Pupil Researcher Initiative

Plants in Space

Setting the Scene

You will be working as a researcher in a university department of bioastronomy. You are part of a team that is putting in a proposal to win a contract to design a life-sustaining unit for a spaceflight to Mars. You and your colleagues will carry out some research into photosynthesis, and seek out other information about dietary needs and energy requirements for astronauts during their mission. You will then write a report of your findings to present at a seminar.

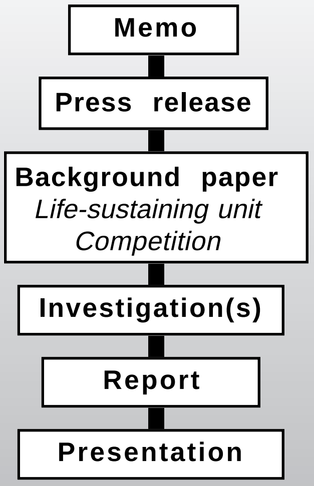
Pupil Research Brief

Study Guide

Syllabus Targets *Science you will learn about in this Brief*

- ❒ green plants photosynthesise when it is light
- ❒ during photosynthesis light energy is absorbed by chlorophyll, found in chloroplasts in some plant cells
- ❒ this light energy is used to convert carbon dioxide and water into sugar (glucose)
- ❒ oxygen is released as a by-product
- ❒ the rate of photosynthesis is limited by low temperatures, shortage of carbon dioxide and shortage of light
- ❒ for healthy growth plants need a range of mineral ions
- ❒ the body needs a balanced diet to remain healthy
- ❒ the more active people are, the more carbohydrate and fat they need for energy

Route through the Brief



Outcome Checklist

You will carry out one or more investigations or written tasks, and produce a written a written report of your findings. This will be presented to the rest of the class. You should make sure you produce the following items as you work through the Brief

Press release and background paper

- ❏ investigation plan
- ❏ investigation report
- ❏ presentation

Department of Bioastronomy

Memo

From: Jan Sorensen
To: Research teams
Subject: Space Agency 'Life-sustaining Unit' competition
Date:

I have just got the details of a new Space Agency project to develop plans for a Life-sustaining Unit for use on possible future space flights. It seems that the Agency has decided to hold a world-wide competition to produce the best design for a life support system for use on long space flights. Astronauts on such flights will need food, water and oxygen supplies for journeys of 2 years or more. The winning team would get the job of designing the system, and developing the technology to go with it. I think that we should have a go - we have some good staff who are imaginative and hard working. I am sure we would have a good chance of getting the final contract. Your job will be to provide advice and ideas about some of the biological issues, e.g. getting maximum oxygen and food production from the plants taken on the spacecraft, and relating this to the needs of the crew. The Space Agency project was announced by a press release, which I obtained from their WWW site, along with further details of the competition. The main item I downloaded was a background paper which I have printed off for circulation in the department (copy attached).

I have looked through the paper and made some notes in the margins about possible investigations and background research we could carry out. Doing this work will help us get to grips with some of the problems we will need to consider when we begin drawing up the design proposal. Perhaps these could be shared out amongst the team. You will need to:

- read through the press release and background paper
- select one or more of the issues I have highlighted and carry out any necessary background research or investigations
- produce a report of your findings
- attend a meeting where the results of the various investigations can be discussed.

At this meeting we will start thinking about putting our ideas together to design the Life-sustaining Unit.

Press Release -
from the Space Agency

Space Agency calls for design proposals to develop a Life-sustaining Unit for use on crewed space flights to Mars and beyond.

The Space Agency is pleased to announce a competition, open to all institutions eligible for Research Council and Agency funding, or their overseas equivalents, to design a Life-sustaining Unit for use on crewed space flights of over two years duration. The competition will result in a short-list of 10 designs, which will form the main feature of a major public exhibition to be held in one year's time to celebrate the imagination, creativity and capability of the world's scientists and engineers. The winning design will be chosen by a team of international scientists and engineers, and announced at a press conference during the final day of the exhibition. The winning team will be awarded a contract to carry out further research, and to produce a working prototype of the Life-sustaining Unit.

The design of a Life-sustaining Unit will be the first step on the road to the achievement of a space flight to Mars carrying astronauts. Following the first crewed space flight in 1958, and then the first crewed Moon landing in 1969, going to Mars represents the next major milestone in the history of human exploration of space.

Further details can be obtained from the Space Agency Home Page.

Space Agency

I have written some ideas on this paper which you might like to follow up

Life-sustaining Unit Competition

Producing the most effective design for a Life-sustaining Unit for use on crewed space flights to Mars and beyond.

At the moment no such mission is planned, but it is inevitable that it will happen during the next century. The recent discovery of structures with a possible biological origin on a meteorite which came from Mars has increased this possibility.

To provide visitors to our Web site with some background, we have produced the following information which sets out some of the key issues in the design of a Life-sustaining Unit.

Creating a Life-sustaining Unit for astronauts on a mission to Mars.

1 Introduction

In every space mission so far carried out all materials needed to sustain the astronauts (food, water, oxygen) have been sent up with the crew. Getting large masses out of the Earth's gravity is very expensive. The longer the mission, the bulkier the payload. There comes a point when the cost of sending up all the food and oxygen needed (water is recycled) is greater than the cost of installing a self-sustaining biological supply system on board the spacecraft. It is calculated that the break-even point is two years. For flights of less than this time, it is cheaper to send the food and oxygen up with the astronauts.

We need a full dietary-needs analysis for 8 individuals on an 800 day journey in space - total the amounts of nutrients, energy needed etc - list the factors which could affect the totals, and **how** they would affect them.

You could come up with and try out various methods for recycling water

For flights longer than this it is cheaper to build a supply system on the space craft. Space missions to Mars will take over two years to complete, and so the Space Agency is seriously considering the possibility of putting a balanced ecosystem, or Life-sustaining Unit, into a Mars-bound space craft, to provide the crew with all the food and oxygen they will need for the flight. It is vitally important to control such an ecosystem precisely, supplying energy in finely judged amounts so that as little as possible is wasted, and using plants that will provide the highest possible yield of food and oxygen from the minimum amount of light and nutrients.

2 Growing Plants in Space.

a Growing medium

An adult human requires, on average, 602 litres of oxygen a day. So, plants used on the space craft must be as efficient as possible at photosynthesis in order to supply the oxygen needed by the crew of the space craft. The plants will not be grown in soil, but instead, a newly developed soil substitute will be used. The material contains all the nutrients plants require and it releases them in controlled amounts, thus making it much more efficient at supplying minerals than ordinary soil.

Can we produce data on how physical activity affects oxygen consumption and CO_2 production - what, apart from physical activity, will affect these levels?

What combination of nutrients needs to be supplied to plants for healthy growth? You could also look at the types of growth mediums which could be used,

b Light

The greatest technical problem is supplying plants with enough light. The Life-sustaining Unit will be powered by panels of photovoltaic cells (solar cells) which will produce electricity. Some of this electricity will power banks of electric lights which illuminate the plants. Plants will use the light energy to photosynthesise, making both food and oxygen for the astronauts.

Each stage in this chain of energy transfers is inefficient. Light is first converted to electricity by the solar cell. This is then converted back into light by the electric lights. Finally, light is converted into chemical energy in plants during photosynthesis. Even under greenhouse conditions, only about 7% of the light arriving at a plant leaf will be used in photosynthesis. This is partly because chlorophyll molecules in the leaf's cells can only process one photon of light at a time. Any other photons arriving at a chlorophyll molecule when it is busy dealing with the last one will be wasted.

How does light intensity affect the rate of photosynthesis?

Do plants need a period of dark during each 24 hour period in order to develop? If they do, what are the implications for oxygen supply to the crew?

Scientists at the European Space Agency in Belgium have suggested using lights that flash on and off very quickly, between 2000 and 12000 times a second. This leaves a gap between the photons arriving at a chlorophyll molecule, allowing enough time for the molecule to be ready to receive its next packet of energy. The only light source which can switch on and off as rapidly as this are LEDs (light emitting diodes). These have the advantage of being very long lasting and using very small amounts of electrical energy. LEDs emit red, blue, green or yellow light, depending on the material used when they are made.

What colour of the spectrum will produce most photosynthesis? - and could plants survive on Mars where the light was mainly at the red end of the spectrum?

c Type of plant

The plants in the Life-sustaining Unit need to be both nutritious, providing the right nutrients to keep the crew healthy, and efficient at photosynthesis so that the maximum food production occurs. One square metre of vegetation supplies between 30 - 31 litres of oxygen per day. Scientists need to know the best growing conditions in which plants can thrive on the long journey to Mars, to ensure that this rate of oxygen production is maintained or improved.

Which plants will produce most food and oxygen given the same amount of light and heat?

The optimum temperature and carbon dioxide levels also need to be studied for the maximum growth of the plants to be obtained.

What are the optimum CO_2 and temperature levels for plant growth?

It is likely that only a limited range of plants can be grown on board, and this could cause problems for the crew. The prospect of having only three or four different vegetables to eat as your entire diet for more than two years would be very unappealing. This is why food scientists at Rutgers University, New Jersey, USA, are developing a machine that can produce food products with a range of textures, colours and flavours. This should help to prevent the diet from being too monotonous.

Since only a small range of plants can be grown, it is important to strike a balance between efficient photosynthesisers, and ones which produce useful amounts of protein. What range of plants do you think would be needed?

Conclusion

The problem of providing a self sustaining environment for a crew of up to eight astronauts on a mission to Mars and back are formidable. The alternative is to send up two year's (and more) supplies of concentrated food and bottled oxygen with the space craft. The cost of doing this would be enormous. It is extremely important that a study is carried out into the most effective way of cultivating the plants that will be needed on the flight. A self sustaining ecosystem will make it possible for human beings to visit the only other planet in our Solar System we could land on safely - Mars.