objects and whether evidence for them might be found in the rock record.*	10

Example grid for *Materials Preservation Activity:*

Write down how long you think the object you have selected would survive in the natural environment.

Material	*In typical UK climate*	*In very hot climate*	*In the polar regions*	*In acid conditions*
Bread				
Paper				
Metal				
Plastic				
Mobile phone				

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"ASTROBIOLOGY IN THE CLASSROOM"

Written by the Astrobiology Summer Academy
Chris Carr

LESSON PLAN

Level: Age 11-16

TITLE: A Frozen World

SUBJECT AREA: Biology

Context of lesson:
If we are to find life in our own solar system, one possible candidate might be Europa. This frozen moon of Jupiter has long been the subject of fascination by astrobiologists as it is thought to harbour a liquid salt water ocean beneath a frozen crust of water ice. This investigation considers the physical nature of saltwater ice compared to freshwater ice and then considers whether extremophile organisms could inhabit these harsh conditions. The organisms investigated include yeast, an example of a single celled fungus and tardigrades, a complex multicellular extremophile organism.

Resources needed:

- 250 ml conical flasks
- Ice cubes – made with saltwater and fresh water
- Food colouring
- Tardigrades
- Hydrogen carbonate indicator solution
- Yeast and glucose solution (pre-prepared)
- Water at different temperatures – hot, warm and cold
- Marker pen
- Salt (to create solutions of different salinities)
- Digital microscope (optional)
- Petri dishes & pipettes

Learning Objectives:

- Respiration
- Cell biology
- Osmosis and water potential
- Enzymes & rates of reaction
- How Science Works – collecting, analysing (via statistical tests) and interpreting data

<table>
<tr><td colspan="3">Key Words/Language/Spellings to display
Spoken Communication
Reading
Writing
Numeracy</td></tr>
<tr><td colspan="3">Learning Outcomes / Success Criteria
All pupils will;
State that frozen saltwater is different to frozen fresh water.
State that frozen saltwater provides a potential habitat for life even in sub-zero temperatures.
Most pupils will;

Some pupils will;
Explain how freezing salt water forms liquid fissures in the ice.</td></tr>
<tr><td>Teaching and Learning Strategies</td><td>Differentiation/Key Questions</td><td>Timing</td></tr>
<tr><td>Starter
The nature of Europa's ice.
Split into groups.
Each group is given two ice cubes, one made with freshwater and one made with saltwater, and some food colouring.
Ask students to add a few drops of food colouring to the top surface of each ice cube
They should see that it pours off the surface of the impermeable freshwater ice cube but is able to penetrate through fissures and cracks in the permeable saltwater ice cube.</td><td></td><td></td></tr>
<tr><td>Discuss observations with students and link to the frozen surface of Europa, which we believe is frozen saltwater.
Discuss idea that salt lowers freezing point of water and is responsible for cracks and fissures in ice that are filled with liquid water; a potential habitat for life.</td><td>What else will be different about salt-water ice?</td><td></td></tr>
<tr><td>Practical

Could organisms inhabit the liquid saltwater that lies beneath the frozen crust of Europa?
The investigation involves subjecting two different organisms (yeast and tardigrades) to different conditions of temperature and salinity.</td><td>Exact volumes of solutions in each flask are not crucial but should be the same for each flask – recommend 200 ml
The yeast, glucose and water should be firmly shaken for about 30 seconds before the</td><td></td></tr>
</table>

<table>
<tr>
<td>Show image of a tardigrade and of yeast cells and explain the extremophile nature of tardigrades and their requirement for hostile conditions. Note: the conditions that tardigrades are subjected to in this investigation lie well within their tolerances and will not cause damage or harm to the organism.
A yeast/glucose solution and a suspension of tardigrades are placed inside four conical flasks containing hydrogen carbonate indicator incubated via water bath at (two flasks at 20 degrees Celsius and two at 40 degrees Celsius). Flasks at each temperature have different degrees of salinity – no salt added and one teaspoon of salt added, thus:
<table>
<tr><th></th><th>Salt at 20 °C</th><th>No sa</th></tr>
<tr><td>Yeast</td><td></td><td></td></tr>
<tr><td>Tardigrades</td><td></td><td></td></tr>
</table>

The colouration of the hydrogen carbonate indicator can be monitored at different points throughout the experiment and/or after a final designated time period. Expected result is that both organisms show greater respiratory activity in warm rather than cold conditions but that tardigrades have greater tolerance to salt than yeast.</td>
<td>investigation commences to ensure the solution is fully mixed.
The investigation has plenty of scope for developments, refinements and improvements – students should be encouraged to carry out an evaluation and/or further research after the investigation is over.</td>
<td></td>
</tr>
<tr>
<td>Lesson End
what do these results mean? Collate results from the class on the main board after the investigation is over.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discuss reasons for differences in results and conclude the lesson by taking a sample of tardigrades from one of the conical flasks and displaying on main board via digital microscope and projector.
Discuss the tolerance of tardigrades to extreme environments and the fact that this gives some hope for the discovery</td>
<td>Temperature – warm temperature will show greatest rate of respiration, due to enzymes in yeast and tardigrades being closest to their optimum temperature. Cold temperatures will show little change to the bicarbonate indicator due to reduced kinetic energy and hence rates of respiration.</td>
<td></td>
</tr>
</table>

of life on remote planets and moons such as Europa.	*Salinity* – the addition of salt lowers the water potential of the solution in the flask. The more salt added, the lower the water potential becomes resulting in water loss from yeast cells (and their subsequent death). Production of carbon dioxide will likely diminish as more and more salt is added to yeast, but tardigrades which are more resilient and can thrive in saline environments should be relatively unaffected.	

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"ASTROBIOLOGY IN THE CLASSROOM"

Written by the Astrobiology Summer Academy
David Cunnold, Emily Quinn, Katie Hanson

LESSON PLAN

Level: Age 11-14 (could be used 14-16)

TITLE: THE EFFECT OF RADIATION ON LIFE (EXOMARS DRILLING)

SUBJECT AREA: BIOLOGY

Context of lesson:
England
- KS3 - food tests (yr 8) / year 7 space and solar system
- KS4 - Physics EM spectrum / Biology effect of UV on living cells

Scotland - solar system, life on other planets, UV radiation

Resources needed:
- access to internet for video clips and google mars
- Projector

UV beads
UV light
Equipment shared by the class (see technician's notes)
- half plastic tubing/ rectangular trough
- Soils samples labeled along the tube
  - ***A.*** 0m - fine sand
  - ***B.*** 0.5m - fine sand, egg albumen powder
  - ***C.*** 1m - fine sand, egg albumen powder, starch, reducing sugar
  - ***D.*** 1.5m - fine sand, egg albumen powder, starch, reducing sugar, grated cheese (or fat substitute)
  - ***E.*** 2m- fine sand, egg albumen powder, starch, reducing sugar, grated cheese (or fat substitute

Equipment per group - boiling tube, test tube, spotting tile, spatula, plastic cup
Equipment at stations
1. Starch test - iodine solution, instruction card
2. Reducing sugar test - Benedict's solution, hot water bath @80ºC, distilled water
3. Protein test - Biuret's reagent, distilled water, pipettes
4. Fat test / emulsion test - ethanol, distilled water

Learning Objectives:
To understand how radiation can affect life
To understand how life can be detected

<table>
<tr><td colspan="3">Learning Outcomes / Success Criteria

All pupils will;
describe the effect of UV radiation exposure on living cells
Most pupils will;
State what a biomarker is
Give an example of a biomarker
Some pupils will;
Explain how to look for life of Mars</td></tr>
<tr><td>Teaching and Learning Strategies</td><td>Differentiation/Key Questions</td><td>Timing</td></tr>
<tr><td>UV beads exposed to UV light for different time lengths (left by the window etc) (0, 10, 20, 30, 40, 50, 60 seconds)</td><td>What does UV light do?
What effect does it have on living things?</td><td></td></tr>
<tr><td>The effect of UV light on living cells
Introduce the ideas that exposure to UV radiation damages cells, causes mutations (changes in the sequence of DNA)
Earth's surface protected from UV radiation by the atmosphere
Mars does not have an atmosphere - is there life on Mars? Video clip - Nasa - evolution of atmosphere on mars
http://m.youtube.com/watch?v=sKPrwY0Ycno</td><td>Why do we use suncream?</td><td></td></tr>
<tr><td>Introduce Exomars Rover activity
Additional resources for background information
http://exploration.esa.int/mars/45084-exomars-rover/

Video clip - Exomars rover -
http://m.youtube.com/watch?v=ZLOneYBsQmM

Link into practical
Searching for life on mars - indicators of life biomarkers / life markers
Pose question - which molecules could be used as life markers / biomarkers?
If there are traces of life on mars where are they most likely to be found.

Practical activity - students given samples of the martian soil core - students test all 5 samples for biomarkers - protein, fats and carbohydrates (sugars and starch)

Classroom layout - 4 stations containing tests for sugar, starch, protein and fat (including solutions and instructions)</td><td></td><td></td></tr>
</table>

<table>
<tr><td>Students collect the soil sample from the core - labelling different depths - collect results to show the presence of the biomarkers at each sample site!</td><td></td><td></td></tr>
<tr><td>Consolidate
Pool class results

Which samples contain biomarkers? Can students explain the distribution of them in the soil core sample?</td><td></td><td></td></tr>
<tr><td colspan="3">Lesson End
Plenary - if the core soil sample was to contain life as well as the biomarkers what would this life look like?

Extension activities / homework
1. Research examples of extremophile organisms on Earth that can tolerated high levels of radiation
2. Create a cartoon / story book to represent the evolution of the atmosphere on mars - if there was life on mars what happened to that life as the atmosphere changes</td></tr>
<tr><td colspan="3">Further lessons
effect of UV radiation on living cells - experiments with microbial cells and agar plates! Using UV sticks to sterilise water at high altitudes (Everest trekking)

If possible immobilising algae or immobilising algae in alginate beads and seeing how UV radiation affects the rate of respiration or photosynthesis</td></tr>
</table>

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"ASTROBIOLOGY IN THE CLASSROOM"

Written by the Astrobiology Summer Academy
Chris McGinlay

LESSON PLAN

Level: Age 13-16

TITLE: METEORITES FROM MARS

SUBJECT AREA: PHYSICS

Teaching Group Ability	**S4 National 5 or KS4/GCSE if done quantitatively (method A)** **S2-3 CfE Level 4 or upper KS3 if done qualitatively (method B)**

Context of lesson:
In the Arctic and Antarctic, researchers find meteorites on top of recent snow. Some of these are identified as originating on Mars. How can this be?

Resources needed: All lengths in millimetres. See Diagram at end of document.
For both methods: large perspex container, possibly 200x500x1000 (width, length, height). Metre rule with high contrast centimetre scale. An 'impactor' of suitable mass and shape (to be determined when testing this experiment), sufficient to get powerballs moving, but not enough to shatter perspex.

For Method A: Selection of elastic power balls (e.g. Waboba ball) with a variety of radii (sufficient in number to completely fill the bottom of the container to a depth of 20-40 mm. A fixed video camera, computer with free Tracker software package (or just pupils' smartphones)

For Method B: Small grains such as rice (too cohesive?), hama beads, polystyrene balls, (powder like flour may be too slow, billowing). Sufficient to fill container to depth of 20 mm. A wooden lattice with small shelves (30x30 squares) at 50 mm vertical intervals.

Learning Objectives: Knowledge, Understanding, Subject Specific Skills

- Assist students to conceptualise energy transfer.
- Review energy types: kinetic, potential, possibly heat, light (if raised by students)
- For later stage classes:
  - kinetic and potential energy calculations,
  - measurement of instantaneous velocity,
  - Use of software to analyse video and extract kinematic data.
  - Notice that low mass objects can end up with quite high velocities after impacts.
  - Know the escape velocity of Mars' gravitational field.
- For early stage classes
  - Notice that low mass objects (fine particulates) can gain significant energy from an impactor.
  - Know that objects travelling fast enough, can escape a planet's gravitational field.

Key Words/Language/Spellings to display
Impactor, meteoroid, meteorite, kinetic energy, potential energy, conservation of energy, transfer of energy, velocity, ejecta.
Spoken Communication
Discussion of pupil groups on how best to conduct or improve the experiment.
Question and answer sessions.
Writing
Recording results
Information Technology
Use of Tracker software for later stage students.

Learning Outcomes / Success Criteria

All pupils will;

- Know that energy is conserved in collisions.
- State that kinetic energy is energy associated with motion,
- Appreciate that small objects can pick up high velocities from large impactors.

Most pupils will;

7. State that kinetic energy increases with mass and velocity. Possibly give equation if relevant to method.

Some pupils will;

- Explain that potential energy increases with height and mass. Possibly define with equation if relevant.

Teaching and Learning Strategies	Differentiation/Key Questions	Timing
Starter Engagement SMSC Clarifying purpose of lesson Throw a powerball at a hard concrete surface. Give two students a chance. Have a spare powerball! Show pictures of martian meteorites on surface of snow in Antarctica, laminated if to be used outside after powerball demo.	*How high could we rebound this? Could we arrange for it never to fall back?* *Where could these rocks possibly have come from? Some actually from Mars!*	5 mins
"Prepare" This will be a demo with opportunities for audience participation at teacher's discretion. Drop the impactor **just once** into the perspex box from a very low altitude so as not to disturb rice or powerballs too much. **Ensure pupils understand purpose of experiment – to see how easily an impactor to knock material into orbit.**	*Let's see how hard or easy it is to eject rocks from the surface of Mars:* *what does the large mass I dropped represent? (Asteroid striking Mars)* *What do the small balls/rice represent? (rocks from crust of Mars)* *What could we do to get a more impressive result?* *How could we take measurements of how the balls/rice respond to the impact?*	5 mins

"Do" Insert either the meter stick or the wooden shelf lattice. With pupil assistance as appropriate drop the impactor from a range of heights, starting with a low altitude (particularly if using the rice method). Some pupils can use smartphones to record too. **A:**Note the highest deposition of rice **B**: or use the video camera and eye-level measurements against the meter stick.		10 – 15 mins
Review Discussion of results from visual measurements. (Tracker software processing is a follow up lesson)	*Is there a link between the impactor energy and the ejecta altitude?* *Is it a linear relationship? If we double the impactor's drop height, do we double the maximum ejecta height?*	2 mins
Prepare Distribute graph paper with predrawn axes, axis labels etc.	*Instead of looking at the numbers, trying to find a pattern, can we turn your data into something more visual?*	
"Do" Pupils plot the data on a preprepared blank graph of impactor height -vs- ejecta height.	*Don't draw a best fit line yet as we'll get more data.*	5 mins
Review Discussion ->	*We have a single data set, can we improve the reliability of our results?* *How do we know our results weren't just a fluke?*	2 mins
Prepare Split into groups, prepare and describe activity stations as described at end of this plan.		2 mins

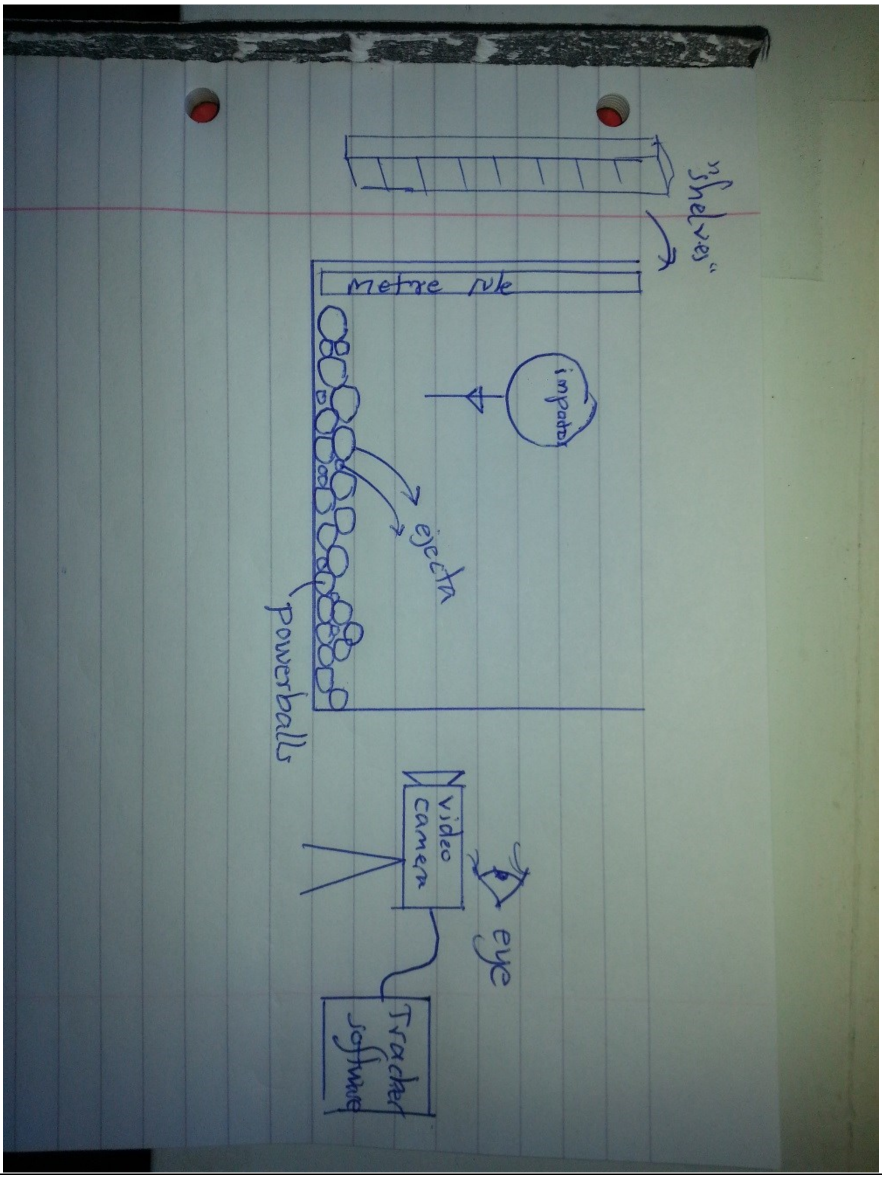
<table>
<tr><td>“Do”

Pupils can repeat the experiment in groups.
Other groups rotate round activity stations.
Add new results to scatter graph.</td><td></td><td>Allow 5+ minutes per group depending on support availability.</td></tr>
<tr><td>Review

Discuss drawing a best fit line.</td><td>Ask some questions about interpolation or extrapolation?</td><td>2 mins</td></tr>
<tr><td colspan="3">Lesson End

What would you do if you found a martian meteorite? Pupils conduct a class survey inventing their own options, or do a class vote.
1. Sell it to rich collector for thousands of pounds.
2. Carefully put in a plastic bag and deliver to the nearest university astrobiology dept.
3. Hide it in a shoe box under your bed
4. Run away screaming as you are terrified of catching Mars 'flu.
5. Throw it at your arch enemy.
6. ????</td></tr>
<tr><td colspan="3">Follow On Activities or possible tasks for 'stations' to set up round the room:
1. Calculate kinetic energy of impactor for each run of the experiment.
2. Calculate the potential energy of the highest ejecta particles.
3. Examine some rocks, pretend they are mars meteorites, calculate what their weight would have been at the surface of Mars (with a set of scales to determine mass).
4. Analyse video footage of above experiment with Tracker software. Obtain maximum velocities, maximum heights.</td></tr>
</table>

5. For the really enthusiastic pupil, see if they can produce a velocity distribution of the powerballs using the Tracker software.



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"ASTROBIOLOGY
IN THE CLASSROOM"

Written by the Astrobiology Summer Academy
ristina Gilruth, Rhona Duncan, Julie Boyle, Alison Matthew

LESSON PLAN

Level: Age 14/15

TITLE: DESIGNING A SPACESUIT

SUBJECT AREA: BIOLOGY/PHYSICS

Context of lesson:

This series of lessons looks to develop the knowledge and understanding in S4 pupils of radiation beyond the visible.

Resources needed:

UV light source
UV beads
various materials with different UV absorption factors e.g. clingfilm, polarising filters, paper, glass, tissue paper
various thickness of some of these materials
Suncream of different factors

Learning Objectives:
Understand how UV light affects human health and how we can protect against it.
Understand some of the dangers of space travel.

Key Words/Language/Spellings to display
Ultraviolet, electromagnetic spectrum
Spoken Communication
Carcinogenic
Reading
Fact files outlining conditions on Mars
Writing
Creating scientific posters
Numeracy
Tables and graphs

Learning Outcomes / Success Criteria

All pupils will; Design an experiment to determine the best material at protecting beads from UV radiation.

Most pupils will; Compile information from both challenges to show the material and thickness that is best.

Some pupils will; Relate these findings to better understand the dangers associated with space travel.

Teaching and Learning Strategies	Differentiation/Key Questions	Timing
Starter Load 'UV sunburn and skin cancer sunsmart UK' video on youtube**.** Show video to class. Show 'garnier skin cancer reality' video.	*How would you summarise these videos in one sentence?*	5
Review In groups, come up with a list of dangers associated with being in space. Share these with the class & discuss.	*What then should a space suit protect you from?* *Pressure* *Heat* *'Radiation' → Remind about the different types of radiation.*	15
Practical Challenge is to create and carry out an experiment to find which materials are most suitable for protecting an astronaut from UV light. Emphasise the safety requirements when using the UV lamp. Pupils should write up a plan including control variables (e.g. distance from light source) and how they will control them before collecting equipment.		25
Review Discuss results Show pictures of a real spacesuit material, emphasise multiple layers. Gold coating on the helmet. Use your results and the information pictures to design your own spacesuit.	*What was the best combination?*	15
Lesson End Look at how these materials e.g. polarised glass are used in everyday life to protect books in museums, clothes in shops, reactive lenses etc.		

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"ASTROBIOLOGY IN THE CLASSROOM"

Written by the Astrobiology Summer Academy
Katie Hanson

LESSON PLAN

Level: Age 11-16

TITLE: EXTREMOPHILES AND THE SEARCH FOR LIFE IN SPACE

SUBJECT AREA: BIOLOGY

Context of lesson: A look at extremophiles on Earth and the adaptations they have which allow them to live in extremes. Looking at conditions on planets and moons in the solar system and whether these adaptations would allow the organisms to survive on exoplanets! This lesson could be used as an introduction to extremophiles or a revision activity after teaching!		
Resources needed: Extremophile starter cards Fact sheets Powerpoint presentation		
Learning Objectives: To have a discussion on the adaptation of extremophiles to their habitats		
Key words/ Languages/ spellings to display: Extremophiles, exoplanets **Spoken communication – discussion on the features of extremophiles that allow them to live in extremes**		
Learning Outcomes / Success Criteria **All pupils will;** Know that extremophiles live in extreme environments; Be able to give examples of extremophiles adapted to different conditions. **Most pupils will;** Be able to understand how specific adaptions help organisms to survive **Some pupils will;** Be able to discuss whether Earth's extremophiles could survive on exoplanets Be able to design an organism adapted to live on a specific exoplanet		
Teaching and Learning Strategies	**Differentiation/Key Questions**	**Timing**
Starter activity / connect: Extremophile starter cards: Hand out cards to students	Students match the adaptations to the organisms then decide which extreme condition they are adapted to survive in	

Students to lay the cards out - there are 5 extreme conditions, 15 organisms, 15 adaptations!		
Follow up activity: Extremophile Olympics	Discuss the card sorts - make sure the students have the correct 3 organisms beside each extreme environment! Students are to rank the extremophiles into bronze, silver and gold position. Allow the students to discuss this in groups , then go through the powerpoint answers – giving facts and figures.	
Discussion: Extremophiles – key to life on exoplanets?	Extremophiles are adapted to survive in extreme environments. Is there life on exoplanets – discuss various exoplanets and link to extreme environments in earth.	
Activity Exoplanets and extremophiles	Extremophiles are adapted to survive in extreme environments! Is there life on exoplanets - discuss various exoplanets and link to extreme environments in Earth	
Discussion	Would any of the extremophiles survive on the exoplanets - if not why not? Discuss tardigrades as polyextremophiles - maybe life on the exoplanets would require adaptations to more than one extreme!	
Activity	Individual or co-operative task Give out information about an exoplanet to each student/group Task: to think about adaptations of an organism that could live on their exoplanet - what would it look like? what size would it be? What adaptations would it have? How do these adaptations allow it	

	to survive in the extreme environment.	
Consolidation/ plenary	Students revise what they have been taught on exoplanets - present their organism to their group / class - students should be prepared to answer questions or challenges from other students Students summarise findings of lesson.	
Extension/ homework: Further research on exoplanets and extreme environments - select an exoplanet within a habitable zone - brief facts on the planet and it's environment, what adaptations would life need to survive their? Brief descriptions of what their organisms look like! This homework activity could be used to compile a list of habitable exoplanets in the class / exoplanet top trumps / exoplanet survival board game!		

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"ASTROBIOLOGY IN THE CLASSROOM"

Written by the Astrobiology Summer Academy
Adam Stevens

LESSON PLAN

Level Upper level GCSE / National 4/5

TITLE: MARS SCIENCE LABORATORY AND CHROMATOGRAPHY

SUBJECT AREA: CHEMISTRY

Context of lesson: Chemical analysis on other planets, detecting types of molecules		
Resources needed: Chromatography practical, plus separate solvent specifically chosen **not** to work for teacher demo, pictures of MSL, video on SAM instrument on MSL, pre made chromatogram on board with (2+) measurements shown		
Learning Objectives: Knowledge, Understanding, Subject Specific Skills *Know that we can look for signs of life on other planets using chemical techniques.* *Understand that the properties of a given compound affect how it responds to a chemical test.* *Describe some of the chemical compounds that might indicate the presence of life and explain why they are suitable.*		
Spoken Communication Discussions **Writing** Observational notes & structure flowchart **Numeracy** Calculating the Rf value		
Learning Outcomes / Success Criteria **All pupils will;** Have performed a chromatography practical at a higher level than in S1-2/Yr7-8 Have identified some of the variables that influence chromatography Produce a flowchart showing the steps involved in the SAM instrument **Most pupils will;** Calculate an Rf value for a chromatograph Produce a detailed flowchart showing the steps involved in the SAM instrument **Some pupils will;** Relate the practical to use in detecting life (possibly on other planets) Calculate Rf values for their own experiment Produce a detailed and accurate flowchart showing the steps involved in the SAM instrument		
Teaching and Learning Strategies	**Differentiation/Key Questions**	**Ti mi ng**

Starter Picture of Curiosity on the board, panels of the different instruments if possible (or just labels). Teacher led discussion on the MSL instruments	*Does anyone know what this is?* *Do you know what the aim of the mission is?* *How is it going to do that?*	10
"Prepare" Link back to chromatography in previous ½ year's science lessons. Introduce kit for chromatography experiment & explain the aim of the practical.	*What does chromatography do?*	5 min
"Do" Produce a chromatogram of different amino acids in the same solvent. (Teacher to set up demo of same experiment with same acid/pigment but different solvents) Leave practical to develop – Introduce the concept of Rf value = (Distance moved by compound / distance moved by solvent) Fake chromatogram on the screen, pupils calculate the Rf value for the spots & write in books.		15
Review Remove chromatogram, note down observations with diagram in books. Now do teacher demo, showing results of different solvent. One should be doctored to not produce a chromatogram.	*Higher ability can measure distances, calculate own Rf value.* Explaining the variables involved in the chromatography. *Can you think of anything else that might affect it?*	10
Prepare Linking back to MSL – explain it uses same principles as they've just done in their practical.		5
"Do" Show video clip https://www.youtube.com/watch?v=wRJpikGEEPs, Tell pupils to think about issues they see with this technique & make notes for final activity while it's playing.		5
Review Pupils to produce a flowchart of how the instrument works. Should split the process into steps and describe what is happening at each		10

one, incorporating info about chromatography where appropriate. (To finish for HW)		
Lesson End/Extension Class discussion – what other kinds of measurements would you want to make?		5

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"ASTROBIOLOGY IN THE CLASSROOM"

LESSON PLAN

Level: Age 11-16

TITLE: BUGS IN SPACE! PHYSICS AND BIOLOGY IN MICROGRAVITY

SUBJECT AREA: PHYSICS/CHEMISTRY/BIOLOGY

Context of lessons

Materials behave very differently in space. If we are ever to explore and settle other worlds we need to understand how they behave. This will influence processes such as making new materials in space, getting microbes to grow properly in life support systems, and using microbes to do useful things like turn planetary rocks into soils. In this lesson we will investigate some of the properties of material behaviour in space, investigating how solids, liquids and gases interact. This lesson plan introduces some interdisciplinary investigation into the links between space science and biology (astrobiology).

Section 1 – What's different about the space environment?
Section 2 – What forces are important in the space environment?
Section 3 – What are the implications for biological processes in space?

Area of curriculum covered by lesson plan

The BioRock Education Project ties directly into the curriculum, Key Stages 3 & 4, in the following ways. The lesson plan has use in any part of the science curriculum under 'Investigating Scientific Questions'.

Key Stage 3:
Physics: i) Motions and Forces; specifically: non-contact forces - gravity forces acting at a distance on Earth and in space. ii) Matter; specifically: similarities and differences, including density differences, between solids, liquids and gases. iii) Space Science; specifically: gravity force.
Biology: Cells and Organisation, Investigating Scientific Questions.
Geography: Extreme Environments
Chemistry: Investigating Scientific Questions, The properties of the different states of matter (solid, liquid and gas).

Key Stage 4:
Physics: i) Forces; specifically: gravity. ii) Forces and motion; specifically: weight and gravitational field strength. iii) The structure of matter; specifically: relating models of arrangements and motions of the molecules in solid, liquid and gas phases to their densities.
Biology: Ecology, Microorganisms, Cell Biology.

Resources needed:
Small closed transparent plastic container, water, food colouring, golden syrup, solids of different sizes, some of which float (very small pieces of polystyrene) and some of which sink (small bits of metal, coins), rulers, timers.

Learning Objectives:
Behaviour of liquids in space.
Surface tension effects in space.
Forces, including gravitational forces in space.
Importance of physical and biological processes in space to materials manufacturing, biological life support and other processes.

Key Words/Language/Spellings to display
Gravity, forces, motion, viscosity, matter, life, microbes.
Spoken Communication
Class discussion of the interaction of different forces in the space environment.
Reading
Read about materials manufacturing and biological life support systems in space.
Writing
Forming conclusions, presenting results.
Numeracy
Rate of movement of solids in a liquid, formulating an understanding of how to quantify the effects of space conditions of materials.

Learning Outcomes / Success Criteria
All pupils will; understand the concept of microgravity and what sorts of processes can be accomplished in space.
Most pupils will; understand how different forces act in space and what the consequences are for the partitioning and behaviour of materials.
Some pupils will; Put together information on different rates of movement of solids and gases in liquids and derived a quantitative understanding of how materials behave in space.

Teaching and Learning Strategies	Differentiation/Key Questions	Timing
SECTIONS		
Starter Discussion (using powerpoint) of space, microgravity, why it is important and what is going to happen during the flight of Tim Peake.	*What is different about space compared to the Earth?* *Why are people interested in going into space?* *What will Tim Peake be doing in space?*	10
“Prepare” Discussion of how gravity influences the way objects behave in space.	*What is the force of gravity?* *How does it influence the way objects behave?*	15
“Do” Groups of students to take small plastic container half full of coloured water, half full of air, shake it vigorously and allow to settle. Measure the time it takes for all the bubbles to leave the water.	*Why does the water and air partition?* *What is going on with the bubbles in there?*	15

Describe what has happened to the liquid and the gas.		
Review Summarise the observations. The students are to predict what will happen in microgravity Watch what happens when Tim Peake performs the vigorous shaking of coloured water in a cube in microgravity, taking particular note of the behaviour of BOTH the liquid and the gas.	*What do we predict will happen in microgravity?* *Explain the differences between Earth and space.* *How do the two phases separate?*	15
Prepare Powerpoint to discuss what might happen if we add solids to the previous experiments. Why is this important? Discuss materials manufacturing, growing crystals in space, microbes growing in rocks (BioRock) and many other processes in space in which solids, liquids and gases are all brought together. Two far future examples might be discussed, e.g. 1) a vat containing rock, liquid and gas for asteroid mining, 2) life support system with liquid, algae, rocks from the surface of Mars and artificial atmosphere. How do the materials in these situations behave?	*Why do we want to do industrial processes in space?* *What complications are there related to the space environment?* *What sort of processes in space require us to understand the behaviour of solids, liquids and gases?*	10
"Do" Each group to take a container, half fill it with coloured water and add a variety of solids of different sizes, some which float and some which do not. Do this same experiment with a container that contains about 50:50 golden syrup/water mix to get a viscous solution. Shake vigorously and measure the rate at which separation occurs in both solutions noting where the objects go and any other behaviour.	*Why do some objects float and some sink?* *Why is this important in industrial processes?* *How does size affect partitioning?* *How does viscosity affect partitioning?*	10
Review Each group to summarise results and predict how similar objects will behave in space. How will size influence behaviour?	*How do different sizes and buoyancies of materials influence where they end up in space?*	20

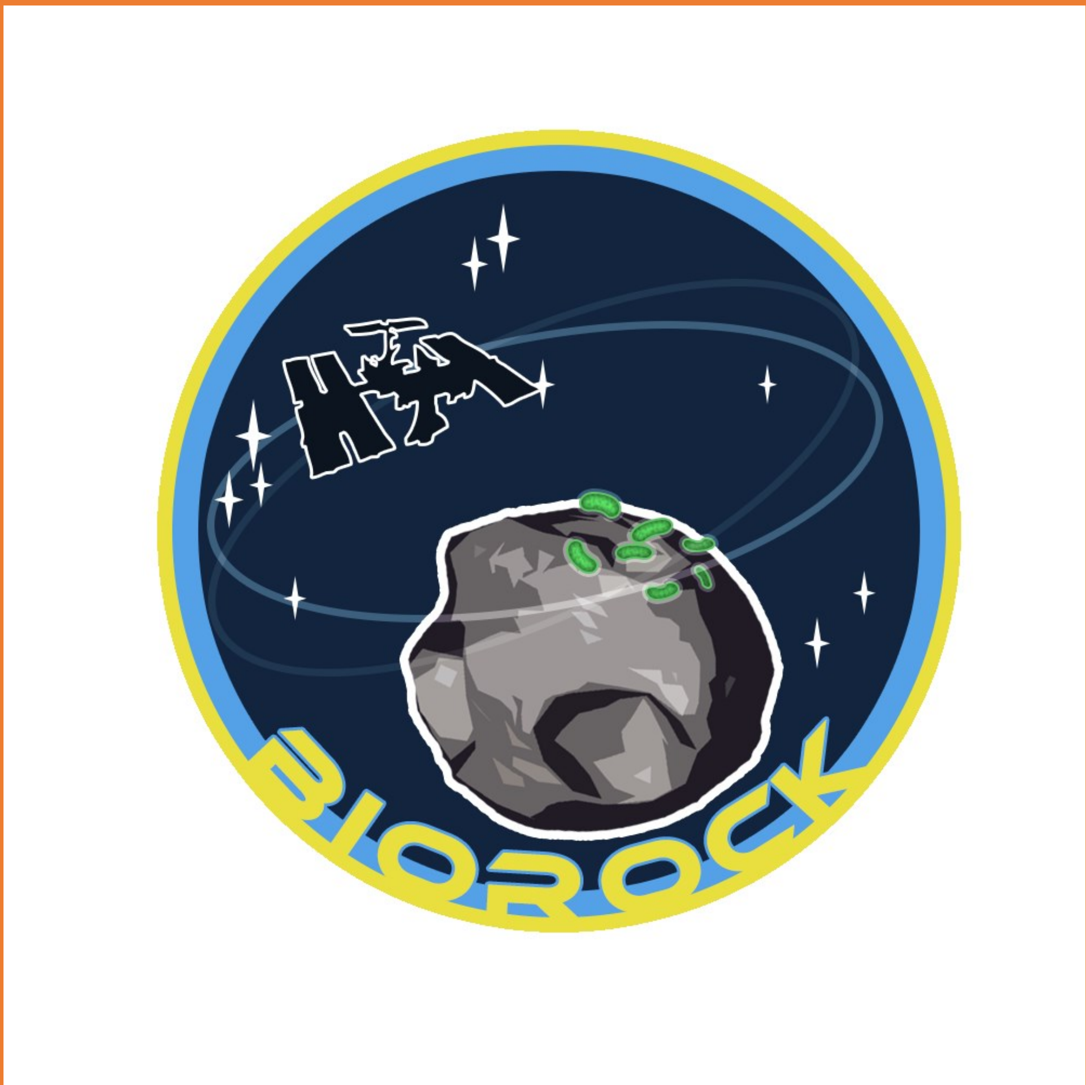
What about buoyancy? How will viscosity affect where the objects end up? Now watch the Tim Peake cube experiments. Discuss and explain the results in terms of surface tension, influence of size of object, viscosity and how surface tension affects the partitioning of different sizes of objects. Higher level students may begin to quantify these affects in terms of how quickly separation and phenomena occur.	*What role does viscosity have in space processes?* *Which forces dominate in space?* *Can you predict the way a tiny neutrally buoyant microbe would behave in space that is one micron in size?*	
Prepare Powerpoint to discuss biological processes in space. Why microbes are everywhere and why they might be important in space as on Earth. Discussion of asteroid mining, life support systems, growth of microbes as contaminants. Consider how microgravity would influence how well a microbe can get access to nutrients in space.	*Could microbes be useful in space?* *What physics would we need in order to to understand how they might behave in space?* *How would microgravity influence the growth and success of microbes in space?*	5
"Do" Carry out experiment by vigorously shaking UV fluorescent microspheres with water and golden syrup mixture. Use UVA lamp to visualise where the microbes are (this could be done by demonstrator).	*What happens to the 'microbes'? Where do they go?* *What forces influence something so small in space?* *What implications does this have for how microbes can move or get access to nutrients in space?*	20
Review Discuss how the experiments tell us about microbial behaviour in space. How would this influence the way we use microbes in space? What about life on other planets. How would different gravity environments affect the ability of life to grow or move around? Could we ever use artificial gravity to exist in space? Watch Tim Peake experiment where the cubes are vigorously shaken as before and	*Will microbes be useful in space?* *What might limit their use?* *How could we manipulate forces in space (e.g. artificial gravity) to overcome the dominant forces in space?* *Will microbes be useful in space settlements in the far future?* *Why are 1g controls important in devising a space experiment?*	20

then swung round on a string to simulate 1g. Discuss the importance of 1 g controls in devising experiments in space. Discuss whether 1 g is necessary. Would lower g levels work?		
Follow-up/homework activities: Write an essay on space life support systems. Do a project to investigate biomining and whether this could be done in space. Do a project to consider the different ways in which microbes might be used in space manufacturing or to live on other planets. Design your own space experiment and consider proper controls.		

BioRock:

Lesson Plans & Supplementary Resources

Tim Peake Education Programme Partners Project



UK Centre for Astrobiology

"ASTROBIOLOGY IN THE CLASSROOM"

Written by the UK Centre for Astrobiology

LESSON PLAN

Level: Age 11-14

TITLE: EXTREMOPHILES IN SPACE

SUBJECT AREA: BIOLOGY

Solar System - SCN 3-6a

Cells - SCN 3-13a

(Following on from SCN 2-01a)

Lesson time: 2 x 40 minute lessons, or 1 x 1hour 20 minute lesson.

Context of lesson:

Extremophiles in Space

Bacteria often have a negative reputation, however many of them can be useful to us because of their adaptations. Adaptations have also allowed some bacteria to become resistant to a host of conditions that would harm or kill most other living organisms. Looking at the environmental extremes in space, we see that some Earth microorganisms might be able to survive the hostile conditions; and when we think about humans colonising space, we might need some of these bacteria to help us on our way.

Resources needed:

'Trump card' sort exercise

Landing site information pack

Tim Peake videos

Pictures of extreme environments – e.g.-deserts, arctic tundra, volcanos, thermal vents etc.

Learning Objectives:

Use information on adaptations to understand how organisms can live in extreme conditions and how they can be used to carry out useful processes.

Key Words/Language/Spellings to display

Extreme, extremophiles, adaptation, exoplanet, desiccation. – These words could be on the board at the start of the class with their definitions.

Spoken Communication

Explain link between extremes, microbes that can inhabit these extremes, and their uses. Discussion in groups and within the class.

Reading

Extract information from cards.

Writing

Homework assignment, summarise/describe uses of microbes in space.

Learning Outcomes / Success Criteria

All pupils will:

Give an example of something that would make an environment "extreme";

State that organisms can live in environments that can be defined as "extreme";

State that the reason these organisms can do this is because of "adaptations";

State that some bacteria can perform useful functions (e.g. producing oxygen, cleaning water).

Most pupils will:

Give an example of a possible adaptation to an extreme environment; give an example of how a microorganism can be 'useful' to humans (e.g. algae & photosynthesis).
Some pupils will:
Be able to explain that exoplanets are likely to have surfaces that are very extreme; list extremophiles that can survive certain extremes; give examples of how space colonisation could be improved with 'useful' bacteria.

Teaching and Learning Strategies	**Differentiation/Key Questions**	Timing
Starter Engagement SMSC Clarifying purpose of lesson *Pictures of extreme environments;* *Terminology on the board/screen for students to review.* *Class discussion*	*What environment would you want to live in?* *Why? (Temperature, water availability etc.)* *What kind of animals live in these places?* *What do animals need to survive in those environments?* *Are there any hard limits of life? (boiling point an obvious one, presence of water…)* *Refresher on pH for trump cards*	5 min
"Prepare" Pupils should go into groups (~4-5). Hand out trump card packs. Introduce the fact that there are microbes able to live in much more extreme environments than animals. Cards have some examples of these. Students' task is to decide if there are any particular microbes suited to living on planets with particular extremes.	*Trump cards are provided in this folder as supplementary materials. There are six extremophiles and ten exoplanets.* *Information on the trump cards make it possible to find an extra-solar habitat for the extremophiles.* *Not all exoplanets will be able to support life, each microbe will have a planet it 'could' live on. Note – Some exoplanets can't host any life, and some extremophiles may be able to survive on more than one planet.*	10 min
"Do" Pupils should try and match as many microbes as they can to different exoplanets.		10 mins
"Review" Ask groups for their answers and to justify them. You may wish to discuss the adaptations the microbes have to live in these environments. (e.g. DNA repair in *Deinococcus radiodurans*) After the discussion, mention that many extremophile organisms do 'useful' things. Ask the class for some examples of 'useful' organisms (animal or bacterial.)	*Are there any environments that none of the microbes could live in?* *Why?* *Back on Earth, where it's not so extreme, microbes can do useful things for us. Such as? ('Pro-biotic' yoghurt, making beer, biomining, helping us digest etc.)*	15 mins

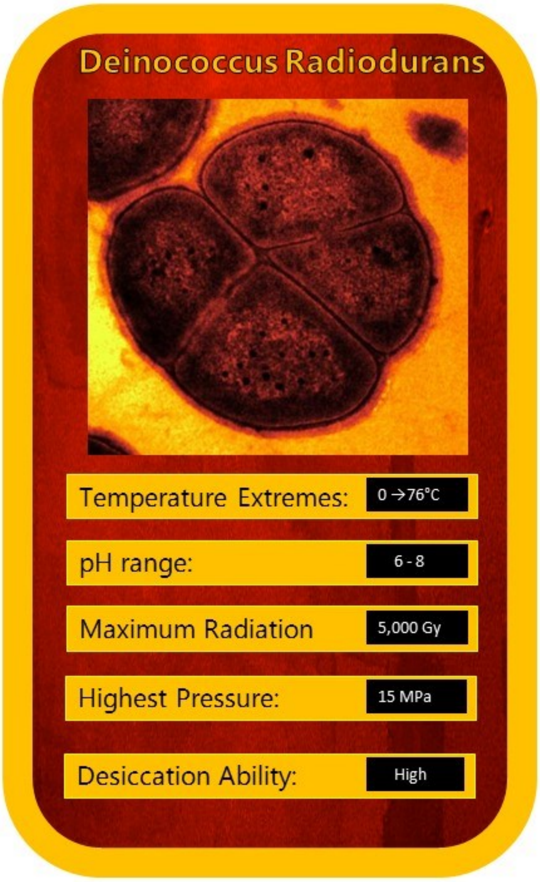
You may wish to split the lesson into two parts here.		
Activity 2: Microbes for Mars **Prepare** (In groups.) Hand out information packs. Read the Activity 2 intro included in the pack, and think about how to survive using the organisms and tools supplied. Explain that pupils will decide which organisms they want to use to help build their own Mars settlement. They can choose a site on the map provided (which are real images of Mars, and is a real potential landing site). Tasks: cleaning air, dealing with waste, creating fuel, transforming planetary regolith (dust) to soil, getting metals, producing oxygen, cleaning water. Confirm tasks with the class.	*Pupils should think about what they'd need to survive on Mars (E.g- water, soil to grow food, etc), and how they would find these resources.* *Look at the Map provided in the landing site information pack, and think about where the water might be, and where the metals could be etc.* *The class could be a whole 'mission team' with different groups solving different tasks, or there could be different 'mission teams' sub-divided to complete tasks. Some 'astronauts' are tasked with securing water, others with finding ores to use, others with setting up the habitation with an air filtration (cleaning) system etc.*	5 min
"Do" Choose a site. Choose which organisms they are going to use. Link organisms to tasks. Draw a diagram of their habitat, including labels of how they are going to use their microorganisms, and any other systems they would like to have (in an exercise books or on paper).	*Using the organisms provided, students must select the appropriate species for the task they've been given, and work the information into their habitat.* *Why have they chosen the site? What qualities do the bacteria have that make them useful for the task? Do the habitats have airlocks? Space for growing plants, storing supplies, radiation shielding? How are their habitats powered (microbial/solar/wind turbine/nuclear)?*	20 min
Review Gather some examples of habitats that students have produced. Ask for the reasoning behind them. Discuss limitations of life support. What do we need other than the biological organisms? Why? Finish habitat designs for homework, and write a summary of why microorganisms would be useful in space. e.g. - 1 mark per example extremophile, and 1 mark per relevant	*Exemplar habitats, or habitats from students who are very enthused, should be kept for a student space conference in 2016 after Tim Peake lands.*	13 min

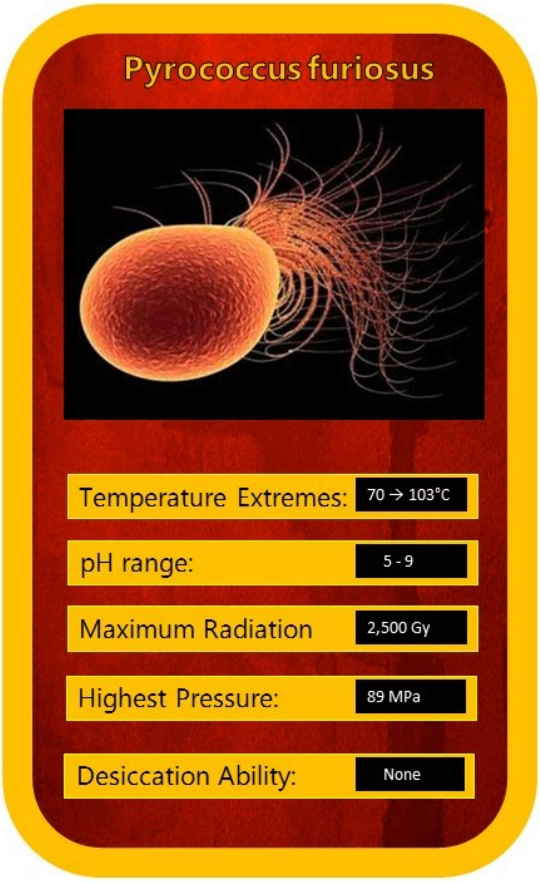
applications of extremophile. Students could also be instructed to look up examples of self-contained habitats, such as Biosphere 2 and HI-SEAS.		
Lesson End: Listen to Tim Peake speech (Speech will be made available around June 2016).		2 min

Supplementary Resources: Extremophiles in Space

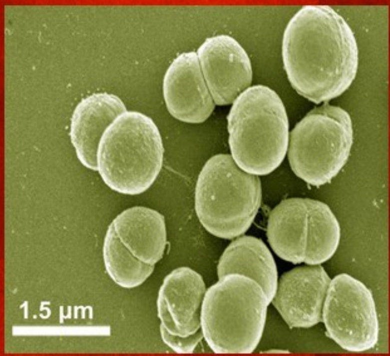
Activity 1

Trump cards; extremophiles:



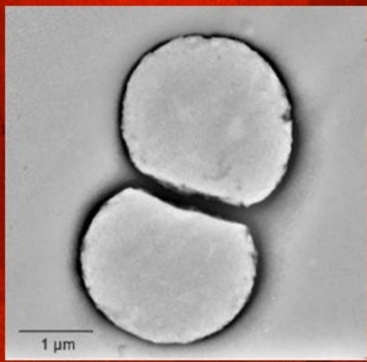


Planococcus halocryophilus



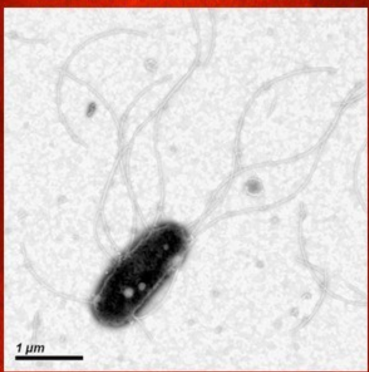
Temperature Extremes:	-25 → 15°C
pH range:	6 - 8
Maximum Radiation	unknown
Highest Pressure:	~200 MPa
Desiccation Ability:	Medium

Picrophilus oshimae



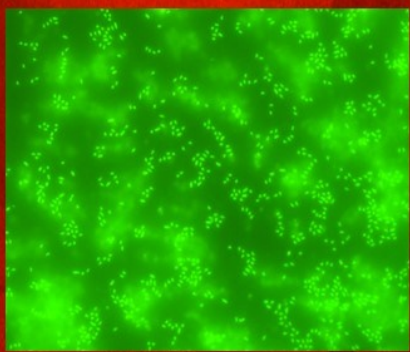
Temperature Extremes:	45 → 65°C
pH range:	0 - 3.4
Maximum Radiation	unknown
Highest Pressure:	unknown
Desiccation Ability:	Low

Bacillus krulwichiae



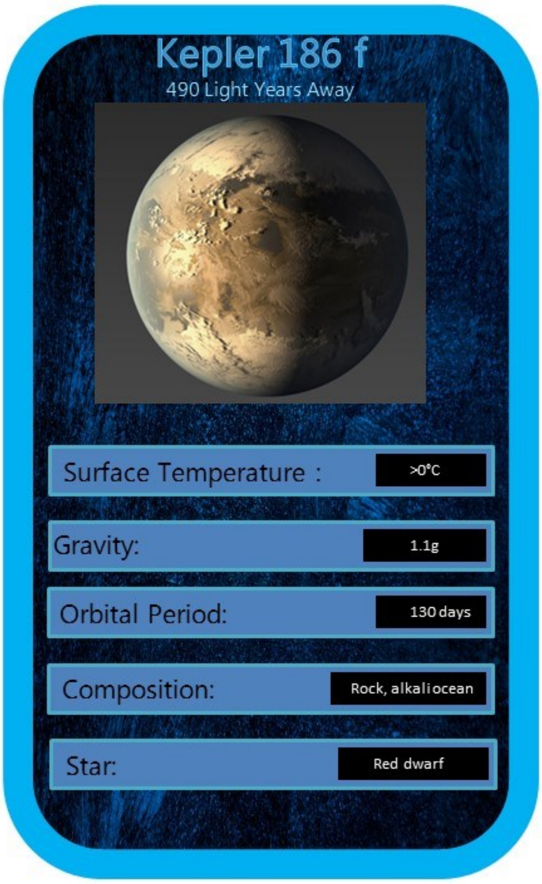
Temperature Extremes:	25 → 40°C
pH range:	8 - 10
Maximum Radiation	Unknown
Highest Pressure:	unknown
Desiccation Ability:	Low

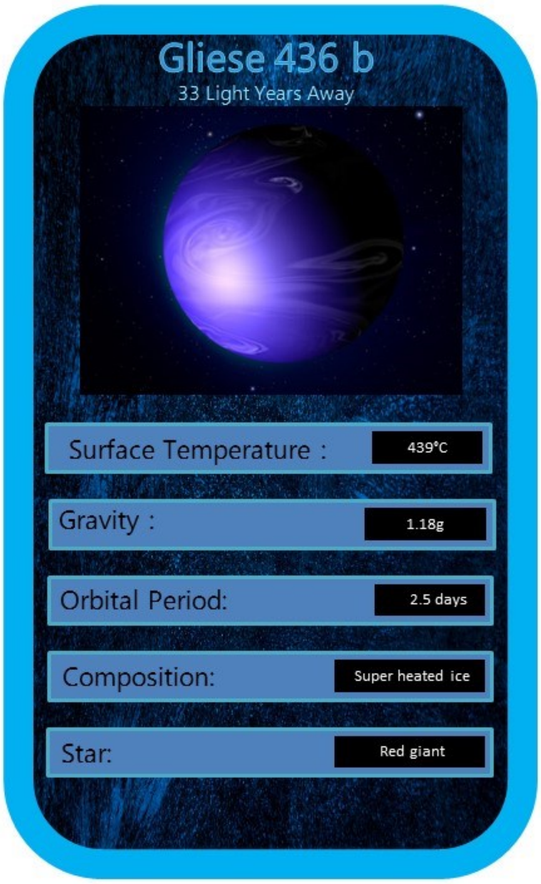
Sphingomonas desiccabilis

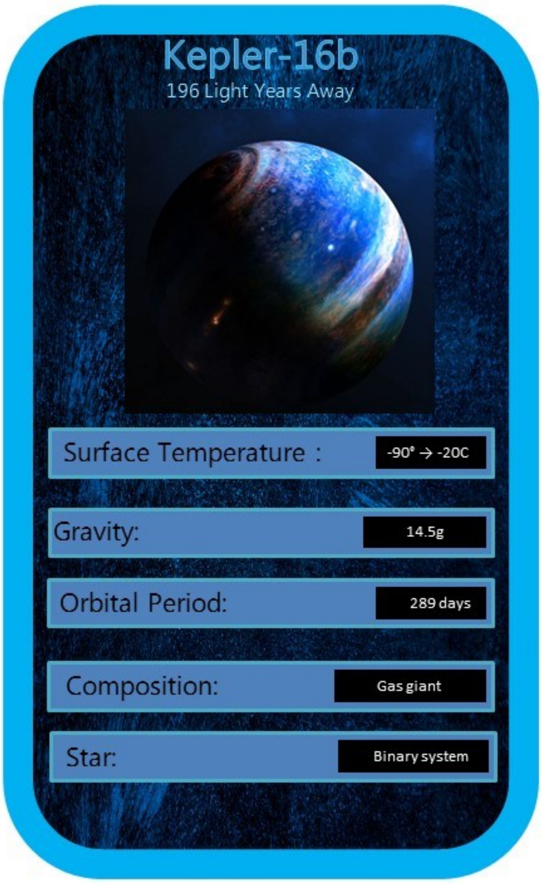


Temperature Extremes:	15 → 37°C
pH range:	6 - 8
Maximum Radiation	unknown
Highest Pressure:	unknown
Desiccation Ability:	High

Trump Cards; Exoplanets:

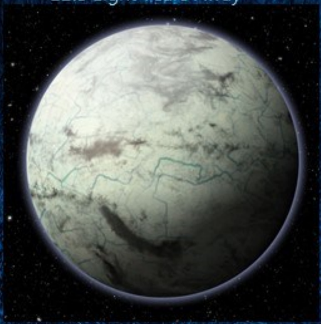






Kapteyn b

12.8 Light Years Away



Surface Temperature :	-30 → +5°C
Gravity:	1.7g
Orbital Period:	48 days
Composition:	Rock and ice
Star:	Red dwarf

Gliese 581e

20.5 Light Years Away

Surface Temperature :	526°C
Gravity:	2.4g
Orbital Period:	3.1 days
Composition:	Rock
Star:	Red dwarf

Sol b

9.5 Light Minutes Away

Surface Temperature :	462 °C
Gravity:	0.9 g
Orbital Period:	225 days
Composition:	Rock, sulphuric acid
Star:	Main sequence

Sol d

14.1 Light Minutes Away

Surface Temperature :	-143 → +35°C
Gravity :	0.3g
Orbital Period:	1.8 years
Composition:	Rock and ice
Star:	Main sequence

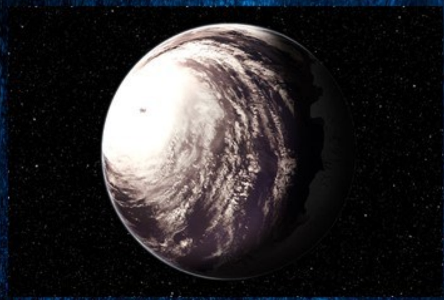
Tau Ceti e

12 Light Years Away

Surface Temperature :	~70C
Gravity:	1.67 g
Orbital Period:	168 days
Composition:	Rock, water vapour
Star:	Main sequence

Kepler 438 b

470 Light Years Away



Surface Temperature :	0–60 °C
Gravity:	1.2 g
Orbital Period:	168 days
Composition:	Rock, water vapour
Star:	Red dwarf

Answer Sheet for Students:

Deinococcus radiodurans Exoplanet:__________ Reason 1: __________ Reason 2: __________	*Pyrococcus furiosus* Exoplanet:__________ Reason 1: __________ Reason 2: __________
Planococcus halocryophilus Exoplanet:__________ Reason 1: __________ Reason 2: __________	*Picrophilus oshimae* Exoplanet:__________ Reason 1: __________ Reason 2: __________
Bacillus krulwichiae Exoplanet:__________ Reason 1: __________ Reason 2: __________	*Sphingomonas desiccabilis* Exoplanet:__________ Reason 1: __________ Reason 2: __________

Answers for Teachers:

Deinococcus radiodurans:
Kepler 438b; Hd40307; Gliese 667c

Pyrococcus furiosus:
Gliese 581e

Planococcus halocryophilus:
HD 40307g; Kapteyn b

Picrophilus oshimae:
Tau Ceti e

Bacillus krulwichiae:
Kepler 186f

Sphingomonas desiccabilis:
Sol d; Gliese 667c

Activity 2

Introduction:

MARTIAN SETTLEMENT

You are all astronauts on your way to Mars, ready to set up the first human colony there.

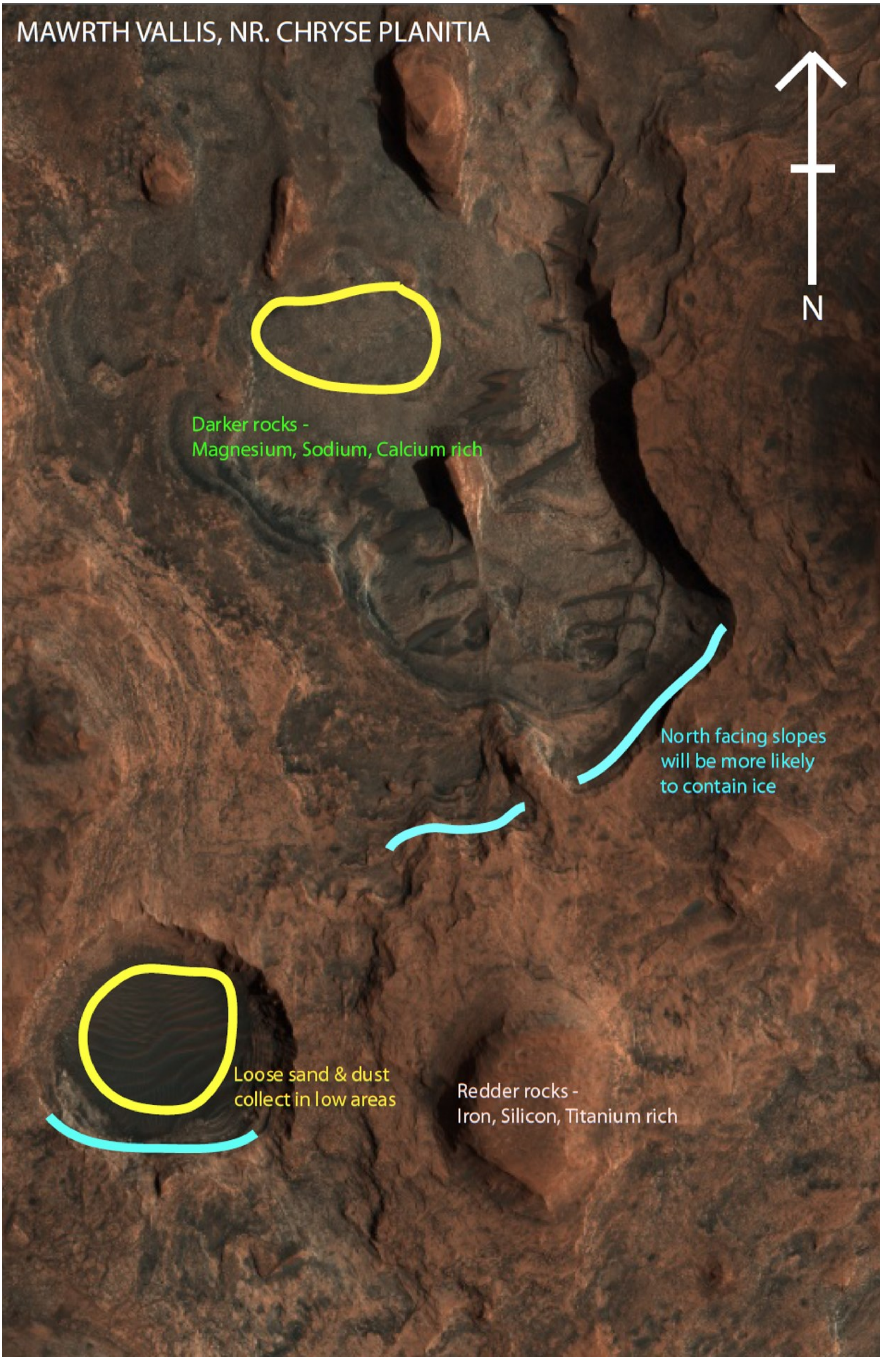
The European Space Agency had made a detailed plan for how to get all your resources and how to set up your life support systems and habitats, but during the journey a wave of particularly harsh cosmic radiation erased a lot of data on your computers and damaged the communications array.
It's a problem, but you're the best and brightest that Earth has to offer, and you know you can figure it out.
You have a map of the landing site, which is an area called Mawrth Vallis.
The map shows you the resources that might be useful around the potential landing site.
You also have a list of bacteria carried on the ship who all perform useful functions that might help you.
You need to combine the bacteria to solve several immediate problems, which are as follows:

- To find ice to melt, and clean it for drinking.
- To generate a breathable atmosphere within the habitat.
- To find and extract some metals to help fix the communications array.
- To clear the dust from the air in the airlock
- To generate fuel and electricity.
- To recycle your waste, since resources are scarce.
- To find or make soil for growing plants and food. Soils needs sandy material, organic matter and a nitrogen based fertiliser.

TASK:

Choose where on the map you want to build your first base. Mark its location.
Design a habitat for the crew. It should include areas for rest, work, eating, and everything human beings need to do.
Describe on your design:

- What the different parts of the habitat are used for.
- Which bacteria you are going to use.
- Why you have chosen those bacteria.


MAWRTH VALLIS, NR. CHRYSE PLANITIA
N
Darker rocks -
Magnesium, Sodium, Calcium rich
North facing slopes
will be more likely
to contain ice
Loose sand & dust
collect in low areas
Redder rocks -
Iron, Silicon, Titanium rich

Useful Bacteria; for students:

Species: *Scytonema javanicum*

Characteristics: Green, able to cope with severe water stress, produces sticky substance.

Food source: Sunlight

Species: *Chroococcidiopsis umbratilis*

Characteristics: Green, lives in some very extreme environments.

Food source: Sunlight

Species: *Sphingomonas desiccabilis*

Characteristics: Yellow, originally found in deserts, produces sticky substance.

Food source: Gets its energy from extracting iron from rocks.

Species *Nitrobacter winogradskyi*

Characteristics: Chocolate-brown bacteria. Grows well with and without oxygen.

Food source: Uses nitrite for food, converting it into biologically available nitrate.

Species: *Geobacter sulfurreducens*

Characteristics: Comma shaped, can produce an electric current when it feeds.

Food source: Animal waste, iron, oil-pollutants and radioactive material.

Species: *Acidithiobacillus ferrooxidans*

Characteristics: Can produce acid, and lives in highly acidic environments.

Food source: Extracts its food, along with iron and copper, from rocks.

Species: *Nitrosomonas europaea*

Characteristics: Slow growing. Converts ammonium into nitrite and fixes it into the ground.

Food source: Ammonium from organic waste, fixes nitrite.

Species: *Fibrobacter succinogenes*

Characteristics: Rod shaped, originally found in cow stomachs. When it eats it releases ammonium and fatty acids.

Food source: Animal and plant waste

Species: *Arthrospira platensis*

Characteristics: Blue-green cyanobacteria, Considered edible in South America, and Africa.

Food source: Sunlight.

Species: *Desulfobacterium indolicum*

Characteristics: Found in water sources.

Food source: Oil-based pollutants and sulphur compounds in water.

Species: *Rhodospirillum rubrum*

Characteristics: Pink, gives off carbon dioxide and minerals that are useful for other bacteria.

Food source: Sunlight and fatty acids.

Species: *Alcaligenes eutrophus*

Characteristics: Can make biodegradable plastic, and produce electrons. Lives in water.

Food source: Pollutants and toxic compounds.

Useful Bacteria; Answers for Teachers:

Sphingomonas desiccabilis	A yellow sticky bacteria, originally found in the Colorado desert in Biological Soil Crusts. Able to extract its food and other elements from rocks.	Extracting metals/dust filter/ making soil
Acidithiobacillus ferrooxidans	Motile rod shaped bacteria originally isolated from rocks, where it lives and finds its food. In the process of removing its food from the rocks it produces sulphuric acid.	Extracting metals
Scytonema javanicum	A green bacteria that produces lots of sticky mucous which can trap fine particulate matter and bind it together.	dust filter
Chroococcidiopsis umbratilis	A green spherical cyanobacteria which can grow in a number of extreme environments, uses solar energy to create sugars.	Photosynthesis/O2
Nitrosomonas europaea	Uses ammonium from organic waste and from the atmosphere for food, converts it into nitrite and fixes it into the ground.	Making soil
Nitrobacter winogradskyi	Rod shaped chocolate-brown bacteria. Uses nitrite for food, converting it into biologically available nitrate.	Making soil
Arthrospira platensis	Free-floating stringy cyanobacteria found in South America, Asia and Africa, uses the sun to make sugars, and is high in protein. A possible food source for humans.	air/food
Rhodospirillum rubrum	Can gather its food from solar energy or from volatile fatty acids, and gives off carbon dioxide and minerals that are useful for other bacteria.	waste treatment (Phase II)
Fibrobacter succinogenes	Gathers its energy from breaking down the bi-products of organic metabolic reactions, and turns them into ammonium and volatile fatty acids.	waste treatment (Phase I)
Geobacter sulfurreducens	Gives off an electric current as it breaks down organic waste.	Microbial fuel cell
Desulfobacterium indolicum	These are oval to rod shaped bacteria which feed off trace metals and hydrocarbons in water, removing them in the process.	Cleaning Martian Ice/water
Alcaligenes eutrophus	Can make biodegradable plastic and produce electrons. Lives in water.	Microbial fuel cell

Lesson Plan:
GraviTEA
KS4

UK Centre for Astrobiology

"ASTROBIOLOGY IN THE CLASSROOM"

Written by the UK Centre for Astrobiology

LESSON PLAN

Level: Age 11-16

TITLE: Gravi-TEA

SUBJECT AREA: CHEMISTRY

Context of lesson: Bioleaching and links to space

Resources needed: Stopwatch, graph paper, measuring cylinders, tea bags, colour chart provided. For the yeast balloon experiment: A packet of yeast (available in the grocery store), A small, clean, clear, plastic soda bottle (16 oz. or smaller), 1 teaspoon of sugar, Some warm water, A small balloon

Learning Objectives: Knowledge, Understanding, Subject Specific Skills

- Resources needed by life, and availability. Chemical reactions for biological processes. Extreme conditions, effects of gravity on the movement of nutrients needed by life.

RWMC

Key Words/Language/Spellings to display
Bioleaching, diffusion, microgravity, resources for life.
Spoken Communication :
Questioning throughout.
Reading:
An article relevant to the topic.
Writing:
6 mark question at the end.
Numeracy:
Plot diffusion distances and time on a graph and work out rate of diffusion. Distance over time
Practical Skills:
Accurate measurements, interpreting data.

Learning Outcomes / Success Criteria

All pupils will:
Understand resources needed by life, and be able to suggest limitations to the availability of those resources in space.
Most pupils will:
Be able to use their data to support their hypotheses/question/concept.
Some pupils will:
Be able to apply additional variables that would impact life in space, link it in to a larger context, and work out diffusion rates.

Teaching and Learning Strategies	Differentiation/Key Questions	Timing
Starter Yeast balloon experiment demo to get the students thinking about requirements (and limiting factors) for life/growth. To do the yeast demonstration:	*'What's happening? What resources are being used, which waste products are being produced?'* Complete a respiration equation (word and symbol) which begins with only glucose, and balance.	5 mins

1. Fill the bottle up with about one inch of warm water. (When yeast is cold or dry the microorganisms are resting.) 2. Add all of the yeast packet and gently swirl the bottle a few seconds. (As the yeast dissolves, it becomes active – it comes to life! Don't bother looking for movement, yeast is a microscopic fungus organism) 3. Add the sugar and swirl it around some more. Like people, yeast needs energy (food) to be active, so we will give it sugar. Now the yeast is "eating!" 4. Blow up the balloon a few times to stretch it out then place the neck of the balloon over the neck of the bottle. 5. Let the bottle sit in a warm place for about 20 minutes If all goes well the balloon will begin to inflate!		
"**Prepare**" Link the above to lack of mineral resources on Earth, motivating a search for resources in space. Mention the thousands of asteroids in Near Earth Orbit. List the resources needed by life (basic elements and nutrients).	*We are running out of mineral resources, e.g. copper, on Earth, could we use bio-leaching in space?*	2 mins
"**Do**" Come up with pros and cons for life in space.	*Would bioleaching in space be possible? What would the requirements be?*	5 mins
Review Tim Peake video addressing these questions, and putting across the problem of nutrient availability in space. BioRock experiment.		5 mins
Prepare Discuss mixing and nutrient availability/distribution.	*How are the nutrients going to get to the microbes? Investigate the role of gravity for this on Earth.*	2 mins
"**Do**" Students will each have a cylindrical tube of cold water. Students will push a tea bag (black tea) to the middle of the cylinder where it will be allowed to diffuse. It will diffuse down, showing little colour at the top and dark colour at the bottom. Every 30 seconds or 1 minute measure the colour at the top and bottom	*Discuss what is happening to the tea and why it is diffusing down (gravity).*	15 mins

against the provided colour chart and will plot this data on a graph.		
Review Teacher shows a way around the problem by mixing the cylinder.	*Explain using your knowledge of today whether bioleaching can occur in space, referencing your data.*	10 mins
Lesson End How could the mixing issue be resolved, suggestions? Tim Peake video. 5 mins		
Homework: Read the article on gold biomining and answer a number of questions. How might biomining be useful in space? On what planets and moons might is be used? What are the requirements for biomining organisms to grow? Would they be available in space? How might gravity affect biomining? What would be some of the complexities of building a biomining reactor in space?		

Some videos you might choose to show the students:

Biomining in Chile – dubbed:
https://www.youtube.com/watch?v=aD4kFmHcEOM (1:08)
Short cartoon explaining gold biomining:
https://www.youtube.com/watch?v=aD4kFmHcEOM (0:19)
Introduction to the concept of mining asteroids (not biomining specific):
https://www.youtube.com/watch?v=KtBob1vTvHE (1:19)

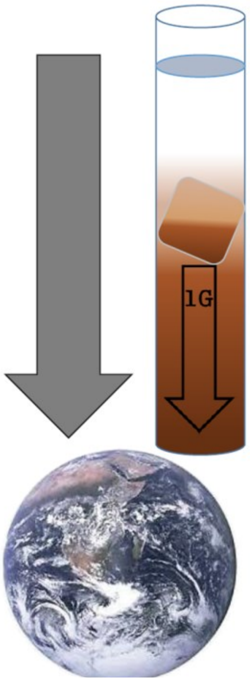
Further Reading:

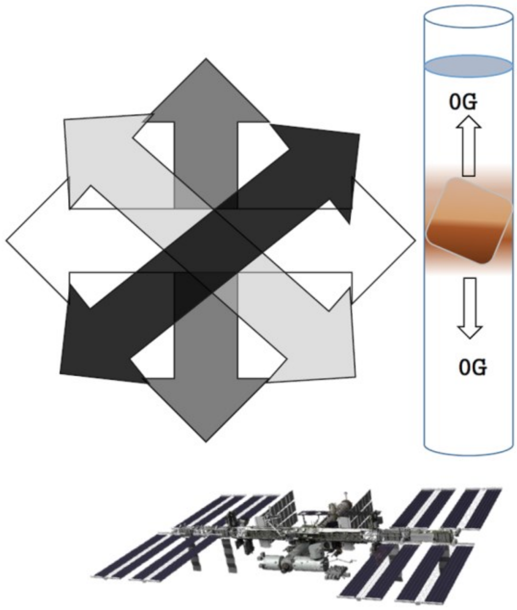
A Microbe Post article on biomining asteroids:
https://microbepost.org/2015/11/10/microbes-martian-miners-of-the-future/
BBC article on biomining:
http://www.bbc.co.uk/news/technology-17406375
Scientific American article on biomining in space:
http://www.scientificamerican.com/article/space-colonists-could-use-bacteria/
Space.com article on biomining in space:
http://www.space.com/28320-asteroid-mining-bacteria-microbes.html
A short SciDevNet article on biomining in Chile:
http://www.scidev.net/global/health/news/biomining-microbes-secrets-revealed.html
A longer Chemical and Engineering News article on biomining in Chile:
http://cen.acs.org/articles/90/i42/Mining-Microbes.html?h=1836741176

Supplementary Resources: GraviTEA

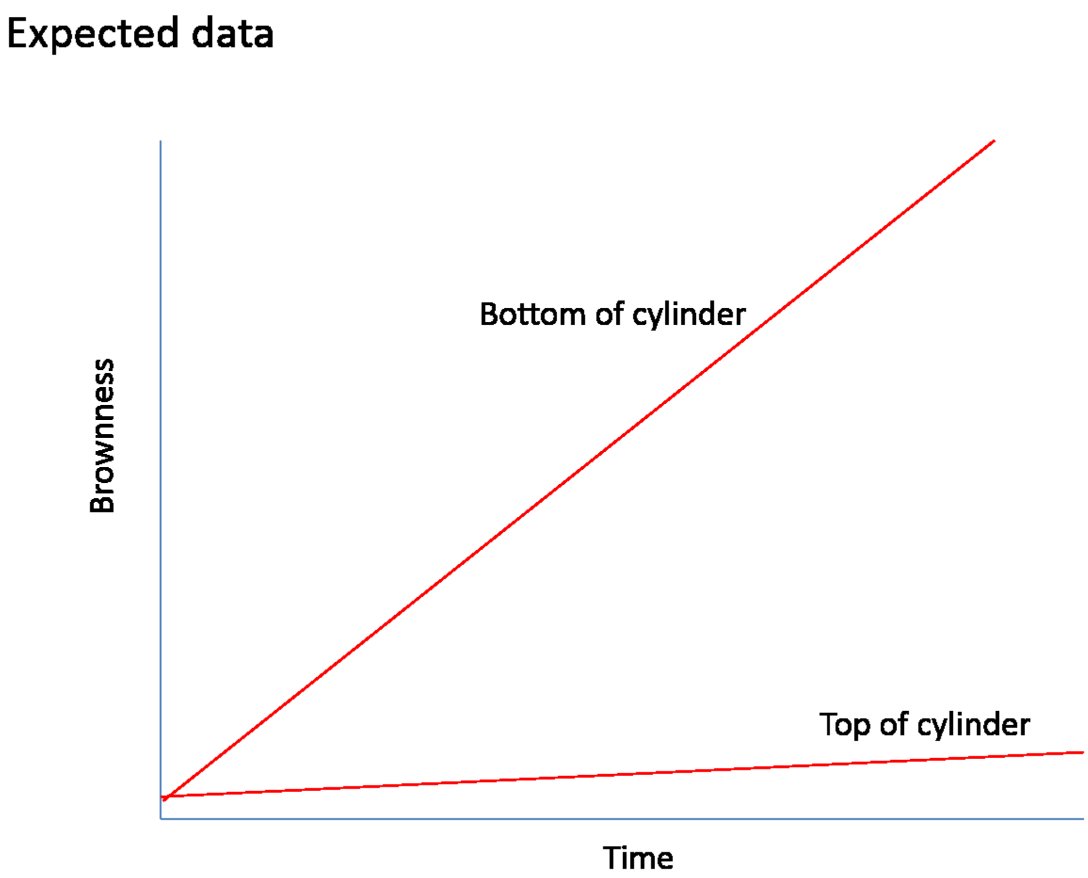
Force Diagram:

Colour Chart for Graph:





Example Chart:



Lesson Plan:
Biofilms in Space
KS4

"ASTROBIOLOGY IN THE CLASSROOM"

Written by the UK Centre for Astrobiology

UK Centre for Astrobiology

LESSON PLAN

Level: Age 14-16 (KS4)

TITLE: BIOFILMS IN SPACE

SUBJECT AREA: BIOLOGY

Cell biology

(Biology: SCN 3-13a)

Lesson time: 2 x 45 minute lessons.

Context of lesson: **Biofilms in Space** **Bacteria can exist as single-celled entities, or in larger cooperative structures known as biofilms. When working in biofilms, the single cells express different genes and behaviours, which benefit the whole cell mass. Understanding biofilms is useful, as we can encourage helpful biofilms, and learn how to eradicate negative ones. Biofilms in space behave differently to those on Earth, as microgravity causes further changes in the genetic expression and behaviour of the cells; if we want to use bacteria to help us achieve our goals in space, we need to understand what these differences will mean for the biofilms.**
Resources needed: GraviTEA resources (from other UKCA lesson plan and resource pack**):** Measuring cylinders or diffusion tubes, black tea bags, colour chart (provided), and Force diagram (provided). Biofilm experiment resources: Measuring cylinders or diffusion tubes, sterile cloth, coloured bacteria (e.g.- *Chromobacterium*, a facultative anaerobe. Use of a different bacteria or yeast may alter the outcome of the experiment, but would still give interpretable results),
Learning Objectives: Knowledge, Understanding, Subject Specific Skills Understanding the concept of a cooperative bacterial biofilm. Understand how gravity can affect growth of microorganisms in a biofilm. Understand how gravity affects mixing of water.
Key Words/Language/Spellings to display Biofilms, microorganisms, prokaryote, microgravity, convection. **Spoken Communication** Explain concept of a biofilm and how gravity affects distribution of particles. Discussion in groups and within the class. **Reading** Outside reading on biofilms and applications. **Writing** Short essay on biofilms in space. Laboratory report on BioRock experiment.
Learning Outcomes / Success Criteria **All pupils will:** **Describe how gravity affects mixing of water and diffusion of nutrients.** **State that biofilms are a complex and social structure formed by microorganisms.** **Most pupils will:**

Apply information gained from the GraviTEA demonstration to generate the hypothesis for the BioRock experiment that gravity will affect nutrient distribution and microorganism growth. **Give an example of beneficial or detrimental roles of biofilms.** **Give an example of practical uses of microorganisms (i.e. biomining).** **Some pupils will:** **Hypothesize that differences in growth in the BioRock experiment may lead to differences in basalt rock weathering in microgravity versus Earth gravity.** **State potential controls needed for BioRock experiment.**

Teaching and Learning Strategies	**Differentiation/Key Questions**	**Timing**
Lesson 1		
Starter Why do we socialise?	*Why do we socialise?* - *Communication, jobs, safety, collaboration, etc.*	5 mins
"Prepare" Explain what a biofilm is with pictures Discuss pros/cons of biofilms.	*What are some of the challenges with biofilms?* *- contamination of medical devices, industrial pumps and devices* *What are some practical applications of biofilms?* *- Biomining (heavy metal recovery), wastewater treatment, etc.* *- Sewage, biofilms degrade waste and break down human waste.*	10 mins
"Do" Teacher: Demonstrate graviTEA. Fill two measuring cylinders with water. Suspend a tea bag in the middle of each cylinder. Wrap the top of each cylinder with a leak-proof, non-absorbing material to create a watertight seal. Tilt one cylinder onto its side and start the timer. Note down the colour change of water around the tea bag every 5 minutes for the 20 minutes, or as long as it takes the students to set up their BioRock practicals. [Additional resources available in the graviTEA lesson plan]. Set up BioRock practical. Pupils will divide into groups of 4. Each group will setup 4 measuring cylinders. All cylinders will be filled with water and contain a bit of cloth at the bottom with microorganisms and a bit of cloth suspended at the top of the cylinder with microorganisms. The top of the cylinder	*It may be best to begin the graviTEA demonstration, and then have pupils setup the BioRock practical. Reassemble pupils to go over the graviTEA experiment results once they've finished setting up the BioRock practical.*	20 mins

should be wrapped in parafilm or another airtight, leak-proof material. Two cylinders should remain upright and two cylinders should be placed on their sides. It is important that none of these cylinders be moved or jostled in any way over the next few days. [Look in Resource pack for 'Equipment List' with more details on set-up].		
Review Discuss results of graviTEA. Detailed prediction of BioRock experiment using data from graviTEA.	*How did tea diffuse in the top-down cylinder? How did tea diffuse in the side-on cylinder?* *What does this tell us about mixing of water in simulated microgravity?* *How will nutrients mix in microgravity?* *How might differences in nutrient mixing affect growth of microorganisms?* *Where do you expect microorganisms to grow in top-down vs side-on cylinders? Why?* *What would be a good control for the BioRock experiment? (Cylinders with nutrients but without microorganisms as a negative control for colour change; cylinders without nutrients but with microorganisms; etc.)*	10 mins
Homework Biofilms and their roles Biofilms in space	*Write short essay on biofilms.* What are they, what are their roles and how they are linked to space? Use the internet to find one or two web sites to support your conclusions.	
Lesson Part 2 **(Recommended 5 days later;** **more than 3 days, less than 8 days).**		
Prepare Recap graviTEA results and BioRock predictions.	*How did tea diffuse in top-down cylinders vs side-on cylinders?* *How might differences in nutrient mixing affect growth of microorganisms?* *Where do you expect microorganisms to grow in top-down vs side-on cylinders? Why?*	5 mins
"Do" Break out pupils into groups of 4. Have 2 pupils examine the top-down tubes and 2 examine the side-on tubes. ➢ Overall observations of the tube (where are the microbes). Each group would have four tubes (2 sets of tubes labelled A and B). One set of tubes upright and the other set on side.	*Potential outcomes:* *In top-down cylinders -* *1) Bottom cloth harbours more organisms. This is likely due to nutrients predominantly sinking to the bottom of the cylinder. This would be the expected outcome based on the results from graviTEA.* *2) Similar growth in each cloth. The original inoculum might sustain growth of each*	20 mins

➢ Remove cloth from A and suspend cells. Look at turbidity (cloudiness) ➢ Remove cloth from B and stain/examine microscopically	*group of microorganisms if it included nutrients.* *3) Top cloth harbours more organisms. Aerobic organisms are more likely to grow at the air interface, thus the top cloth would see more microorganism growth than the bottom cloth due to lack of aeration in the bottom of the cylinder.* *In side-on cylinders -* *1) Similar growth of organisms in each cloth. This is the likely outcome since both cloths should see similar nutrient levels and be equally aerated.* *2) One cloth harbours more organisms than another. Was the cylinder mixed in any way? Is there an air pocket at one end of the cylinder as opposed to the other? May need to consider technical aspects of the experiment.*	
Review Discuss results within group. Have pupils make an outline to write up a lab report. Introduction Hypothesis Methodology Results (images, colour of turbidity) Analysis/Conclusion Evaluation References BioRock – implications for provision of nutrients to biofilms in bioreactors	*Introduction - what were the main scientific concepts of this lab?* *Hypothesis - State the outcomes you anticipated for the experiment. Explain how you arrived at this hypothesis based on the information presented in the Introduction.* *Methodology - State the experimental procedure.* *Results - Describe what you observed (turbidity, microscopically)* *Analysis/Conclusion - Did the results support your hypothesis? If they didn't, consider whether the experimental design was flawed and other potential explanations for your results. Consider what your results mean for biological systems in general - how might these results be applied to other situations? Given what you've learned, what differences might you predict for the BioRock project between Earth gravity and microgravity? What controls do you think you would need for the BioRock project, and why?* *References - cite literature used to inform the Introduction and Discussion.*	15 mins
Lesson End: Watch Tim Peake Video		5 mins.
Homework: Write lab report		

Supplementary Resources: BioFilms in Space

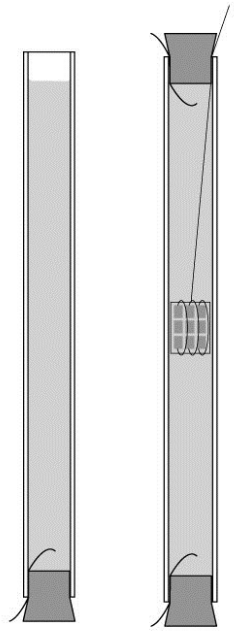
Technician's Guide:

Secure the top of the cylinder with leak proof material, such as parafilm. Parafilm can then be secured with tape.
Alternatively, you may wish to use a large test tube or other container, especially if you are able to fit one with a rubber stopper or leak-proof bung.
Pictures of the BioRock setup:

Close up views of side-on cylinder. Note the middle cloth containing nutrient solution is suspended by a sterile wire (top cloth with microorganisms, too). If the cylinder leaks, transfer materials to a new cylinder and try again to make the opening leak-proof, especially if this occurs very early in the incubation period. If this occurs later in the incubation period, try to transfer cloths containing microorganisms carefully to a new cylinder so as to avoid dispersing microbes throughout the new cylinder.

Bio Rock Experiment: Equipment List

Each group should have:
2 diffusion tubes, 4 bungs or para film, thin cotton thread, 2 empty tea bags filled with Agar chunks, 4 pieces of cloth innoculated with micro-organisms (e-coli or yeast), 4 Petri dishes with Nutrient Agar or Nutrient Agar and Sugar, 4 Pipettes, 3 Clamp Stands.

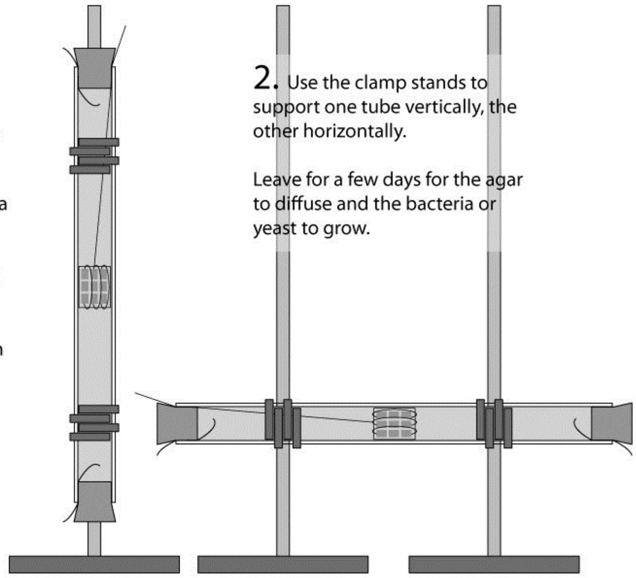


1. Take a diffusion tube with 2 bungs, 2 strips of innoculated cloth, and a tea bag filled with agar chunks.

Put a bung in one end with a piece of innoculated cloth, fill with water and put the tea bag and the other bung and cloth in.

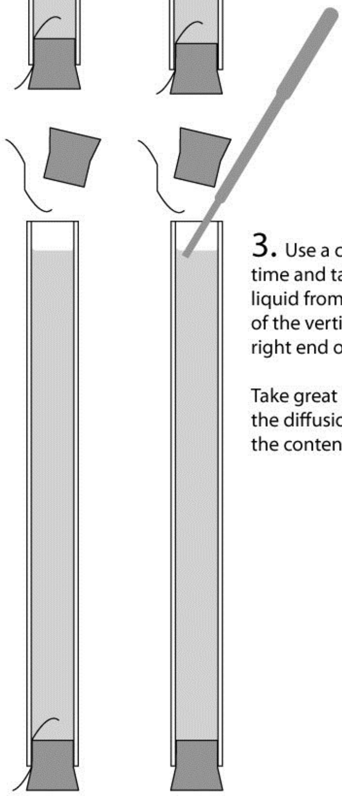
Ensure that the tea bag is an equal distannce from each end of the diffusion tube.

You will need two sets like this.



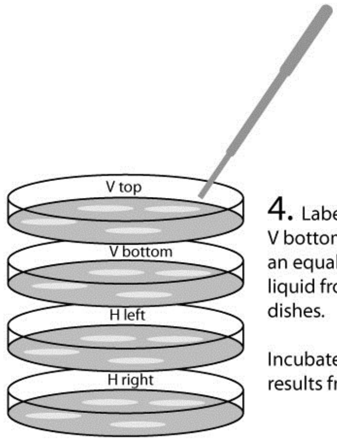
2. Use the clamp stands to support one tube vertically, the other horizontally.

Leave for a few days for the agar to diffuse and the bacteria or yeast to grow.



3. Use a clean pipette each time and take a sample of the liquid from the top and bottom of the vertical tube, and left and right end of the horizontal tube.

Take great care when rotating the diffusion tube not to shake the contents too much.



4. Label 4 petri dishes, V top, V bottom, H left, H right, and drop an equal number of drops of the liquid from each position into the dishes.

Incubate, record and compare the results from each.