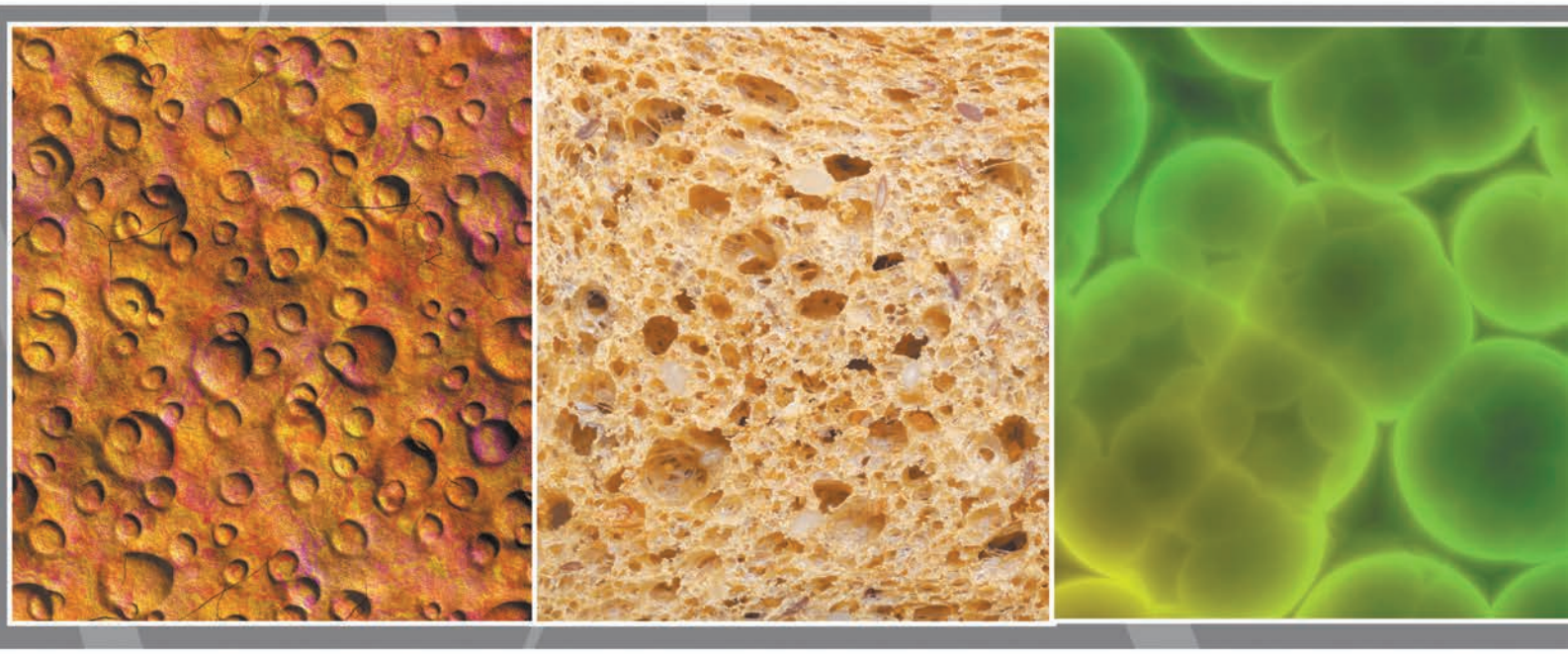
Handbook of Scenario Resources for Inquiry Learning in STEM

IS-IT Learning? Online interdisciplinary scenario — inquiry tasks for active learning in large first year STEM courses



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AUSTRALIAN LEARNING & TEACHING COUNCIL
Promoting excellence in higher education

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Introduction

This booklet contains a compilation of inquiry-based tasks set in contemporary contexts that have been developed as part of a project funded by the Australian Learning and Teaching Council (ALTC). This project, *IS-IT Learning? Online Interdisciplinary Scenario-Inquiry Tasks for active learning in large, first year STEM courses* was undertaken to develop methods for addressing diversity in large science, technology, engineering and mathematics (STEM) classes, and at the same time encouraging students to identify links between science, their program of study, and issues of current and future concern. These tasks know as IS-ITs (interdisciplinary scenario inquiry tasks) have been designed to create interdependency between students working collaboratively in groups of four.

This resource has been collated to inspire teachers across tertiary and secondary sectors in designing student-centred activities. The tasks can be utilised in a number of ways, including, but not limited to: the original complete format, contexts for problem solving exercises or individual research tasks.

Why encourage students to undertake an IS-IT?

At universities and other tertiary institutions, the aim is to give students the best possible preparation for the future. This is achieved by giving them opportunities to gain graduate attributes. These are not skills that students can acquire by simply sitting in lectures or doing experiments – they also need to work together (collaborate) with their peers to solve problems and achieve common goals.

In many professions (engineering, medicine, science), students will be required to work as part of teams where each individual completes a task that must be integrated into a larger solution by the team. They will also be required to critically review the work of other people/teams as part of these professions. IS-ITs, and the workflow associated with them, are designed to give students a chance to develop some of these skills.

How do you implement an IS-IT?

The basic principle of an IS-IT is that students can select their scenario and form their own groups. Each IS-IT comprises a context, four individual quests (IQs) and a metaquestion. The task design involves each group member nominating for one of the four IQs and then researching the related information. Once they have completed this phase of the task, the group works collaboratively to develop a response to the metaquestion.

More details on the project can be found in the final report available at http://www.altc.edu.au/project-online-interdisciplinary-scenario-inquiry-tasks-uq-2009.

Available IS-ITs and relevant discipline areas

The table below provides a handy reference to identify IS-ITs and their relevant discipline areas.

		STEM Discipline					
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Images have been obtained from iStockphoto® unless otherwise stated.

Alternative Energy

Scenario Context Synopsis:

The world's thirst for energy increases unabated, with the drivers being the industrialization of the third world (e.g. China and India), and increased consumption by first-world economies[1]. Up to now, our energy needs have been met using fossil fuels, such as oil, coal and natural gas. This situation will have to change in the future however, as global warming and peak oil both loom large. Governments, businesses and researchers are thus turning their attention to the next generation of power sources, including renewable systems (solar, biofuels, wind, geothermal and tidal), hydrogen, and nuclear energy (both fission and fusion). Already, some of these alternatives, e.g. wind, are being rolled out around the world. Still others are experiencing a rebirth in their fortunes (e.g. nuclear), with new developments in technology.

IS-IT Question

To what extent will future fuels be sustainable and have a minimal impact on the environment?

To answer this question you must consider the leading technologies that are either currently available, or which are in development, as well as their impacts during their lifecycles. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

[1] http://www.eia.doe.gov/oiaf/ieo/world.html; accessed 23rd Sept 2009

Individual Quests (IQs)

IQ1: Going Green: Biofuels

Biofuels have been touted by some as the next great hope for fueling the global economy without destroying the planet. Advocates argue that, because growing plants absorb carbon dioxide from the atmosphere, which, upon burning, is simply returned again, this method has a very low impact on atmospheric carbon dioxide concentrations. The technology required to utilize this fuel is also well understood and relatively easy and reasonably economical to implement, especially when compared to other sources of renewable energy. However, there are also some who question the validity of using what limited arable land we have for fuel instead of food. They argue that redirecting crops from food to fuel leads to higher food prices and an increased burden on the poor and underprivileged.

You might like to consider:

- *What chemistry and engineering is involved in the production and use of biofuels?*
- *How is production of biofuels sustainable using current practices and methods?*
- *What innovations are looming that may see biofuel use increase?*
- *What is the cost per unit (e.g. kW or fuel efficiency) of biofuels?*

IQ2: A Full Circle: Nuclear Power

If there is one topic that stirs passionate debate in Australia, it would have to be nuc lear energy. Although Australia is a s ignificant miner of Uranium ore, and happy to export it to other countries, we have so far avoided using it for power generation ourselves. Proponents argue that it is the only alternative fuel that can meet our baseload power needs at a reasonable cost, whilst at the same time avoiding greenhouse gas emissions. On the other hand, critics point to the significant issue of the radioactive waste arising from its use, as well as the potential for devastating consequences should there be an accident, such as what happened at Chernobyl in the former Soviet Union

You might like to consider:

- *What chemistry and engineering is involved in the production and use of nuclear energy, including waste disposal?*
- *In what ways might the nuclear cycle (i.e. mining through to waste) be different in the future?*
- *What is the lifecycle of nuclear power and can it be considered sustainable?*
- *How much energy is currently produced by nuclear power, and what is its cost per unit (e.g. kW)?*

IQ3: A Fuel Odyssey: Hydrogen

The promise of a hy drogen-fuelled economy has been with us for nearly half a century. Indeed, the technology to utilise hydrogen was developed and implemented during the race to the moon in the sixties. Despite the extensive research and development that has been undertaken into it though, we still do n ot have ready access to cars powered by hydrogen. Why not?

You might like to consider:

- *What chemistry and engineering is involved in the production, storage and use of hydrogen?*
- *How sustainable is hydrogen as a power source in our future?*
- *What technological innovations are on the horizon for hydrogen powered vehicles?*
- *What is the cost per unit (e.g. kW or fuel efficiency) of hydrogen?*

IQ4: Exploiting Earth's Energy Sources

Every hour, the sun bathes the Earth with enough energy (4.3×10^{20} J) to power humanity's needs for an entire year (4.1×10^{20} J). Harnessing that energy is what plants have been doing since the dawn of time, and research into solar energy has produced great strides. But there are other sources of energy as well, such as wind, geothermal and tidal. These are also attracting more and more attention, not just from scientists.

You might like to consider:

- *What chemistry and engineering is involved in the production and use of these alternative energy sources?*
- *How do these options compare, e.g. efficiency of power conversion/cost per kW?*
- *What resources does each system consume in production, as well as during its lifetime?*
- *What environmental impacts do these systems have, and are they sustainable?*

Detect Me Not!

Investigating techniques in Explosives Detection

Scenario Context Synopsis:

Terrorism prevention at airports now requires you to carry less than 100mL of liquids, remove your shoes, belts and jackets, X-ray detection for metals, and random swabs and pa t downs for explosives. In the interest of personal privacy, and more importantly saving money new, fast and potentially automated, detection methods are being investigated.
In every airport in every country, passengers are screened, swabbed and searched on a massive molecular witch hunt in the interests of National, and International Security. Concealed explosives can be detected at limits as low as a few ppb[1] (part per billion). The detectors are searching for mere molecules of the materials.

There are two common methods used for the detection of explosives at airports: Sniffer dogs and mass spectrometry. Trained dogs have incredibly sensitive noses and can detect explosives in extremely low concentrations and have been widely used since WWII. The Mass Spectrometry used, Desorption Electrospray Ionisation Mass Spectrometry (DESI-MS) is portable and extremely fast, requiring a total of six seconds to analyse the sample.[2] However, our safety isn't only jeopardised at airports and prevention of explosions at train and bus stations as well as other crowded places are also required to prevent bombings and protect civilians. People also require protection from landmines, which are notoriously difficult to detect and remove due t o being buried underground, often in hostile environments. Will new developments in explosive detectors lead to a safer world? Or just to the development of new explosives?

1. “Field detection and monitoring of explosives” Jehuda Yinon, TrAC Trends in Analytical Chemistry, Volume 21, Issue 4, April 2002, Pages 292-301
2. *“Airport explosive detection made easy”*; K. Sanderson; Chemistry World; April **2005**

IS-IT Question

To what extent can new technology prevent the concealment of explosives?

To answer this question you will need to be aware of the current security methods in place and emerging technology for the detection of explosions. You should consider the economic and ethical implications of increased security, assess the importance of current restrictions such as only being allowed 100 mL of liquids and understand the different types of explosive material and r eaction kinetics. You should begin by discussing this question in your group and then each group member must opt to complete one of the

individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Risky Business

To know the past is to know the future. One of the important factors in determining what risks are out there and what types of explosives need to be detected is to know the history behind past events. Your job is to describe the different types of explosives that have been used in military, civil and terrorist activities, and which could have been detected.

You might like to consider:

- *Are the kinetics of an explosion the same for all types of explosives?*
- *How does the electronic configuration relate to the behaviour of explosive materials?*
- *Why can people only take 100 mL of liquids onto aeroplanes?*

IQ2: Prevention by detection

This task asks you to look at the technology available for the detection of explosives in real time. Different detection techniques are suitable for different types of explosive materials. Detection methods are developed by identifying a feature of the target compounds that is easily detected, for instance, the mass of the compound is determined by Mass Spectrometry and this can be used to identify compounds of interest. However, using one point of identification is susceptible to mistakes. These are classified into two parts: 'false positives' such as perfumes, coffee and glycerin (found in makeup and sunscreens) which can give the same response as the target explosive compounds; and 'false negatives' in which an explosive compound is failed to be detected.

You might like to consider:

- *What methods are currently used by airport security? How do they work?*
- *Why do instruments give false negatives and how can they be avoided?*

Article of interest: R.M.Burks and D.S. Hage, Current trends in the detection of peroxide-based explosives, Analytical and Bioanalytical Chemistry, Vol 395, no 2, 2009

IQ3: Land mine detection:

Land mines pose a particular problem, with the UN Mine-Action Project stating that in 2010 $589 million will be required to remove landmines and explosives in 27 countries. Can this enormous undertaking be improved using new detection technology?

You might like to consider:

- *How does the underground location of landmines complicate detection?*
- *What effect does new technology have on the cost of removing landmines?*
- *Can chemical mines be neutralised without having to be removed?*

IQ4: Post-blast analysis

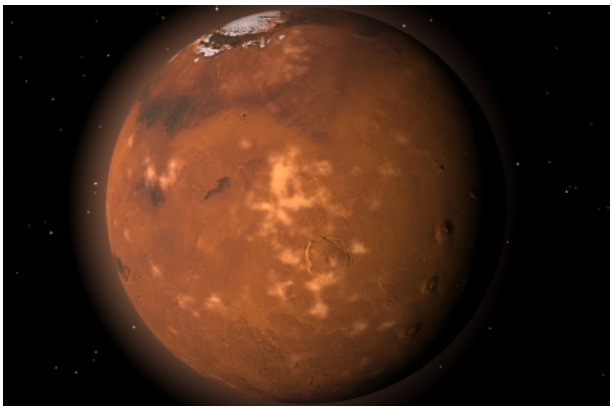
In the event of an explosion forensic teams are required to analysis the site, detect the explosives used and gather information to identify the perpetrators.

You might like to consider:

- *Compare and contrast the priorities and the instrumental methods available for a post-blast analysis team with pre-blast detection.*

Exploration of Distant Worlds: Mars

Scenario Context Synopsis:



On December 14, 1972, astronauts Eugene Cernan and Harrison Schmitt were completing their Apollo 17 mission to the surface of the moon. As Cernan approached the lunar module to prepare for his return journey to Earth, he must have looked over his shoulder and peered through the Perspex visor of his spacesuit for a final view of the lunar landscape stretching to the horizon. He was one of only twelve men that had stood on the moon. He could not have imagined that he would be the last person to see the lunar landscape for at least 40 years.

Since Cernan and Schmitt returned from the moon, there have been no manned missions beyond "low Earth orbit", only a few hundred kilometers above the surface of the Earth. But this could soon change. The US space agency now plans to establish a permanent colony on the moon to serve as a base for a manned mission to Mars. China has also announced plans to send astronauts to the moon. A golden age of manned space exploration beckons.

IS-IT Question

If there is life on Mars, how do we identify it and send a person visit it?

To answer this question you must consider the methods available for identifying life, as well as the technologies for propelling humans off of Earth and protecting them from the dangers of space. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Identifying Life

One of the mission statements from NASA is “To find life beyond”. But how do we know if or when we have found life? What is life exactly? For a long time, most tests sought to identify life through the chemistry we know, based on carbon compounds and water. Indeed, these chemicals were what the Viking missions to Mars tested for back in 1976. In particular, one experiment, the Labelled Release (LR) experiment, did appear to provide a positive finding for life on Mars, although it is still a matter of great debate. Opinions over what life is and how to detect it have also arisen in the debate over the meteorite from Mars – ALH 84001. The quest to find life beyond Earth is expensive too, with orbiting telescopes and probes to Mars and other planets/planetoids costing billions of dollars. It is therefore important to have a firm grasp on what we are looking for.

You might like to consider:

- *How do we know if we have found life?*
- *What technologies and tests are used to measure and characterise life?*
- *To what extent is the evidence obtained by these technologies unambiguous?*
- *What set of experiments could be used to detect and confirm the existence of life on Mars, both remotely and* in situ*?*

IQ2: Escape from Planet Earth

The Saturn V rocket which propelled the Apollo missions to the moon was the largest rocket ever constructed. Loaded with fuel for blast-off, it had a mass of about 3,000 tonnes. The main (first) stage was propelled by the reaction of kerosene with liquid oxygen. Liquid oxygen is an extremely powerful oxidizing agent. Even below its boiling point of - 183^{o}C, it instantly ignites on contact with kerosene or other fuels.

Each of the five rocket engines powering the first stage of the Saturn V burned 2,800 litres ***per second*** of kerosene and liquid oxygen, and produced enough force to lift 20 fully-loaded cement trucks into the sky. Within the first 8 minutes after take-off, a Saturn V rocket discharged as much fuel energy as is released by a small atomic bomb, hurling a small, fragile spacecraft at over 40,000 km/h towards a distant world in the hostile depths of space. But what will be required for the next generation of spacecraft?

You might like to consider:

- *What types of propellants are currently available, or are being developed?*
- *What chemistry is involved in the reactions of these fuels to produce thrust?*
- *How do they compare for energy released, toxicity, and ease of storage and handling?*
- *What are the chemical requirements of the materials used to build the rockets, capsules, and descent vehicles?*

IQ3: It is very cold in space

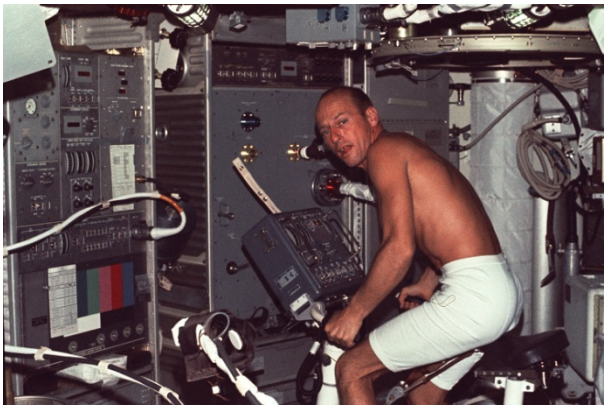
...and at times, very hot, too! The hazards of space travel have been well documented. Firstly, there is no atmosphere. That is why, in space, no-one can hear you scream. Disconcerting as that may be, a lack of atmosphere is not the only problem astronauts will encounter as they cross the vast distance between the Earth and other planets. Cosmic particles will stream through their bodies, leading to visions of flashes arising from the impact of these particles with the cells in the astronauts' eyes, and highlighting the damage being done to their DNA and the associated cancerous growths that may develop. Extremes in temperature will also test the design of their space ships. For example, on a trip to Mars the occupants must be protected from temperatures ranging from -101°C to 121°C.

On a more mundane level, the spacecraft NASA intends building will not be large enough to carry sufficient air and water to sustain the astronauts to, say, Mars and back (a journey that may take up to a year each way), without recycling. Consequently, there is a very real danger of asphyxia, if the air the astronauts breathe is not scrubbed of the excess CO_2. Toxins and waste molecules also need to be removed from the water to enable it to be re-used. Even the water vapour in the air of the capsule needs to be controlled, in order to avoid the growth of mould and other microorganisms that could make the crew sick.

You might like to consider:

- *What chemistry and engineering is required to protect astronauts from exposure to cosmic radiation and temperature extremes in a vacuum?*
- *What systems exist, or are soon to be developed, to effectively recycle waste water and air?*

IQ4: Dealing with Inner Space



In addition to the increased risk of cancer due to cosmic radiation, exposure to microgravity leads to significant changes in human physiology. These changes include a decrease in bone density, muscle tone, and heart function. In effect, the human body responds to the freedom from gravity by altering its structure to one requiring less maintenance. The trouble comes, of course, when the astronaut seeks to return to a planet with gravity. Landing on a planet is usually a rapid process, and the body has little time to adjust and reassemble all of the lost bone and muscle. The trick, then, is to maintain one's body during times of spaceflight, so that the negative impacts of microgravity, like fractured bones, do not manifest themselves.

You might like to consider:

- *What biochemical changes take place when humans venture into microgravity?*
- *What chemistry (e.g. therapeutics) and engineering is required to prevent deterioration in the physiology of astronauts on a trip to Mars?*
- *What steps would need to be taken to deal with human waste containing therapeutic compounds and their metabolites on a spaceship?*

*Images for this IS-IT were sourced from NASA/courtesy of nasaimages.org

Fermentation Fever

Scenario Context Synopsis:

Fermentation is some of the oldest known chemistry with records of its use dating back to 900 AD. It is widely used in society in the food, beverage, pharmaceutical and biotech industries.

Fermentation refers to a group of chemical reactions which convert complex organic molecules into simpler substances using a ferment, which can be either living or non-living. A common example of this is the conversion of sugars to alcohol.

However, industrially ethanol, and other fermentation products, are synthesised from petrochemical feedstock due to faster reaction and greater purity or products. Those in the fermentation business claim that using biosynthesis reduces our dependency on limited oil based resources. But how true is that? This task investigates the future of fermentation in industry and weighs up the advantages of using fermentation chemistry in synthesis vs. other reactions.

IS-IT Question

What is the future of fermentation in industry?

To answer this question you must consider the different industrial uses of fermentation and the products produced. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

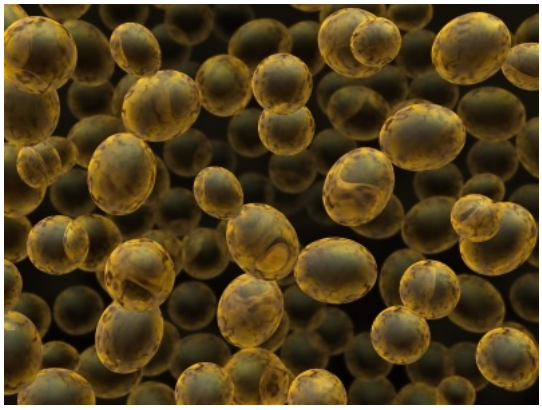
IQ1: Brewing beverages.

Fermentation is a biochemical process responsible for some of our favourite beverages, such as beers and wines. Combined with distillation, fermentation can be used to make a range of spirits and liqueurs. The wide variety of alcoholic beverages available is due to the vast range of ingredients available for fermentation.

You might like to consider:

- *What is the basis of carbon neutral beer?*
- *Despite grains and fruits containing different sugars, all these drinks contain ethanol. What's up with that?*
- *What are some of the limitations in scaling up home or micro breweries and distilleries into large scale productions?*
- *How does the type of yeast employed affect the product?*

IQ2: Super yeasts are brewing drugs!



Fermentation is utilised in the pharmaceutical and biotechnology industries to produce antibiotics, anti-fungals, pigments and bioactive proteins. The ability to take inexpensive starting materials and convert them into expensive products makes the microbes used for these purposes extremely valuable. To increase the efficiency of these reactions, yeasts have been genetically modified to live for longer, tolerate harsher conditions and react faster. Stronger and faster yeast lead to more efficient reactions and thus larger profit margins.

You might like to consider:

- *What are the current limitations of commercial yeast? For example what are the tolerances to alcohol, temperature, lifespan, and speed of the reaction?*
- *Are there any environmental/ethical concerns with breeding new strains of yeast?*
- *Is there alternative chemistry which produces the same result? Why is fermentation the most suitable method for this chemistry?*

IQ3: Chemical gain from fermenting grain?

Fermentation may be the oldest known chemistry used to produce alcohol, but it can also be used to prepare the raw materials used in the production of polymers, detergents and even cosmetics. Consequently, more attention is being payed to improving the efficiency of fermentation, as well as the range of by-products available.

You might like to consider:

- *How many different types of raw materials and products are accessible using fermentation and what are they?*
- *What chemistry is involved in producing these products using fermentation and subsequent processes?*
- *What is the energy difference between fermentation and traditional methods of production, and how much impact can genetically modified yeasts have on these energy differences?*

IQ4: Fermented Fuels

This quest looks at using fermentation to produce fuels. There are two proposed fuels that can be created this way, ethanol and hydrogen. Both Bio-Ethanol and Bio-Hydrogen have been proposed and clean green fuels for cars. Hydrogen farms utilizing hydrogen producing algae are already being designed and tested around the world

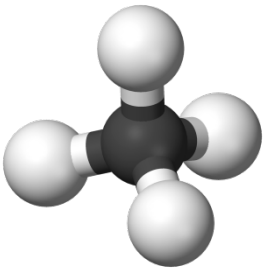
You might like to consider:

- *What are other sources that can be used as fermented fuels and what chemistry is involved in producing and using them?*
- *What is a 'green' fuel? Are fermented products 'green'?*
- *How will competition for resources between food crops and fuel crops affect the production of fermented fuel?*

Article of interest: http://www.science.org.au/nova/newscientist/111ns_002.htm

It's a gas! Methane: Friend or Foe?

Scenario Context Synopsis:



There is strong evidence that the accumulation of greenhouse gases (GHGs) is forcing changes in the climate including rising ocean temperatures and melting ice caps. Methane (right) has been linked to global warming because its molecular structure promotes the entrapment of heat within the Earth's atmosphere. Although it is about half as effective as trapping heat as carbon dioxide, the relative contribution that it makes compared to carbon dioxide is an important factor in carbon offset calculations. The media focuses on the fate of methane in the environment due to its production as a result of industrial and mining activities; however it results as a by-product of other human (anthropogenic) activities. It is less well known that some of the methane that ends up in the atmosphere is also derived from natural sources. Economic pressure exists to continue to extract natural methane which is a valuable fossil fuel and a source of energy, despite global warming and it must be remembered that the products of methane combustion carbon dioxide and water (the other two GHGs!). The control of the amount of methane in the environment is perceived by many to be easier than the control of carbon dioxide emissions but where do we as society begin?

IS-IT Question
To what extent have human activities contributed to the contribution of methane to global warming?

To answer this question you must consider the balance between natural processes and human activities which are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1:

Methane clathrates represent a significant source of natural methane where methane molecules are trapped in an ice cage and are slowly released. They represent a double edged sword in the methane environmental audit as both a c ontributor to natural methane emissions and as a reservoir of fuel for anthropogenic use.

You might like to consider:

- *Are methane clathrates the only viable natural source of methane that may be released naturally?*
- *Compare the relative scale of all natural environmental reservoirs of methane (eg swamps & rocks).*
- *How will global temperature changes impact on the release of methane in its natural forms?*
- *Is there an environmental drivers for extraction and use of methane as a fossil fuel rather than let it release naturally into the environment from natural sources?*
- *Does the extraction process have any impact that must be addressed by carbon offsets?*

IQ2:

Living organisms such as cows & sheep are perceived as major contributors to global methane emissions. In fact, this threat has stimulated significant research effort towards developing fodder which remediates the production of animal-derived methane. Government agencies are placing pressure on farmers to face a choice of paying a tax to offset carbon emissions or opting to purchase expensive cattle feed to reduce emissions.

You might like to consider:

- *What is the scale of the contribution of methane to the environment by animals that are farmed by humans?*
- *How much does this source of methane contribute to global warming?*
- *Will consumers backlash against the proposed remediation (is there evidence of potential impact on the quality of dairy products)?*
- *Compare the relative scale of all living organisms that make a significant contribution to methane emissions? Which are manageable by human activity?*

IQ3:

Carbon dioxide, methane and water are all considered to be greenhouse gases and contributors to the process of global warming. The ocean effectively acts as a large sink for carbon dioxide gas so as the atmospheric concentration of CO_2 increases, more gas 'dissolves' in the oceans.

You might like to consider:

- *Are there any parallel natural systems or processes which occur to reduce the concentration of methane in the atmosphere?*
- *How much does the natural level of methane in the atmosphere fluctuate over extended time frames (millions of years)?*
- *What, if any, are the seasonal fluctuations in relative gas concentrations in the atmosphere?*
- *What is the minimum amount of methane required in the environment to sustain 'good health' of our climate or natural cycles?*

IQ4:

International agencies are putting pressure on the governments of countries to remediate or offset GHG emissions. The Kyoto protocol was a significant step towards achieving this. Methane is an important fossil fuel which offers an alterative to petrochemical reservoirs and so has high economic importance. It is also the by-product of many industrial processes.

You might like to consider:

- *What evidence is there that the Kyoto protocol will have an impact on the worldwide consumption of methane as a fuel due to its contribution to carbon dioxide emissions?*
- *Do we as individuals have the ability to impact on the contribution of methane to global warming in comparison to industrial emissions?*
- *Is there potential for CO_2 to be a by-product of future alternative energy sources?*
- *Has there been any progress in research to design a remediating technology or process which removes CH_4 but the products do no increase the amount of GHGs?*

The Pharmaceutical Journey

Scenario Context Synopsis:

Medicine has made tremendous ground in the last 60 years, starting with the widespread introduction of penicillin towards the end of World War II, through to heart transplant surgery, made possible by anti-rejection drugs such as Cyclosporin A and Tacrolymus. More recently, modern breakthroughs in targeted therapeutic development, particularly for cancer treatment, have led to a significant increase in the survival rate amongst diagnosed cancer sufferers. But just how are new medicines to be discovered or created in the 21st century?

IS-IT Question

To what extent do naturally derived drugs represent a 'shortcut' in the evolution of a pharmaceutical to the market?

To answer this question you must consider how drugs are discovered, made and tested, which are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Discovery and Design

It is estimated that nearly 70% of all drugs brought to market in the last 25 years were derived from plants and animals. This is in spite of amazing developments in scientists' ability to identify target proteins and receptors in the body, and t heir increasing skills in synthesising new molecules. It seems that it is still hard to beat Mother Nature when it comes to producing biologically active compounds suitable as drugs. In recognition of this fact, pharmaceutical companies have, after spending millions of dollars and years on c ombinatorial chemistry and o ther novel synthetic techniques, refocussed their discovery programmes on t he rainforests of the world

You might like to consider:

- *How are biologically active compounds discovered, and what chemistry is involved in doing so?*
- *Are there any tools that can or will assist with the discovery process, and what are they?*
- *What properties do scientists look for in potential drug molecules?*

IQ2: Rational Drug Design

Combinatorial chemistry was touted some years ago as being a game-changing tool that would reinvigorate medicinal chemistry. Suddenly, chemists would have access to thousands of new molecules to test against disease targets in the body. The reality, although impressive, has been a little underwhelming, with few drugs arising from this approach. Medicinal chemists have not been daunted however, and new methods, such as rational drug design and *in silico* techniques are beginning to bear fruit. Or are they?

You might like to consider:

- *What is meant by combinatorial chemistry and rational drug design, how do these approaches work, and are they delivering the promised-for benefits to medicine?*
- *How does the in silico method of drug design compare to the above methods?*
- *Just what do a pharmaceutical company, doctors and patients want in a drug anyway?*

IQ3: Manufacture

Once a drug has been selected to progress into development, scale-up of the synthesis must commence. This involves chemistry, chemical engineering, and p ossibly also biology (in the case that an expression system is chosen). In addition, the quality of the final product must be determined and controlled for, to ensure that it is suitable for human use.

You might like to consider:

- *How does the route of administration influence the composition and method of manufacture of a particular medicine?*
- *What are the chemical and engineering issues with scaling up manufacture?*
- *What chemical techniques are used to determine the quality (i.e. purity) of a drug?*
- *How is the shelf-life of a drug determined, and how can it be modified?*

IQ4: Preclinical Testing

Traditional toxicology studies require that new drugs be tested in animals prior to administering them to people. Ideally, the species chosen should display similarities to humans, e.g. mammalian with similar response to certain drugs. Historically, mice and rats have tended to be used as the first point of call, due to their frequent reproduction (hence ready availability) and their genetic purity. Prior to a Phase I clinical trial, researchers are also required to include a second, non-rodent, species in their testing. In spite of their purported usefulness in ascertaining human drug toxicity however, a growing body of evidence is emerging that highlights that a mouse is not a human, meaning that the results obtained in animals may not reflect the reality of human reactions to a given drug. Even a chimpanzee, the closest relative to humans in terms of its genetic code, can display responses to a drug that are quite different to those shown by a person.

You might like to consider:

- *What are the chemical and biological reasons for testing new drug candidates in animals?*
- *What chemistry is involved in determining the pharmacokinetics (PK) and pharmacodynamics (PD) of a drug, including sample handling?*
- *What performance characteristics (e.g. plasma half-life, CYP450 activity) are important for drug makers and why?*

The Limits of Global Food Production

Scenario Context Synopsis:

The world's population is currently estimated at 6.7 billion. That number is expected to grow to nearly 9.1 billion by 2050, with most of the increase occurring in the developing world. This increase is equivalent to the entire world population in 1950. Notwithstanding the fact that currently 800 million people already suffer hunger and malnutrition, feeding our growing population is an immense challenge, requiring farmers to raise yields by an additional 70% by 2050 to cope. Improvements in agricultural practice, agricultural technology and their adoption by developing nations' farmers are all urgently needed.

One fundamental problem that faces farmers the world over is that all plants need to absorb sufficient carbon dioxide to produce carbohydrates, while minimizing water loss through evaporation (transpiration). While humans and animals breathe oxygen, comprising 21% of the air, plants breathe carbon dioxide, comprising just 0.038% of the air. Although present at only one-five hundredth the concentration of oxygen, carbon dioxide is the main "raw material" for plants to build tissues through photosynthesis. Since plant cell membranes cannot discriminate between carbon dioxide and water molecules, huge amounts of water vapour are lost during plant growth. Agriculture consumes most of the fresh water in Australia and around the world, and water availability is the major factor limiting production of food and agricultural products.

Articles:
http://news.bbc.co.uk/2/hi/8303434.stm

IS-IT Question

How can we feed the world's population in 2050 using our finite resources?

To answer this question you must consider current and future agricultural and food technologies and their interactions. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Water, Water, Everywhere!

Food crops are intensive users of water. It is estimated that up to 70% of the freshwater supplies drawn for human consumption are used to irrigate food crops. The demands and limitations on the supply of freshwater, exacerbated by climate change and increased population, are a cause for concern. Investigate the sourcing and use of freshwater for crop production.

You might like to consider:

- *What chemistry is involved in identifying, accessing and possibly treating water supplies to yield freshwater for crop and livestock use?*
- *The sustainable use of freshwater for food production.*
- *Investigate the uses of freshwater. How do freshwater supplies vary through a year and what issues do variability and distance from supplies to crops create for farmers?*
- *Is there enough freshwater to supply the world's needs now and into the future (e.g. by the year 2050)?*

Article: http://www.lenntech.com/water-food-agriculture.htm

IQ2: Sources and Use of Fertilisers

In many places, the quality of the soil being farmed is terribly low, having been drained of its nutrients over time. Fertilisers are then used to replenish these nutrients to stimulate rapid, healthy crop growth. In accomplishing this task, the world's agricultural industry has become largely dependent on nitrogenous fertilisers made from fossil fuels, rather than by using legume plants and recycling of nutrients in traditional agricultural practices. The sustainability of using fertilisers manufactured this way is therefore questionable, and new sources and methods are being investigated. Research the current status of fertilizer use around the world and what the future holds.

You might like to consider:

- *The chemistry involved in soil degradation, and fertiliser production and use (including run-off).*
- *The sustainability of fertiliser use.*
- *What are the impacts of fertiliser use on arable and semi-arable land (good and bad)?*
- *What future options are likely to become available prior to 2050?*

Articles: http://www.scientificamerican.com/article.cfm?id=nitrogen-fertilizer-anniversary

http://www.shanghaidaily.com/sp/article/2009/200902/20090218/article_391416.htm

IQ3: Impacts of Greenhouse Gas Emissions

Agricultural scientists have postulated that increasing concentrations of carbon dioxide in the atmosphere will lead to greater "water efficiency" (kilograms of dry plant mass per kilolitre of water) and crop productivity, but this may be offset by other impacts of rising carbon dioxide levels on global climate. Investigate and report on the likely overall impact of increasing carbon dioxide levels on the production of food crops and water consumption.

You might like to consider:

- *The chemistry involved in the utilisation of carbon dioxide and water by plants.*
- *What are the implications of higher CO_2 levels and temperatures for crop growth in 2050?*
- *What are the likely effects of increased levels of greenhouse gases on the water supply, and distribution and availability of arable land in 2050?*

IQ4: Food Consumption

Growing food is one thing, but making sure everyone in the world has access to enough nutritious food to sustain themselves is quite another. Today, it is mainly those in the Western World who can honestly say they have enough to eat (perhaps too much!), whilst those in the developing world (which makes up over 80% of the world's population) struggle to survive. With a growing population, the world must continue to innovate around its agricultural practices, focussing in on the types of crops grown and consumed, and evaluating whether these are the best ones suited to that geographical and cultural situation.

You may like to consider:

- *The chemistry involved in crop and livestock growth, in particular, nutrient requirements (e.g. vitamins and minerals) for both?*
- *What types and quantities of food crops and livestock are grown and consumed in different geographical and climatic zones, and are these sufficient for the local population?*
- *How do climatic and soil conditions affect the types of food that can be produced in a region?*
- *What is the dietary quality of the food being produced now? By 2050? How sustainable is its production?*

In the Shadow of the Mushroom

Scenario Context Synopsis:

Far from “riding on the sheep’s back”, modern Australia is “shovelling” its way to world recognition; with information from 2005-2007 showing Australian mineral and fuel commodities as being exported in the greatest volumes. One mineral with a claim on both mining and fuel export revenues is Uranium.

With debate about coal’s reputation as a ‘dirty’ fuel and the world’s hunger for electricity it seems inevitable that uranium will again come to be seen as ‘green’ energy; although the associated and inherent bias in the reporting media it will be an eventful discourse. Can nuclear power, if considered solely in terms of carbon emissions, be a viable energy alternative? Could it be, with access to significantly less intensive mining techniques, that uranium will again be the next big thing in fuel raw material?

Australia and Canada have the greatest portion of the world’s uranium reserves and, as such, there will be a large international market for this resource in the near future with increased pressure for mining activity. So what associated industries have built up around this mineral? Neither of these countries has nuclear weapons capability and has a stipulation not to sell uranium for weapons purposes. How can nations selling uranium be secure in their markets whilst not contributing to nuclear proliferation?
As with all mining there is clean-up. Intense investigation needs to be brought to bear to make sure there is accountability for environmental protection and the legacy of contamination. Issues of clean-up do not stop at the mine door. Inevitably, there is the waste generated during energy conversion and this leads to more probing questions - how dangerous is this waste, by what means is it responsibly disposed, and who should be responsible for its disposal?

IS-IT Question

How feasible is it that Australia's Uranium resources can be extracted and distributes to other countries ethically?

To answer this question you must consider Australia’s mining and export practices and policies for uranium as well as the impacts on the community and environment from such activities. These ideas are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Mining and Refining

As mining is a profit driven industry there are many considerations strategic, logistic and economic which play a part in the success of any mine. Market share and competition with the coal industry is just one example of the pressures involved in mining. Add to this the sensitive issue of "nuclear industries" and you have a very touchy commodity. Australian has many potential sites for uranium extraction with open-cut mining the most widely adopted method. However there are other techniques such as *in-situ* mining that could be employed. Although the chemical aspect of these techniques may not differ much their engineering practices do.

You might like to consider:

- *Are there sufficient ore bodies in Australia to support both an export and domestic market?*
- *What is the chemistry involved with current methods available for uranium mining and extraction?*
- *Are there more effective ways to mine/extract uranium than those used currently?*

IQ2: Uses and Impacts

Although uranium sourced power is not, as yet, available locally, Australian uranium is exported to countries where it is used. The question is often asked could Australia support a uranium power industry. As such a vast country with the relatively small population situated mainly on the coasts and given that it seems not many people would put their hands up to have a nuclear power plant in their backyard could there really be a future for this industry in Australia?

You might like to consider:

- *What are the chemical and engineering considerations of uranium power?*
- *How suitable would nuclear power be for Australia in comparison to coal?*
- *How do the environmental impacts differ between coal and nuclear power?*

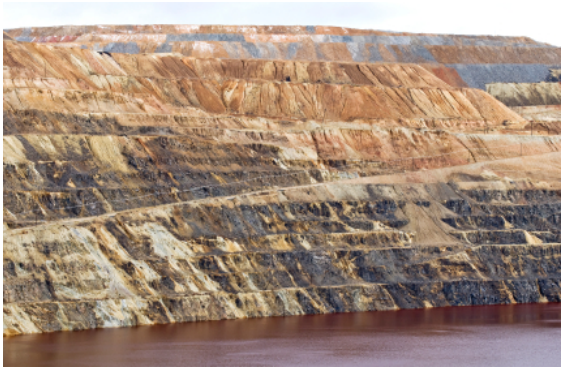
IQ3: Protect or Profit?

As a signatory to the pact for nuclear non-proliferation, Australia is stating its intention to sell its uranium resources only to states also signed up to this treaty. As a responsible nation the uranium sold should be used for its stated purpose, but how can we ensure that this is the case? If in turn this second party nation on sells Australian uranium could we tell? Is there physical or chemical means by which the Australian government could track uranium sourced from Australia and ultimately the role of uranium in the global power system?

You might like to consider:

- *Are there policies and laws in place to control to whom Australia could sell its uranium product and how they use it?*
- *Is there a chemical means to distinguish between different uranium ore bodies?*
- *What type of chemical means could be used to track the export path of uranium sourced in Australia?*

IQ4: Obligations and Responsibilities



Careful mining practices aside, there is always the danger of environmental contamination in ore extraction. This issue is particularly hot when uranium contamination is concerned. All mines should be setup to minimise the environmental impact of the process both during and after the mine has closed.

Apart from the mine rehabilitation issue there is the waste disposal issue. Waste and mine tailings are a fact of life during ore extraction and there are standard practices in managing these non-profit consequences. However, what happens to the waste uranium products generated after use? What disposal/storage options exist for this “flow-on” waste?

You might like to consider:

- *What is the effect both chemically and physically on the environment as a result of current mining practices?*
- *What should Australia’s policy be towards waste generated from uranium originally sourced here?*
- *What are the current world standards for uranium waste management?*
- *How informed about uranium waste should the general public in Australia be?*

Waste Not Want Not

Scenario Context Synopsis:

Waste has been a part of our existence since time immemorial, be it in a cave or cosmopolitan city. All aspects of our daily lives generate waste from bodily functions and food scraps to more modern waste such as paper, plastics and even cars; we always make it and wonder what to do with it.

You don't have to look very far to see the devastating cost of irresponsible waste management. Swirling slowly around in the calm waters of the North Pacific Gyre (NPG) is an anthropomorphic rubbish collection estimated at 3.5 million tons; a grand homage to our love of plastic. The anonymity of the rubbish problem seen in the NPG stems from this consequence being so far away from the rubbish sources, It can be hard to see how our daily practices are contributing. But there are rubbish issues a lot closer to home, in the fridge actually!

A study by PlanetArc estimated that in Australian households 25% of domestic food purchases ends up wasted. Is this endemic waste a function of better preserving techniques or over supply? Seeing as we are responsible for generating waste and sweeping it under the proverbial carpet can only go on so long, it is ultimately up to us to find out how to deal with this end product. A few solutions have been presented over the years with the primary option being to throw it away or store out of sight. This method may be effective for small amounts of waste or rapidly decomposable waste but populations quickly expand making this option not sufficient to cope with large volumes or non-decomposable waste. A more sophisticated method is to recycle as much waste as possible.

IS-IT Question

What measures can be developed to create sustainable options for food and packaging waste?

To answer this question you must consider factors including waste accumulation and disposal as well as issues to do with food spoilage, packaging and recycling, which are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Waste food production and prevention (The good, the bad and the ugly of packaging)

One of the joys of the modern era in Australia is the access to a wide range of fresh and packaged foods all year round. Advancement in techniques aimed at increasing the shelf life and seasonal availability of foods has helped to supply the Australian consuming public with a di zzying amount of choice all year round. Techniques involving preservation through both physical and chemical means as well as genetically modifying foods for longevity have been the main areas of advancement but are these self-same preservation techniques that extend shelf life contributing to the rise in food spoilage found in Australian households?

You might like to consider:

- *What is the chemistry involved with food packaging?*
- *What kinds of preservation techniques are available for food products, physical, chemical, genetic?*
- *What has been the shift in the kinds of foods available as a result of different preservation techniques?*

IQ2: Sustainable diet and food waste

Australia exports food produce to the world. As such, we should be living in a land of plenty and there is little doubt the average dietary intake has increased. But how much should we really be eating? And what impact is there on the supply and demand of food items as a consequence? Could over indulgence and over eating, in fact, be the cause of the food wastage issue?

You might like to consider:

- *What are the links between an Australian diet and food waste?*
- *How much food should the average Australian family be eating per week?*
- *Looking at the calorific value of foods available could this volume be converted to an appropriate shopping list?*

IQ3: Disposal options

Everyone is familiar with the weekly garbage collection routine and in Australia the vast majority of domestic waste, including food and packaging, ends up in landfill sites. This might be the end point for waste as far as the person who threw it away is concerned but this is not the end of the journey for the waste itself. H ere in the landfill site decomposition occurs with many processes taking place to break down waste products As a result these urban rubbish centres are closely regulated to handle all manner of waste items and must be equipped to deal with the resulting decomposition.

You might like to consider:

- *What types of design constraints exist for landfill disposal in Australia?*
- *What kinds of degradation products, detrimental or beneficial, can come from decomposing waste?*
- *What are the environmental implications of degradation products from landfill sites?*

IQ4: Reduce/Re-use/Recycle

Regulatory bodies in Australia have come to the waste party with campaigns with the slogans of Reduce/Re-use/Recycle. The principle of these educational movements is to decrease waste before it reaches the dump stage. Facilities are often restricted in what can be recycled and the availability of materials. There also needs to be a market for the recycled goods.

You might like to consider:

- *How is recycling conducted in Australia?*
- *What is the science/engineering behind recycling?*
- *How could this type of campaign be successful in reducing the food and packaging waste going to dumps?*

A Drop of Life

Scenario Context Synopsis:

For many years research has been carried out on the health benefits of different foods, with varying results. Dairy products made from cow's milk are commonplace in the human diet in western culture, but up to 90% of Asians and Africans are unable to consume dairy products from cows due to lactose intolerance.

Historically, milk was produced by farmers within small villages who would then provide the rest of the village with fresh milk. With urbanisation, milk needed to be transported further to reach consumers. As a result, milk may now takes days or weeks to reach consumers, during which time it must be kept free of harmful bacteria. This has resulted in milk undergoing a complex process of sterilisation prior to being bottled for consumption. There is some evidence to suggest that this process affects the quality of milk, and its digestibility.

IS-IT Question

To what extent has our meddling with milk in western society impacted on its global role of sustaining life?

To answer this question you must consider why some people are unable to consume cow's milk and the alternative options as well as the effect of processing and transport on the quality of milk. These ideas are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Milk and society

History suggests that humans began consuming ewe's milk before they started to drink cow's milk. On the central Asian plateaus, yak and mare's milk are common sources of milk, while camels are most common in Africa. The milk common to all cultures and all species, is breast milk for newborn babies. The first production of breast milk after the birth of a newborn is referred to as colostrum and contains a range of essential antibodies. These antibodies protect newborns from illness and disease until such time that they can produce their own antibodies.

You might like to consider:

- *Can the beneficial effects of colostrum be obtained through other sources?*
- *How do different cultures perceive the benefits of breast milk for newborns?*
- *How do different cultures perceive the benefits of milk for growing children, adults and the elderly? Include the underlying physiological reasons for these beliefs?*

IQ2: Origins of milk

All milk is comprised of the same basic substances, carbohydrates, protein, lipids, vitamins and minerals, but milk from different sources exhibits different combinations of these substances. More than a t hird of commercially available milk contains added minerals, vitamins or oils. For example, vitamin D is often added to milk sold in areas where people have little exposure to sunlight. To counteract lactose intolerance, *lactobacillus acidophilus* is sometimes added to milk. Reduced fat milk sometimes contains palmitate to restore vitamins lost in processing.

You might like to consider:

- *How does the chemical structure of cow's milk differ from milk produced from plants and other animals?*
- *Is there anything present in milk from other sources that make it healthier than cow's milk?*
- *How does soy milk differ from cow's milk?*
- *Are the additives in milk really beneficial or just a marketing ploy?*

IQ3: Intolerance to milk?

Milk is a source of many essential nutrients, including the carbohydrate lactose. Lactose is metabolised by the enzyme lactase. While babies have sufficient lactase to digest milk, this enzyme is not present in much of the adult population.

Recently however, it has been suggested that it is not the carbohydrate present in milk that causes the intolerance to milk, but rather the protein. Milk contains two types of protein, whey and beta-casein. It has been hypothesised that the a2 variant of B-casein is the traditional variant present in cow's milk, and that recent dairy breeding practices have led to the presence of a1 beta-casein, rather than a2, and that it is the presence of a1 beta-casein causing the symptoms associated with lactose intolerance.

You might like to consider:

- *How does lactase break down lactose?*
- *What happens when lactase is not available to break down lactose?*
- *What is the structure and function of beta-casein?*
- *How do different variants of beta casein affect the ability to digest milk?*

IQ4: When is milk no longer milk?

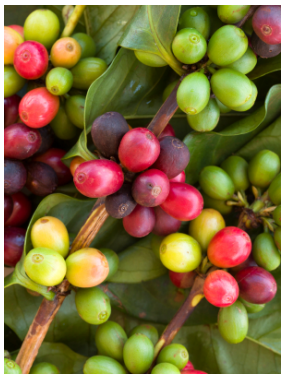
The cow's immune system ensures that milk is sterile until it is extracted, at which point it comes into contact with any bacteria present around the udder, and the open air. This is not generally an issue when the milk is consumed immediately as bacteria are not provided the opportunity to multiply to a degree where they are harmful to the human digestive tract. However, with urbanisation, milk needs to be transported further and for longer to reach the consumer.
Processing of the milk is designed to eliminate any bacteria, but is only effective when milk is kept at a temperature cold enough to inhibit bacterial development. There are believed to be multiple causes of milk going off, including chemical and biological causes.

You might like to consider:

- *What makes milk smell 'off' or appear curdled?*
- *What effects do the processes used in treating milk for consumption have on the nutrients in the milk?*
- *What is the ideal temperature for the storage of natural milk? Is this a different temperature for processed milk?*
- *How close are we to having transgenic cows that can produce human milk?*

What Are You Drinking?

Scenario Context Synopsis:



The consumption of caffeine has a long history in society, with some reports dating back to the stone ages. Caffeine was first isolated from the coffee bean in the early 1800's and is now found in many foods and drinks, including tea, coffee, soft drinks and chocolate. Today, caffeine is one of the most widely consumed and socially accepted central nervous system stimulants in western society.

Caffeine is the most commonly ingested methylxanthine, and is well known to improve alertness. Methylxanthines have also been used in the treatment of asthma and apnea and caffeine can also be found in some medications, specifically appetite suppressants and headache preparations. It can be either ingested or administered (generally subcutaneously), and quickly spreads throughout the body. Caffeine has its greatest effect on the brain, cardiovascular system and renal system. While caffeine has been ingested in combination with sugar for some time, the past decade has seen a b urst of alternative additives including taurine, guarana and alcohol introduced to the market.

IS-IT Question

To what extent does adding caffeine to a beverage improve our ability to function?

To answer this question you must consider the way caffeine affects different systems in the body, and how these are interrelated. You must also consider the effects of common alternative options, such as taurine, sugar, guarana, theobromine and alcohol to obtain a clear overview of the effects of caffeine/energy drinks on t he human body. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Do we need that first cup of the day?

Traditionally, caffeine has been ingested, but recent claims have suggested that caffeine can also be absorbed through the skin. When caffeine is ingested, it travels quickly throughout the body, altering the action of key molecules and energy metabolism in the brain. The obvious signs of caffeine's effect on the body include changes to social behaviours.

You might like to consider:

- *What are the mechanisms involved in transporting caffeine across the blood-brain barrier?*
- *How does caffeine affect metabolism in the brain?*
- *What is serotonin and what effect does caffeine have on its action in the body?*
- *Which social behaviours are affected by caffeine and what mechanism is involved in its action?*

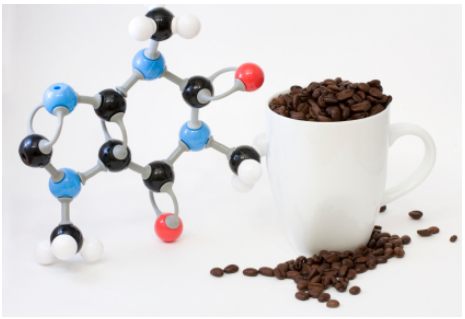
IQ2: Going the extra mile

At high concentrations, caffeine is known to increase energy and in extreme cases, can cause tachycardia or cardiac arrest. The cardiovascular system is primarily regulated by the sympathetic and parasympathetic nervous system. Within the heart, sodium, calcium and potassium channels located in the plasma membrane of the pacemaker cells of the sinoatrial node are responsible for regulating contraction of the heart. When sodium and calcium channels are opened, spontaneous depolarization and firing of the sinoatrial node occurs, leading to contraction on the heart. Alternatively, opening of the potassium channels decreases the firing rate of the sinoatrial node.

You might like to consider:

- *How are catecholamines affected by caffeine and what effect does this have on the cardiovascular system and ability to carry out exercise?*
- *How does caffeine give the illusion of having more energy?*
- *What role do renin, adenosine and angiotensin II have in regulation of the cardiovascular system and how are they affected by caffeine?*

IQ3: Keeping it real



Caffeinated beverages often contain additives such as sugar, taurine and guarana. Taurine is commonly used to supplement or replace caffeine. It is a non-essential, sulfur-containing amino acid derivative of cysteine and functions with glycine and gamma-aminobutyric acid as a neuroinhibitory transmitter. Guarana is a plant commonly found in South America. It produces a coffee bean shaped fruit, which has been found to contain large amounts of caffeine. Theobromine is a methylxanthine, very similar in structure to caffeine. It is sourced from the cacao plant and commonly found in cocoa products such as chocolate.

You might like to consider:

- *What effect does taurine have on blood pressure, heart rate and memory? How can it substitute caffeine as an energy source?*
- *How might guarana berries replace coffee beans as a source of caffeine? What effect does the berry have on the body?*
- *What effect does theobromine have on the cardiovascular system?*
- *Is there any adverse affect of combining caffeine, sugar, taurine, guarana and theobromine together?*

IQ4: Mixing it up

There is a long held belief that a cup of coffee will sober up an inebriated individual and recently, caffeine has been advertised as a sobering agent and hangover cure. This has led people to believe that by consuming caffeine along with alcohol, it will change a person's ability to perform thinking (cognitive) and manipulative (psychomotor) performance tasks.

You might like to consider:

- *How do the effects of caffeine and alcohol on calcium channels interact?*
- *How do the effects of caffeine on neurotransmitters and hormones interact with the effects of alcohol on GABAa receptors in the central nervous system?*
- *What effects do caffeine and alcohol together have on cholinergic receptors?*

A Sugar Rush!

Scenario Context Synopsis:

The human body needs oxygen, water and food to provide energy to essential organs for survival. Food provides energy to the body in the form of carbohydrates, protein, lipids, minerals and vitamins. There are four processes involved in converting food to energy: ingestion, digestion, absorption and metabolism. These are complex processes, and may not always occur efficiently, such as in the case of diabetes, obesity, and some cancers.

Nutrients for energy are stored in the liver, adipose tissue and muscle until required by cells throughout the body. During times of fasting, energy enters the bloodstream to be transported to cells in the form of glucose, fatty acids, ketone bodies and lactic acid. Some organs are able to utilise multiple sources of energy. For example, the heart and liver have a preference for fatty acids (and ketone bodies in the case of the liver), but will metabolise all energy sources to some extent.

In the case of diabetes, the body is unable to effectively digest glucose. When insulin sensitivity is decreased, there is a domino effect on the efficiency of energy production and metabolism in the body, resulting in bouts of hypo- and hyper- glycemia, where glucose levels are not regulated properly.

IS-IT Question
What is the future of lifestyle changes in western society in reducing the incidence of diabetes?

To answer this question you must consider the mechanisms of diabetes, how major nutrients are digested normally and in the case of diabetes and how energy stores are managed. These ideas are interlinked. You should begin by discussing this question in your group, collating and appraising the information and data collected in your IQs, and using this data to formulate your group answer to the IS-IT question. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

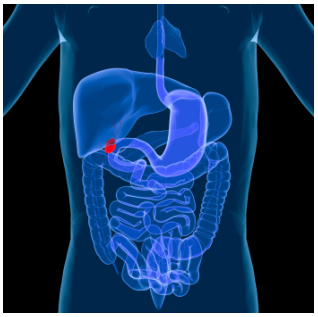
IQ1: Fuel for the body

The different arrangements of carbon, hydrogen and oxygen atoms in the form of saccharides (carbohydrates); hydrocarbon chains terminating in acids (lipids) and polymers of amino acids (proteins) represent different fuels for the body. Each has an essential role in the body, from regeneration of cells in the brain, muscle, skin, hair and nails to absorption and transport of fat soluble vitamins.

You might like to consider:

- *What are the different forms of carbohydrates? How do they differ? Are some forms healthier than others?*
- *What is the energy pathway involved in metabolism of digested carbohydrates?*
- *How do protein, lipids and carbohydrates compare as an energy source?*

IQ2: Digestive warriors



Production of energy from food is not as simple as energy in = energy out. There is a v ery complex process of digestion, absorption and metabolism involved in the production of energy from food. Each food source is digested by different enzymes in a different part of the digestive tract. For example, protein digestion begins in the stomach, where pepsin is able to break down some of the peptide bonds to create short chain polypeptides. These polypeptides are then transported to the small intestine for further digestion. Alternatively, lipid digestion begins in the duodenum through a process called emulsification, where fat droplets are broken down into individual triglyceride molecules. The molecules can then be further broken down in preparation for transport across the intestinal wall, into the blood stream.

You might like to consider:

- *Where does carbohydrate digestion occur?*
- *What are the enzymes responsible for digesting carbohydrates? How do these differ with different forms of carbohydrates?*
- *What is the end product of carbohydrate digestion? How is this transported into the bloodstream?*

IQ3: Diabetes- when the sugar rush ends

Diabetes is most commonly associated with an inability to digest glucose. However, it is not a c ontemporary disease. The first recorded incidences of diabetes can be traced to ancient Egyptian times, where cases of extreme thirst and polyuria were reported. More recently, diabetes has been divided into two categories: type I and type II. While each of these has similar symptoms, the physiology and t reatment is different. Other common symptoms of diabetes include weight loss, ketoacidosis and macro- and micro-vascular disease, which are all interlinked.

You might like to consider:

- *How is ketoacidosis implicated in diabetes? What effect does this have on dietary requirements and digestion?*
- *How do the differences between type I and type II diabetes affect digestion of different nutrients? How does this affect prescribed dietary changes?*
- *How are common beliefs about diet involved in causing diabetes?*

IQ4: Diet Danger

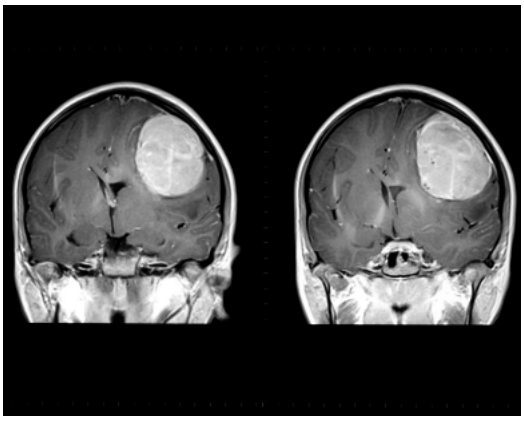
The first thing someone hears when they ask how to lose or gain weight is “just eat less/ more and exercise more/ less”. When nutrients present in the bloodstream are not required for energy, they are stored until such time as they are required in the form of adipose tissue. This process involves a num ber of hormones, including leptin, insulin, adrenaline, cortisol, ghrelin and diponectin. While the majority of the population has sufficient (and even excessive) stores of adipose tissue, some people do not possess any adipose tissue, causing energy to be sourced from other organs in the body.

You might like to consider:

- *What is the role of insulin in the production of adipose tissue?*
- *In the absence of adipose tissue, what organs are able to provide energy for the body? How does this impact on the structure and function of these organs?*
- *How does malnutrition affect the production of antibodies? What effect does this have on general immunity to disease?*
- *Is weight loss and gain really as simple as changing diet and exercising habits?*

Bottom(s)-up! A New Approach to Cancer Treatment

Scenario Context Synopsis:



The number of cancer patients has increased significantly in recent years and cancer is actually the leading cause of premature death in Australia. It is true that the survival rate for many common cancers has increased by more than 30 per cent in the past two decades, but a reliable and all-purpose cure has yet to be discovered and substantial research goes into its eradication everyday.

In simple terms, cancer is the growth of abnormal cells that divide uncontrollably within the body. The arrest of this division has proven to be the most difficult battle of all and a universally beneficial method has still not seen the light of day. The most common strategies used as the first line of defence against cancer today include chemotherapy and radiation therapy. In chemotherapy cytotoxic drugs are introduced to kill off the abnormal cells, while radiation therapy utilizes ionizing radiation as a mode of attack. Both strategies possess devastating side-effects and both are non-specific resulting in damage to the normal body cells in addition to the cancer cells.

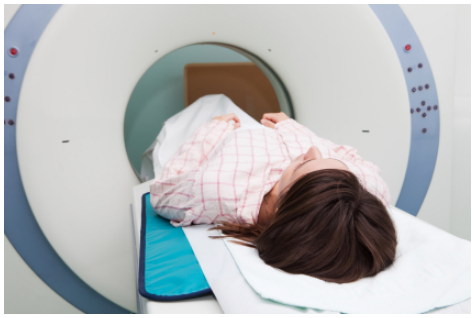
IS-IT Question

To what extent does nanotechnology represent the most promising route to success in the combat of cancer?

In order to answer this question your group will need to consider each of the individual steps involved in the process of fighting cancer. You will need to be aware of recent developments that have taken place in this field and take an in-depth look at what has been done already and what still can be done, with the aid of nanoscience. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Action is preceded by detection

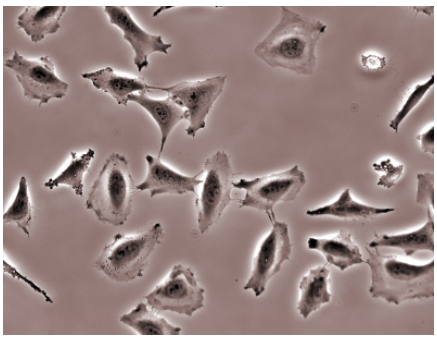


Early detection of tumour cells provides the best opportunity to kill them successfully. There are multiple methods of cancer detection currently in use. Nanosized particles (e.g. quantum dots) are being developed as diagnostic tools; however, their performance must surpass that of existing detection methods.

You might like to consider:

- *What is the success rate of the common detection methods used today and how early can the onset of cancer be detected?*
- *Are there any disadvantages in the methods that are currently in use?*
- *Are nanoparticles a viable option in the detection of cancer?*
- *What is their fate in the body after they have served their purpose*?

IQ2: Conventional drug delivery systems are not perfect



Delivering an anticancer agent to the cancerous cells is not easy! The shortcoming of indiscriminate drug distribution can be overcome by targeted drug-carriers that ferry the drug to the tumour site.

You might like to consider:

- *What are the pros/cons in delivering an anticancer agent to a specific tumour site?*
- *What options are there in nanosized drug delivery systems in use today? Are there any others are currently under research?*
- *How do the nanoparticles get to a specific target site?*
- *What is the fate of any target specific drug carrier once it has performed its task?*

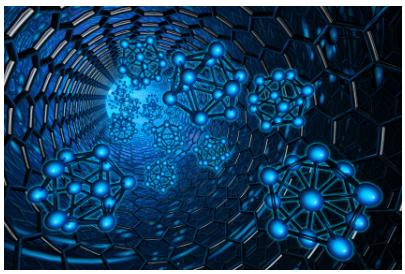
IQ3: Prevention and control

Prevention is always better than cure. There are several agents, acting alone or in combination, that are thought to cause cancer and actually pinpointing the correct one is a perplexing problem. Your task is to evaluate these and methods used for preventing the manifestation of cancer.

You might like to consider:

- *What are some of the suspected causes of cancer and how do they meddle with the chemistry of our body cells?*
- *How may they be detected, before they actually initiate the production of tumor cells?*
- *What are some of the cancer prevention agents in use today?*
- *How might nanotechnology offer alternatives or enhancements in cancer prevention?*

IQ4: The use of nanoparticles may be dangerous



The use of nanoparticles in medicine is somewhat like the use of a double-edged sword. Your task is to identify the possible adverse effects that may occur by interaction of nanoparticles with living species.

You might like to consider:

- *How can cells come in contact with nanoparticles on an everyday basis?*
- *What is the chemistry behind nanoparticle interactions that cause mutations in cells?*
- *Will the body's defence mechanisms react to nanoparticles and how can this be prevented?*
- *What measures can be taken to prevent the harmful side-effects that may occur due to the use of nanoparticles.*

Bodybuilding: Biomaterials as an Elixir For Future Humanity?

Scenario Context Synopsis:

The use of biomaterials in medicine is not in any way novel. They have been used since the first bark bandage was pressed onto a wound. Today, physicians worldwide implant more than 200,000 pacemakers, 100,000 heart valves, 1 million orthopaedic devices, and 5 million intraocular lenses each year. [1]

Although it is difficult to define biomaterials exactly, a working definition that might be used is 'any material that is used to replace or restore function to a body tissue and is continuously or intermittently in contact with body fluids'.

Traditionally, there are 3 main categories of applications in which biomaterials are used. The first is fo r extracorporeal uses, that is, in applications external to the body, such as in catheters, dialysis membranes/artificial kidneys, ocular devices, wound dressings and artificial skin. Biomaterials are also used in permanently implanted devices, such as sensory devices, cardiovascular devices, orthopaedic devices and dental devices. Finally, they play a vital role in the application of temporary implants, such as degradable sutures, implantable drug delivery systems, scaffolds for cell or tissue transplants and temporary vascular grafts.[2] The application of biomaterials in sectors other than primary healthcare is also on the rise.

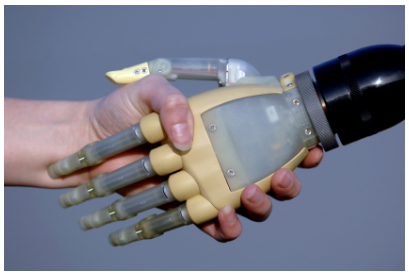
IS-IT Question

How realistic is the existence of a completely bionic person in the future?

In order to answer this question your group will need to review the use of biomaterials in their numerous applications, evaluate their pros and cons and integrate this information to come to a conclusion. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and ap praise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Biomaterials in medicine



The application of therapeutic biomaterials in everyday life is on the rise. For example, new adhesives that work in both dry and wet environments have been made by incorporating the naturally occurring chemical adhesive secreted by mussels, to stick o nto wet surfaces, with the topography found in the toes of geckos, which facilitates strong adhesion in dry environments.

You might like to consider:

- *Which biomaterials are currently commercially realized in medical applications? What are the chemical and physical characteristics that allow them to be used in their individual applications?*
- *What are the typical challenges that face their success in their application?*

IQ2*: *There is always room for improvement

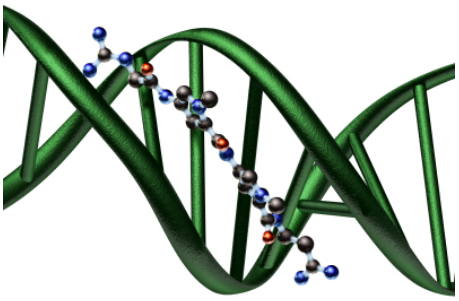
However much work goes into creating the perfect product, there are always a few glitches left. Technological, scale-up and socio-economic barriers need to be overcome for a product to arrive in the market.

You might like to consider:

- *What are the physical and chemical disadvantages of currently used biomaterials?*
- *What medical factors should be considered when designing biomaterials?*
- *What are principle challenges to designing a permanent replacement for a body part?*
- *Are there ethical issues related to the use of biomaterials?*

IQ3: Inspired by Nature

Biomaterials are one of the most researched fields by scientists today. One of the most intriguing areas is the engineering of biomaterials through biomimicry. The applications of such materials are numerous. Your task is to determine how research and development opportunities in biomaterials will solve the existing problems and help eliminate existing weaknesses of products.



You might like to consider:

- *What emerging biomaterials are inspired by biomimicry?*
- *What are their implications for industrial application?*

IQ4: Foreseeable problems that may crop up

There are many risks that have to be faced when launching a new product in a market. The greatest of all is the difficulty faced in getting people to accept it. Your task is to identify the threats and risks associated with the evolution of biomaterials and give a measure of how much of an impact they have on the continuation of research in novel directions.

You might like to consider:

- *How long does it take and what hurdles are faced in bringing a biomaterial product to general use?*
- *How well accepted will the final outcome be by society? What are some of the issues that may have to be overcome?*
- *What are the ethical issues that may have to be addressed?*

Algae-From Little Things Big Things Grow

Scenario Context Synopsis:

A quick inspection of almost any water body will turn up an algal species or or twenty. Whether present as a tiny single cell form or massive giant kelp, algae are the ultimate colonisers. Their abundance and bounty providing the basis of many a food chain and ecosystem, almost 300,000 species catergrised by the Smithsonium to date.

With the majority of species powered by the sun, readily multiplying with nutrient supply and able to sequester carbon dioxide, algae presents a significant opportunity to produce positive outcomes for human endeavours.

The microscopic nature of algae and its growth characteristics have come to represent a significant advantage to the biofuels industry. The running costs of algal fuel-farms and their adaptability for both municipal and remote locations and with small or large volumes significantly increases the market value of this resource.

The fuel industry is not the only one to benefit from these organisms. The clean-up side of fuel use is also getting a look in. Algal scrubbers have been installed to reduce the carbon dioxide emissions from power plants and other carbon emission sources.

Other waste industries where traditionally the high nutrient loading of effluent could cause an algal bloom, a potentially toxic and deadly over population of algae, are now looking to algae as more of a help than a hindrance in the treatment processes of liquid waste.

But why stop at effluent, algae also has a great impact on what we eat. For centuries, algae in the form of seaweed has been a staple feed for livestock and humans as well as being a source of nutrients as a fertiliser.

So from biofuels, air scrubbers, food sources and waste disposal could Algae take us to the stars? Could we make science fiction controlled atmosphere “Biodomes” a reality with the help of algae?

IS-IT Question

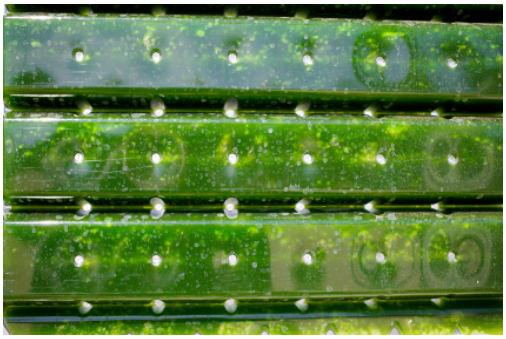
To what extent can Algae provide a sustainable human lifestyle in controlled environments?

To answer this question you must consider the kinds of research needed to keep an isolated community self-sufficient using algae which are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT

question. You must also decide how you would like to present your answer – refer to the IS-IT 'product' list and, as a group, decide which one you will opt for. Once this is decided you cannot change your option.

Individual Quests (IQs)

IQ1: Fuelling Exploration

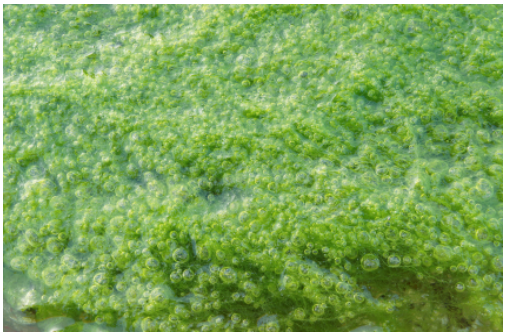


With fuel sources under the spotlight the "green" fuels are getting more air-time. Biofuel and hydrogen production from algae has many advantages in this field arising from the versatility of using so small and abundant an organism. But after so long being accustomed to the kind of processes involved with extracting, refining and using conventional fossil fuels are we going to be able to adapt to new sources such as algae?

You might like to consider:

- *Outline the kinds of engineering and chemical processes involved with producing fuel from algae.*
- *What are the limitations on production of biofuels from algae?*
- *Is there scope for this feedstock to be used in extreme conditions such as space?*

IQ2: Breathing Easier



An abundance of nutrients, light and a soluble carbon source is pretty much all your average bunch of algae asks for. The result is massive reproduction! These properties have been view by industries eager to reduce carbon emissions as a possible shining light. And it may not just be carbon that algae can remove from waste air. The instillation possibilities for an algae emission scrubber are many and varied as the size and shape of the units can be tailored to suit a wide range of applications.

You might like to consider:

- *What are the chemical processes behind carbon sequestration algal style?*
- *How viable are the types of algal products currently available for this purpose?*
- *What options are there for the algae produced by this process?*

IQ3: Green is Clean

There is no way around waste, it is a fact of life but an excess of nutrients in a w ater column such as sewage effluent combined with an a bundance of sunlight can spell disaster. These conditions are ripe for an extensive outbreak of harmful algae but in careful containment this natural response can be harnessed. But what are the realities of sewage treated with algae?

You might like to consider:

- *What issues result from processing waste pond water?*
- *Is there sufficient reduction of nutrients and other harmful constituents in effluent by algal treatments?*
- *How effective will this kind of effluent treatment be for treating waste in extreme environments?*

IQ4: Algal Ambrosia

Far from being only in the realms of science fiction Algae is an important food additive. Most of the food grade additives are extracted from the macro-algae harvest from marine sources. In the main products extracted are used as thickeners but there are also wider applications for beverages and substitutes.

You might like to consider:

- *What chemical methods are used to extract and purify algae products?*
- *How can the food potential food products from micro-alga be developed?*
- *How can these products provide sufficient nutrition for life in controlled environments?*

Copper Ore Concentrate Spill at Wharf

Scenario Context Synopsis:

Recently it was reported that several tonnes of copper ore concentrate were inadvertently washed or dumped into Darwin Harbour during the loading of the commodity item into shipping vessels. The Darwin Port Authority did not report the incident(s) immediately after the spill(s) occurred. The wider community, which usually relies on the green groups to campaign for action in environmental events, backlashed against the lack of disclosure of the spilling of copper ore into Darwin Harbour which was not reported. To exemplify what might happen when toxic levels of copper enter the water:

> In 1999 a zebra-striped mussel outbreak occurred in the Darwin Harbour precinct. It was mainly isolated to one exclusive housing development and treated by the addition of copious amounts of copper sulfate / copper oxide to the water, which was an isolated lock. Unfortunately such remedies as this are toxic to more than the target organism and a wide range of biota were destroyed by the use of copper.

The office of the supervising scientist has since released a report that examined the balance between copper as a nutrient and copper as a toxin in the marine environment. 'Speciation' and 'location' of the copper are important to describing the toxicity of the element.

IS-IT Question

How should the director of the Port Authority ethically respond to the spill of several tons of copper ore concentrate into Darwin Harbour?

To answer this question you must consider factors including time, toxicity, mobility, availability and the public interest. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Toxicity of copper in the marine environment

Of critical importance in reacting to a spill of this type is getting the right advice on the adverse effects of toxic components of the spill and how significant those effects might be for the flora and fauna of the local marine environment.

You might like to consider:

- *How does the chemical speciation of copper influence its toxicity to marine life?*
- *What flora and fauna are most susceptible to high copper loads?*
- *What are the physiological outcomes of copper toxicity toward marine life?*

IQ2: Availability - Bio-availability of copper in the marine environment

It is not just as simple as saying a toxic spill has occurred to prove it is or will be toxic. To better understand how and why some compounds of the same metal have a greater impact on the environment it is important to know how the compound interacts with its surrounding conditions as well as chemical changes over time. Some organic matter can chelate metals and metals can also bind to sediment under the right conditions all influencing the bio-availability, transport through the food chain, and the inherent toxicity of the metal of interest.

You might like to consider:

- *What factors are associated to the ore concentrate solubility?*
- *How does time impact on bioavailability of copper in the marine environment?*
- *Are there any ways for interrupting/manipulating availability?*
- *Why is the interplay with water and physico-chemical parameters important?*

IQ3: Remediation of the spill

Where the adverse effects of contamination are deemed too egregious to allow the contaminant to remain, some form of clean up must be considered and put into action. There are ways to clean up a spill without the need to remove anything from the site of contamination; on the other hand it may be cheaper and simpler to remove the problem.

You might like to consider:

- *What physical ways are there to remove spilled ore?*
- *How could biological / chemical means be use to treat in situ?*
- *What are the difficulties with these methods?*
- *How much will it cost?*

IQ4: To what extent should environmental incidents be publicised on a need to know basis?

In most cases of site contamination the public have a right to know. These rights are linked to the usual activities associated to the site of contamination. For example: contamination of a waste-pond at a mine site is expected and therefore not in the public interest to disclose; on the other hand, the contamination of a river has negative downstream effects that need to be managed for health and safety reasons.

You might like to consider:

- *How informed about ore-spills in the harbour should the general public in Australia be?*
- *What are the current world standards for waste ore management relating to this spill?*
- *Who owns the ore when it is spilled into the harbour and why?*
- *What should Australia's policy be toward mined resources and the management of spoiled minerals?*

A Family Affair

Scenario Context Synopsis:

Though the ages great progress in the human endeavour have been linked with developments in technology, and m ore often than not these advances in technology have come with the harnessing of energy.

We have gone from chasing the sun to dominating direct combustion to utilising steam and production of electricity, each with a following technological revolution. Now we have come full circle and are again reaching out for the stars and capturing solar power.

The vast majority of energy production relies on t he combustion of carbon based materials. However, with our eyes to the sky, we have begun to harness the rocks at our feet!

Silicon, the second most abundant element in the Earth's crust and the big sister of carbon is coming into its own with developments in solar energy capture and storage innovations. We now are on the verge of tapping into an extremely abundant energy commodity.

But silicon, like her sister carbon, must be collected, refined and manufactured all at an energy cost. There are also the impacts on the environment, both positive and negative, from energy production from both silicon and carbon to consider.

Australia, abundant in both these energy resources should be poised to be the world leaders in energy production technology.

IS-IT Question

How can Australia develop its Si and C resources into efficient and sustainable energy technologies for the future?

To answer this question you must consider Australia's access to carbon and silicon resources and the types of energy output that can be achieved with current and newly developing energy technologies. These ideas are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a g roup you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Carbon and Silicon in nature

Finding these two elements is not difficult, both carbon and silicon can be found in their elemental forms, although this is very rare for silicon. Both elements make strong bonds with oxygen, although producing compounds with very different properties. The incorporation of other chemical elements leads to a b eautiful array of structures and formations many of which will have applications in energy production.

You might like to consider:

- *What are the similarities and differences between compounds of silicon and carbon?*
- *How does the electronic configuration for these elements influence the form or structures of silicon and carbon compounds?*
- *Differences in chemistry between the two elements (e.g. ability to be doped)?*

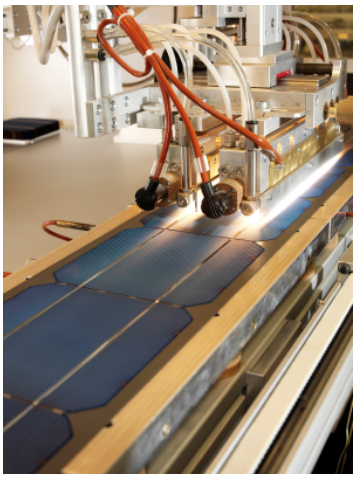
IQ2: Energy from carbon

In Australia we have access to carbon reserves for power production as well as for export. Traditionally the supply has been sustained by coal, but more recently other carbon sources have become favourable. There are many considerations both chemical and physical when extracting, refining and s upplying carbon for power production.

You might like to consider:

- *What are the chemical and engineering considerations of preparing carbon for power supplies?*
- *How is energy from carbon sources accessed?*
- *What is the energy output from energy conversion of carbon sources?*
- *How can carbon be incorporated into "solar panels" (nanotubes, organic dye solar panels).*

IQ3: Energy from silicon



Although silicon is the second most abundant element of the Earth's crust it needs to be mined, extracted and refined before it is suitable for use in the energy industry. Unlike carbon the process of energy production is not straight forward, and there is a deal of engineering to be undertaken. The technology for energy harvesting using silicon is still developing.

You might like to consider:

- *What are the chemical and engineering considerations of preparing silicon for power supplies?*
- *How is energy from silicon sources accessed?*
- *What is the energy output from energy conversion of silicon sources?*

IQ4: Environmental impacts of energy production

From mining to the end product (being energy production) there are economic and environmental costs to consider. At the moment the environmental returns from energy production is the driving force for industries involved, irrespective of carbon or silicon based sources. However the environmental cost cannot be ignored and needs to move at the same pace as technology.

You might like to consider:

- *What is the effect both chemically and physically on the environment as a result of energy production from carbon and silicon?*
- *How are waste products from these industries utilised or disposed of?*
- *What happens/will happen to the solar panels that we are producing once their useful lives have been reached?*

Chocoholics Anonymous

Scenario Context Synopsis:

Chocolate: food of the gods! It was introduced to Europeans as a drink by the South Americans, and later developed into a solid edible form by Englishman Joseph Fry in the 19th century. Today it is a confectionary phenomenon and worth over $50 billion each year worldwide. Chocolate tastes good, it can make us feel good (some would even describe it as slightly addictive), and we all know we shouldn't eat too much of it (but often do anyway).

The manufacture of solid chocolate is a sophisticated process that includes steps such as fermentation, mixing immiscible liquids to homogeneity, and crystallization. In the modern era chocolate manufacturers have also employed biotechnology to bring us a range of premium products that go beyond the humble block of dairy milk

Scientists have broken chocolate down into its fundamental components to work out why it holds such power over us mere mortals, and have found compounds with remarkable physiological effects on processes including neurotransmission and vasodilation. There may also be health benefits from the high levels of antioxidants in some chocolates. When it comes to over-consumption though, the high fat and sugar content is usually a greater concern than the possibility of a chocolate-related drug overdose.

IS-IT Question
How will you create the next chocolate sensation?

To answer this question you must consider processes and ingredients in chocolate making. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Naturally wonderful

From bean to bar, the process of chocolate making is part art and part science. In order to be able to modify the properties of chocolate, one requires a thorough understanding of the role of each step in the production process.

You might like to consider:

- *Does it all come from a bean?*
- *Fermentation, emulsification, and controlled crystallisation are all crucial aspects of chocolate making (among other steps which are also important!). What is the chemistry behind these processes?*
- *What innovations are appearing in chocolate processing?*
- *Is it taste or texture that chocolate lovers seek?*

IQ2: The good, the bad and the ugly!

The balance between sugar and fat content in chocolate can be extremely wide ranging depending on the intended taste or quality. The addition of fats and sugars beyond the natural content of the cacao been can also heavily influence how the production needs to be managed with regard to mixing, temperature control, and the need for emulsifiers.

You might like to consider:

- *What types of fats and sugars are found in chocolate and how do these affect taste?*
- *How do the properties of fats and sugars influence chocolate manufacture?*
- *What are the health implications associated with the specific fats and sugars found in chocolate?*
- *Why does it always seem that foods that are among the worst for our health are also among the most delicious?*
- *Could you produce a sugar-free chocolate bar for diabetics?*

IQ3: Design me a centre

Gooey caramel centres, crunchy honeycomb filling, slithers of marshmallow, air pockets and many other glorious formulations with chocolate rely heavily on c hemistry and, in some cases, biotechnology.

You might like to consider:

- *What types of molecules appear in the list of optional extras?*
- *What different physicochemical properties do monomers and polymers of various sugars have?*
- *What practical difficulties in manufacturing liquid-centre chocolates have been solved with biotechnology?*

IQ4: Lifting spirits!

Most of us have an appreciation for the effect that chocolate can have on emotion and alertness, but it contains compounds that can affect physiology and health in a number of other ways.

You might like to consider:

- *What are the chemical compounds behind chocolate's physiological and psychological effects?*
- *What is meant by the potential antioxidant benefits of chocolate? Is there a biochemical basis for this?*
- *Is there a relationship between the cocoa content and health outcomes?*
- *Do white chocolate or even the alternative, carob, have similar benefits/impacts?*

Cleaning Up Green With Bioremediation

Scenario Context Synopsis:

Intensive chemical research by several countries during World War II led to a suite of new chemical products for civilian purposes during the post-war period. Among these were pesticides from the organophosphate and organochloride families. The highly effective nature of these new pesticides led to them being used heavily in a wide range of applications including weed and insect control in crop farming, and control of the malaria-transmitting *Anopheles* mosquito. It was not realised until much later that many of these chemical agents can accumulate in the environment and can be hazardous to other non-target organisms, including humans. Many developed countries now have controls over the use of the most hazardous of these compounds, but there are still many regions where long-term contamination exists. Bioremediation is a strategy of using living organisms to degrade environmental pollutants to other non-hazardous compounds. The organisms used in bioremediation either naturally produce enzymes that are able to break down the specific chemical of interest, or may be modified to produce the required enzyme. The bioremediation approach has the potential to help clean up not just pesticides, but an almost unlimited range of other persistent and hazardous environmental pollutants including explosives, nerve gas and petroleum products.

IS-IT Question

What is the future of bioremediation as a tool for cleaning up environmental pollution?

To answer this question you must consider the balance between natural processes and human activities which are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Invisible Stockpiles

Many chemicals, including a range of herbicides and insecticides, are not readily biodegradable and can accumulate in soils and ground water, polluting them at dangerously high concentrations. The use of organisms such as bacteria and plants to clean up environmental pollution is a bioremediative option.

You might like to consider:

- *What properties of a molecule make it tailored for its intended purpose, but also lead it to accumulate in particular environments?*
- *How can an insecticide or herbicide adversely affect organisms other than their intended target?*
- *What other types of chemical pollutant might need cleaning up with bioremediation?*
- *What approaches could be taken to try and control the distribution of a chemical once released into the environment.*
- *Consider the pros and cons of other alternative approaches to bioremediation.*

IQ2: Nature's Soldiers

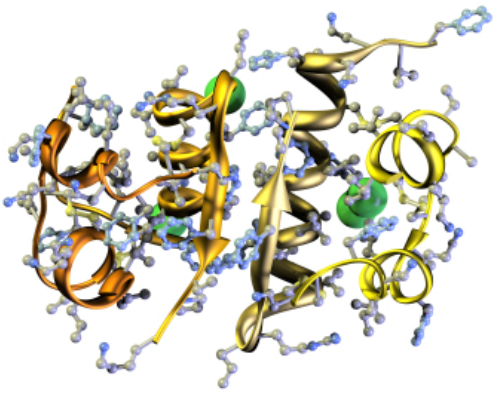
Enzymes that provide mechanisms for breaking down stubborn environmental pollutants can often be found in Nature, frequently in microorganisms. Because many environmental pollutants are not natural compounds, a microorganism with an enzyme capable of breaking down a given pesticide will have usually evolved the enzyme in order to exploit some similar natural compound occurring within their ecological niche as an energy source.

You might like to consider:

- *What strategies could be used to identify microorganisms suited to breaking down environmental pollutants?*
- *What mechanisms are possible for enzymatic degradation of a highly stable chemical pollutant?*
- *How could you go about trying to use naturally occurring enzymes for bioremediation?*

IQ3: Intelligent design of enzymes

Sometimes the enzymes found in nature need to be modified to work on a specific compound or under certain conditions. The relationship between protein sequence, structure, and function is still too poorly understood to create custom made enzymes from scratch, but there have been a number of notable successes in modifying existing enzymes to have novel functions.



You might like to consider:

- *What are some mechanisms by which an enzyme can interact with a chemical substrate?*
- *What are some of the key aspects of an enzyme's structure in determining whether or not it can accept a particular substrate?*
- *What features might you consider in designing a theoretical ideal enzyme for metabolising a particular environmental pollutant?*
- *What considerations might be important when choosing how to apply the enzyme to the environment? (as purified enzyme or in a host organism, or in some other format?)*

IQ4: Chaos at mission control?

There are many considerations when finally applying a bioremediation solution. Any release of a genetically modified organism into the environment must be c arefully planned and controlled, and even applying a pur ified enzyme may not be as straightforward as it seems...

You might like to consider:

- *How long will your bioremediation agent last in the environment?*
- *Can you remove or destroy your bioremediation agent after release?*
- *What if the product you get when degrading a pollutant is also undesirable? What strategy could you apply in this situation?*
- *What ethical and regulatory considerations need to be taken into account?*

Survival in the 'Death Zone': The Ocean Floor

Scenario Context Synopsis:

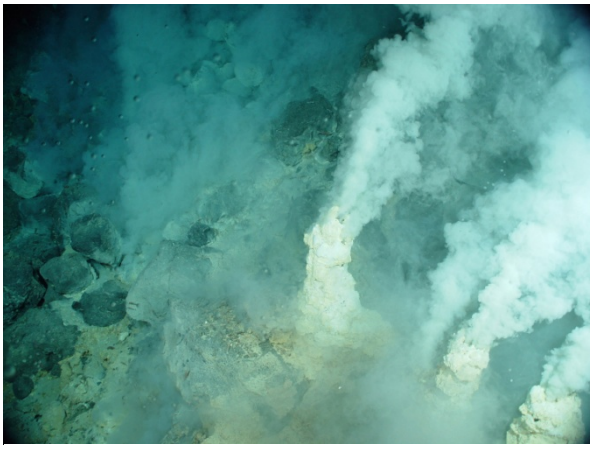


Image courtesy of the National Oceanic and Atmospheric Administration, USA

Extremophiles is the name given to organisms that survive under extreme conditions such as very cold or very hot temperatures, harsh pH, or anerobic conditions such as hydrothermal vents and high salinity. Plate tectonics are responsible for some of the most extreme habitats on earth. Where the continental plates are being pushed together the land crumples and is pushed into mountains such as the Himalayas. At the other extreme where the plates are moving apart there exists volcanic activity. Hydrothermal vents occur at cracks in the earth's surfaces, typically where the tectonic plates are moving apart and the lava which spews forth from the mantle causes extremely high temperatures of water (>400^{O}C). The sulphur and iron compounds which are erupted from the earth's mantle cause high acidity and the depth of water means virtually no sunlight reaches these depths. The communities of organisms that live around these hydrothermal vents are the only known organisms that don't depend on sunlight for energy.

As the terrestrial mineral resources become increasingly scarce one option for continued mining of metals such as gold, silver and nickel, could be to exploit the ocean floor, and even develop underwater settlements. Such a venture would be technologically difficult to enable survival and societal development of human communities in such an environment. However, humans are able to adapt to living in harsh environments by engineering protective clothing, habitats and equipment.

IS-IT Question

How can current chemistry enable sustainable human activities on the ocean floor?

To answer this question you will need to consider how the energy requirements and adequate exposure protection for the extreme environments the ocean floor presents could be achieved. The strategies your team comes up with should be a combination of mechanisms employed by organisms native to the extreme environments and technological solutions such as new fabrics, and/or machinery.

Individual Quests (IQs)

IQ1: Hazards and Limitations

Humans have developed means of surviving in vastly different environments on earth. However there exist no underwater communities. Development of the ocean floor would require humans to live underwater presenting obvious dilemmas such as, how to breathe? What are the limitations to human survival underwater?

You might like to consider:

- *What are some of the hazards divers face when diving to very large depths?*
- *What is the highest pressure the human body has been known to withstand?*
- *How does operating machinery under water complicate mining procedures?*

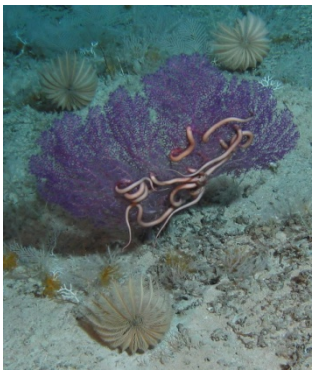
IQ2: Exposure Protection

Humans require shelter from extreme environments. Wearing appropriate exposure protection can enable survival in extreme temperature environments preventing hypothermia and/or heat stroke. New fabrics and m aterials can provide enhanced protection and allow travel to previously impenetrable places. Humans also face sensory deprivation underwater. In the depths, there is not enough light to see and communication underwater is severely limited.

You might like to consider:

- *What level of exposure protection is required for humans to travel to and settle on the ocean floor?*
- *What technologies exist for effective communication in extreme and isolated environments?*

IQ3: Natures Solutions



Extremophiles survive in habitats thought inhospitable to life by using different chemical strategies than life found in temperate environments. For example, Antarctic fish and snow fleas are able to survive in sub-zero conditions because they have anti-freeze molecules in their blood. Nature also provides a chemical source of luminescence found in dark dwelling organisms such as glow worms. Examining the way native organisms survive may provide potential means for human survival in extreme environments.

You might like to consider:

- *How do the anti-freeze molecules found in the blood of Antarctic extremophiles enable sub-zero survival?*
- *How are extromophiles already used in medicine and industry?*
- *How can the biochemical luminescence produced by glow worms be adapted for applications under the sea?*

Image courtesy of the National Oceanic and Atmospheric Administration, USA.

IQ4: Food and energy requirements

What are you going to do for food in an environment that appears to be inhospitable for life?
It was assumed that light and oxygen were essential for life, however there is evidence on a r ich ecosystems living around hydrothermal vents, which have little to no exposure to sunlight and sulphurous atmospheres.

You might like to consider:

- *Without photosynthesis where does the energy for life come from?*
- *What types of food have the potential to be farmed in extreme environments?*

Walk Like a Eukaryotic Cell

Scenario Context Synopsis:

Most cells in the body are linked together in a tight network to form organs like the lungs, brain, nerves skin and liver. But within the body some cells can move around (motility) and are constantly patrolling. These cells can migrate to areas of the body triggered by signals which can direct a specific type of motile cell to a location (chemotaxis), where its functions are required. Since 1888, it has been observed by many researchers that the concentration difference of an attractant chemical could influence the direction of movement of neutrophils in tissue culture. Motile cells constantly monitor their environment for concentration changes of specific chemical compounds (chemoattractants or chemorepellants) by comparing the current chemical concentration, to the concentration detected a few seconds earlier. During chemotaxis this gradient change influences the direction of the cells movement. It seems as if cells possess intent and 'know' what to do!

Chemotaxis plays an essential role in many diverse processes by allowing cells to approach sources of attractant chemicals, or to avoid sources of repellent chemicals, directing sperm to swim towards an egg, attracting immune cells to sites of inflammation and facilitates cancer metastasis. The combined application of live cell and real time *in vivo* imaging and fluorescent microscopic techniques have been utilised to record video footage of chemotaxis, including chemosensing and pseudopod protrusion by eukaryotic cells.

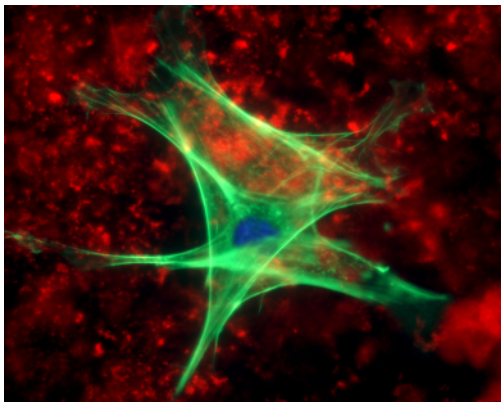
IS-IT Question
How do we know that cells know where to go, and how do they get there?

To answer this question you must consider the chemical signalling involved in cell movement and how these signals affect the direction of cell movement. This includes the molecular functions performed by the cell that are required to alter its shape and move. There are many different techniques used by researchers to study cell motility, which have provided striking visual examples of cell movement, providing insight into what is required for a cell to move. It is important to grasp how these cells are studied and what different patterns of movement a cell can perform. These ideas are interlinked. You should begin by

discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a g roup you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: How are observations of cell motility possible inside animals and what has it shown us?

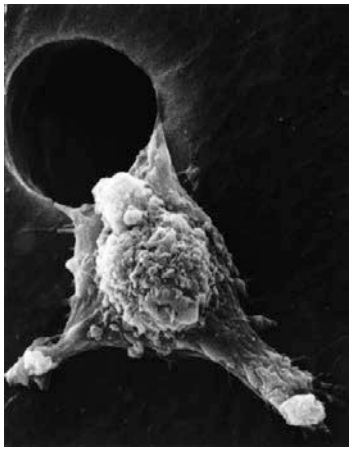


Live cell imaging techniques allow us to visualise the movement of cells (http://www.youtube.com/watch?v=I_xh-bkiv_c). Fluorescence is most striking when radiation is absorbed from the ultraviolet spectrum and emitted in the visible region, giving rise to brilliant colour displays. Specific cells can be h arvested from a fluorescent genetically modified animal and transferred into another animal to observe its movement. Confocal laser microscopy combined with fluorescence allows us to visualise live cell movement within live animals. These video images allow us to systematically measure changes of chemotactic signalling components at various points in real time and space (spatiotemporal). They also demonstrate the many ways in which cells can move inside our bodies.

You might like to consider:

- *How is fluorescence used to study chemotaxis and cell motility?*
- *What different types of motility have been observed by eukaryotic cells and what techniques have been used to identify them?*
- *Can motile cells utilise multiple types of movement to travel from one part of the body to another?*
- *What environmental changes trigger a cell to move?*

IQ2: How does a cell walk (motility)?



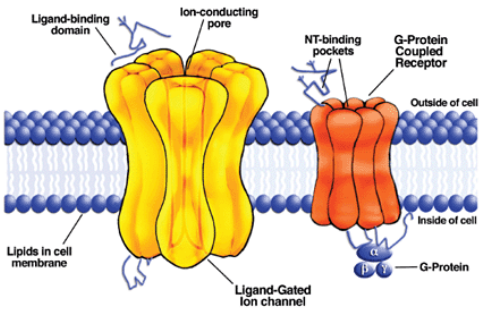
Cells undergo rapid, constitutive motility and assemble a large actin-filament network at the leading edge. The force required for pseudopod extension is regulated by the growth of a branched network of actin filaments that underlie the plasma membrane at the cell's leading edge. Activation of cell surface receptors generates the formation of actin filaments that branch from pre-existing actin cytoskeleton. Rapid growth of the new actin branch pushes the membrane forward. Formation of actin networks at the leading edge is mediated by proteins, which in concert coordinate extension of the actin network.

You might like to consider:

- *What is a pseudopod, and how does it facilitate a cell's movement?*
- *What chemical processes catalyse the formation of a pseudopod?*
- *How does polarity determine the leading edge of a cell?*

Image courtesy of National Cancer Institute, USA, Dr. Raouf Guirgus. Dr. Liotta's Laboratory Author: Susan Arnold (photographer)

IQ3: The molecular compass



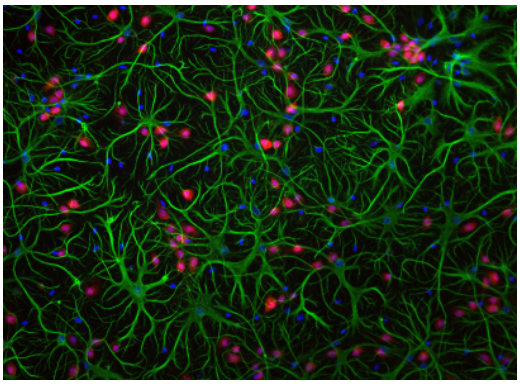
The G-protein coupled receptor (GPCR) chemosensing network (or molecular compass) regulates assembly of the actin cytoskeleton. A membrane-bound inositol lipid PIP_3 provides intracellular cues for the formation of actin cytoskeleton. PIP_3 accumulates at the 'leading front' where actin filament polymerisation leads to cell migration. GTPases play essential roles in chemotaxis. The GTPase superfamily of comprises more than 150 human members with evolutionarily conserved orthologs in all eukaryotes. They function as molecular switches, cycling between active (GTP-bound) and inactive (GDP-bound) forms.

You might like to consider:

- *What is the molecular compass and how does it work?*
- *How do enzymes determine which way a cell should move?*
- *What is chemosensing and how does a cell sample its surrounding environment?*
- *What are Chemokines and Chemokine receptors and how do they facilitate tissue homing?*

Image courtesy of National Institute of Health, USA.

IQ4: What environmental factors promote cell movement in the body?



Chemotaxis is a complicated cell behavior that conceptually consists of three inter-connected cellular processes: cell polarity, cell motility and the ability to detect chemoattractant gradients. The body controls these processes by altering the extracellular chemical milieu by the blood and lymphatics system. Different tissues express chemokines and chemokines and receptors are expressed aberrantly in cancers. For cancer cells to become metastatic, they must acquire the ability to move. When an infection is detected in the body, signals are distributed, which result in an influx of lymphocytes such as dendritic cells, T-cells, neutrophils and granulocytes which control the infection or kill tumours.

You might like to consider:

- *How does the body create chemical gradients to guide a cell to where it's needed?*
- *How does the destruction of tissue induce infiltration of the tissue by immune cells?*
- *What networks in the body are used for cell migration and how do they promote cell trafficking?*
- *How does a cancer cell migrate and where would it go?*

Immunity: Good Versus Evil

Scenario Context Synopsis:

The human body provides an ideal environment for viruses, parasites and bacteria to thrive. Your body is protected from pathogenic infection by an amazing set of mechanisms which make up the adaptive immune system. Different white blood cells or "lymphocytes" circulate throughout the body searching for foreign organisms or infected cells. When a foreign organism is detected, the immune system launches a defensive counterattack, which acts by neutralising trespassing organisms and kills infected cells, while ignoring healthy tissue. T and B lymphocytes make up the majority of the adaptive arm of the cellular immune response, providing cell-mediated or humoral immunity. All of these mechanisms involve molecular interactions.

Immune responses can go wrong. The symptoms of a cold, such as congestion, cough, fever, headache, nausea, and chills are caused during infection, because the immune system is in overdrive. When the immune system gets out of control it can produce a feedback loop which drives a potentially fatal "cytokine storm". The cytokine storm is responsible for sepsis fatalities, graft versus host disease and is suggested to be responsible for influenza-related deaths.

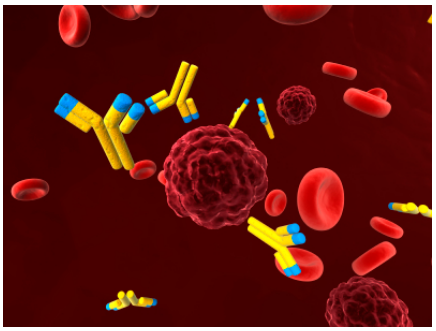
IS-IT Question

How can the immune system orchestrate protection from disease without killing us in the process?

To answer this question you must consider the role of different cellular and molecular components in the immune system. You should understand how the immune system works in synergy to prevent disease and fight persistent infections, while being controlled by a tight regulation. It is important to understand how the immune system can cause diseases, and how diseases may arise from a faulty immune system. These ideas are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Antibody response: The good guys

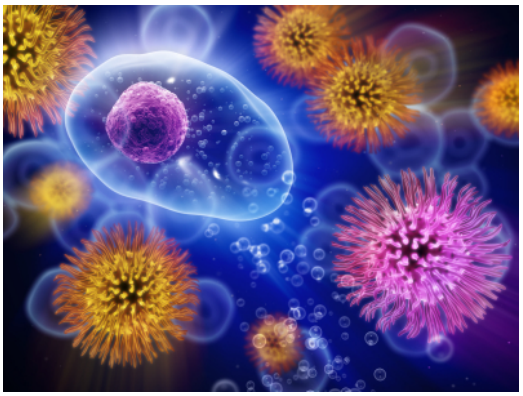


Antibodies or immunoglobins are complex conformational glycoprotein structures that have hypervariable antigen binding sites that discriminate self from non-self. A response to invading pathogens is highly complex and involves many different classes of proteins. Antibodies are secreted by B lymphocytes and can bind to extracellular antigen epitopes and eliminate them from the body.

You might like to consider:

- *What types of antigens (large or small molecules) trigger a B-cell response?*
- *Why are immunoglobulins so diverse, and how do they differ chemically?*
- *What is the basis of the interaction between an antigens and an antibody?*
- *What are the different classes of antibodies, and how do they differ structurally?*

IQ2: Viruses are the bad guys. To kill a virus, you must first kill yourself.



Within normal cells of the body the proteasome, a large cytoplasmic enzyme complex, degrades misfolded or unneeded proteins. This process of degradation yields 8-10 amino acid peptides, which can be recycled to make new protein. When a virus invades a cell its own proteins are expressed by the cell and t hese proteins are also subject to proteasomal degradation. This process creates foreign epitopes, which are ligated into a major histocompatibility complex molecule (MHC). When a T-lymphocyte (type of white blood cell) recognises an epitope bound to MHC on the surface of a cell, the T-cell delivers a toxic payload of enzymes which force the infected cell to commit suicide. This is how viral infections and cancers are eliminated from the body.

You might like to consider:

- *How does an epitope bind to an MHC molecule?*
- *How does a T-cell recognise a foreign epitope?*
- *What happens to a T-cell when it is activated by the interaction with foreign epitope/MHC?*
- *How do other immune cells know if and where there is an infection?*

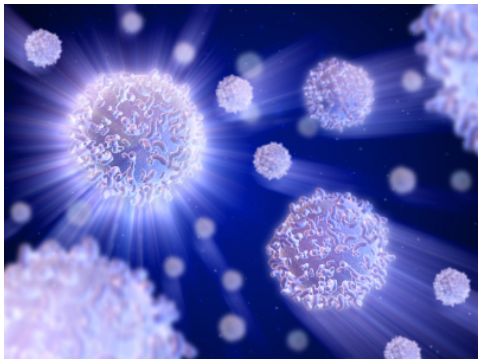
IQ3: Malfunction: Try to keep smiling.

During autoimmune disease the immune system loses its ability to recognise 'self' and in doing so tries to kill 'self'. Interferon-gamma (IFN-γ) is a critical component of adaptive immunity against viral and intracellular bacterial infections and control of tumour. Deregulated IFN- γ production is associated with autoinflammatory and autoimmune diseases, such as arthritis and encephalomyelitis. Autoimmune progesterone dermatitis occurs when women develop antibodies against their own progesterone during menstrual periods, leading to a cyclical rash. Pemphigus vulgaris is a painful chronic blistering skin disease, caused by the production of antibodies against desmogelin 1 and 3, resulting in a loss of cohesion between keratinocytes and the epidermis.

You might like to consider:

- *How is disease caused by autoantibodies?*
- *When does a cellular immune response cause autoimmune disease?*
- *What role do cytokines play in autoimmune diseases?*
- *Are there other factors involved in the onset of autoimmune disease other than stimulation of the immune system?*

IQ4: Homeostasis: A balance of the good and bad



B- and T-lymphocytes are derived from bone marrow-derived lymphoid precursors. Before maturation, naive T-lymphocytes (T-cells) must pass through the thymus where they undergo positive and negative selection. A tumour encounters the immune system frequently during its progression from a neoplasia to carcinoma, which can often take several years. There are a number of host mechanisms that are exploited by the tumour to deceive and subvert the immune response. One exploit drives the production of regulatory T-lymphocytes (T-reg cells), which are able to kill activated cytotoxic T-lymphocytes (T-cells) and dendritic cells (DCs), which are able to kill tumour cells and prevent tumours from forming. The gut is colonised by a wide variety of foreign microorganisms which live in a symbiotic relationship with the host. Normal gut immunity is maintained with a balance where good bacteria are tolerated while the immune response to toxic bacteria is restricted to the site of infection and proportional to the extent of infection.

You might like to consider:

- *What factors influence immune system balance?*
- *How does the immune system learn what is 'self' and 'non-self' and what role does a thymus perform?*
- *What is immune tolerance, and how does the immune system regulate T-cells from killing 'self'?*
- *What types of immune cells are there, how are they different, and how do they stop a bacterial infection?*

We Are What We Wheat

Scenario Context Synopsis:

Food energy has been one of the greatest motivating factors for the growth and complexity of living organisms. Plants are beautifully adapted to producing their energy from the sun, building mechanisms to access energy for growth and development, finally storing energy for their progeny, giving them a starter boost until they can produce energy of their own. Somewhere along this line other organisms developed that were able to access these plant energy stores rather than make their own and thus were no longer reliant on the sun. For humans, the ability to supplement carnivorous diets with plant-originated foods has led to the development of the social groupings we have today. The domestication of cereal crops such as corn, rice and wheat has enabled humans to transcend a nomadic hunter-gatherer existence and form large settlements with food on tap.

In wheat, the most popular cereal crop after corn and rice, we have access to not only starch, the food storage chemicals native to the plant, but also dietary proteins, fibres, minerals and nutrients. The outstanding success of wheat cultivation across the world has led to the dominance of this cereal with it being the staple behind flours for breads, pastries, cakes, biscuits, not to mention fermentation for beer and more recently as a feedstock for biofuels.

Wheat production in Australia represents a >$5 billion industry, and the largest agricultural land allocation. However variations in temperature and rain regimes have had an effect on the productivity in this industry, not to mention an escalation in associated costs relating to irrigation, fertilisation and innovations in genetic varieties.

IS-IT Question

How will the wheat industry progress its product in response to global population growth and therefore food security?

To answer this question you must consider what makes wheat such a staple dietary component and what are the pro's and con's of a diet heavily weighted to this energy source. Concepts of processing and waste need to be followed through with the cost analysis of growing wheat under contemporary and changing environmental conditions.

These ideas are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Wheat structure and properties

Looking inside the wheat kernel to unlock the secrets of nutrition uncovers a fascinating and multifaceted group of chemicals all working together to store and provide the essentials of life to the germinating wheat plant. Subtle differences in the chemical structures and concentrations of these molecular stores changes the properties of the food that can be produced.

You might like to consider:

- *What are the properties and structures of the chemicals found in wheat kernels?*
- *How are these storage chemicals produced and utilised within the plant?*
- *What can be done to influence the structure and/or properties of the chemicals within the kernel?*

IQ2: Digestion

In Australia we have a great reliance on wheat starch in our diets, and given wheat is not only made into flour we may not even know the extent to which wheat provides us a source of fibre, minerals and nutrients. In the modern, more sedentary lifestyle, what impact is such a dietary source having on the health of the world's population?

You might like to consider:

- *What portion of the average Australian dietary intake is provided by wheat, and how does this compare with other communities?*
- *What heath effects come from a diet rich in processed wheat?*
- *How can health be maintained with the presence of wheat in a diet or are there replacement sources we could utilise?*

IQ3: Innovation - Products and Processing

Although wheat is a staple food source in Australia for an industry to prosper there must be diversification. So wheat needs to branch out. A not so modern application for wheat is in the production of beer while a much more modern fermentation process leads to biofuels. There is also the potential for value adding to wheat production, be it at the farm or the processing plants - if we can only find them!

You might like to consider:

- *What kinds of outputs are currently produced from wheat?*
- *What avenues are available for by-products and waste materials from the wheat industry?*
- *How will changes in product demand and food security affect the wheat industry?*

IQ4: Innovation - Farm Production

From sowing to harvesting there are economic and environmental implications to growing wheat in Australia; water, fertilisers, pesticides, processing and transport. Weather variations complicate the yields and growth patterns of this crop. Major innovations in the physical processes of cultivation, management and harvesting will impact the viability of a wheat growing operation. These may be combined with more modern innovations like genetic modifications to drive the wheat industry forward.

You might like to consider:

- *What innovations can be made to improve the current wheat cultivation practices?*
- *How much influence do fluctuations in weather conditions have on crop viability?*
- *What adaptations and innovations will be effective in sustaining and even growing the wheat industry into the future?*

The Return of the King

Scenario Context Synopsis:

In the 1880's a mine at Mt Lyell in Western Tasmania was opened for the extraction of copper. Copper miners will typically concentrate their ore on site before shipping the ore to a smelter. Concentrating of the ore requires water and without holding ponds, the process / waste water has to go somewhere and unfortunately for Tasmania that somewhere was the Queen River, a tributary of the King. At Mt Lyell this pre-concentration of the ore began in 1922.

The first thing a visitor to the King River will notice is the bright pigmented appearance of the rocks and sediment. What might then cross their mind is "how did it get like this"?, "should it look like this"?, and "can it be fixed"?

IS-IT Question

To what extent will the King River ever recover from the environmental impacts of mining?

To answer this question you must consider factors including the underlying causes for the appearance of the river, as well as methodologies to restore it to the original state. Study of other impacted rives globally will aid in determining the indicators of success or recovery. These issues are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: See no evil!

Tasmania is considered by many as pristine wilderness, untouched by the masses of tourists that visit mainland Australia each year. But there is a river in the West that looks unusual. It is reasonable to assume the biota of the King should be similar to that found in neighbouring rivers and streams. On closer inspection, biologists might find minor deviations due to evolutionary impacts of isolation; however, the biology would not be expected to be exceptionally different. Does this idea follow in the context of such an atypical river?

You might like to consider:

- *What has caused the pigmentation/colour of the King River?*
- *What is the chemistry behind the striking appearance of this river?*
- *How do the populations of flora and fauna of the King River compare with other local rivers and streams in the region?*
- *Why have the environmental conditions led to the current biodiversity of the King River?*

IQ2: Mining your own business

Although Tasmania is considered wilderness it does not mean industry is absent nor does this view take into account the variation in "natural" concentrations of minerals in the environment. One industry present in this region is mining for precious metals. The age of the mine and the past and present mining techniques will have had an impact on the environment.

You might like to consider:

- *What ores are found in Tasmania?*
- *What mining and extraction processes are / have been used at the Mt Lyell mine?*
- *Identify the causes and chemistry of Acid Mine Drainage (AMD)?*

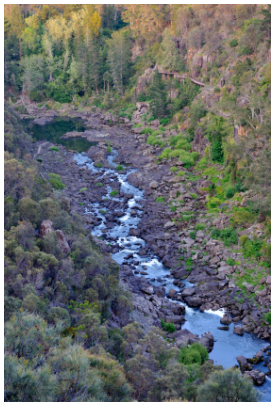
IQ3: Changing the course of water

As population and industry spreads across the landscape, demands on the natural resources increase and rivers become much more than just a supply of drinking water. For example, Tasmania is blessed with a rugged terrain that lends itself to hydro-power, and recreational fishing is an important part of Tasmanian tourism. Industries such as logging alter the water demands on the hydrological system, which may influence the way water drains across and through the landscape.

You might like to consider:

- *What are the demands for water in the region?*
- *How does water supply to the King River influence the appearance and health of the river?*
- *What industry/tourism implications are there for the appearance of the river now and in the future?*

IQ4: Historical patterns for unwinding the damage?



It is possible under the right conditions for a river to self-heal. Self-healing is less likely if the source of a problem / pollution is not stopped. If there is pollution of a river, the environmental question becomes do we remediate the river and make it healthy again, mitigate against further pollution or do nothing? Globally, there are many affected rivers and assessing those systems for how AMD was addressed might provide valuable insight into how the King River can be brought back to its former glory.

You might like to consider:

- *How do we mitigate against further impacts on the King?*
- *What physico-chemical parameters in the river water will serve as indicators for success at remediation efforts?*
- *What has been achieved in other AMD-affected systems globally?*

A Pandora's Box of Oil

Scenario Context Synopsis:

Oil! Our modern age is built from this natural resource. We hunt for it everywhere, from the poles to the equator, from deserts to the sea. And we are good at finding it. But for as long as we have had oil we have had oil spills, it is inevitable. None can deny either the quintessential "oil blowing out the drill hole" view of land-based oil wells or the dramatic images of oil soaked animals dead and dying amidst blackened, tar-stained beaches.

Though as the oil age has developed so have the methods and technologies to clean it up. However there is never a low-impact, all encompassing solution to the devastations of oil in the environment, and the more sensitive the environment the more delicate the clean up needs to be.

All of this restorative action requires time, effort and above all money - but who pays?

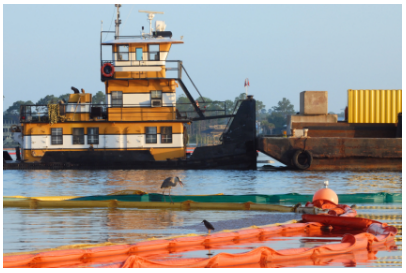
IS-IT Question

How will cleaning up the oil spill in the Gulf of Mexico lead to globally sustainable and economically viable practices?

To answer this question you must consider the oil chemical constituents and impact on the gulf environment, as well as the chemical nature of the clean up processes. Liability and cost of clean up must also be a consideration. These ideas are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Clean up!



Oil spills can and do happen into all sorts of environments, where impacts can vary and individual situations call for different approaches to cleanup. Most spills will be approached using a combination of methods - chemical, biological and physical. These methods however will leave their own residues in the environment. A key point to remember is that cleanup may not just be a matter of oil removal.

You might like to consider:

- *How do the types of chemical and biological agents used in this work function in the marine environment?*
- *What kinds of chemical classes are best suited for this particular context of the Gulf of Mexico oil spill?*
- *What impact will breakdown or metabolism products from oil residues and the cleaning processes have on the marine environment?*

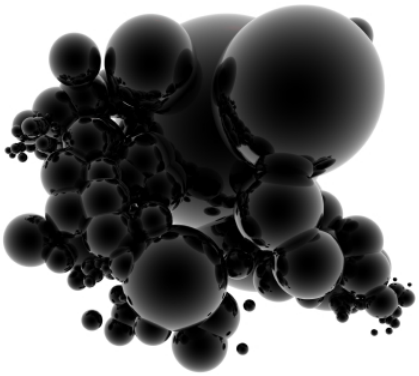
IQ2: History repeating?

This disaster in the Gulf of Mexico is not the first nor will it be the last mass oil contamination event. We do however have a relatively long-term history of spill events/responses to study and learn from. The advantage to following up other spills and cleanup attempts will help us to tailor the best approach to this particular disaster in the Gulf.

You might like to consider:

- *What previous cleanup operations have been counted successful/unsuccessful?*
- *How could this previous knowledge be put to best practice for the Gulf of Mexico spill situation?*
- *How can the success of a cleanup operation be measured?*

IQ3: Miss Ability



Critical, informed decisions regarding the cleanup approach are based on an u nderstanding of the constituents of the contaminating oil and interactions with water. The classic scenario of oil and w ater won't mix is not the simple answer. Just as there are many and varied ingredients in any one oil spill so are the point sources varied, wells/rigs/ships spilling out crude/refined/fuel oils. All these factors will interact to create the specific conditions of each oil spill.

You might like to consider:

- *How does the origin and extraction of oil relate to the chemical constituents of the spill in the Gulf of Mexico?*
- *How do these chemicals interact/change once released into the aquatic environment?*
- *Explain how the behaviour of the spill would differ depending on mode of release?*

IQ4: The smoking gun

There can be no doubt the cleanup of any oil spill will be costly not only in terms of harm to the environment but also in the very real cost of cleanup. Money must be paid to physically carry out the cleaning process but money is also spent in research and development of physical, chemical and biological cleanup agents that may be used. One of the most difficult tasks in apportioning the costs of cleanup is to determine responsibility, and with chemical monitoring and analysis the field of possible sources can be narrowed.

You might like to consider:

- *How do we determine liability for these cleanup costs and how can the funds be collected?*
- *How will understanding the processes that form oil deposits help to research the effects of spilt oil?*
- *What instrumental/analysis methods are available for monitoring and determining point sources of oil spills?*

Chemistry To Get Your Teeth Into!

Scenario Context Synopsis:

Humans have evolved with a mouth full of tissue complexity; teeth, tethered by roots, into our jaws supported by fleshy gums. We get two sets and a chance to learn from our mistakes. The fact that our teeth can grow old and die before our time is up means we need to look after them and care for them to our gain.

Our first set of teeth as children are soft and the adult version are built to withstand wear and tear. Through daily use/misuse a progression of decay from weakness to cavities and gingivitis will ensue, leading to poor health outcomes if not prevented. But how do we get cavities if our teeth are tough enough to crack walnuts and coated with hardening enamel?

As a result of the modern diet, our teeth are exposed to a massive biochemical molecule attack that, unchecked, will lead to cavity production, but may also provide its prevention. Most of us know that we need to clean our teeth as this will help to slow down the negative oral outcomes of food intake, but what other means of fighting tooth decay are open to us? Industry has introduced a range of oral health co-factors, but has nature provided us with these already in the form of beneficial foods? In the future, will we look to our gardens for the majority of our oral hygiene defence? Maybe the old saying “an apple a day” will be aimed at dentists in future years!

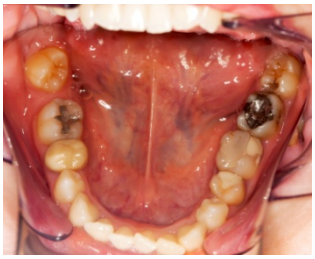
IS-IT Question

To what extent do co-factors (new age remedies) offer an ideal option for prolonging the life of a tooth?

To answer this question you must consider what makes a tooth decay, what methods we have to combat decay currently and what innovations are on the horizon to strengthen our ability to protect teeth. These ideas are interlinked. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: Cavity formation



Cavities are the visual result of tooth damage from biochemical processes triggered by food and eating. With teeth as an important, if not vital aspect of nutrition it is necessary to understand what cavities are, how they form and evolve.

You might like to consider:

- *What are the biochemical processes behind cavity formation?*
- *What are the underlying co-factor causes for cavity formation?*
- *To what extent is diet a factor in cavity formation?*
- *How does Australia compare with worldwide demographics in dental health?*

IQ2: Daily Therapy

Intrinsically we have understood the need to protect and care for our teeth. This need has led to the inventive uses of sticks and salt all the way up to angled bristle toothbrushes, floss, mouthwashes and toothpastes. Some of these protective aids use physical processes whilst others rely on m ore chemical means.

You might like to consider:

- *What benefits/detriments to tooth health come from physically protective actions?*
- *How do chemical methods prevent tooth decay and cavity formation?*
- *Which components of toothpaste are essential and which simply make it appealing?*
- *Fluoride can be toxic, what are the challenges in making fluoride bioavailable and formulating it into usable treatments?*

IQ3: Innovation – "New Age" Prevention

Besides the accepted methods of decay prevention, unusual and innovative approaches have found markets. Chewing gum is the most visual example of this. Other novel ideas are following the chewing gum model; for example Cavistat tablets. However, these products rely directly on mastication and saliva production, which aids cavity prevention. So can effective co-factors be found in alternative foods?

You might like to consider:

- *What kinds of chemical processes and molecular interactions are occurring with products such as chewing gum and Cavistat?*
- *What other sources of cavity preventative chemicals could be considered?*
- *How might we incorporate new age chemical prevention into daily habits?*

IQ4: Nature's Armoury

Understanding the anatomy of a tooth and its setting (the mouth) are intrinsic to long-term health. The body produces enamel as the first and last line of defence for teeth. Saliva, though produced as a digestive aid, provides a measure of protection because of enzymes and buffering capacity.

You might like to consider:

- *How do the molecules/ions that assemble to for teeth combine to produce such strong structures?*
- *What parts of a tooth can regenerate?*
- *What is the composition and chemical action of saliva?*
- *What other means for cavity defence have evolved in the human mouth?*

Paper Mate?

Scenario Context Synopsis:

Paper has been a critical medium of communication for humanity for over two millennia. Before the advent of modern paper (from Asia) papyrus was the closest comparable substrate used to communicate ideas. Paper replaced vellum and papyrus, which followed on from clay or stone tablets.

Paper is made from the pulp of trees. To make pulp, a tree must be cut into small pieces and then boiled and macerated into even smaller pieces. This is when lignin can be separated from the cellulose. Once lignin is removed the cellulose is quite pure and can be used for many alternative purposesbut primarily – acid-free paper. The familiar paper found in books and photocopiers is not made purely from cellulose; other binding, cross-linking and coating agents are added to it to improve its appearance and texture. Newsprint is the simplest type of paper and contains the fewest additives, however it is usually discarded or burned after it has been covered in ink, i.e. in the form of newspapers. Although the paper itself is typically harmless as a waste material, the additives and inks are not so harmless. Paper can be recycled butonce it has been printed on or coated, it does not make a good substrate for newsprint and only a small percentage can be used in photocopy paper before the quality of the paper is lost. On the face of it, then, the world seems to be poised to enter a situation where the production of paper greatly outweighs the recycling.

IS-IT Question
If we have paper in 100 years, what might it be made from?

To answer this question you must consider factors that are linked including how paper is made, what hazards and pollution need consideration, is paper sustainable and can we use other materials to make paper. You should begin by discussing this question in your group and then each group member must opt to complete one of the individual quest (IQ) tasks. As a group you will collate and appraise the information and data collected in your IQs to formulate your group answer to the IS-IT question.

Individual Quests (IQs)

IQ1: The paper forming process

Paper is essentially wood that has been torn apart and reassembled in a way that imparts useful qualities in the final product. Lignin is removed during pulping for acid-free papermaking. Papermaking factories often have a particular odour and for that reason factories are often placed as far away from houses/communities as possible.

You might like to consider:

- *What is the chemistry of the pulping process?*
- *Why is acid-free paper demanded by consumers?*
- *What are the energy requirements to form 1 tonne of paper?*
- *What waste and contaminating agents are generated during papermaking and how might they be managed?*

IQ2: Issues of lifecycle

Many tonnes of paper are burned and/or buried each year as waste disposal options. Recycling is a contemporary strategy and the product has been included as a component of feedstock for certain types of paper/cardboard. However, additional materials on/in the paper like ink and binding agents can add to the negative impacts of both recycling and disposal, from a life-cycle perspective.

You might like to consider:

- *What is the ratio of recycled vs discarded paper products?*
- *What environmental and economic cost of burning of paper?*
- *Compare recycling to plantation wood as feedstocks in terms of cost and convenience?*

IQ3: Managing our resources

Trees don't always end up as paper and paper wasn't always made from trees! The next innovations in paper production may relate to the sources of materials that can be used to make "paper". There are many tonnes of waste crop materials each year that could form the basis of a sustainable papermaking business. If we can find alternative uses for these forestry resources now, then perhaps the amount of paper going into landfill, or the number of trees being cut down for paper, can be reduced over time.

You might like to consider:

- *What would be the impact on food supply and current processing methods for pulp production if alternative crops/crop-trash became a source material?*
- *To what degree would there be a reduction in logging if paper was no longer made from trees?*
- *How could non-arboreal cellulose be adapted for papermaking industries?*

IQ4: Innovations in paper making. Composition and structural properties

For paper making businesses to grow, like any other business, they innovate. This might mean that research leads to improvements in the machinery, chemistry, drying or coating processes to improve profitability. Paper is not just cellulose. The majority of paper articles contain coating-fillers like calcium carbonate, binders for the cellulose and binders for the coating. There are already paper-replacements in widespread use in many paper-like applications one example being stickers.

You might like to consider:

- *What is the chemical reason for the strength of materials like paper and wood?*
- *Why might polyelectrolytes be used in papermaking?*
- *How do coatings and binders affect the structural properties of paper?*
- *How can the process of solvation of cellulose improve papermaking processes and save trees?*
- *Identify the properties a viable alternative source material would need to express to be considered for making "paper".*