SL Paper 3

Golden rice is a genetically modified variety of rice (*Oryza sativa*). The golden colour comes from beta-carotene, a precursor of vitamin A, in the edible parts of rice. The modification was achieved by the addition of two beta-carotene biosynthesis genes, one from a flower (*Narcissus pseudonarcissus*) and the other from a soil bacterium (*Erwinia uredovora*).

a. Using this information, outline the reason for Golden rice being considered a transgenic organism. [1]

b. Outline the bioinformatics method used to identify the target gene in the plant. [1]

Markscheme

a. a. transgenic organisms produce proteins that were not previously part of their species' proteome

b. golden rice has genes belonging to other species «flower and bacterium» that were not there naturally/originally

b. database/NCBI/BLAST/BLASTn/BLASTp search «to find target gene»

Examiners report

a. [N/A]
b. [N/A]

Discuss the environmental risks of the cultivation of genetically modified crops.

Markscheme

a. antibiotic resistance «from marker genes» in the crops could be transferred to bacteria

b. but this has never been demonstrated

c. the precautionary principle should be applied

d. genetically modified crops could hybridise with wild plants/other crops

e. escape «of GM crop» could lead to outcompeting endemic species/wild plants / becoming invasive/superweed

f. herbicide resistance could develop in wild plants
OR
pesticide resistance could develop in pests

g. modifications can affect pollinating insects

h. example of genetically modified crop
eg Amflora potato / Bt maize

Examiners report

[N/A]

Explain how microorganisms can be used in response to pollution incidents such as an oil spill.

Markscheme

a. «bioremediation» is the use of microbes to remove environmental contaminants from oil spill

b. some pollutants are metabolized/degraded by microorganisms

c. microorganisms can be eubacteria/archaeans

d. microorganisms are useful in bioremediation because they can multiply very quickly «by binary fission»

e. microorganisms can use pollutants/oil spills/crude oil as energy sources/carbon sources/electron acceptors in cellular respiration

f. *eg*: *Pseudomonas* used «in bioremediation»

g. Pseudomonas requires nutrients «such as potassium and urea» to metabolize the oil at a faster rate «so sprayed on to an oil spill to aid the bacteria in their work»

Examiners report

[N/A]

Outline the use of viral vectors in gene therapy.

Markscheme

viral vector used to replace defective gene in somatic cell;

virus genetically engineered to carry normal copy of gene;

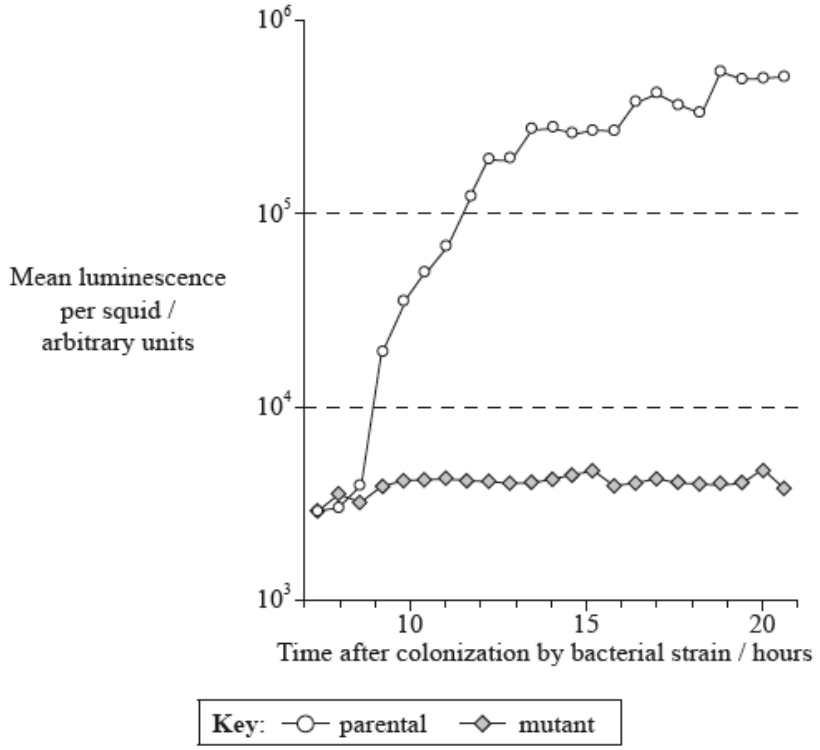
normal gene expressed in body cells;

valid example; (*e.g. used to treat severe combined immune deficiency disease (SCID)*);

Examiners report

Again, very few gave clear answers on the use of viral vectors in gene therapy. Some received a mark for indicating a valid example such as SCID.

The bacterium *Vibrio fischeri* produces an enzyme called luciferase. This bacterium often colonizes the squid (*Euprymna scolopes*). A mutant strain of *V. fischeri* was obtained that was unable to produce luciferase. The graph shows the mean luminescence per squid after being colonized by the parental and mutant bacterial strains.



[Source: K. L. Visick and M. J. McFall-Ngai (2000) '*Vibrio fischeri lux* Genes Play an Important Role in Colonization and Development of the Host Light Organ.' *Journal of Bacteriology*, **182**, pp. 4578–4586. Fig. 2. Reproduced with permission from American Society for Microbiology.]

a. State the mean luminescence per squid 11.5 hours after colonization by parental *V. fischeri*. [1]

b. Between 8.5 and 10.5 hours after colonization with the parental bacterial strain, luminescence increases by a factor of approximately 10. [1]

Estimate the factor by which luminescence increases between 8.5 and 17 hours after colonization with the parental bacterial strain.

c. Using the data in the graph, distinguish between luminescence in squid colonized by the parental and mutant bacterial strains. [2]

d. Bioluminescence only happens when *V. fischeri* becomes part of a population with high density, for example when bacteria colonize the light organs of squid. Evaluate whether the data supports this hypothesis. [2]

Markscheme

a. 10^5 (per squid)

b. 100

c. low luminance in mutant strain while high luminance in parental strain (after 8 hours);

increase between 8 and 15 hours in parental strain but no increase in mutant strain;

d. only when more bacteria have grown (7 hours after colonization) luminescence can be seen;

luminescence has a rapid increase which could be caused by exponential growth of bacteria / population growth curve / example of quorum sensing;

there is no data for the number of bacteria colonizing the squid;

Examiners report

a. Many correctly read the graph for the 1 mark.

b. Only a few of the better candidates were able to estimate that 100 was the factor by which luminescence increased during the given time frame.

The scale on the Y axis seemed to confuse candidates.

c. Few candidates were able to score more than 1 for noting that there was low luminescence in the mutant strain while high luminescence in the parental strain (after 8 hours).

d. Again, candidates struggled with this question and did not seem to understand the data sufficiently to evaluate the hypothesis given.

Gene therapy is a new technology which can be used to treat hereditary diseases.

Outline **two** risks of gene therapy.

Markscheme

undesired effects e.g. cancer/death;

virus may infect cells other than the target cells;

inserted gene may disrupt vital genes already in the genome;

virus entry may trigger an immune response;

treatment must be repeated at regular intervals and all medical treatments carry risk;

Examiners report

N/A

State **two** fuels that can be produced from biomass using microbes.

Markscheme

ethanol;

methane;

Examiners report

Generally well answered.

State **two** roles of microbes in ecosystems.

Markscheme

producers

decomposers

nitrogen fixers

Two needed for one mark.

Examiners report

All parts of this question seemed to prove difficult.

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b. Explain how Gram staining is used in microbiology. [3]

c. Discuss the possible consequences of gene therapy. [2]

Markscheme

b. a. Gram staining is used to classify bacteria/Eubacteria;

b. cell wall structure determines how Gram stain is received;

c. bacteria termed as Gram-positive or Gram-negative;

d. Gram-positive bacteria appear purple;

e. Gram-negative bacteria (stain less intensely and) appear pink/red;

c. most attempts have been unsuccessful/caused harm or death/caused emotional trauma/conflicts of interest/ethical issues;

might alleviate (genetic) condition / correct a (genetic) defect;

Examiners report

b. Most of the well prepared candidates knew about the varied structural features among viruses in a, could explain how the gram stain is used in b and that most attempts at gene therapy have been unsuccessful, although it could potentially correct a (genetic) defect.

c. Most of the well prepared candidates knew about the varied structural features among viruses in a, could explain how the gram stain is used in b and that most attempts at gene therapy have been unsuccessful, although it could potentially correct a (genetic) defect.

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a. Gene therapy may offer cures for inherited diseases and, perhaps, improve quality of life. Distinguish between somatic and germ line therapy. [2]

b. Discuss risks of gene therapy. [3]

Markscheme

a. somatic (gene therapy) involves changes to body cells whereas germ line (gene therapy) involves changes to egg cells/gametes;
somatic cell changes are not passed on to offspring whereas germ line changes may be passed on to offspring;
somatic cell genes affect only a small proportion of the total cells in a body whereas the changes to germ line cells will be passed on to all cells of the offspring (as it develops);

b. prevents/reduces symptoms of a disease so taking the risk is worthwhile;
immune response to the vector may cause damage to the recipient;
long-term effects to the patient are unknown;
impact on offspring of the treated person is unknown;
risk of “designer babies” which poses risks to social norms;
risk of consent during research trials being uninformed / other reasonable answer about research trials;

Examiners report

a. Candidates had some trouble distinguishing between the two types of therapies.

b. N/A

Outline how a defective gene can be replaced using viral vectors.

Markscheme

a. viral vector modified to include healthy gene;

b. virus is taken up by cells;

c. inserts normal gene into chromosome;

d. white blood cells / bone marrow / other cells replaced into patient;

Examiners report

Surprisingly few students could outline how a defective gene can be replaced by viral vectors.

Identify **one** risk associated with gene therapy.

Markscheme

a. stimulate autoimmune response/tissue rejection / infection resulting from vector;

b. cancer/oncogenes / overexpression of gene;

Do not accept death as a response

Examiners report

Candidates recognised that cancer was a potential risk factor of gene therapy.

Researchers are studying several ways to treat cancer using gene therapy.

Discuss the risks of gene therapy.

Markscheme

a. virus vector might infect another cell by mistake;

b. (virus vector) might place the new gene in the wrong section of DNA/cause cancer/mutation;

c. genes may be over-expressed/make too much protein which may be harmful;

d. (virus vector) might stimulate an immune reaction;

e. (virus vector) might be transferred from person to person;

f. children might be more sensitive to long-term hazards since their tissues are still developing;

Examiners report

There was often no discussion in the weaker answers but the better candidates could discuss the risks of gene therapy.

Describe the use of viral vectors in gene therapy.

Markscheme

gene therapy involves replacing defective genes;

desired gene is inserted into the viral genome;

viruses can be modified to infect only target cells and not self-replicate / modified for safe use;

somatic cells are removed (for receiving the new genes);

the desired gene is introduced into the target/somatic cells;

altered cells are returned to the patient for expression of the gene;

properly described verified example *e.g.* replacement of gene for production of ADA in SCID / introduction of gene/RPE65 (in retina) to restore vision in inherited blindness (LCA) / replacement of factor IX/blood clotting factor gene in hemophilic patients;

Examiners report

N/A

Discuss the risks of gene therapy.

Markscheme

at present, gene therapy treatment effects may be short-lived / process may need to be repeated/fails;

reintroduction of cells/introduction of viral vector to the patient risks immune response;

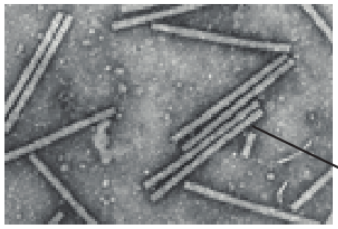
viral vectors may infect the patient;

insertion of DNA may lead to tumours;

Examiners report

Although this was a discuss section, few candidates could make more than one or two correct points about the risks of gene therapy.

Tobacco mosaic virus (TMV) was used as a vector in the development of a new process for Hepatitis B vaccine production.



a. State the role of a vector in biotechnology. [1]

b. Explain how the Hepatitis B vaccine is produced using TMV. [3]

c. State the importance of marker genes in genetic modification. [1]

Markscheme

a. carries/transfers genetic material into a cell

b. a. TMV contains RNA/is a retrovirus

b. gene of hepatitis B «virus» codes for antigen

OR

hepatitis B «virus» has a gene that induces an immune response

c. «antigen» fuses to capsid gene for TMV

d. two fused genes enter/infect the plant cells «using the virus as a vector»

e. mice fed with infected plants produce antibodies against hepatitis B

f. antibodies are extracted from mouse serum/blood

Allow other mammal

[Max 3 Marks]

c. marker genes show the «target» gene has been inserted

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

Outline the role of saprotrophic bacteria in the treatment of sewage.

Markscheme

saprotrophs/decomposers feed on/break down organic material;

requires high oxygen/aerobic environment;

nitrifying bacteria convert ammonia to nitrates;

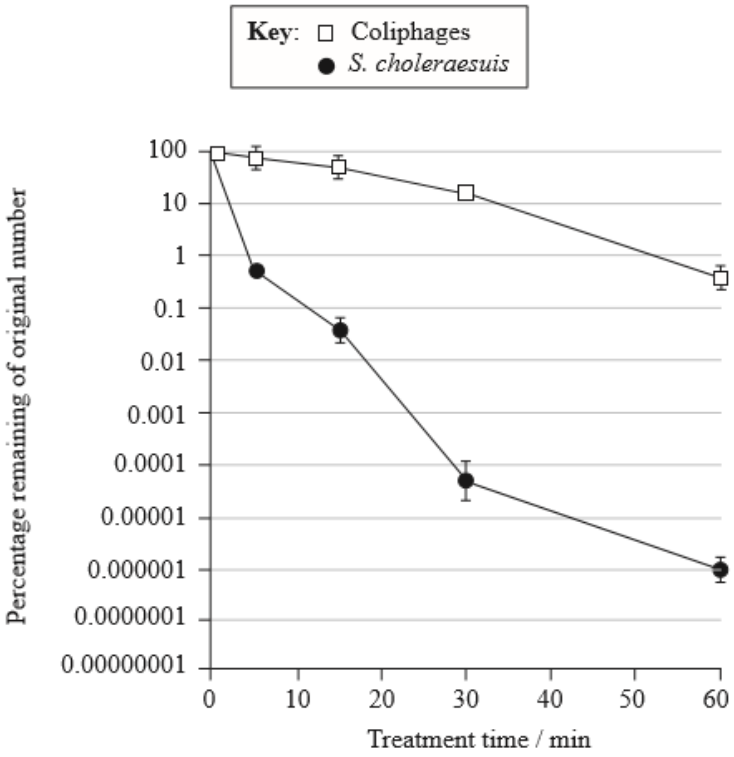
trickle filter bed/reed bed systems optimize environment for saprotrophs;

Examiners report

In (b) (i), there were many poor responses on sewage and the role of saprotrophs.

The sludge produced in sewage treatment plants contains pathogenic microorganisms. In a study, sludge was heated to 80°C in order to kill the pathogens and the effectiveness of this treatment was compared using viruses (coliphages) and bacteria (*Salmonella choleraesuis*) which were added as indicators. The level of activity of either of these two indicators shows whether pathogenic microorganisms may have survived in the sewage sludge.

The resistance of the indicators to heat treatment was studied and their level of activity is shown in the following graph.



[Source: adapted from L Mocé-Llivina, *et al.*, (2003), *Applied and Environmental Microbiology*, **69** (3), pages 1452–1456]

State which indicator was more resistant to the heat treatment.

Markscheme

coliphages/viruses

Examiners report

The correct indicator was generally given.

Explain the consequences of releasing raw sewage into rivers and the involvement of microorganisms in this process.

Markscheme

a. eutrophication;

b. algal bloom deprives other organisms of light;

c. death of organisms;

d. microorganisms/decomposers increase oxygen demand/BOD;

e. causing deoxygenation of river;

f. formation of hydrogen sulphide/ammonia/nitrites;

g. which are toxic to some organisms;

h. pathogenic organisms released into water;

Examiners report

Some good answers gaining 3 or 4 marks were seen for this section on the consequences of releasing raw sewage into rivers. However, there was still quite a bit of confusion with ideas not being clearly expressed.

Explain, with reference to **one** example, how a polluted ecosystem can be restored through bioremediation.

Markscheme

Bioremediation is the use of microorganisms to metabolize toxins to remove them from the environment

Specific area or ecosystem affected by pollution

Name of pollutant

Source of pollutant

Identity of microorganism used

Manner in which microorganism makes use of pollutant

Supporting steps technicians have to undertake

Examiners report

Most candidates scored marks in explaining bioremediation.

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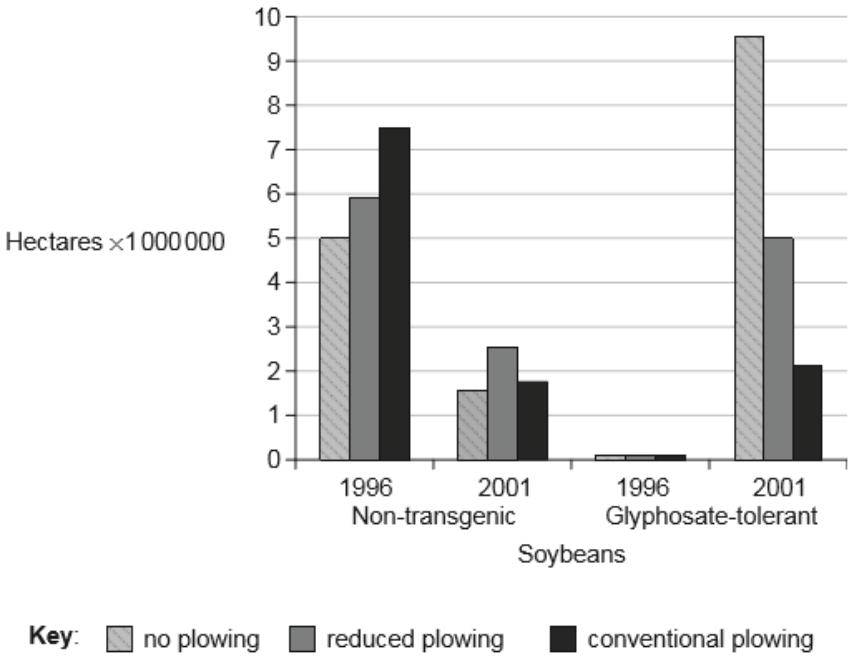
a. Before planting their crops, farmers have traditionally plowed their land to suppress weed growth. Unfortunately, plowing causes the loss of valuable topsoil. Modern farming is shifting toward the use of chemical weed killers such as glyphosate in combination with genetically modified glyphosate-tolerant (GT) crops. The graph shows the area of plowed land in the USA for soybeans in 1996 and 2001. During that period GT soybean planting increased from a few percent to about 70 %. [2]



[Source: adapted from A. Cerdeira and S. Duke (2006) *Journal of Environmental Quality*, 35, pages 1633–1658. Reprinted by Permission, ASA, CSSA, SSSA]

Evaluate the hypothesis that increased planting of glyphosate-tolerant crops has resulted in the reduction of plowing.

b. Explain the role of bioinformatics in the determination of the function of an unknown target gene. [2]

c. Outline what is meant by open reading frame (ORF). [1]

d. Genetic engineers sometimes use physical methods to transform cells. Describe the method of biolistics. [2]

Markscheme

a. «The hypothesis is supported as» less total land is plowed in 2001

«The hypothesis is supported as» the amount of land used for conventional plowing is less in 2001

«The hypothesis is supported as» the amount of land used for reduced plowing has increased in 2001

There is a negative correlation between increased GT soybean planted and area of land plowed

b. Involves database search for DNA sequence similar to unknown gene

Function of similar sequence used to infer the function of the unknown target gene

Use of nucleotide blast/BLASTn

c. Continuous/unbroken stretch of DNA between start codon and stop codon

d. Biolistics uses a gun device

Fires particles coated with DNA/gene

At plant tissue

Examiners report

a. The graph proved quite difficult to interpret as longer bars show less plowing.

b. Most scored for comparing function of a known sequence with an unknown gene.

c. N/A

d. Very few mentioned the use of a gun device in biolistics.

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b. Outline the role of saprotrophic bacteria in the treatment of sewage. [2]

c. Explain the formation of methane from biomass. [3]

Markscheme

b. sewage trickled over bed of rocks with (biofilm of) saprotrophs and oxygen added;

saprotrophic bacteria feed on/break down organic matter (found in sewage);

transforming it into harmless/re-usable products/ $\mathrm{CO_2}$, $\mathrm{H_2O}$, ammonia;

c. bioreactor with anaerobic conditions;

bacteria convert organic matter into organic acids/alcohol/acetate/ $\mathrm{CO_2}$ and $\mathrm{H_2}$;

methanogenic bacteria produce methane from breakdown of acetate/ $\mathrm{CO_2}$ and $\mathrm{H_2}$;

(Accept correct word or chemical equations)

Examiners report

b. As was stated in the N12 Examiners' Report, candidates did not do well in this question on the treatment of sewage. One mark for saprotrophic bacteria feed on/break down organic matter (found in sewage) was common but seldom was a second mark awarded.

c. This proved to be a discriminating question as 1 mark may have been given but seldom 2 marks and not 3.

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a. State the role of *Rhizobium*, *Nitrobacter* and *Azotobacter* in the nitrogen cycle. [3]

Rhizobium: .....
Nitrobacter: .....
Azotobacter: .....

b. Explain the production of methane from biomass. [4]

Markscheme

a. *a. Rhizobium:* nitrogen fixation;

b. Nitrobacter: oxidizes/changes nitrites to nitrates;

c. Azotobacter: nitrification / bind atmospheric nitrogen / nitrogen fixation;

b. a. anaerobic digestion of biodegradable material;

b. fermentation (of carbohydrates) by bacteria;

c. methanogens produce methane;

d. methane/biogas used as energy;

e. waste products used as fertilizer;

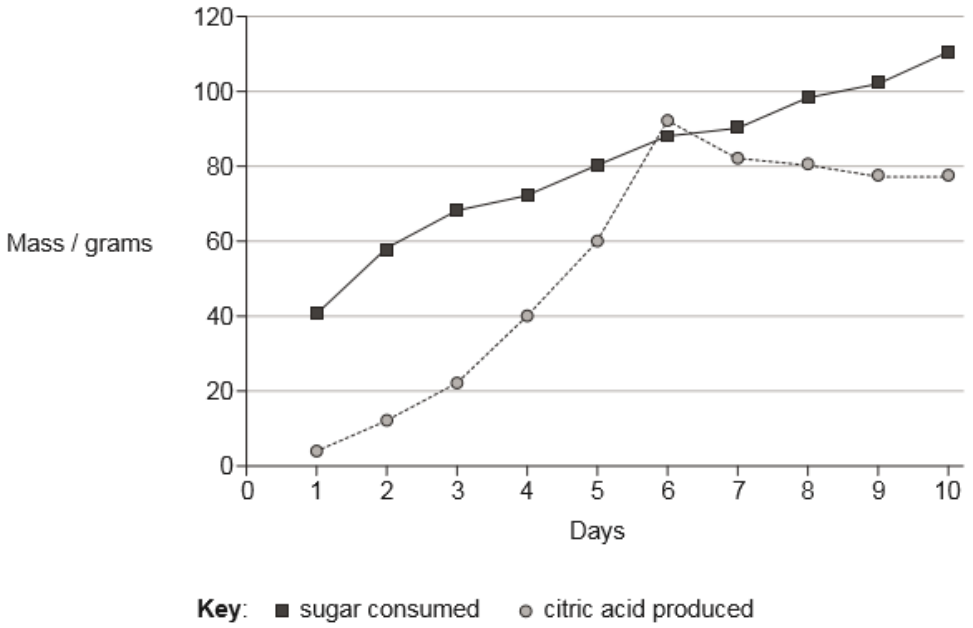
f. CO_2 produced (as a by-product);

Examiners report

a. N/A

b. Some students gave comprehensive explanations of the production of methane from biomass. Most students scored at least one point.

Sugar solution in a fermenter was inoculated with a culture of fungus, incubated at 30°C and left for 10 days to produce citric acid. The mass of sugar consumed and the mass of citric acid produced was measured daily.



[Source: adapted from Ali, S.; ul-Haq, I.; Qadeer, M.; Iqbal, J. (2002), Production of citric acid by Aspergillus niger using cane molasses in a stirred fermentor. *Electronic Journal of Biotechnology*, Vol. 5, No. 3]

a. State a suitable fungus for the production of citric acid in the fermenter. [1]

b. Suggest a reason that fermentation is most successful at 30°C. [1]

c. Suggest reasons for the changes in mass of sugar and citric acid after day 6. [2]

d. State **two** uses of the citric acid produced. [2]

1. . . . . .

2. . . . . .

Markscheme

a. *Aspergillus/A niger/Aspergillus niger*

b. enzymes work optimally/well/efficiently at this temperature

"Enzyme" is essential for the mark.

c. a. sugar consumption continues to increase because it is used in respiration / produces energy

b. products inhibit the reaction so no increase in citric acid
OR
negative feedback inhibits the reaction so no increase in citric acid
OR
decrease in pH may inhibit the enzymes

d. a. add a sour/acidic flavour to food/drink / change flavor / enhance taste

b. can act as a preservative in food/drink/cosmetics

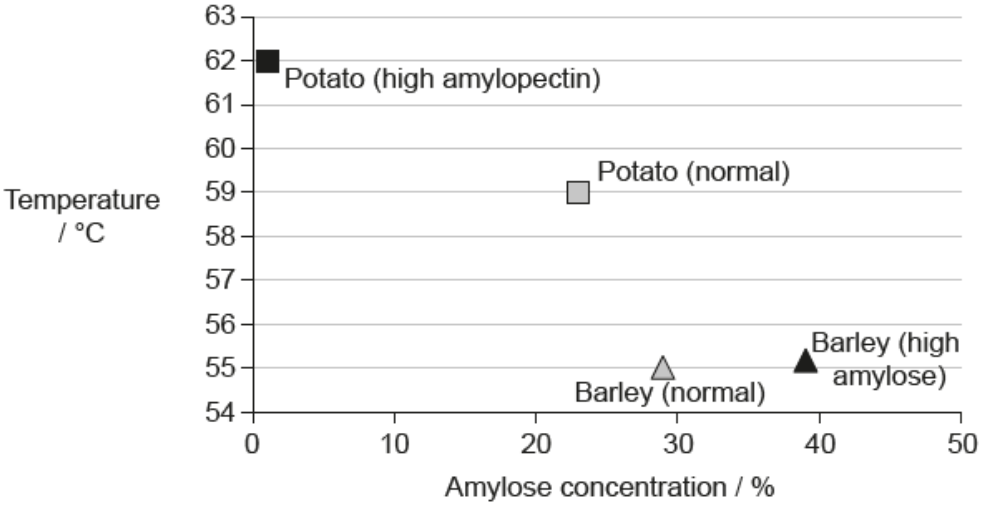
c. controls pH in food/drink/cosmetics

Do not accept "food additive".

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]

Starch from different sources contains differing proportions of amylose and amylopectin. Potatoes (*Solanum tuberosum*) have been genetically modified to produce high-amylopectin starch (Amflora potatoes). Heat induces starch to form a gel in excess water. The graph shows gel formation temperature at different amylose concentrations.



[Source: adapted from H Fredriksson et al. (1998) *Carbohydrate Polymers* 35, pages119–134, with permission from Elsevier]

a. Discuss the hypothesis that the temperature at which starches form a gel depends on the degree of cross-linking of amylopectin. [2]

b. State **one** advantage of potatoes with a high amylopectin content. [1]

c. The Amflora potato was approved for industrial applications in the European Union (EU) in 2010 and was withdrawn in January 2012 due to opposition. Discuss reasons for people supporting or opposing the introduction of the Amflora potato in the EU. [3]

Markscheme

a. a. high amylopectin potatoes/low amylose need more heat to form gel «so hypothesis supported» ✓

b. «normal» potato and normal barley have similar amylose concentration but different gel formation temperatures «so hypothesis not supported» ✓

c. normal barley and high amylose barley have same gel formation temperature «so hypothesis not supported»

b. a. «high amylopectin potato starch is» used in paper production because it forms a clearer film «when forming a gel»

b. «high amylopectin potato starch is» used in adhesive production as it forms a stickier paste

c. «high amylopectin potato starch is» used in paper/adhesive production because there is less thickening of starch film/paste during storage compared to regular potato starch

c. *supporting*:

a. potatoes cheap to grow

b. benefits farmers/local producers «so less pollution»

c. reduces costs in «paper» industry *eg: paper **or** adhesives*

d. beneficial uses in industry

opposing:

e. perceived health risks/allergens

f. may cross pollinate with existing species

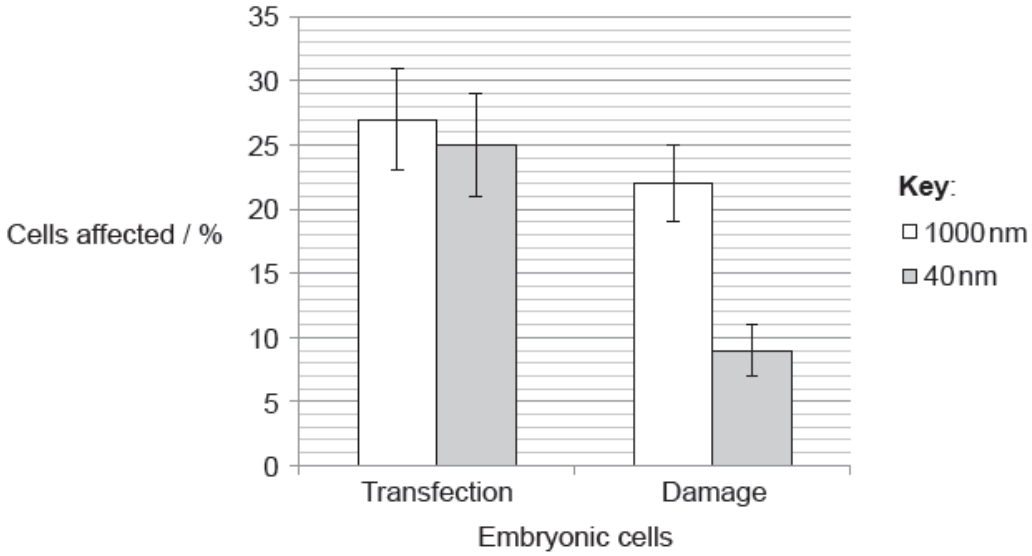
g. could be eaten accidentally

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

Usually the size of particles used in biolistics with plant cells is 1000 nm. Researchers tested the effect of using smaller sized particles (40 nm) in the biolistic treatment of animal cells.

The degree of transfection by DNA and the damage to embryonic kidney cells was assessed using particles of the two different sizes. The amount of DNA attached to each particle, whether large or small, was the same.



[Source: John A O'Brien and Sarah C. R. Lummis (2011) 'Nano-biolistics: a method of biolistic transfection of cells and tissues using a gene gun with novel nanometer-sized projectiles.' *BMC Biotechnology*, 11: p. 66.]

a. Describe the effect of the different sized particles on the treatment of these animal cells. [2]

b. State **one** other physical method used to introduce DNA into plants. [1]

Markscheme

a. a. there is little/no significant difference in the success of transfecting DNA

b. there is «significantly» less damage to the cells with the smaller/40nm particles

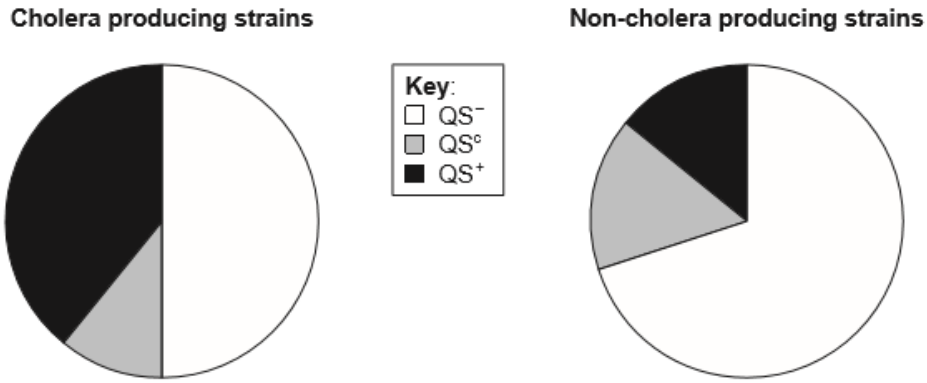
b. electroporation / microinjection

Examiners report

a. [N/A]
b. [N/A]

Vibrio cholerae live in aquatic environments and cause cholera. Some *V. cholerae* form aggregates that show characteristics not seen in individual bacteria. The bacteria in these aggregates monitor the population densities by quorum sensing. They produce quorum sensing proteins (QS+). Some *V. cholerae* strains do not produce quorum sensing proteins (QS–) and some only produce quorum sensing proteins in low amounts (QSc).

V. cholerae strains isolated in China were examined. The pie charts show the percentage of different quorum-sensing systems in strains that contain cholera toxin genes and in strains that do not contain cholera toxin genes.



[Source: © International Baccalaureate Organization 2015]

a. State the percentage of cholera producing strains that do not produce quorum sensing proteins (QS^-). [1]

b. Determine the approximate percentage of non-cholera producing strains that produce quorum sensing proteins in low amounts (QS^c). [1]

c. Compare the percentage of strains that do not produce quorum sensing proteins (QS^-) in strains with and without the cholera toxin genes. [2]

d. Deduce, using the data, whether the genes for quorum sensing and for toxicity of cholera evolved together. [1]

e. *Vibrio cholerae* is Gram-negative. Describe the structure of the cell wall of this bacterium. [2]

Markscheme

a. 50 (%) *(allow answers in the range of 48 (%) to 52 (%))*

b. 16 (%) *(allow answers in the range of 12 (%) to 20 (%))*

c. a. there are less QS^- strains that produce cholera than those that do not produce cholera;

b. approximately 50 % in cholera producing and approximately 70 % in noncholera producing;

c. greatest percentage in QS^- in both so most are not quorum sensing;

d. (*the hypothesis is supported as*)

a. more sensing in bacteria that cause cholera than in those that do not;

b. forming aggregates to facilitate the propagation of the pathogen / bacteria working together can produce pathogenicity;

c. bacteria with QS^+ and cholera producing strains are positively selected;

e. a. thin layer of peptidoglycan sandwiched between outer and inner membrane layer;

b. outer layer containing lipopolysaccharide and (protein);

c. high lipid and low peptidoglycan content;

Accept correct answers on a clearly labelled diagram.

Examiners report

a. Option F data was two pie charts comparing the amount of quorum sensing proteins in bacteria that produce cholera and those that do not. The questions were quite difficult in their language and this confused many students as there were negatives in both questions and responses.

b. Option F data was two pie charts comparing the amount of quorum sensing proteins in bacteria that produce cholera and those that do not. The questions were quite difficult in their language and this confused many students as there were negatives in both questions and responses.

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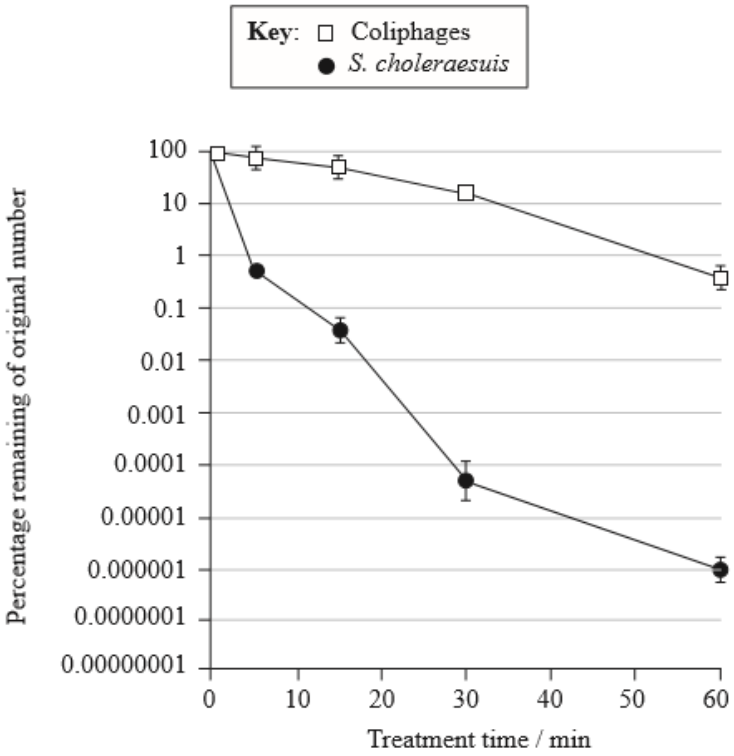
The sludge produced in sewage treatment plants contains pathogenic microorganisms. In a study, sludge was heated to 80°C in order to kill the pathogens and the effectiveness of this treatment was compared using viruses (coliphages) and bacteria (*Salmonella choleraesuis*) which were added as indicators. The level of activity of either of these two indicators shows whether pathogenic microorganisms may have survived in the sewage sludge.

The resistance of the indicators to heat treatment was studied and their level of activity is shown in the following graph.



[Source: adapted from L Mocé-Llivina, *et al.*, (2003), *Applied and Environmental Microbiology*, **69** (3), pages 1452–1456]

b. Compare the effect of the 80°C heat treatment on coliphages and *S. choleraesuis*. [2]

c. Discuss whether the heat treatment should be continued beyond 60 minutes if this technique were to be used in sewage treatment plants. [2]

d. In many areas, sewage is discharged directly into the environment. State **two** potential environmental consequences of releasing sewage into rivers. [2]

Markscheme

b. number of both types (bacteria and viruses) is reduced;

the reduction of bacteria was greater than for viruses;

in the first 10 minutes reduction of bacteria is large whereas reduction of viruses is gradual;

after 30 minutes less than 0.0001 % of bacteria remain while about 10 % of viruses remain; *Accept any other reasonable comparison*.

c. not necessary for bacteria as nearly all have been killed;

necessary for coliphages as they take longer to denature/destroy/are still present;

depends whether pathogens in sewage are heat tolerant;

depends on the cost of the treatment;

depends whether presence of a few microbes in treated sewage is harmful;

d. anaerobic conditions / increases BOD (biological oxygen demand) / eutrophication;

low dissolved oxygen may kill (aerobic) organisms;

pathogens/cause health hazards (bathing or drinking water);

algal blooms;

diversity falls/favours organisms able to survive low oxygen levels;

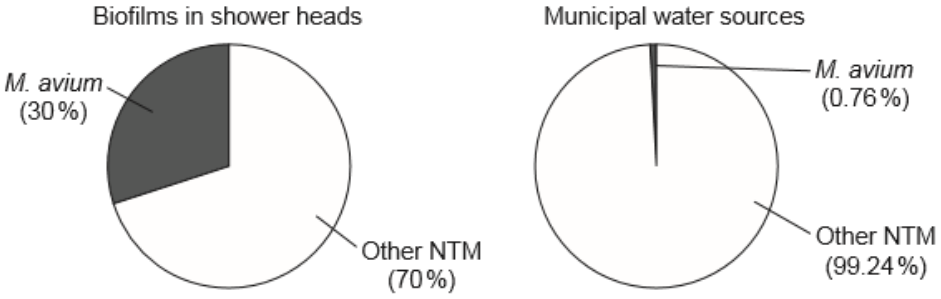
Examiners report

b. Those students who answered this mainly gained only one mark for saying that both bacteria and viruses were reduced in number.

c. This proved to be very difficult for most, with those who attempted it only gaining one mark by mentioning possible cost factors.

d. Most candidates could refer to algal blooms and eutrophication.

Many people around the world wash themselves under a warm shower. This personal hygiene may expose individuals to harmful microorganisms such as *Mycobacterium avium* through inhalation of water droplets from the shower head and direct water contact. Samples taken from biofilms inside shower heads and municipal water sources were analysed. Proportions of other non-tuberculous mycobacteria (NTM) were also analysed. The results are shown in the pie charts.



[Source: L. M. Feazel *et al.* (2009) 'Opportunistic pathogens enriched in showerhead biofilms.' *PNAS*, 106 (38), pages 16393–16399, Figure 3 (pie charts B & C).]

a. List **two** properties of biofilms. [2]

b. Distinguish between the data for shower head biofilms and municipal water sources. [1]

c. Suggest reasons for biofilms developing inside shower heads. [3]

Markscheme

a. They show emergent properties

They contain cooperative aggregates of microorganisms

The microorganisms cooperate through communication/quorum sensing

The microorganisms are highly resistant to antimicrobial agents

They adhere to a variety of surfaces

Formation/secretion of EPS/extracellular polymeric substances

b. Biofilms show a much higher percentage of *M. avium* than water

Accept inverse answer
Accept numerical answers

c. Conditions on the shower head favour bacterial growth

eg: moisture/temperature/nutrients

«Solid» surface on which to accumulate

Quorum reached
OR
critical concentration of signal molecules

Shower heads are seldom cleaned

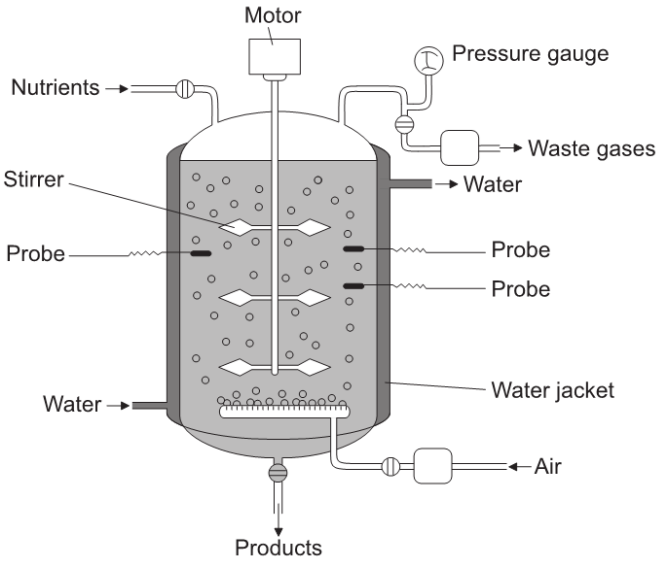
Examiners report

a. Generally well answered showing good knowledge of biofilms.

b. Generally well answered showing good knowledge of biofilms.

c. Generally well answered showing good knowledge of biofilms.

The diagram shows a simplified fermenter used in the production of penicillin.



[Source: Valero, F, del Rio, JL, Poch, M and Sola, C (John Wiley and Sons, 1992). Studies on Lipase Production by Candida rugosa Using On-line Enzymatic Analysis. Annals of the New York Academy of Sciences, 665, pp. 334–344.
doi: 10.1111/j.1749-6632.1992.tb42596.x]

a. State **two** conditions in the fermenter that would be monitored by the probes. [1]

b. Suggest a reason that the fermenter is surrounded by a water jacket. [1]

c. Identify the waste gas produced. [1]

d. Explain the process of penicillin production in the fermenter. [3]

Markscheme

a. a. pH

b. temperature

c. oxygen levels

d. viscosity

e. foam

f. carbon dioxide

Accept any two conditions for the mark

[Max 1 Mark]

b. a. maintain constant temperature/insulation

b. cooling

[Max 1 Mark]

c. carbon dioxide/CO_2

d. a. inside of fermenter is sterilized «to prevent growth of other organisms»

b. «penicillin» fungus/Penicillium added to fermenter

c. nutrients are provided to allow the fungus to grow

d. when nutrients are used up, penicillin is produced

e. penicillin extracted from mixture in fermenter

f. penicillin purified ready for medical use

Accept named nutrient eg: glucose

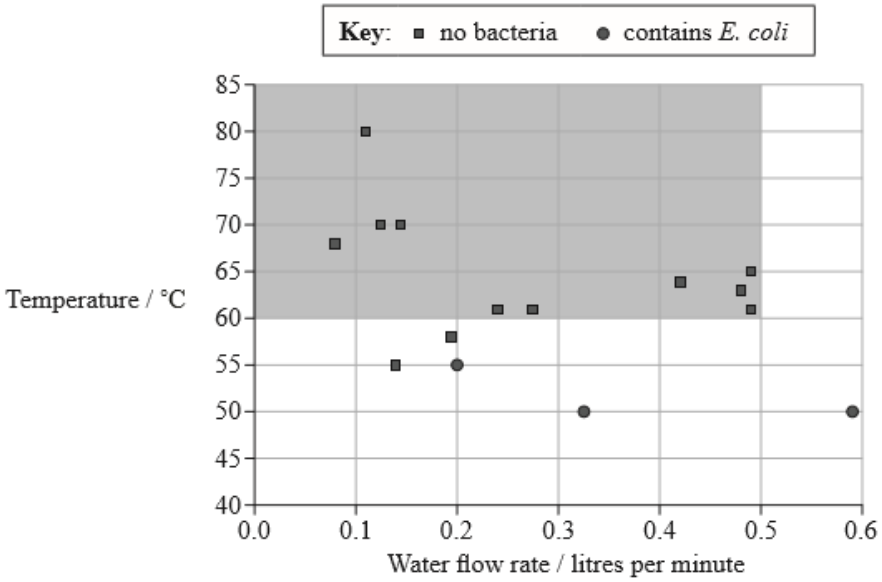
[Max 3 Marks]

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]

In 2003, the Integrated Approach to Community Development (IACD) organization introduced the chulli water purifier to homes in Bangladesh that had not previously had access to safe drinking water. It was designed to be made cheaply from local materials. The purifier uses sand filtration to remove organic particles and heat treatment to eliminate microbes from water.

Water samples from 15 different locations containing high levels of the bacterium E. coli were passed through the purifier at different flow rates and temperatures to test its effect on contaminated water. The shaded area of the graph below represents the recommended temperature and flow rate for using the purifier.



[Source: S. K. Gupta et al. (2008) *American Journal of Tropical Medicine and Hygiene*, 78, pages 979–984]

Evaluate the chulli purifier as a method of controlling microbial growth.

Markscheme

a. water purifier is effective in removing bacteria;

b. no bacteria in 12/15 test sites, regardless of temperature or flow rate;

c. flow rate is less important than temperature;

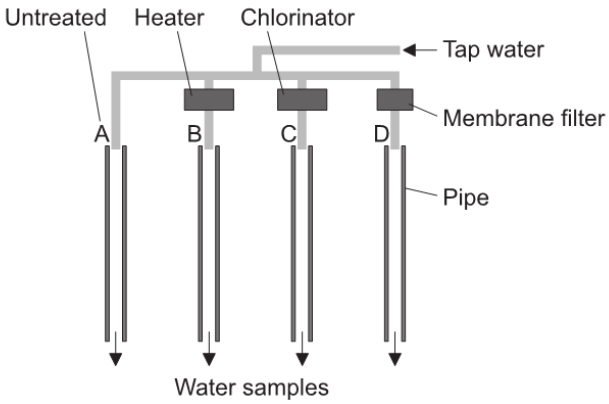
d. no information about how contaminated the water was before various treatments;

e. no information about how effective the water purifier is in removing other harmful bacteria/substances;

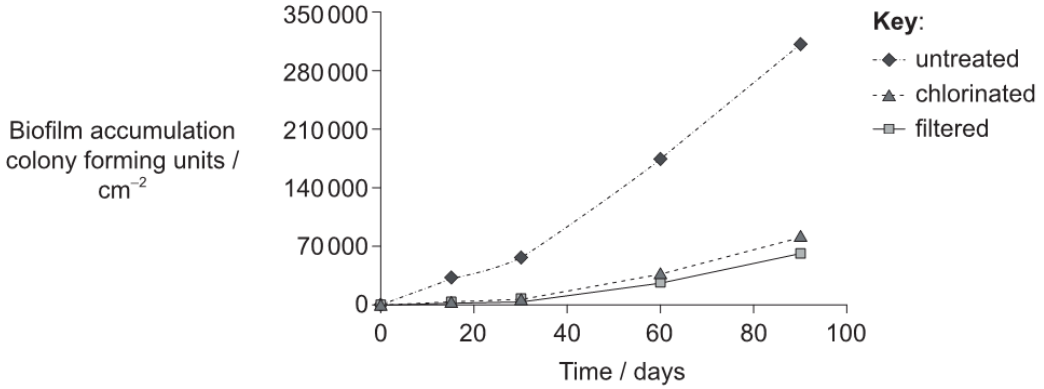
Examiners report

In e most were able to say that it was effective in removing bacteria, but few were able to spot that there was no information on how contaminated the water was beforehand or how effective it would be in removing other bacteria.

Researchers in Korea set up an experiment to measure how accumulation of biofilm changes in water pipes under different conditions.



The graph shows the accumulation of biofilm in steel pipes when the water was untreated, treated with chlorine and filtered through a membrane.



[Source: adapted from Yoonjin Lee, (2013), Journal of Environmental Research Public Health 2013, 10 (9), pages 4143 – 4160]

a. State the effect chlorination has on the accumulation of biofilm in the pipe. [1]

b. Suggest why membrane filtration may be more suitable than chlorination in purifying the water. [1]

c. Identify which **two** pipes would be required to study the effect of heat on biofilm accumulation. [1]

d. Explain how quorum sensing benefits the bacteria within the steel pipes. [2]

Markscheme

a. reduces «the accumulation of biofilm»

b. a. does not affect taste of water/no chemicals added

b. lower biofilm accumulation over time

[Max 1 Mark]

c. A and B

Both required

d. a. quorum sensing is a means of communication between bacteria

b. allows the bacteria to synchronize their activities/work together

c. they can change according to the environment/conditions in the pipe

d. control cell density/gene expression

[Max 2 Marks]

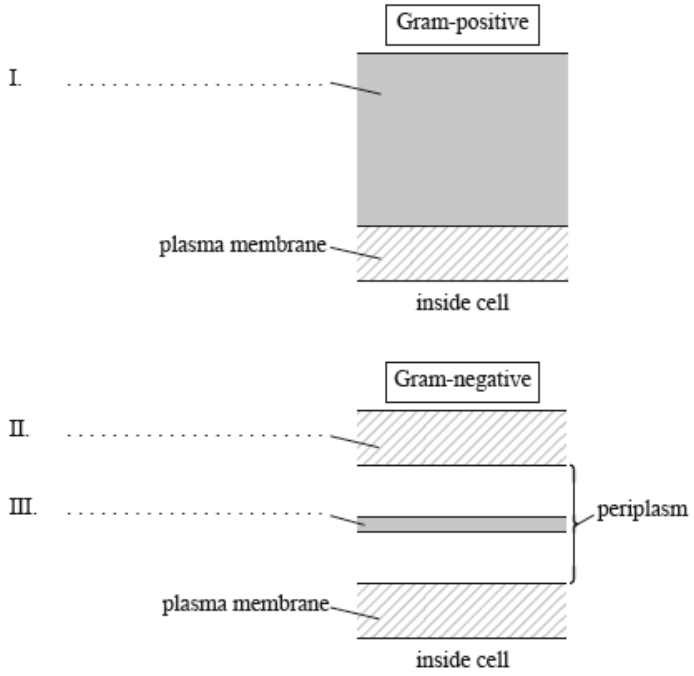
Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]

---

a. Distinguish between Archaea and Eukarya. [2]

b. Label the parts of the cell walls in Gram-positive Eubacteria and Gram-negative Eubacteria shown below. [3]



Markscheme

a. a. membrane-bound organelles present in Eukarya but absent in Archaea;

b. 70S ribosomes in Archaea whereas 80S ribosomes in (cytoplasm of) Eukarya;

c. nuclear envelope in Eukarya, not in Archaea;

d. introns are present in Eukarya but only in some genes of Archaea;

e. histone proteins present in all Eukarya but only in a few Archaea;

f. the membrane lipid structure is unbranched in Eukarya but branched in Archaea;

g. Archaea can inhabit extreme habitats while Eukarya cannot;

b. I. peptidoglycan;

II. outer membrane/layer of lipopolysaccharide and protein;

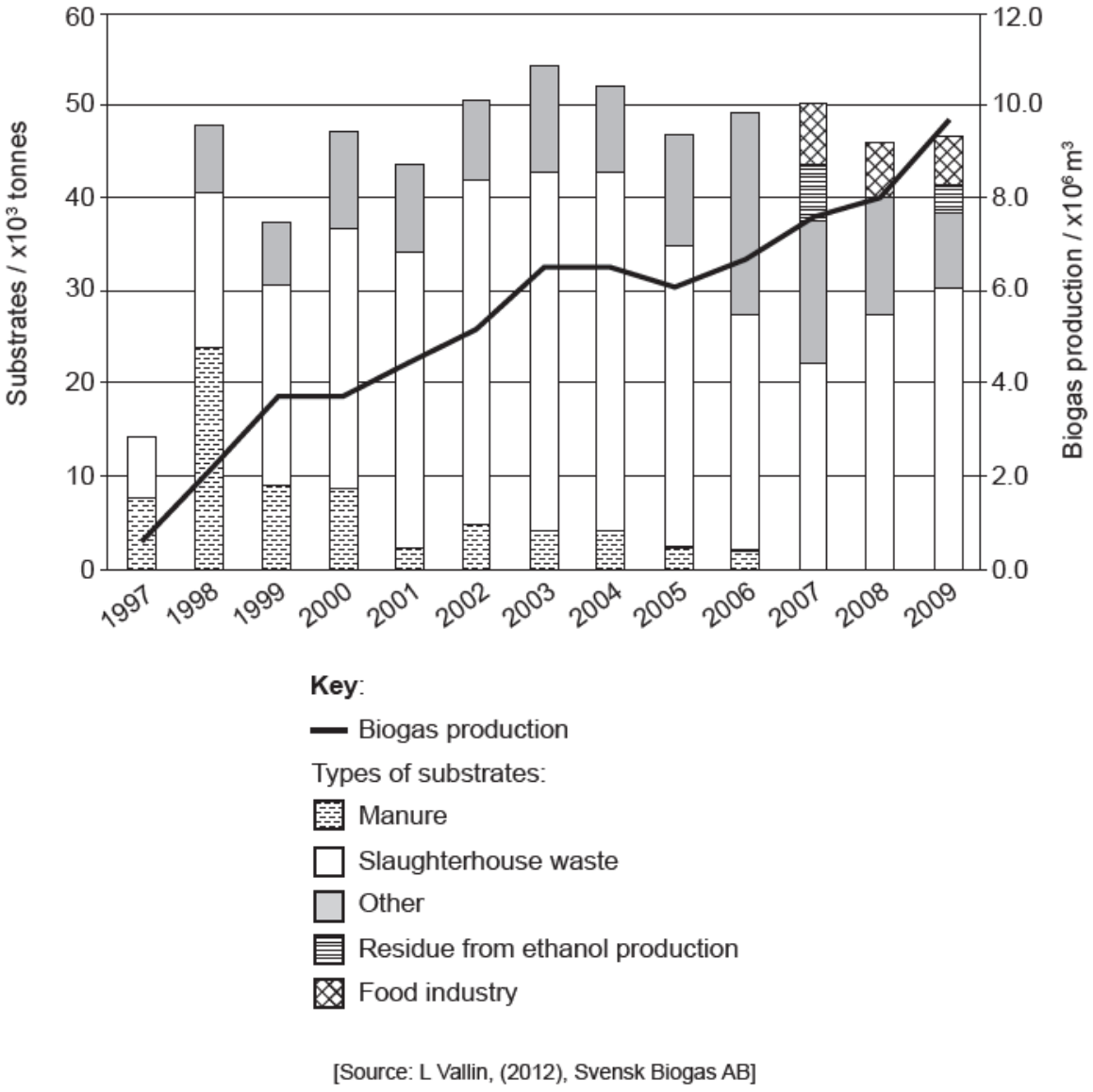
III. peptidoglycan;

Examiners report

a. Many candidates were not able to distinguish between Archaea and Eukarya. A few mentioned the different size ribosomes but that was all.

b. Labelling the part of the Gram-positive and Gram-negative cell walls was a problem as many candidates did not know the names of the layers.

The graph shows the development of biogas production and substrate utilization at Svensk Biogas (Sweden) from 1997 to 2009.



[Source: L Vallin, (2012), Svensk Biogas AB]

a.i. Biogas production in a fermenter requires a substrate. State another requirement for this process. [1]

a.ii. Suggest reasons based on the data in the graph for increases in biogas production at Svensk Biogas. [2]

b. Outline the principles of fermentation by continuous culture. [3]

Markscheme

a.i. lack of oxygen/anoxic/anaerobic conditions / acidic pH / warm temperature / methanogens / acidogenic bacteria

a.ii a. increased variety of substrates used

b. change in the proportion of substrates used
OR
from 1997 to 2004 increase in slaughterhouse waste

c. less reliance on manure/increase use from food industry

d. waste from food industry results in higher biogas yield

b. a. microbial population can be maintained in a state of exponential growth for a long time

OR

concentration of microorganisms in fermenter stable

b. «balanced growth is» maintained by keeping nutrients/medium/pH/ temperature/ oxygen level constant

c. nutrients are added AND products removed «at steady rate»

d. probes used to monitor conditions within fermenters

e. open fermentation/fermenter

Examiners report

a.i. [N/A]
a.ii. [N/A]
b. [N/A]

Freshwater invertebrates were sampled by students at three sites along a river in central France. The animals were identified and counted. The diversity of each site can be compared using Simpson's reciprocal index.

	Number of animals in the sample		
Species	**Site A**	**Site B**	**Site C**
Baetis rhodani	0	30	7
Ecdyonurus dispar	1	0	9
Ephemerella ignita	4	0	0
Limnephilus lunatus	0	0	2
Brachycentrus subnubilus	2	1	0
Polycentropus flavomaculatus	0	1	0
Rhyacophila obliterata	1	0	0
Gammarus pulex	0	1	0
Asellus aquaticus	8	0	0
Simulium equinum	17	0	0
Dexia	0	5	0
Chironomus annularis	0	0	1
Hirudinea	0	4	2
Simpson's reciprocal index	**3.09**	**1.91**	

Simpson's reciprocal index is given by the following formula:

$$D = \frac{N(N-1)}{\sum n(n-1)}$$

a. Calculate the diversity of site C. Working should be shown. [2]

b. Site A has a higher Simpson's reciprocal index than Site B showing that its diversity is higher. [2]

Explain the reason that ecologists consider Site A to have a higher diversity than Site B, despite both sites having six different species present.

c. Discuss the advantages and disadvantages of in *situ* conservation methods. [4]

Markscheme

a. a. $\frac{21 \times 20}{42+72+2+2}$

b. = 3.56 «allow 3.55»

b. a. the species in Site A are more evenly represented than site B

b. site B has a large number of one species «but very few in the other 5»

c. Simpson's reciprocal index is a measure of species evenness as well as species richness

c. *Advantages*:

a. conservation in the natural habitat / ecosystem

b. the species will have all the resources that it is adapted to

c. the species will continue to evolve in their environment / can maintain genetic diversity

d. the species have more space so a bigger breeding populations can be kept

e. it is cheaper to keep an organism in its natural habitat

f. established food webs/ species interactions can be maintained

Disadvantages:

g. it is difficult to control illegal exploitation «*eg* poaching»/harder to monitor populations

h. the area may need restoring / may be required for other purposes

i. alien species are difficult to control

j. species close to extinction are harder to conserve

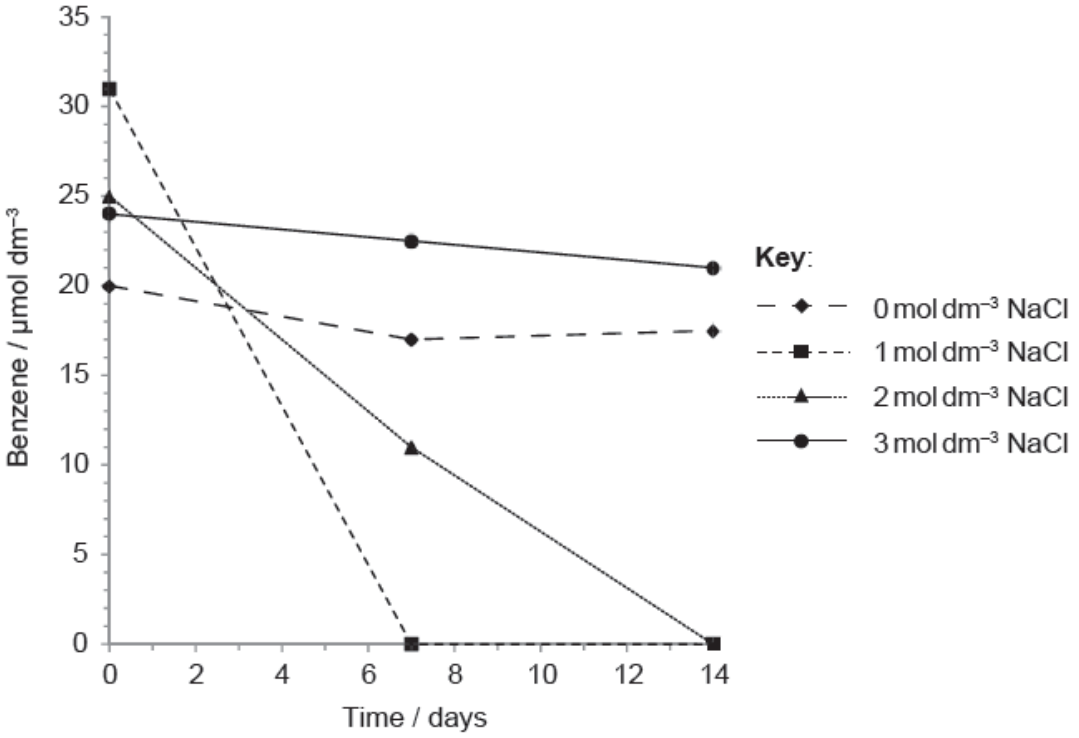
k. management/protection may represent a significant cost

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

Benzene is a cancer-causing component of crude oil. Some halophilic bacteria degrade benzene. Using a culture of bacteria obtained from an oil fi eld in the US, degradation of benzene was studied by microbiologists.

The microbiologists cultured the bacteria at different concentrations of sodium chloride (NaCl) and measured the amount of benzene left at different times.



[Source: C A Nicholson and B Z Fathepure, (2004), *Applied and Environmental Microbiology*, pages 1222–1225]

a. Determine the optimum concentration of sodium chloride for benzene degradation. [1]

b. State the genus of halophilic bacteria in the soil that could be degrading the benzene. [1]

Markscheme

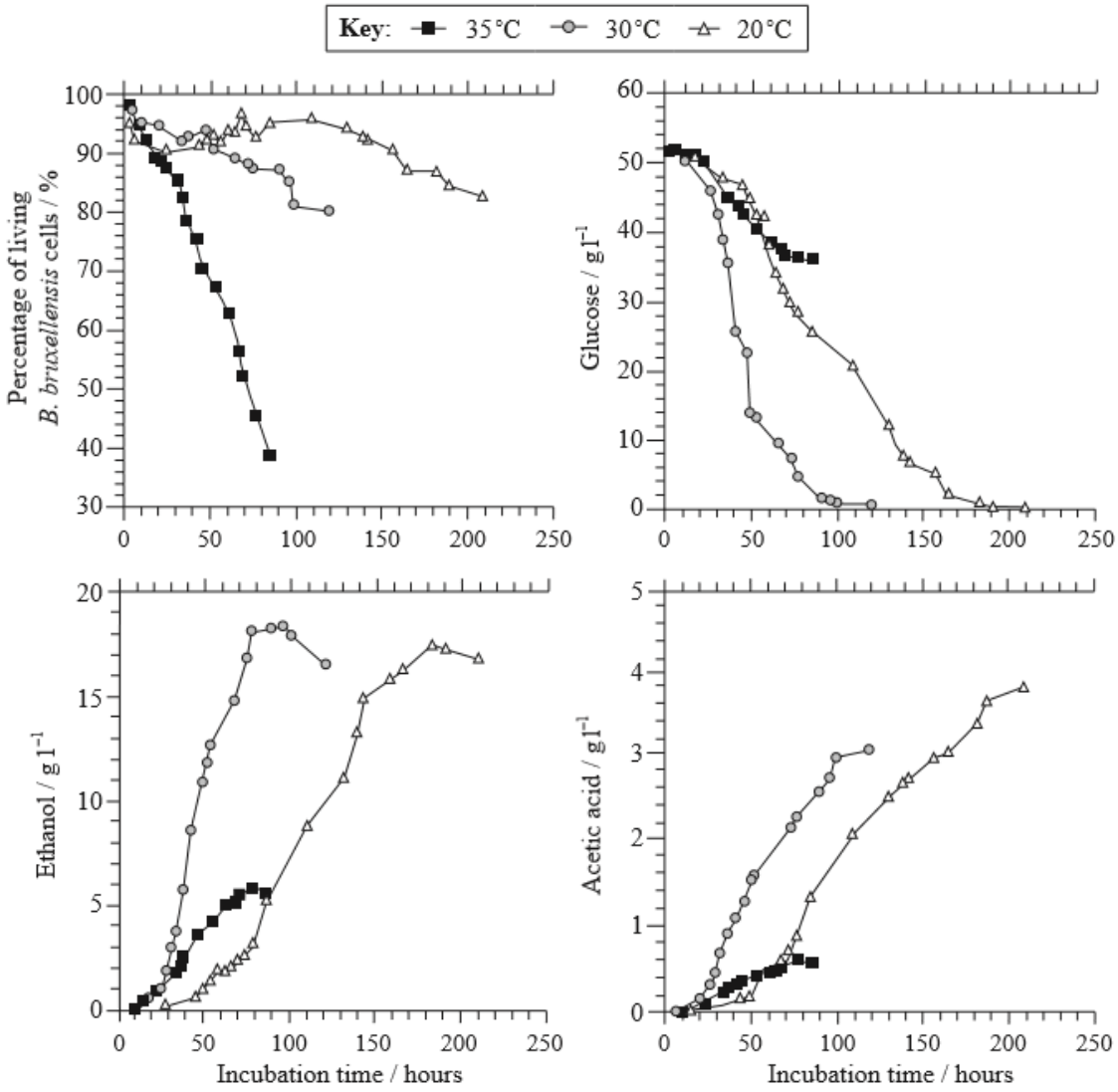
a. 1 mol dm^{-3}

b. Marinobacter

Examiners report

a. [N/A]
b. [N/A]

The yeast *Brettanomyces bruxellensis* is a contaminant of wine which when present produces acetic acid, the main component of vinegar. The presence of acetic acid can lead to economic losses as it alters the taste of the wine and inhibits the growth of *Saccharomyces cerevisiae*, thus decreasing the ethanol production. Scientists investigated the effect of changing the temperature in fermentation tanks containing only *Brettanomyces bruxellensis* and a growth medium containing glucose in order to understand the dynamics of this contaminant.



[Source: Cédric Brandam, Claudia Castro-Martínez, Marie-Line Délia, Felipe Ramón-Portugal, Pierre Strehaiano (2008) "Effect of temperature on Brettanomyces bruxellensis: metabolic and kinetic aspects", *Canadian Journal of Microbiology*, vol 54 (1), pp. 11–18 © Canadian Science Publishing or its licensors.]

a. State the concentration of glucose at 20°C after 110 hours of incubation, giving the units. [1]

b. State the effect of increasing temperature from 20°C to 30 °C on the rate of production of ethanol. [1]

c (i) Deduce one reason why there were no more rises in ethanol concentration after 120 hours at 30°. [1]

c (ii) Deduce one reason why the concentration of ethanol and acetic acid at 35°C does not rise after 80 hours despite the fact that the concentration of glucose is still high. [1]

d. Discuss the idea of producing wine using a lower temperature range to avoid economic losses due to contamination by yeasts other than *S. cerevisiae*. [3]

Markscheme

a. 20 g l^{-1} (*Accept answers from 20 to 21. Units required.*)

b. at 30 °C ethanol produced more quickly/increased rate of production/positive correlation

c (i) glucose ran out

c (ii) cells are dying / enzymes denatured

d. *Arguments against low temperature*

a. high temperatures kill *B. bruxellensis*;

b. high temperatures results in low acetic acid in wine;

c. high temperature results in low alcohol content;

Arguments for low temperature
d. rate of fermentation/use of glucose/alcohol production is higher;
e. no real arguments for low temperature as *B. bruxellensis* growth rate/acetic acid production high;

Must include at least one for and against point for full marks.

Examiners report

a. Few candidates answered this option.

In F1 the data was a challenge for students who attempted this option and responses to this section were quite poor.

b. Few candidates answered this option.

In F1 the data was a challenge for students who attempted this option and responses to this section were quite poor.

c (i) Few candidates answered this option.

In F1 the data was a challenge for students who attempted this option and responses to this section were quite poor.

c (ii) Few candidates answered this option.

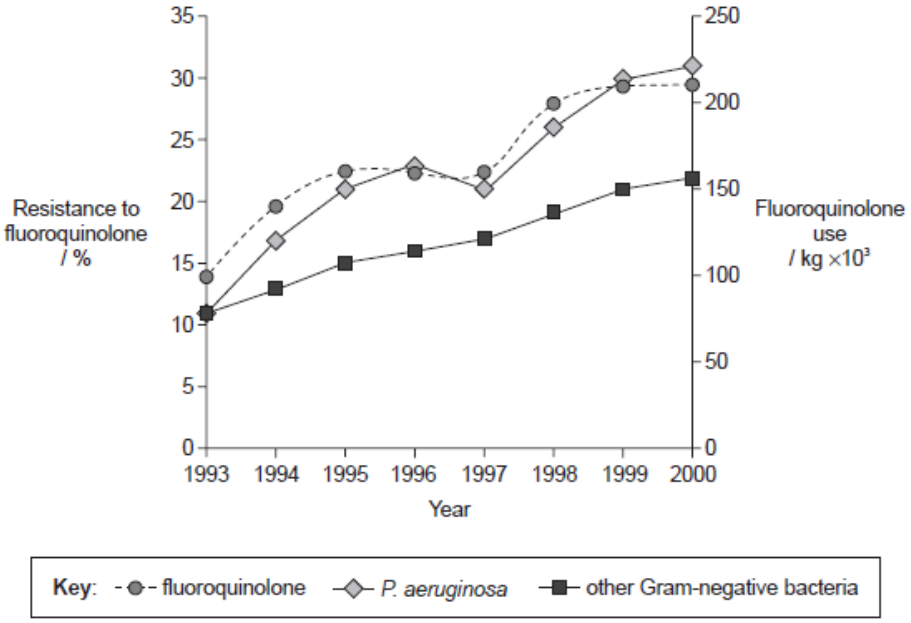
In F1 the data was a challenge for students who attempted this option and responses to this section were quite poor.

d. Few candidates answered this option.

In F1 the data was a challenge for students who attempted this option and responses to this section were quite poor.

Data on microbial resistance to the fluoroquinolone family of antibiotics was collected in US hospitals. The graph shows the relationship between

Pseudomonas aeruginosa, other Gram-negative bacteria and the use of fluoroquinolone from 1993 to 2000.



[Source: adapted from M Neuhauser, *et al.*, (2003), *Journal of the American Medical Association*, **289** (7), pages 885–888]

a. State the percentage of *P. aeruginosa* that were resistant to fluoroquinolone in 1996. [1]

b. Compare the trends in fluoroquinolone use and resistance to fluoroquinolone in other Gram-negative bacteria between 1993 and 2000. [2]

c. Predict the results if data from the same hospitals were collected for *P. aeruginosa* resistance in 2001. [1]

d. Discuss the implications of the data in the graph for the health of patients. [3]

Markscheme

a. 23 (%)

Accept answer in the range of 22(%) to 24 (%).

b. a. positive correlation / other Gram-negative bacteria resistance increases as fluoroquinolone use increases;

b. other Gram-negative bacteria continues to increase / slight decrease of fluoroquinolone use (in 1997);

c. from 1998, other Gram-negative bacteria resistance continues to rise even though fluoroquinolone use starts to level off/decreases;

c. *P. aeruginosa* resistance would increase (slightly)/level off

d. a. there is rising incidence of antibiotic/fluoroquinolone-resistant *P. aeruginosa*/ other Gram-negative bacteria;

b. use of antibiotics/fluoroquinolone is increasing/becoming less effective;

c. careful use of antibiotics/fluoroquinolone is recommended;

d. other antibiotics (that do not promote resistance) need to be developed;

e. continued monitoring of the situation is needed;

f. less chance of treating the disease / more severe symptoms / more people with the disease;

Examiners report

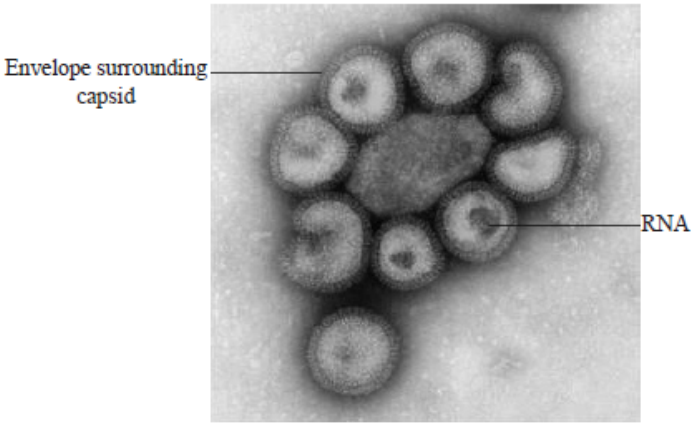
a. Most got all marks.

b. Most got all marks.

c. Most got all marks.

d. Discriminated well with most candidates scoring at least 1 mark and the better candidates scoring all 3.

The electron micrograph below shows a pathogen.



[Source: Professor Frederick A Murphy (University of Texas Medical Branch). Reprinted with permission.]

a. Identify the type of pathogen shown in the electron micrograph, giving reasons for your answer. [2]

b. Outline the use of viral vectors in gene therapy. [3]

Markscheme

a. virus;

protein coat;

RNA/riboprotein;

b. removal of white blood cells / bone marrow cells;

using a vector; insert gene into chromosome;

cells are replaced in the body of the patient;

the normal gene can be expressed;

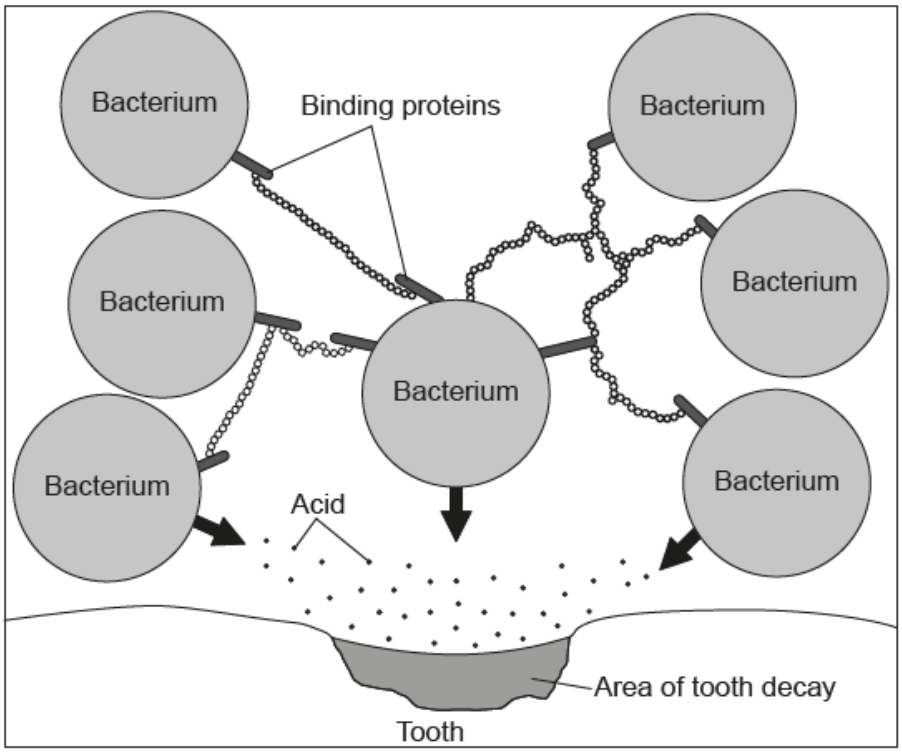
e.g. SCID where the replaced gene allows for the production of ADA/Adenosine deaminase;

Examiners report

a. Candidates could successfully state which pathogen was shown, but few gave correct reasons.

b. Candidates either answered this correctly or did not answer it at all.

The diagram shows a biofilm that has formed on a tooth.



[Source: © International Baccalaureate Organization 2017]

Using the diagram, explain the concept of emergent properties of biofilms.

Markscheme

a. «in biofilms» bacteria exhibit «emergent» properties not predictable from the individual components of the system

OR

biofilm exhibits its own properties, quite different in comparison with those shown by the single species

b. biofilms form when bacteria adhere to surface of tooth and begin to excrete an EPS/extracellular polymeric substances/exopolysaccharides

c. formation of EPS maintains bacteria together «in biofilm»

d. interspecies relationships are favourable
OR
one species produces growth factors for/facilitates attachment of another species

e. individual forces are low but the overall binding force can exceed that of covalent bonds

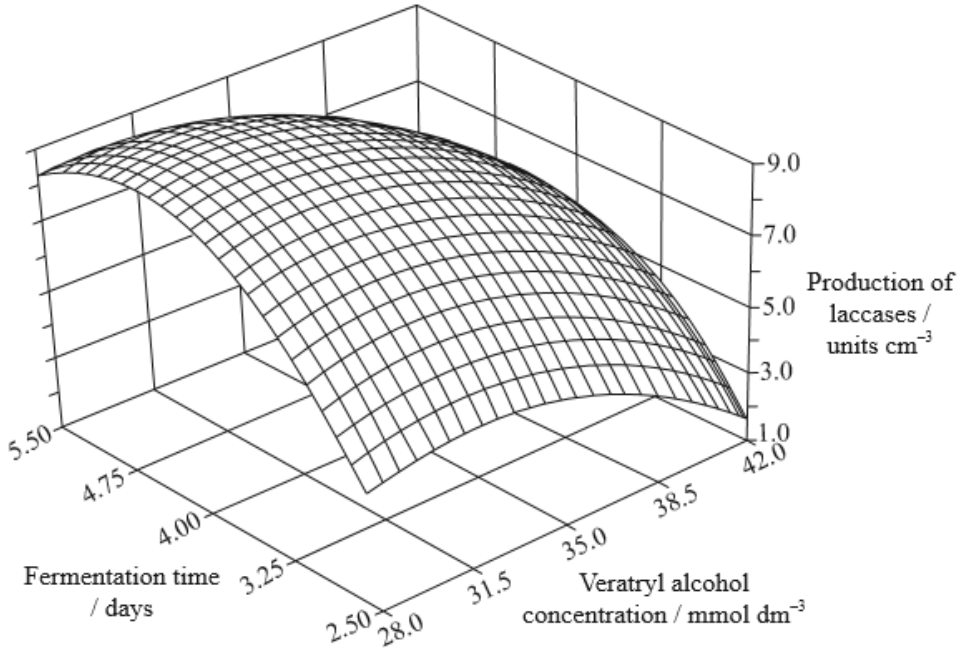
f. glue properties/cohesiveness given by different types of bonding

g. biofilms show resistance to antibiotics/other pathogen

Examiners report

[N/A]

Fungi of the genus *Botryosphaeria* have been found to produce certain oxidizing enzymes, laccases, that are effective in treating contaminated water and soils. Studies were undertaken to test the effects of veratryl alcohol concentrations and fermentation time in order to optimize the industrial production of laccases. Statistical analysis of the data was used to develop the graph below.



a (i) Identify the amount of laccases produced when the veratryl alcohol concentration is at its highest level and the fermentation time is at its shortest. [1]

a (ii) Identify the amount of laccases produced when the veratryl alcohol concentration is at its lowest level and the fermentation time is at its longest. [1]

b. Analyse the overall effects of the veratryl alcohol concentration and fermentation time on the production of laccases. [3]

c. Deduce from the graph the optimal conditions for maximizing the biotechnological production of laccases. [2]

Markscheme

a (i) 1.6 (units) cm^{-3} (*accept answers in the range of 1.5 units cm^{-3} and 1.7 units cm^{-3}*)

a (ii) 8.3 (units) cm^{-3} (*accept answers in the range of 8.2 units cm^{-3} and 8.4 units cm^{-3}*)

b. as fermentation time increases laccase production rises then falls; (*accept converse*)

as veratryl alcohol concentration increases laccase production rises then falls; (*accept converse*)

optimum fermentation time is 4.75/5.0/5.25 days; (*accept converse*)

most laccase overall with low veratryl alcohol concentration and long fermentation; (*accept converse*)

optimum veratryl alcohol concentration is 33/34/35 mmol dm^{-3};

fermentation time has greater effect than veratryl alcohol concentration;

c. the best time for fermentation appears to be 4.75 days; (*allow 4.75 to 5.25 days*)

with a veratryl alcohol concentration of 33 mmol dm^{-3} / moderate veratryl alcohol concentration; (*allow 33 to 35 mmol dm^{-3}*)

Examiners report

a (i) F1 (a) was challenging for candidates as they appeared to find the data was very difficult to interpret, though candidates were only required to interpret it in two dimensions. Despite the small numbers taking this option, there were more complaints from teachers about this part of the exam than any other.

a (ii) F1 (a) was challenging for candidates as they appeared to find the data was very difficult to interpret, though candidates were only required to interpret it in two dimensions. Despite the small numbers taking this option, there were more complaints from teachers about this part of the exam than any other.

b. N/A

c. N/A

One method of inserting new genes into plants is by gene gun.

[Source: adapted from www.genomicon.com]

a. Outline how a gene gun inserts genes into plants. [2]

b. Marker genes are often inserted together with the new gene. State the function of the marker genes. [1]

c. Outline the characteristics of an open reading frame. [2]

d. Explain, using an example, how gene transfer to a plant could help increase crop yield. [3]

Markscheme

a. a. metal/tungsten/gold/bullet is coated with DNA/gene

Biolistics on its own not accepted.

b. «this DNA is» fired in to a leaf containing the target cells

Accept any plant part, plant suspension, etc.

c. DNA is released and incorporated in to some of the cells

b. marker genes can be detected easily and show the gene has been inserted

Allow a specific example (eg, green fluorescent protein).

c. a. a length of DNA that codes for a polypeptide/protein

OR

length of DNA that can be translated

b. begins with start codon/TAC/ATG/DNA for methionine

c. stop codon occurs after sufficient length *OWTTE.*

d. a. name of GM plant *eg: Soybean.*

b. source of the inserted gene *eg: (Cry1Ac gene) from Bacillus thuringiensis.*
OR
organism used for transfer *eg: plasmid from Agrobacterium tumefaciens.*

c. purpose of the transfer *eg: increased resistance to glyphosate herbicide.*

d. how it increases yield *eg: reduced competition with weeds killed by glyphosate.*

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]

The photograph shows apparatus used to culture microorganisms in order to produce a metabolite.

[Source: adapted from www.medicalexpo.com]

a. State the general term for the reaction, involving microorganisms, that takes place in the apparatus shown. [1]

b. Other than temperature and pH, state **one** variable that should be monitored during continuous culture in the apparatus shown. [1]

c. State the binomial name of an organism used in continuous culturing to produce citric acid used as a preservative. [1]

Markscheme

a. Fermentation

b. O_2 «uptake»

CO_2 «production»

Cell density

Pressure

Speed of stirrer

Quantity of nutrients/substrate/named nutrient

c. *Aspergillus niger*

Complete genus and species name is required.

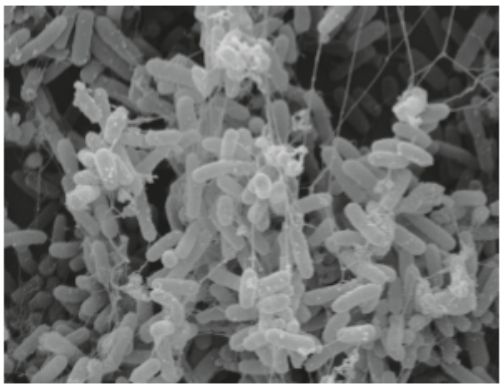
Examiners report

a. Fairly well answered by the few candidates attempting this option.

b. Fairly well answered by the few candidates attempting this option.

c. Fairly well answered by the few candidates attempting this option.

Cooperative aggregates of microorganisms can form biofilms. The micrograph shows a biofilm of *Escherichia coli*.



[Source: Brigit Pruess for North Dakota State University]

a. Outline the emergent properties of biofilms. [2]

b. Explain **two** ways in which bacteria of the genus *Pseudomonas* can be used for bioremediation. [4]

Markscheme

a. a. the properties of the biofilm are greater than the sum of their individuals

b. the properties are not predictable from looking at the individual

c. quorum sensing

d. adhere to a variety of substances

e. resistant to antibiotics / antimicrobial

f. formation of EPS

Cooperative aggregates on its own is not accepted.

b. *award **[2 max]**:*

a. oil spills

b. oil is used as an organic source by the bacterium
OR
the bacterium changes the crude oil into less harmful substances

*award **[2 max]**:*

c. mercury from paint/fluorescent lights can leak into soil/water
OR
can form methyl mercury which travels along food chain/bioaccumulation

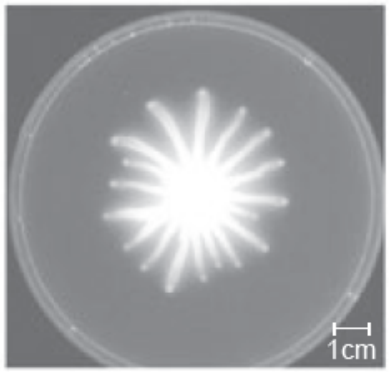
d. bacteria can remove methyl group from the methyl mercury/reduces toxicity

Allow other verified examples that include the danger to the environment (problem) and how the bacterium improves the situation (solution).

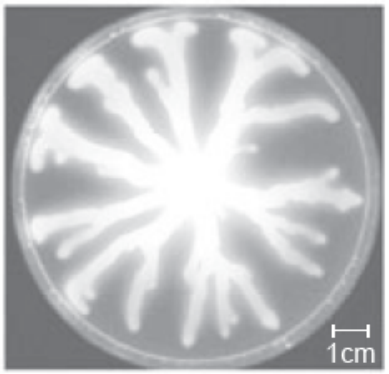
Examiners report

a. [N/A]
b. [N/A]

Korean microbiologists tested the effect of ginger root (*Zingiber officinale*) extracts on biofilm formation by the bacterium *Pseudomonas aeruginosa*. Formation of a biofilm prevents the bacteria from spreading. These bacteria were cultured on plates of agar and the results after 24 hours of growth are shown in the photographs below.



Control



1% ginger root extract

[Source: Han-Shin Kim and Hee-Deung Park (2013) Ginger Extract Inhibits Biofilm Formation by Pseudomonas aeruginosa PA14. *PLOS ONE*, September, 8(9). https://doi.org/10.1371/journal.pone.0076106.]

a. Evaluate the effect of 1 % ginger root extract on biofilm formation. [3]

b. Outline the importance of avoiding biofilm formation in pipes carrying drinking water. [2]

Markscheme

a. a. bacteria spread out further with ginger/more than twice the distance with ginger/more spreading with ginger

b. more spreading means less biofilm formation

c. biofilms are usually made up of many species
OR
only tested the effect of ginger on one species

d. only tested over 24 hours

e. only tested with agar substrate/other substrates may have different effects

b. a. biofilms reduce flow rate in pipes

b. contamination of the drinking water supplies by biofilm microbes

c. biofilms may cause corrosion of pipes

Examiners report

a. [N/A]
b. [N/A]

The picture shows workers cleaning up a polluted stretch of coastline in Alaska after oil was leaked from a tanker.

[Source: https://commons.wikimedia.org/wiki/File:OilCleanupAfterValdezSpill.jpg] (https://commons.wikimedia.org/wiki/File:OilCleanupAfterValdezSpill.jpg])

Explain how oil pollution can be treated by bioremediation.

Markscheme

a. bioremediation is the use of organisms to remove «or neutralize» pollutants

b. Pseudomonas species used in bioremediation of oil

c. oil biodegrades naturally at a very slow rate

d. bioremediation increases the rate that the oil breaks down

e. microorganisms feed/get energy from the oil

f. break the oil down into smaller nontoxic molecules

Accept other valid microorganism

[Max 4 Marks]

Examiners report

[N/A]