HIGHER BIOLOGY: Assignment

Resource Pack: The Production of Microorganisms

This resource pack is designed to support learners' completion of the Higher Biology Assignment Assessment.

This pack contains:

- Advice to candidates.
- Links to the relevant key areas.
- Suggested practical investigations. The data produced can be used as a source for the assignment, and the experiments could also be used to generate evidence for Outcome 1. This provides the opportunity for an integrated approach to assessment. It is recommended that candidates should be given the opportunity to do the practical work.
- A set of experimental data from the growth of microorganisms investigation.
- Background information on microorganisms with links to additional sources for further research.

Section 1. Advice to candidates

The assignment assesses the following skills, knowledge and understanding:

- applying knowledge of biology to new situations and analysing information
- selecting information from a variety of sources
- presenting information appropriately in a variety of forms
- processing the information/data collected (using calculations and units, where appropriate)
- drawing valid conclusions and giving explanations supported by evidence/justification
- evaluating experimental/practical investigations
- communicating findings/information effectively

The assignment is worth 20 marks out of a total of 120 marks. The assignment is one of two components of course assessment. The other component is a question paper.

This assignment has two stages:

- a research stage
- a communication stage

The research stage involves gathering information and data from any appropriate source. Candidates must record their referenced sources. An appropriate experiment/practical activity can be used as one of the data sources, and then experimental data can be processed, analysed and presented.

In the course of their assignment, candidates are required to:

- choose a relevant topic in biology (the assessor must review the appropriateness of the topic chosen)
- state appropriate aim(s)
- research the topic by selecting relevant data/information
- process and present relevant data/information
- analyse data/information
- state conclusion(s)
- evaluate their investigation
- explain the underlying biology of the topic researched
- present the findings of the research in a report

Of the total of 20 marks available for the assignment, the marking instructions provide 15 marks for skills and 5 marks for knowledge and understanding.

The table below shows the breakdown of how the marks are allocated to each criterion.

Table 1 Allocation of marks

Criteria	Assessment of:	Mark allocation
Aim(s)	Skills	1
Applying knowledge and understanding of biology	Knowledge and understanding	5
Selecting information	Skills	2
Processing and presenting data/information	Skills	4
Analysing data/information	Skills	2
Conclusion(s)	Skills	1
Evaluation	Skills	3
Presentation	Skills	2

Pay particular attention to the allocation of marks for each section. For example there are 8 marks available (out of 20) for selecting information, processing and presenting data/information and analysing data/information. Students may find that it is more straightforward to access these marks through having the opportunity to do an investigation and use their own data for processing and analysis.

This advice should be used in conjunction with SQA documents, Biology Assignment General Assessment information (downloadable from SQA website) and for teachers, the Biology Assignment Assessment Task document (downloadable from the SQA secure website). *Please note this document contains some information from 'Biology Assignment General Assessment information'.*

Choosing the aim of the assignment

Students may choose to investigate an aspect of microbial technology for their assignment. Suggested starting points based on the information in this pack are listed below:

- An investigation into the growth of *Chlorella sp.* in the school lab.
- An investigation into the optimum conditions for the growth of *Chlorella sp.*
- An investigation into population changes of algal growth under different conditions.
- An investigation into maximising microbial growth in industrial production.
- Could algae provide a solution to global warming?
- An investigation into algal growth and algal fuel.
- An investigation into algal growth and its use as a health food supplement.
- An investigation into the production of Quorn™.
- An investigation into the production of Yeast extracts.
- An investigation into the autolysis of yeast and its applications in industry.

Section 2 Key areas

Table 2 gives an overview of the key areas covered by this resource pack.

Table 2 **Relevant key areas.** Areas relevant to this resource pack are in **bold.** Unit and Key area information from SQA 'Higher Biology Course Support Notes, published June 2014 (version 1.0)

Course Unit and Key area	Suggested learning activities	Exemplification of key areas
Metabolism and Survival **6 Environmental control of metabolism** Microorganisms to include archaea, bacteria and some species of eukaryota.		Microorganisms include species that use a wide variety of substrates for metabolism and produce a range of products from their metabolic pathways. Microorganisms are used because of their adaptability, ease of cultivation and speed of growth
(a) Variations in growth media and control of environmental factors. Microorganisms require an energy source (chemical or light) and raw materials from simple chemical compounds for biosynthesis. Many microorganisms can produce all the complex molecules required, including amino acids required for protein synthesis. Other microorganisms require more complex compounds to be added to the growth media, including vitamins and fatty acids. Culture conditions include sterility to eliminate any effects of contaminating microorganisms, control of temperature, control of oxygen levels by aeration and control of pH by buffers or the addition of acids or alkali	Investigate the growth of microbes under different cultural and environmental conditions using standard laboratory equipment and simple fermenters. Isolate yeast from grapes using selective media and appropriate growing conditions	Energy is derived either from chemical substrates or from light in photosynthetic microorganisms. Growth media can be composed of specific substances or can contain complex ingredients such as beef extract.
(b) Phases of growth and doubling or mean generation time of exponential growth and changes in culture conditions. Phases to include lag (enzymes induced), log/exponential, stationary (culture depleted and secondary metabolites produced) and death (lack of substrate and toxic accumulation of metabolites). Viable and total cell count		Interpretation of exponential growth on normal and semi-logarithmic scales
(c) Control of metabolism through the addition of metabolic precursors, inducers or inhibitors to give a required product. Secondary metabolism can confer an ecological advantage by producing substances not associated with growth.	Experiments on the induction of enzymes in microorganisms. Research industrial processes that use microorganisms. Suitable processes that involve underpinning biology include: citric acid production, glutamic acid production, penicillin production and therapeutic proteins such as insulin, human growth hormone and erythropoietin.	
8 Ethical considerations in the use of microorganisms — hazards and control of risks.	Research the development of a microbiological product from discovery to market.	

Section 3. Suggested Practical investigations

1. An Investigation into the growth of *Chlorella sp* using BabyBio™ fertiliser

Introduction

Chlorella sp can be easily cultured in the school laboratory under a light bank. This protocol uses BabyBio™ to investigate the growth of the *chlorella sp* under different concentrations of the liquid fertiliser. The quantities of BabyBio™ used are the minimum and maximum concentrations recommended for use by the manufacturers. The basic protocol could easily be adjusted to investigate different concentrations and types of fertiliser.

Aim

To investigate the growth of *Chlorella sp* using recommended maximum and minimum concentrations of the plant food BabyBio™.

Hypothesis

Based on the manufacturer's recommended concentrations to enhance plant growth, it may be expected that the *Chlorella sp* populations will grow better with increasing concentrations of liquid fertiliser. ***It is expected that students can generate their own aims and hypotheses to suit your particular investigation***.

Equipment

- Distilled water
- Conical flasks
- BabyBio™
- *Chlorella sp.* stock solution
- Air pumps
- Cotton wool
- Disposable plastic pipettes
- 50 µl Gilson pipette and disposable tips
- Bijou bottles
- Mod-Fuchs Rosenthal Haemocytometer (or similar)
- Lightbank

Method

1. Add 500 cm^3 distilled water to three 1 dm^3 conical flasks and label them A, B and C.
2. Flask A is the control and nothing should be added to the flask.
3. Add 5 drops of Baby Bio™ to flask B and swirl the flask to mix it thoroughly.
4. Add 10 drops of Baby Bio™ to flask C and swirl the flask to mix it thoroughly.
5. Add 5 cm^3 of *Chlorella sp* stock solution to each flask and swirl to mix.
6. Set up the air pumps by plugging the flask around the air pump tubing in the neck of the flask with cotton wool, and set to the minimum speed to permit gentle aeration of each culture.
7. Place the flasks under a light bank to allow uninterrupted illumination for the duration of the experiment. The light bank should not be switched off at any time. If no light bank is available, flasks could be grown under a strip light or at a sunny window.

8. Leave the flasks for 1 hour, and then take the first sample.
9. To take a sample, swirl each flask to distribute the *Chlorella sp* evenly and then remove a 1ml sample using a pipette. Transfer this into a labelled bijou bottle and store at 4°C until the sample is to be counted. This will stop any further growth of the *Chlorella sp* population. Population counts can then be done at a convenient time.
10. Take samples each day at the same time as the first sample on day 0, following the same procedure.
11. To count the *Chlorella sp.* population, shake each Bijou to distribute the *Chlorella sp* evenly though the sample and transfer 50 µl (one drop) onto a haemocytometer for counting.
12. Using the Mod-Fuchs Rosenthal haemocytometer, count the number of *Chlorella sp.* in the central 4x4 (1 mm^2) grid. Record the count. Take three counts of each sample. The count gives the *Chlorella sp.* number x $10^4/cm^3$.

It is recommended that samples are taken for 30 days to allow the population trends to be investigated. Sufficient data can be generated by sampling during the school week only. The experiment could be run as a class practical with a rota set up for daily sampling and samples can be stored in the fridge until population counts are made.

Results processing and analysis

Population graphs could be hand drawn or computer generated and students may choose to use semi-log graph paper. This can be downloaded free from
Interactive Mathematics: http://www.intmath.com/

Additional notes

Instructions for setting up and counting using a haemocytometer can be found on the SSERC website:
http://www.sserc.org.uk/index.php/biology-2/biology-resources/microbiological-techniques265/enumerating-micro-organisms141/982-counting-cells-using-a-haemocytometer?highlight=WyJoYWVtb2N5dG9tZXRlciJd

Chlorella sp. can be purchased from Sciento (http://www.sciento.co.uk/; now on PECOS) along with algae growth media. The culture could be used directly as the stock solution, or sub-cultured and grown to create an ongoing line of stock..

This protocol was developed by SSERC.

Sample set of experimental data

Results from an investigation into the growth of Chlorella sp using the BabyBio™ fertiliser

Chlorella population growth data

Below (Table 3) are the raw results from the Investigation into the growth of *Chlorella sp* using the BabyBio™ fertiliser. Students can process these to use in the assignment and to compare them with their own results. Six marks are available in the assignment for

processing and presenting data/information (4 marks) and analysing data/information (2 marks) and so this is an important part of the work. Students should consider carefully how best to process and present the raw data given here in addition to their own experimental data. Population graphs could be hand drawn or computer generated and students may choose to use semi-log graph paper.

Notes

- 5 cm^3 *Chlorella* incubated in 500 cm^3 distilled H_2O (+ stated supplement). 1 cm^3 samples taken every day.
- One drop (50µl) taken from each sample and *Chlorella* content counted on a Mod-Fuchs Rosenthal Haemocytometer. Three counts per sample.
- Counts expressed as *Chlorella* numbers x $10^4/cm^3$

Table 3 Results

	Flask A **No Supplement**			**Flask B** **5 drops** BabyBio™			**Flask C** **10 drops** BabyBio™		
Day	**Count 1**	**Count 2**	**Count 3**	**Count 1**	**Count 2**	**Count 3**	**Count 1**	**Count 2**	**Count 3**
0	8	9	6	4	9	7	10	8	13
1	5	6	6	11	20	10	10	10	6
4	6	8	6	16	19	27	10	9	6
5	6	7	7	24	31	38	19	13	14
6	16	11	12	70	99	43	59	57	37
7	14	16	15	146	110	122	68	86	68
13	126	127	130	330	120	350	85	74	69
14	152	144	159	180	350	180	79	81	80
15	229	221	257	240	200	260	90	68	100
18	444	372	380	380	230	280	103	99	80
19	432	396	425	410	350	440	126	129	100
20	412	496	472	430	440	470	145	175	115
21	428	460	508	480	580	390	138	120	176
22	475	455	440	440	580	450	114	110	279
25	645	260	435	720	840	740	216	92	236
26	385	490	410	1030	720	1070	168	184	228
27	400	450	465	910	1050	1080	236	232	184
28	550	430	340	1130	870	860	224	252	268
29	410	455	480	880	1220	910	296	264	230

N.B. Results presented do not show average results or any analysis of the raw data into graphs. This means students will be able to process and analyse information to give them access to as many marks as possible for data analysis and processing in their assignment.

2. The Autolysis of Yeast Investigation

This is an investigation into the autolysis of yeast. Autolysis involves killing the yeast and the breakdown of the cells by enzymes. This treatment is an example of Downstream Processing in industrial production, and is used to produce a wide variety of yeast-based end product for the food industry. Several experiments investigating this yeast have been developed by SAPS (http://www.saps.org.uk/) for senior pupils to research this application of biotechnology in food production. Full details and experimental protocols can be downloaded from:

http://www.saps.org.uk/students/projects/172-student-biology-extended-project-idea-investigating-autolysis-

Data from the investigation could be used to support many assignment topics, in conjunction with the background information presented in this pack.

Background Information

Background information is presented on a range of aspects of microbial biotechnology. It is expected that students would focus on one or two areas and use this information in conjunction with their experimental work and further research to complete their assignment research stage.

1. Introduction
2. Why use microorganisms?
3. The microbial growth curve
4. Optimisation of microbial growth
5. Control of growth/ control of environmental conditions
6. The importance of algae
7. Can algae offer a solution to climate change?
8. The health benefits of algae
9. Food from microorganisms
10. Yeast and the food industry

2.1 Introduction

Humans have used microorganisms to produce food for thousands of years. The characteristics of microorganisms make them ideal to provide us with goods and services. Research is ongoing into new uses of microbial technology to solve problems and to continue to improve and refine industrial processes and production.

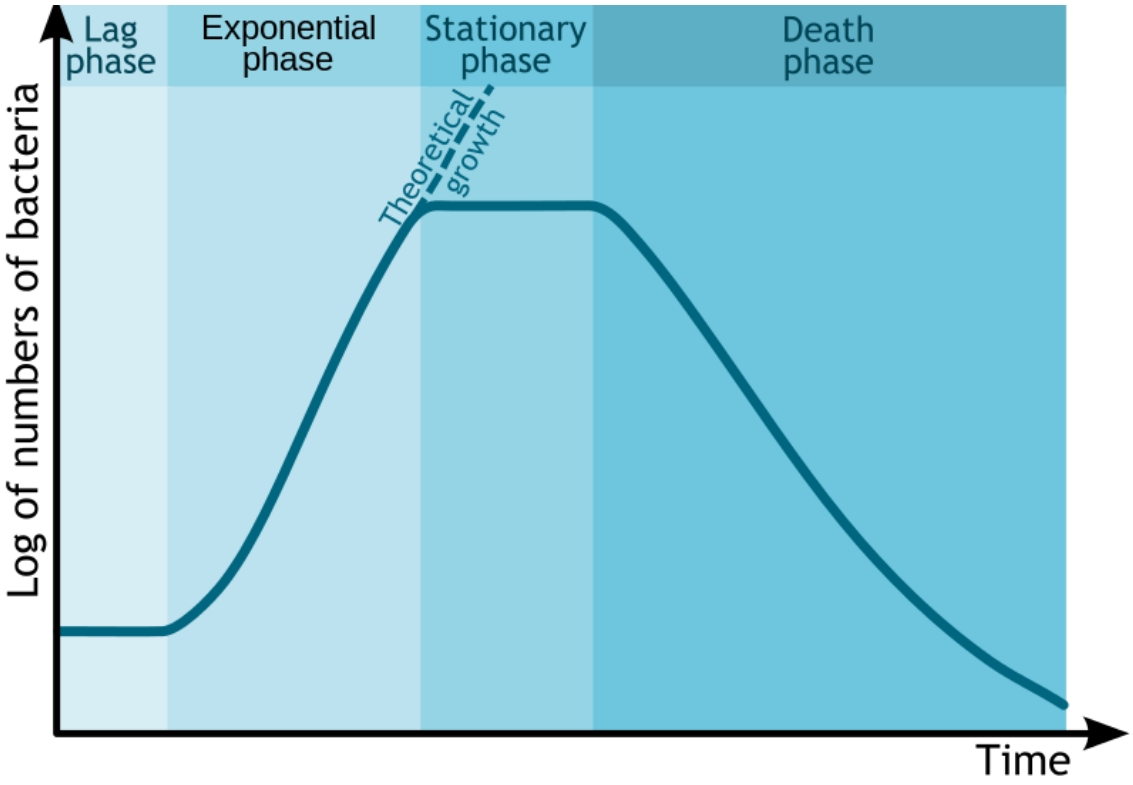
Microorganisms are an important part of our everyday lives and are essential to human health and the health of our environment, in addition to their importance to the economy. Microbes can utilise a range of substrates to fuel their metabolism and produce a large variety of products, many of which have proved valuable to mankind. A summary table of the uses of microbes can be found at: www.misac.org.uk/PDFs/MiSAC_Activities_1.pdf.

2.2 Why use microorganisms?

- Microbes are easy to culture both in the lab and on an industrial scale.
- Microbes grown in optimum conditions reproduce very quickly to produce high volumes of a desired product.
- There are many different species that utilise a variety of substrates.
- The food substrates are often cheap, and include many waste products from other industrial processes.
- Microbes produce many different products from their metabolic pathways that are useful to us.
- Environmental control of metabolism is possible, and metabolic pathways can be manipulated to maximise production of the desired products.
- The metabolism and growing conditions of microbes can be more easily controlled that those of larger multicellular organisms.

2.3 The microbial growth curve

*Figure 1 Growth pattern of a microbial culture (*From http://commons.wikimedia.org/wiki/File:Bacterial_growth.svg#mediaviewer/File:Bacterial_growth_en.svg)



When microorganisms are inoculated into a suitable medium and then the cell number counted over a period of time, the data will show a typical growth curve when plotted. Figure 1 shows a typical growth curve for bacteria, but could describe the growth of any microorganism population when grown in a closed system. The generation time or doubling time is the time it takes for a cell to divide, and hence the population number to double.

This varies between species and the doubling time for some common microorganisms can be found here: http://textbookofbacteriology.net/growth_3.html

A cell culture will grow and reproduce, using up all the nutrients in the medium and produce metabolites. The changes in population follow a very typical pattern of results as shown by the growth curve. There are four phases to the growth curve:

- The lag phase
- The log or exponential phase
- The stationary phase
- The death phase

The lag phase

During this phase the population remains the same, with little or no increase. Cells increase their metabolic activity as they synthesise proteins, nucleic acids, enzymes etc., and increase in size. Enzymes may be induced during this phase to enable the microbes to start using a new substrate in the media that they have been inoculated into.

The log/exponential phase

In this phase cells grow and divide at their maximum rate. They have a good supply of substrate and there are no limiting factors to their growth. The population size doubles with each cell division and therefore population size increases exponentially.

The stationary phase

Exponential growth cannot continue indefinitely if new media is not provided. The population growth is limited due to:

- Shortage of nutrients as they have been used up.
- Secondary metabolites/end products that build up and can limit growth.
- There may be a lack of space.

The death phase

In this phase the number of cells being produced is less than the number dying. Death is caused by lack of nutrients and toxic accumulation of metabolites. The population declines rapidly and may die out altogether or remain as resistant spores.

Growth curve data is usually plotted on semi-log paper due to the very high numbers of organisms produced in cultures. Plotting and manipulation of this type of data is a skill that students could include in their assignment. See:

- http://www.academia.edu/3801106/Teaching_the_microbial_growth_curve_concept_using_microalgal_cultures_and_flow_cytometry
- http://textbookofbacteriology.net/growth_3.html

2.4 Optimisation of microbe production

Microorganisms are grown in closed systems, from the smallest petri dish, to bioreactors which may hold up to 200,000 litres of liquid. In both research and industry the aim is to maximise production and this involves controlling and manipulation of environmental conditions at every stage of culture to optimise the yield of the desired microorganism or product.

2.5 Control of growth/ control of environmental conditions

Aseptic techniques
These are employed at every stage of production of microbes to ensure that there is no contamination by unwanted microbes that could affect growth and production. Details of basic aseptic technique for the laboratory can be found here:

- http://www.sserc.org.uk/index.php/biology-2/biology-resources/microbiological-techniques265/preparation-basic-aseptic-technique?highlight=WyJhc2VwdGljIiwidGVjaG5pcXVlIiwiYXNlcHRpYyB0ZWNobmlxdWUiXQ

Choice of growth media
Growth media is carefully controlled for each species of microbe to maximise production. Even single celled algae that use photosynthesis require the correct balance of nutrients for maximum growth. Microbes need the raw material for biosynthesis of proteins, nucleic acids, carbohydrates and lipids that are essential for growth and reproduction. Some can manufacture these from simple chemicals; others need specific vitamins or fatty acids. There is a variety of growth media available tailored to the requirements of different microorganism.

Control within industrial fermentation[1]
Industrial fermenters (or bioreactors) are used to produce huge quantities of substances. Fermenters vary in size, but can hold up to 200,000 litres of liquid. They are controlled automatically by computers and contain sensors to continuously monitor the conditions inside the fermentation vessels. This is to ensure that optimum conditions are maintained for microbe growth. Sensors are used to monitor oxygen concentration, carbon dioxide concentration, pH, temperature, nutrient concentration etc. Any deviation from optimum is detected and adjustments made automatically. Figure 2 shows a typical bioreactor.

[1] *Please note*- The term fermentation refers to both aerobic and anaerobic processes when related to industrial microbiology, and not just to the anaerobic reactions such as those involved in production of alcohol.

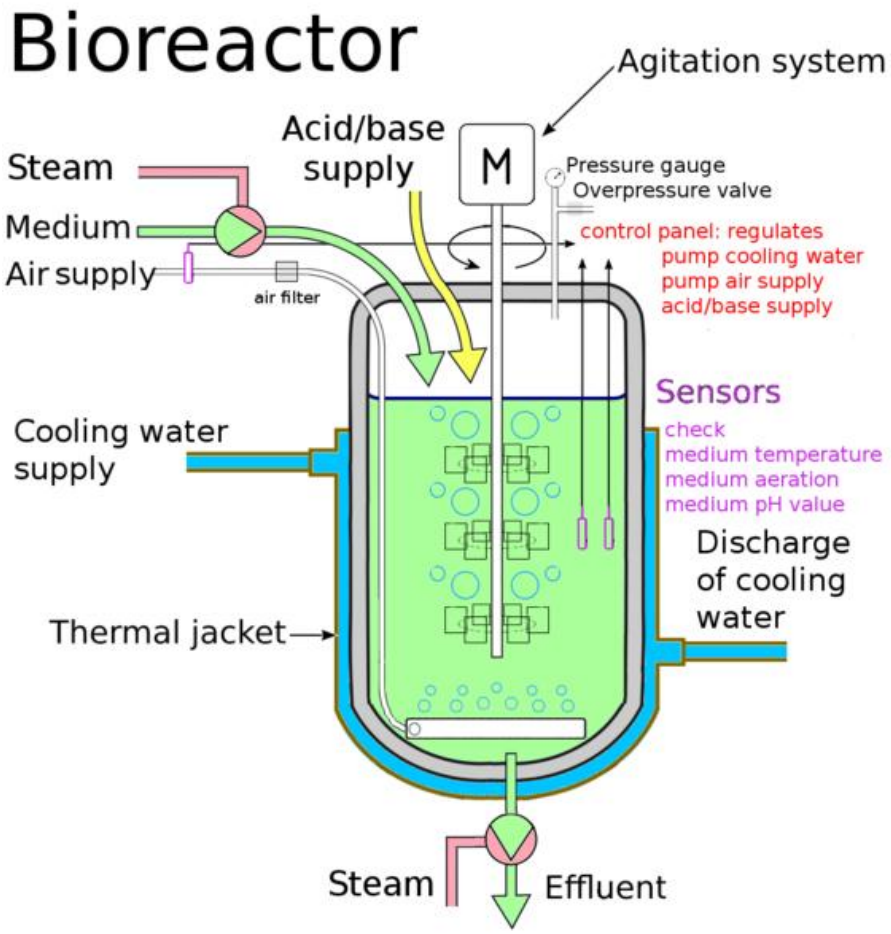


Figure 2 Bioreactor (http://commons.wikimedia.org/wiki/File:Real_life_bioreactor.png)

The respiration of microbes can produce a great deal of heat, and so the vessels are often surrounded by a continuous flow of cooling water as shown in the diagram. Under optimum conditions microbes will grow and reproduce rapidly and the product produced very efficiently. Product quantity and quality is also monitored in the process.

Control of microbe primary and secondary metabolism

Primary metabolism occurs during the log/exponential phase of growth, when microbes are actively growing and reproducing. Amino acids are primary metabolites produced by many microbes to use in protein synthesis. They are also a product that is useful to humans, and many of them are manufactured using microorganisms for use in either the food or pharmaceutical industries. Useful links can be found here:

- http://www.britannica.com/EBchecked/topic/20691/amino-acid/277273/Analysis-of-amino-acid-mixtures#toc277274
- http://en.wikipedia.org/wiki/Amino_acid

Secondary metabolism takes place at the end of the log/exponential phase and in the stationary phase. The secondary metabolites that are produced are not involved in growth, but can give ecological advantages over competitors. An example of this is the production of antibiotics by filamentous fungi which inhibit bacterial growth. Antibiotics are only one

example of the many secondary metabolites that are useful and produced on an industrial scale.

Manipulation of metabolic pathways
In industry, the products that are required are often one specific metabolite from within a metabolic pathway. It can be from any stage in the pathway, and the industrial process is designed to produce and accumulate the desired chemical.

This may mean adding more of an earlier metabolite to act as a precursor to produce the desired metabolite. It may also require using additional metabolites that act as inducers, or adding enzyme inhibitors to stop the breakdown of the desired metabolite. Inhibitors can also be added to stop the pathway at a particular point to allow the desired metabolite to accumulate before it is collected for use.

Manipulation could therefore be done to produce any one of the metabolites in the pathway above.

Further information and named examples can be found here –

- http://textbookofbacteriology.net/index.html
- Higher Biology for CfE, J. Torrance (Editor), Hodder Gibson 2012

2.6 The importance of algae

Algae are of great importance to humans for both ecological and commercial reasons
Algae are essential to support life on earth. It is the primary producer in the oceans and supports virtually all marine life, and it is estimated to release 30-50% of the oxygen required for respiration by living organisms. Oil and gas deposits were formed from the photosynthetic products of algae formed millions of years ago. Algae and the extracts of algae have an important role as food, health supplements and also have many industrial uses. See http://www.britannica.com/EBchecked/topic/14828/algae/31714/Ecological-and-commercial-importance for more details.

The production of oil producing algae as an alternative to using fossil fuels has been proposed as part of the solution to the climate change problem.

2.7 Can algae offer a solution to climate change?

Seeding the oceans with iron
Some scientists think that one solution to climate change is carbon sequestration. This is the removal of the greenhouse gas carbon dioxide from the atmosphere by 'locking it up' and storing it in some way.

It has been proposed that the oceans could be fertilised with iron which would stimulate a huge growth in phytoplankton. Phytoplankton growth in the oceans is partly limited by low levels of iron which it needs for photosynthesis. The phytoplankton would remove the carbon dioxide from the atmosphere. The ocean chemistry and biochemistry of how this results in carbon being locked up in the ocean for a long period of time is complex. Iron seeding of the ocean is also a controversial idea. To find out more follow this link - http://www.rsc.org/education/eic/issues/2010September/IronOceanSeeding.asp

Oil from algae

Algae use photosynthesis to manufacture all the proteins, nucleic acids, carbohydrates and oils that make up their cells. The oils can be extracted and turned into fuel which, when burned, only releases the carbon that was initially fixed by the algae back into the atmosphere. Therefore using oil from algae as fuel will not increase the amount of carbon dioxide in the atmosphere and so will not add to the problem of global warming (i.e. it will be carbon neutral). Algae fuels are thought to offer a low carbon alternative to fossil fuels. The advantages include:

- Many algal species have the potential to produce oil, although they vary widely in the quantity produced. This includes *Chlorella sp* and *Dunaliella sp* which are easily grown in the school laboratory.
- They can be grown in saline and waste waters as well as in freshwater.
- Algae are biodegradable.
- They could be grown on land that is not suitable for crops to grow on.
- Algae oil can be refined into several different types of fuel, including jet fuel.
- Their fast growth rate and very high yields means they can produce more oil per unit are than other crops e.g. rapeseed, palm oil, soybeans.
- They could produce clean energy without causing environmental problems and could be a greener alternative to biofuels.

Disadvantages include:

- Very high cost of research and development of the technology required and more research is needed to make production efficient and commercially viable
- Some companies e.g. Solazyme and Saphire Energy have made some small scale sales to date, but it is estimated that it may take years for algal fuels to become commercially viable.
- The biodiesel produced from algae differs in stability at low temperatures to biofuels from other sources.

Links –

- http://allaboutalgae.com/ (*N. B. This website is produced and hosted by the Algae Biomass Organization, which advocates for the US algae industry)*
- http://en.wikipedia.org/wiki/Algae_fuel
- http://en.wikipedia.org/wiki/Algae_fuel#cite_note-1
  http://www.bbsrc.ac.uk/web/files/resources/activity-3a-culturing-algae.pdf
- http://www.bbsrc.ac.uk/web/FILES/Resources/algal-biofuels.pdf

2.8 The health benefits of algae

Algae can be a good source of protein and is also rich in some amino acids, vitamins and minerals. It has been recognised as a food supplement that may have benefits for health, and there are many claims that it could improve the health of people suffering from numerous diseases and health problems. *Spirulina sp* is one example thought to be a 'superfood', and *Chlorella sp* is also amongst the species of algae that are thought to have the potential to be used in this way. Many benefits have also been put forward for blue green algae and are used for many health conditions. However, evidence for all these claims need to be carefully evaluated.

The links below will help you investigate this further:

- http://www.telegraph.co.uk/health/wellbeing/6028408/Chlorella-the-superfood-that-helps-fight-disease.html
- http://allaboutalgae.com/benefits/
- http://www.nlm.nih.gov/medlineplus/druginfo/natural/923.html

2.9 Food from microorganisms

Mycoprotein

Mycoprotein is produced from the filamentous mycelium of the mould *Fusarium venenatum*, which was first found in the soil. The mould is made into Quorn™ and marketed as a healthy high protein alternative to eating meat.

Mycoprotein production

The mycoprotein is produced in an air lift fermenter of 40m^3 volume which pumps compressed air through the vessel to mix the mould and growth medium continuously. The growth medium is made up of glucose, minerals, biotin and ammonia (which are the source of nitrogen for protein synthesis). The system is designed to keep the culture in continuous exponential growth to give maximum production, with the continuous addition of new nutrient medium and harvesting of the mycoprotein to maintain this. *Fusarium venenatum* is grown at pH 6.0 and 30^{o}C (see previous section for more details of optimum microorganism production in industry).

After removal from the fermentation vessel the mycoprotein is processed by heat shock at 65^{o}C for 20-30 minutes to reduce the RNA content, and the product is filtered under vacuum for collection. It is then mixed with egg albumen to bind the mixture and mechanically processed to align the mycelia filaments to create the desired texture. Further details can be found at http://www.mycoprotein.org/, and http://www.misac.org.uk/PDFs/MiSAC_Briefings_1.pdf

How does it compare with meat?

Quorn™ is marketed as a healthy alternative to meat, containing no cholesterol or animal fat and it is high in fibre. To compare the nutritional composition of Quorn™ with meats you can view a fact sheet here : http://www.mycoprotein.org/assets/ALFT_V2_2.pdf. The

factsheet was produced by Marlow foods Ltd and Quorn™ is a brand name of Marlow foods.

2.10. Yeast and the food industry

Yeast has been used for thousands of years to produce alcoholic drinks and leavened bread. In 1850 the yeast *Sacromyces cerevisiae* began to be produced on an industrial scale to make bread, and nowadays the yeast industry is a multi-million pound industry. Yeast is produced as a food ingredient for both animals and humans as it is high in protein, rich in B vitamins and is suitable for people who do not want to eat animal products, and processed yeast is used as flavouring in many processed foodstuffs.

Umami is the fifth taste perception and is the savoury taste that was first described in 1908 by Kikunae Ikeda, a Professor of Chemistry at the University of Tokyo. Umami or 'pleasant savoury taste' is the results of the amino acid L-glutamate and the ribonucleotides 5'GMP (guanosine monophosphate) and 5'IMP (inosine monophosphate). Yeast extracts are processed to produce these. The yeast cells are processed by autolysis, where they are killed and then broken down by enzymes. The yeast cells which are rich in RNA (ribonucleic acid) are then treated to create the extract 5'GMP and 5'IMP which have the flavour enhancing properties. The extracts are used to flavour almost every processed savoury food that you can buy.

Further information can be found on this via the following links:

- http://yeastextract.info/about
- http://www.umamiinfo.com/
- http://www.theguardian.com/lifeandstyle/wordofmouth/2013/apr/09/umami-fifth-taste
- http://www.saps.org.uk/students/projects/172-student-biology-extended-project-idea-investigating-autolysis-

An investigation into the use of yeast extracts would go very well with the Autolysis of yeast experiment for your assignment.