Supervisor's report and declaration

The supervisor must complete this report, sign the declaration and then give the final version of the extended essay, with this cover attached, to the Diploma Programme coordinator.

Name of supervisor (CAPITAL letters) _____ _____

Please comment, as appropriate, on the candidate's performance, the context in which the candidate undertook the research for the extended essay, any difficulties encountered and how these were overcome (see page 13 of the extended essay guide). The concluding interview (viva voce) may provide useful information. These comments can help the examiner award a level for criterion K (holistic judgment). Do not comment on any adverse personal circumstances that may have affected the candidate. If the amount of time spent with the candidate was zero, you must explain this, in particular how it was then possible to authenticate the essay as the candidate's own work. You may attach an additional sheet if there is insufficient space here.

It seems appropriate in the International Year of Soils that a student should attempt to devise their own study of extra-terrestrial soils. As a keen hobby astronomer the student has linked an interest from outside school to one of his academic higher level subjects, using age appropriate techniques and school equipment to generate some interesting data. In extending class syllabus and lab work this way, the student was hugely challenged by the difficulties of controlling variables to effect repetition of trials. His subsequent wealth of data showed some unexpected results. The difficulty of deciphering complex published material from academic studies at a tertiary level was also hugely challenging, in trying to make sense of the data found in this study.

This declaration must be signed by the supervisor; otherwise a grade may not be issued.

I have read the final version of the extended essay that will be submitted to the examiner.

To the best of my knowledge, the extended essay is the authentic work of the candidate.

I spent [3] hours with the candidate discussing the progress of the extended essay.

Supervisor's signature Date: 20/1/15

Extended essay

One small step in the search for extraterrestrial life

Investigating the affect of varying sugar type and concentration on respiration in Clay soil

Word Count: 3927

Contents

Abstract

This extended essay investigates which sugar out of glucose, fructose and sucrose is most effective in increasing the rate of respiration in a clay soil sample and at which concentration, 12, 8 or 4 grams per litre. The topic was chosen as it helps in the search for extra terrestrial life, in that it could allow for the accelerated growth of extra-terrestrial life, assuming they are in the form of micro-organisms, and easier study. It led to the research question: "How can respiration help in the search for extraterrestrial life?"

The experiment were conducted in a school laboratory, with the blinds closed and each sugar was tested separately to begin with varying the concentration from 12, 8 and 4 grams per litre while leaving one soil sample as a control, only adding water. Concentrations were made by mixing 0.12, 0.08 and 0.04 grams with 10 ml of distilled water. The results were recorded as carbon dioxide production (PPM) on the computer software logger pro using carbon dioxide probes. Logger pro produced a graph which was analysed as well as calculation of the rate of carbon dioxide production (referred to as the rate of respiration) to help with further analysis.

The results attained corresponded with the initial hypothesis as there was a increase in carbon dioxide production as the concentration of glucose was increased, shown by the increase in rate in trial one from 4g/l to 12g/l as 406.9233 to 953.9046 PPM per hour. This raised the question of whether other sugars may be more effective than glucose at increasing the rate of respiration, which led to further experimentation of sucrose and fructose at the same concentrations. These results showed glucose to be most effective at 12 g/l and sucrose and 4 g/l which means these would be the two most effective sugars, depending on the length of the trip, to be taken to accelerate the growth of extra terrestrial life.

Word Count: 320

Introduction

Since the beginning of civilization, man has looked to the heavens and asked "are we alone in the universe?" Early research was limited to optical observations and the search for "little green men" but once space exploration became a reality the search intensified on a more scientific basis, so far however with little success. The modern search for life is focused on the building blocks of life in the form of micro organisms and fossil records. Soil and rock samples are very difficult to study not only because they are so far from Earth but also because they would be of limited size and, most likely, lack the conditions and nutrients for growth. However, if it were possible to promote growth of any organisms discovered by providing additional nutrients, they would become far easier to study. Micro-organisms discovered on far off planets wouldn't survive the journey back to Earth and samples could even be contaminated by the very machines collecting them. The answer, if it were possible, is to promote growth within the organism while keeping it in its natural conditions. Analysis would become far more accurate and much easier. Robots could be sent to remote planets, carrying nutrients required to promote growth, performing analysis and reporting data, in the form of gas analyses, back to Earth bound scientists. Current NASA Mars exploration is conducted in a similar manner using the Curiosity probe. Mass spectrometers are employed to analyse gases produced by reactions in soil and rock samples. This technique has to be treated with caution as material from Earth, no matter how rigorously screened, is involved and could lead to imperfect results. Following this process "outer planet farms" could be established where any newly discovered micro-organisms are grown for analysis.

Let us start by considering which processes within organisms are responsible for growth, i.e cell division. Although many processes are involved I will be focusing on respiration as it is an important pathway for production of energy and can be easily studied and measured using simple laboratory methods.

This leads to my research question: How can respiration help in the search for extraterrestrial life?

Cellular Respiration is defined as :" A series of metabolic processes that take place within a cell in which biochemical energy is harvested from organic substance (e.g. glucose) and stored as energy carriers (ATP) for use in energy-requiring activities of the cell." (Biologyonline)
It occurs within all living organisms, and can be written out in simple terms as:

$$C_6H_{12}O_6 \text{ (sugar)} + O_2 \rightarrow CO_2 + H_2O + \text{Energy}.$$

Increase respiration and the organism will produce more energy in the form of ATP (Adenosine triphosphate) and potentially allow for increased cell division as there is more available energy for use by the cell. For the purpose of my experimentation I must find an organism which uses anaerobic or aerobic respiration.

In order to investigate respiration an organism with some relevance to other planets is needed. I chose soil as it contains various micro-organism such as bacteria, protozoa and Fungi, which I am assuming are most likely to be found on other worlds. The terrestrial soil I chose did not contain any arthropods or nematodes as these would most likely not be present in extra-terrestrial samples.

Therefore I need to focus on the respiration of Bacteria, protozoa and Fungi. Bacteria and fungi can respire both anaerobically and aerobically while Protozoa respire mostly aerobically.

Both respiration pathways start with glycolysis (figure 7). Gylcolsis occurs in 4 steps:

1. Phophorylation: Where a hexose sugar (e.g. glucose) becomes phosphorylated by two ATP molecules and turned into Hexose biphosphate.

2. Lysis: Hexose Biphosphate splits into two triose phosphates (3 carbon sugars)
3. Oxidation: Triose phosphates are oxidised, losing hydrogen and NAD is reduced into $NADH+H^+$
4. ATP formation: Four ATP molecules are released as the triose phosphates are converted into pyruvate.

Products: 2 pyruvate, 2 ($NADH+ H^+$) and 2 ATP (per glucose molecule)

(source Bio ninja)

Anaerobic respiration in bacteria and Fungi, also known as fermentation, occurs in the cytoplasm where pyruvate from gylocysis is converted into ethanol and carbon dioxide with the bio product of NAD^+. The NAD^+ is used in glycolysis while the Ethanol is excreted as the cell cannot use its energy.

Aerobic respiration in protozoa takes place in the mitochondria and s initiated by pyruvate, it can be split into three steps:

1. Link reaction:
    - Pyruvate is transported to the mitochondrial matrix.
    - In a reaction where NAD^+ is oxidised to produce $NADH+H^+$ and the pyruvate loses a carbon in the form of CO_2.
    - The other two remaining carbons are formed with Coenyzme A to form acetyl CoA
2. The Krebs cycle:
    - In the mitochondrial matrix acetyl CoA combines with a 4 carbon compound to create a 6 carbon compound.
    - The 6 carbon compound is broken down into the original 4 carbon compound by a series of reactions, which result in the formation of 2 CO_2 molecules, 1 ATP , 3 ($NADH+ H^+$) and 1 $FADH_2$.
3. The electron transport chain: