2017 Bacteria and Viruses STQ

2017 / H2 / ACJC PRELIM / P2 Q8 (BE)

1 Speciation events have been observed to occur very frequently in bacteria. It was suggested that the high rate of speciation is due to the high level of variation in bacteria.

(a) Transformation and conjugation are two processes which increase the level of variation in bacteria.

Distinguish these two processes.

[3]

Bacterial evolution is one of the most dynamic and exciting areas in current biological research.

Over the years, a barrier in this field of research is the difficulty in classifying bacterial species. However, in recent times, new analytical tools in molecular biology have offered new insights into the classification of bacterial species.

(b) (i) Suggest why scientists had difficulties in the classification of bacterial species.

[2]

(ii) Explain how analytical molecular tools have helped overcome this barrier in research.

[2]

(c)

The outer layers of the two types of bacteria with peptidoglycan cell walls known as Gram-positive and Gram-negative bacteria are shown in Fig. 8.1 below.

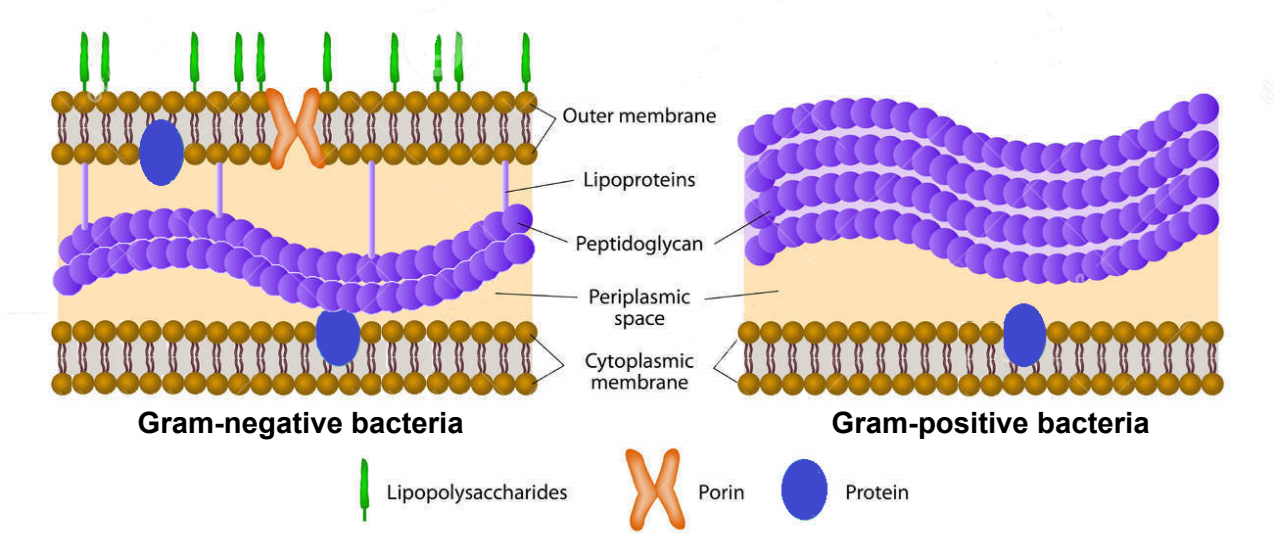

Fig. 8.1

Penicillin is an antibiotic that is known to be effective against only one of the two types of bacteria above.

With reference to the information given and your own knowledge, deduce which type of bacteria is susceptible to the action of penicillin and explain why.

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..... [3]

(d)

Explain how antibiotic-resistant bacteria can become increasingly common in a population of bacteria.

[4]

[Total: 14 m]

2017 / H2 / AJC PRELIM / P2 Q5

2 Fig. 5.1 represents a bacteria DNA and a eukaryotic chromosome in metaphase of mitosis, not drawn to scale.

Fig. 5.1

(a) State **two** ways in which the organization of genes found in these two structures differ and suggest **one** advantage of this to the bacterium.

[3]

(b) In 1946, Joshua Lederberg and Edward Tatum proposed that bacterial cells undergo genetic recombination. To test their hypothesis, they conducted experiments using two bacteria strains of *Escherichia coli (E.coli*), A and B, with different nutritional requirements.

Strain A, B and a mixture of both strains were grown on culture plates containing minimal medium that does not contain essential amino acids. The results are shown in Fig. 5.2.

Mutant genes (–) do not code for enzymes that synthesize amino acids. Note that all five amino acids are required for bacterial growth.

Bacterial strains	Genes for biosynthesis of amino acids	Mutant genes for biosynthesis of amino acids
A	thr^+ leu^+ thi^+	met^- bio^-
B	met^+ bio^+	thr^- leu^- thi^-

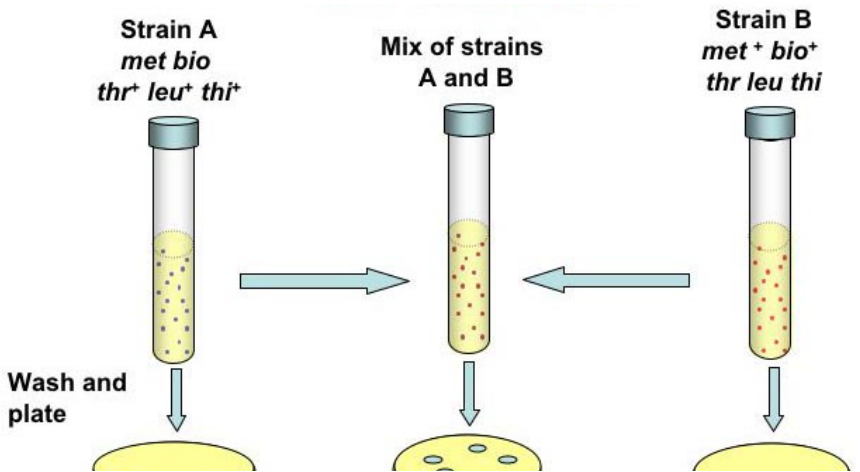

Fig. 5.2

Another researcher, Bernard Davis also worked with the same hypothesis. In his experiment he constructed a U-tube in which the two arms were separated by a fine filter. The pores of the filter were too small to allow bacteria to pass through but large enough to allow easy passage of the fluid medium, any dissolved substances and free DNA. The results are shown in Fig. 5.3.

Fig. 5.3

(i) Using the results of the two experiments shown in Fig. 5.2 and Fig. 5.3 and your understanding of genetic recombination in bacteria, state the genetic recombination that has taken place between Strain A and B. Explain your answer.

[6]

(c) In 2016, a pathogenic strain of *E.coli* found on unwashed salad caused food poisoning in 151 people in Britain, leaving two of them dead.

Describe how such pathogens are usually treated using a named example.

[3]

[Total: 12 m]

2017 / H2 / CJC PRELIM / P2 Q8 (ETA)

3 Transpeptidase is a bacterial enzyme that cross-links cell wall peptides during the formation of bacterial cell walls. The antibiotic penicillin inhibits the activity of transpeptidase. Fig. 8.1 shows part of each of the molecular structures of a cell wall peptide and penicillin.

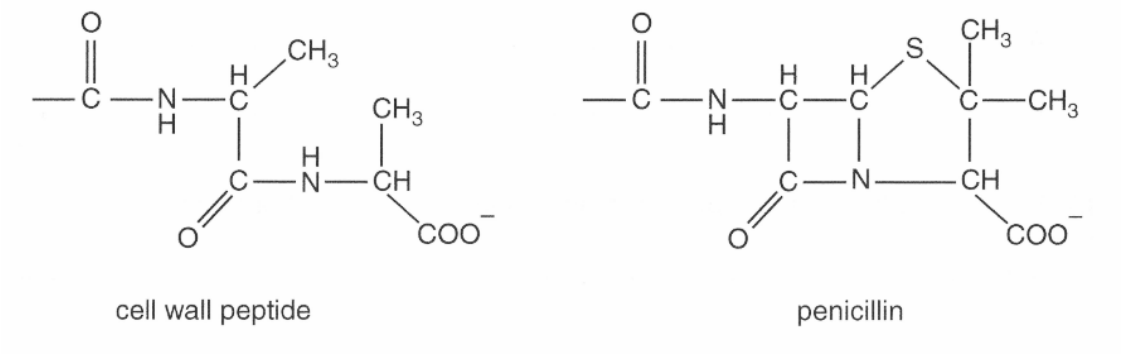

Fig. 8.1

(a) Comment on the structure of cell wall peptides and penicillin.

……[1]

(b) Suggest why the penicillin molecule is an effective inhibitor of transpeptidase.

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……[2]

(c) Fig.8.2 shows an electron micrograph of an alveolar macrophage isolated from a tuberculosis patient.

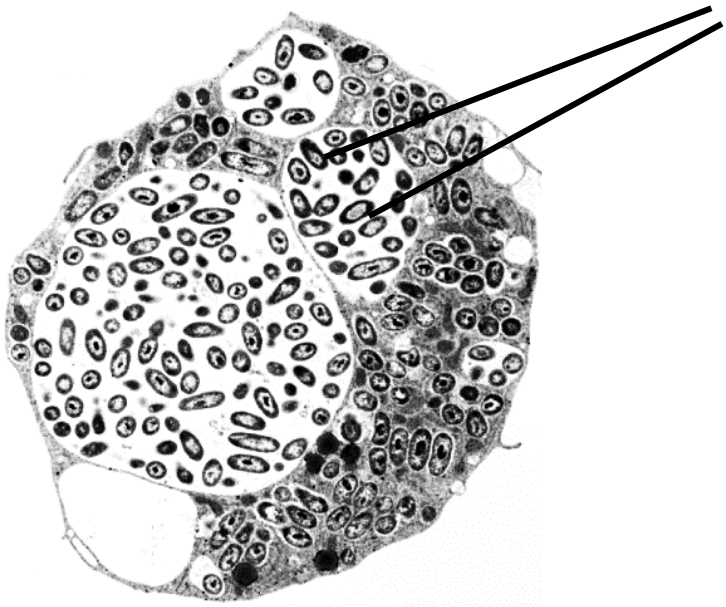

Fig. 8.2

(i) Describe the mode of transmission of Mycobacterium tuberculosis.

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[1]

(ii) Explain the appearance of the alveolar macrophage in Fig. 8.2.

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……[2]

(d) Tuberculosis patients are commonly treated with antibiotics, isoniazid and rifampicin. Recently, there is an increase in number of multi-drug resistant tuberculosis cases.
State **one** reason why multi-drug resistant tuberculosis continues to emerge.

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[1]

[Total 7]

Question 4

A student wanted to introduce ampicillin resistance gene (Amp^R) to a strain of bacteria. **Fig. 4.1** shows a drawing done by the student to summarize his experimental procedure and expected results.

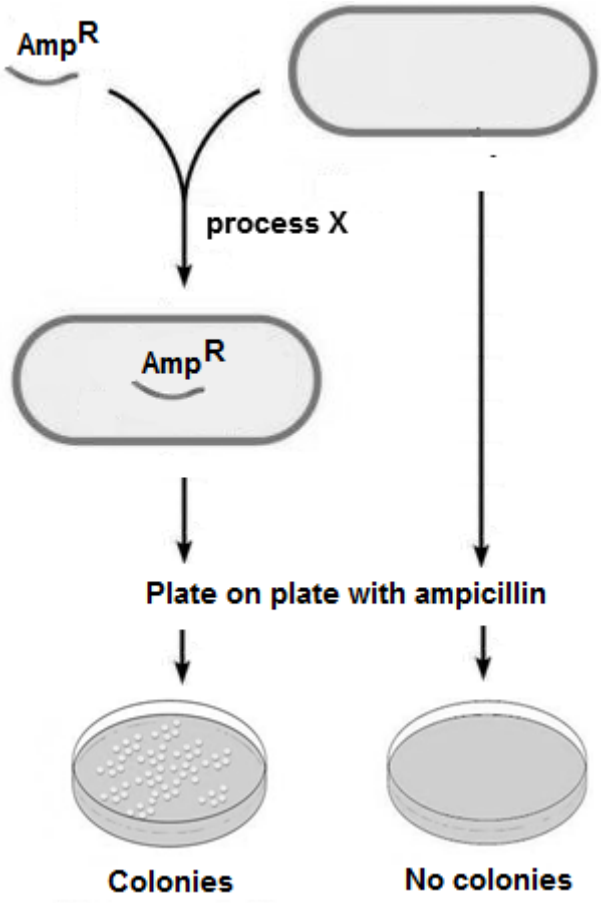

Fig. 4.1

(a) (i) What is process **X**? [1]

(ii) What is the significance of the plate with no colonies? [2]

(iii) When the student carried out the experiment, he did not obtain any colonies on either plates. Explain why. [1]

In bacteria, genes coding for enzymes involved in the same metabolic pathway are arranged into operons. **Fig. 4.2** shows the changes in the concentration of enzymes that synthesise tryptophan and utilise lactose in a bacteria cell after the addition of tryptophan and lactose.

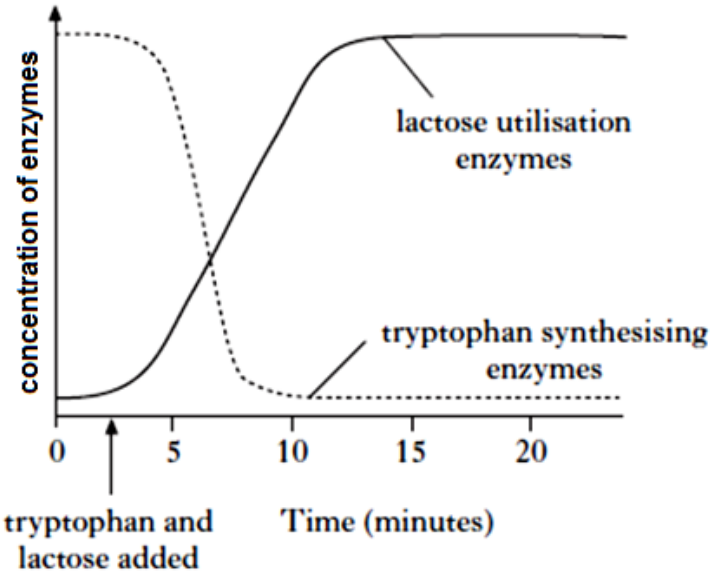

Fig. 4.2

(b) (i) Describe the difference in the shape of the graph after the introduction of tryptophan and lactose. [2]

(ii) Explain the change in concentration of tryptophan synthesizing enzyme after the introduction of tryptophan. [3]

(c) Name one lactose utilisation enzyme and suggest why the bacteria cells maintain some of this enzyme before the introduction of lactose? [2]

Total: [11]

2017 / H2 / JJC PRELIM / P2 Q3

5 Antibiotic resistance is rising to dangerously high levels in all parts of the world. A growing list of infections – such as pneumonia, tuberculosis, blood poisoning and gonorrhoea – are becoming harder, and sometimes impossible, to treat as antibiotics become less effective.

Some bacteria are naturally resistant to certain types of antibiotics. However, bacteria may also become resistant either by a genetic mutation or by acquiring resistance from another bacterium.

(a) Outline the process of how a bacterium is able to acquire resistance from another bacterium. [3]

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More than 2 million Americans each year are infected by antibiotic-resistant bacteria, and at least 23,000 die annually from those infections. Antibiotic-resistant bacteria have become a global health crisis and alternative treatments such as Phage Therapy are being considered for combating bacterial infections.

Phage Therapy involves the targeted application of bacteriophages that, upon encounter with specific pathogenic bacteria, can infect and kill them. Phages are currently being used therapeutically to treat bacterial infections that do not respond to conventional antibiotics.

Fig. 3.1 is an electron micrograph showing a phage infecting a bacterium during Phage Therapy.

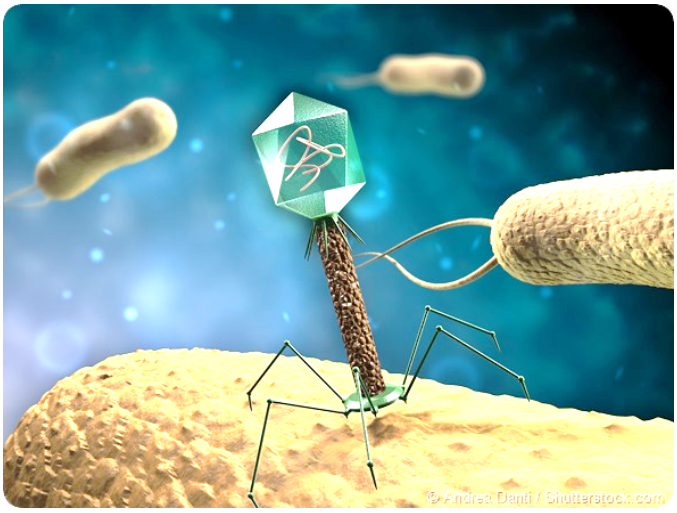

Fig. 3.1

(b) Suggest the reproductive cycle of a phage used for Phage Therapy. [1]

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(c) Describe how a structural feature of the phage allows for targeted application to specific pathogenic bacteria. [2]

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(d) Explain how the use of phages can prevent the spread of bacterial infection. [2]

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(e) Suggest characteristics of phages that make them attractive therapeutic agents. [2]

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[Total: 10]

2017 / H2 / MJC PRELIM / P2 Q5

QUESTION 6

In May 2014, the Middle East respiratory syndrome coronavirus (MERS-CoV), which was first reported in Saudi Arabia in 2012, infected two Americans who travelled to Saudi Arabia.

Coronaviruses are enveloped RNA viruses that infect and cause lower respiratory tract disease in a broad array of animals and humans. Virus particles range from 70 to 120 nm in diameter and are surrounded by characteristic spike-shaped glycoproteins, as shown in Fig. 5.1. Coronaviruses contain the largest single-stranded, positive-strand RNA genomes currently known, which range from 25.5 to nearly 32 kb in length.

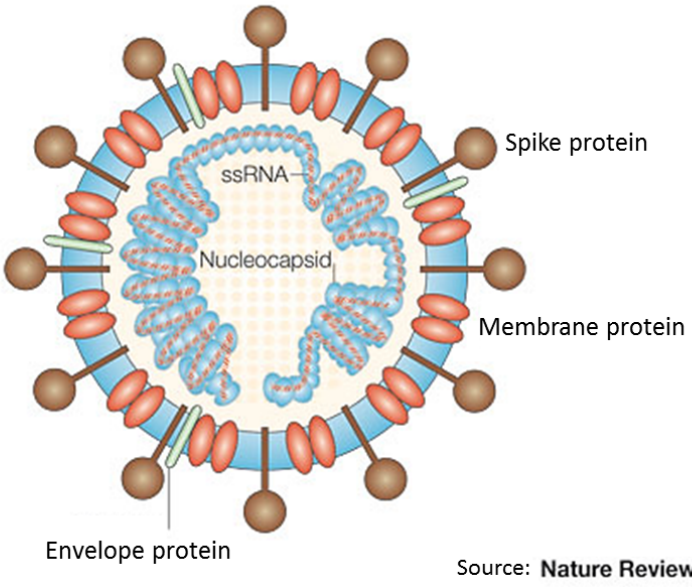

Fig. 5.1

(a) Describe **two** structural differences between the genome of the coronavirus and the influenza virus. [2]

1. ……..

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2. ……..

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(b) Describe how the coronavirus enters its host cell. [3]

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(c) Describe the process which allows the coronavirus to infect a *broad array of animals and humans* overtime. [2]

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(d) Unlike the human immunodeficiency virus, the coronavirus genome is not integrated into its host DNA.

Suggest how the coronavirus produces more copies of its genome. [2]

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(e) The fatality rate of coronavirus infections is approximately 60%.

Briefly explain how the coronavirus can cause death in humans. [1]

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[Total: 10]

2017 / H2 / MJC PRELIM / P2 Q6

QUESTION 7

(a) Fig. 6.1 is an electron micrograph of a process that bacterial cells undergo which results in the formation of two daughter cells.

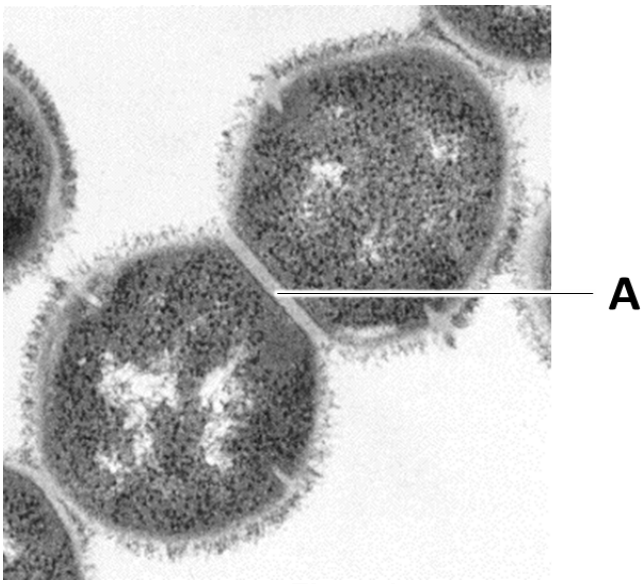

Fig. 6.1

(i) Name the process above and state the main component making up structure **A**. [1]

Process …….

*Component making up Structure **A*** …….

(ii) "*The process above will always produce two genetically identical daughter cells"*.

Comment on the validity of this statement. [1]

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(b) The *xyl* operon is a catabolic operon involved in the breakdown of the sugar xylose. Fig. 6.2 shows how a *xyl*-*lac* fusion operon is constructed, which consist of 2 structural genes from *lac* operon, regulatory sequences and the regulatory gene of the xylose operon. The arrows indicate the direction of transcription.

To test its effects, the fusion operon was constructed and packaged into bacteriophages. The fusion operon was then inserted into the chromosomes of these bacterial cells upon infection.

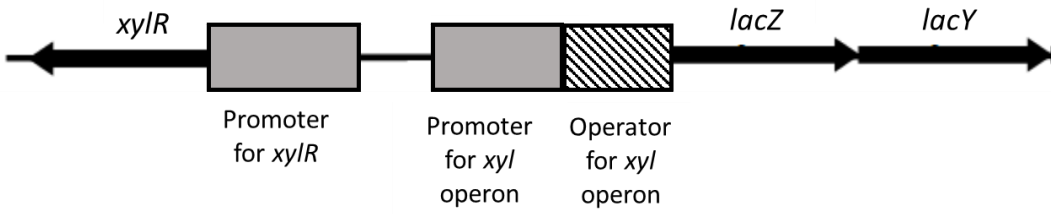

Fig. 6.2

(i) State the process of this gene transfer. [1]

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(ii) Suggest and explain one advantage of the process stated in **(i)** over transformation in bacteria. [2]

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(iii) Explain the condition required for *lacZ* gene to be expressed in bacteria cells in which the *xyl*-*lac* fusion operon has been introduced. [3]

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(iv) Suggest why the direction of transcription of the regulatory and structural genes may differ. [2]

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(c) Colibacillosis is a fatal condition caused by *E. coli* in poultry. In a study to examine the effectiveness of bacteriophages in treating colibacillosis, broiler chickens were first subjected to an aerosol spray containing bacteriophages *on day 0*. They were then separated into five treatment groups. Each treatment group was subsequently injected with *E.coli* on days 0, 1, 2, 3 and 4 respectively. The mortality rate for each treatment group was determined after 21 days. The result of the study is represented by Fig. 6.3 below.

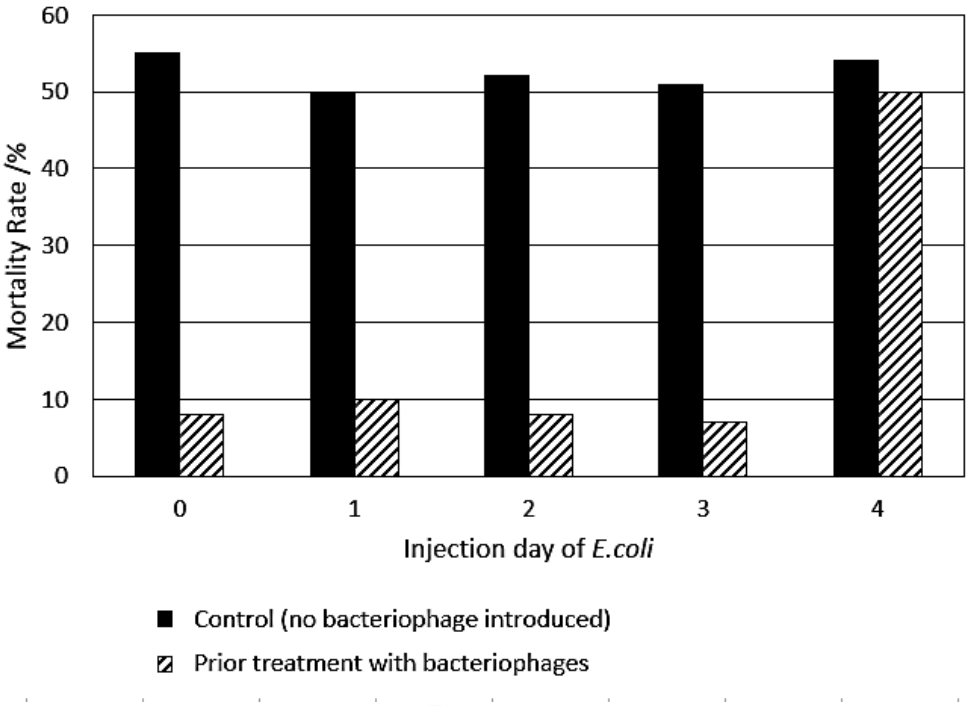

Fig. 6.3

With reference to Fig. 6.3 above,

(i) Compare the trends observed in the control group and the groups that have been treated with bacteriophages, and comment on the effectiveness of such treatment. [3]

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(ii) Suggest why the use of bacteriophages is a better alternative to antibiotic therapy for the chickens. [1]

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[Total: 14]

2017 / H2 / NYJC PRELIM / P2 Q8

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2
3
4
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6
7

8 *Morbillivirus* causes measles. The structure of *Morbillivirus* is shown in **Fig. 4**.

Haemagglutinin (H) and fusion protein (F) are glycoproteins embedded in the viral envelope.

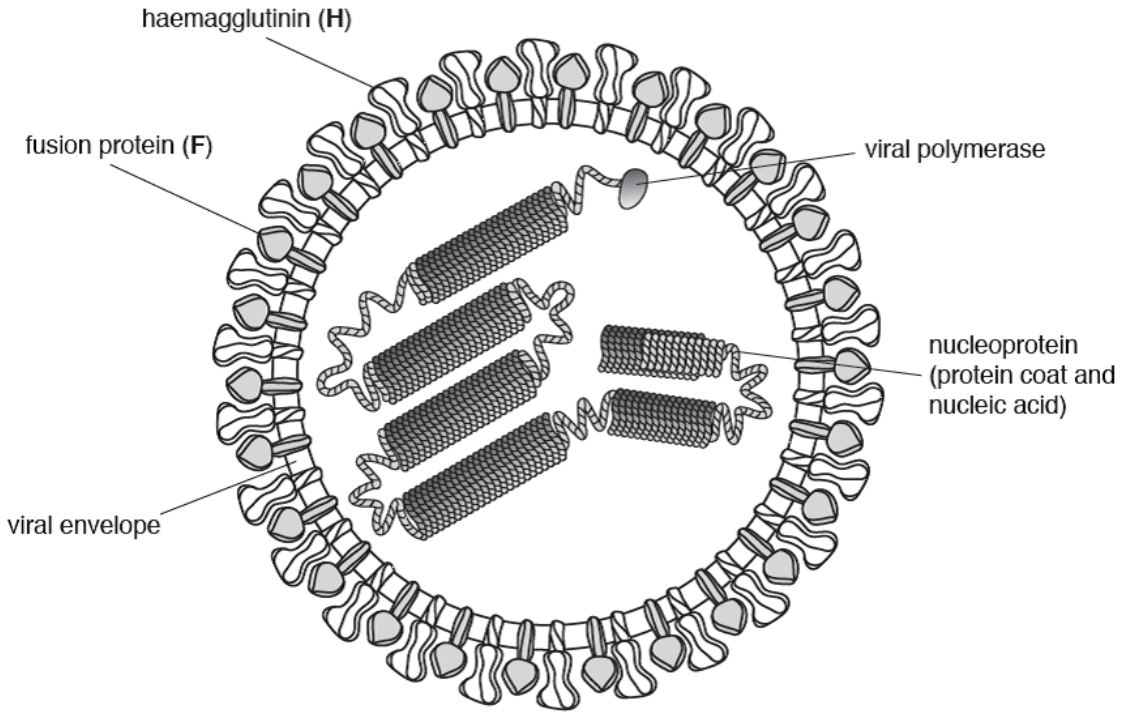

Fig. 4

Morbillivirus only infects cells that have a membrane glycoprotein known as signalling lymphocyte activation molecule (SLAM).

When *Morbillivirus* infects a cell, **H** acts before **F**. After the virus binds to the host cell, only the nucleoprotein with the viral polymerase enters the host cell and the virus is replicated.

Morbillivirus replicates its genetic material in the same manner as influenza virus.

New viral particles leave the host cell by budding from the cell surface membrane of the cell.
This forms the main part of their envelope.

(a) List two ways in which the structure of *Morbillivirus*:

(i) is similar to HIV

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[2]

(ii) differs from the HIV

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[2]

(b) With reference to **Fig. 4.1** and the information provided,

(i) suggest how *Morbillivirus* infects a cell with SLAM glycoproteins so that only nucleoprotein and viral polymerase enter.

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[2]

(ii) suggest the role of viral polymerase in *Morbillivirus*.

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[3]

(c) Measles has only one serotype. Within this serotype, there are 24 genotypes recognised to date.

Describe how these 24 genotypes could have arisen.

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[2]

[Total: 11]

2017 / H2 / RI PRELIM / P2 Q7

8 *Streptococcus pyogenes* bacteria causes a range of diseases including skin infections and respiratory illnesses. Treatment of the diseases is carried out using antibiotics such as penicillin and erythromycin.

In 1988, a nation-wide movement to reduce the use of the antibiotic erythromycin to treat patients infected with *S. pyogenes* was started in Finland.

Fig. 7.1 shows the number of doses of erythromycin used per thousand people per month, over a period of eleven years from 1984 to 1994. The figure also shows the percentage of infections each year caused by erythromycin-resistant strains of *S. pyogenes*.

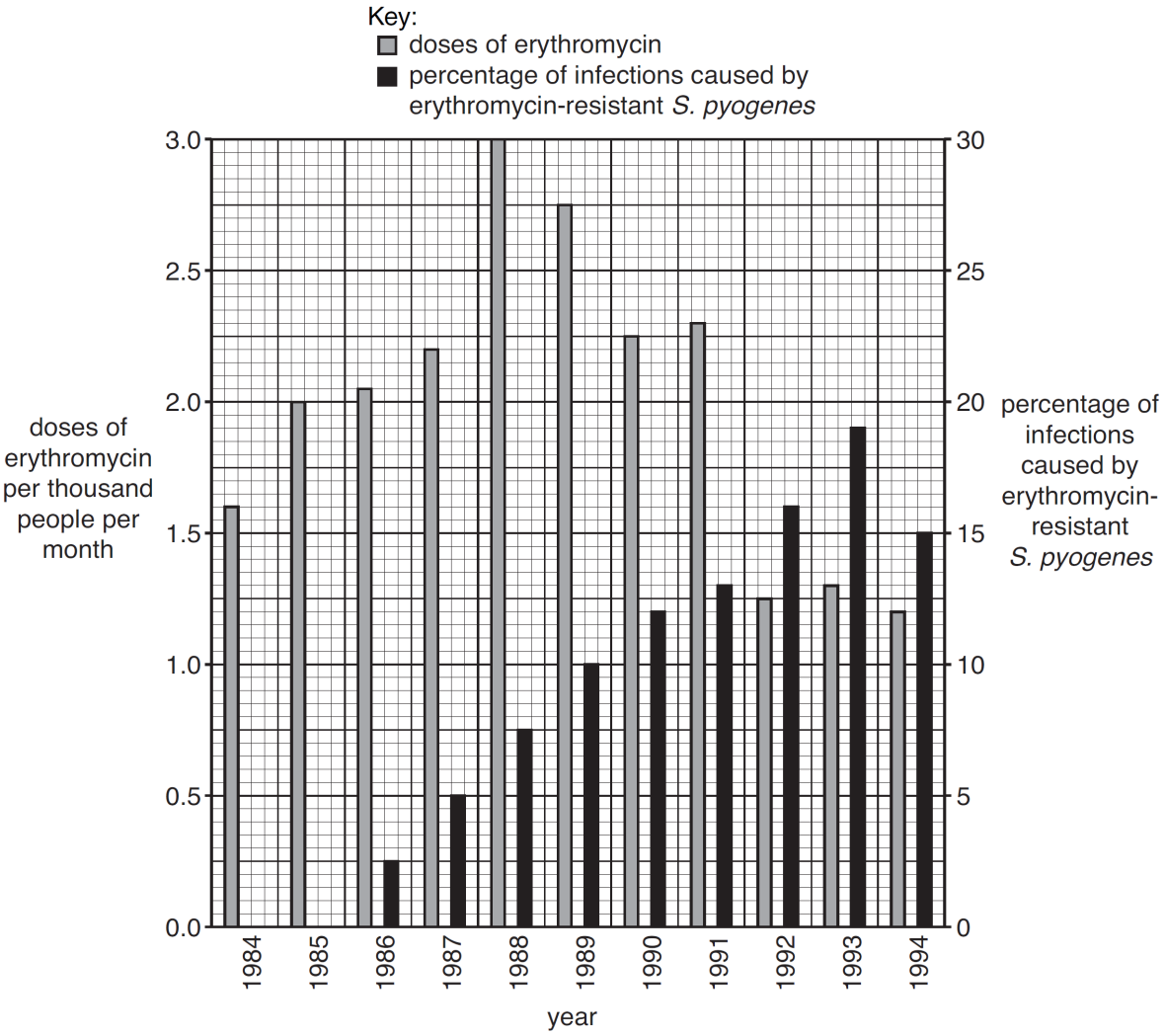

Fig. 7.1

(a) **(i)** Describe two structural features that are typical of bacteria, including *S. pyogenes*.

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.....[2]

(ii) Explain the advantages to scientists of giving the bacterium *Streptococcus pyogenes* a binomial Latin name.

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……[2]

(b) **(i)** With reference to Fig. 7.1, describe the trend in the use of erythromycin between 1984 and 1994.

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……[3]

(ii) Apart from mutation, suggest how the erythromycin-resistant *S. pyogenes* may have originated in Finland in 1986.

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……[1]

(iii) Explain why the percentage of erythromycin-resistant bacterial infections increased between 1986 and 1993.

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……[4]

(iv) Suggest why the percentage of erythromycin-resistant bacterial infections fell between 1993 and 1994.

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……[2]

(c) In 2014, the World Health Organisation highlighted the prevalence of antibiotic resistance in bacteria as a global health threat. This prompted the urgent development of alternative methods to the use of antibiotics to treat bacterial infections.

Phage therapy, which is the use of bacterial viruses to defend against pathogenic bacteria is a strategy to address this issue.

Suggest an advantage of using phage therapy.

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……[1]

[Total: 15]

2017 / H2 / RVHS PRELIM / P2 Q5

9 Fig. 5.1 shows the structure of a T4 virus.

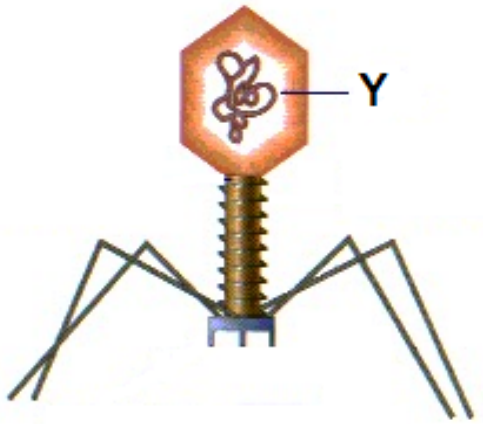

Fig. 5.1

(a) Identify structure **Y**. [1]

The T4 virus cannot reproduce by itself and relies upon a host cell for reproduction.

(b) State specifically why T4 viruses rely on host cells for their reproduction. [2]

T4 viruses use bacteria as its host. Fig. 5.2 shows the results of an experiment in which T4 viruses were added to a culture of bacteria. Samples of the culture were then taken at intervals to determine the number of free T4 viruses present.

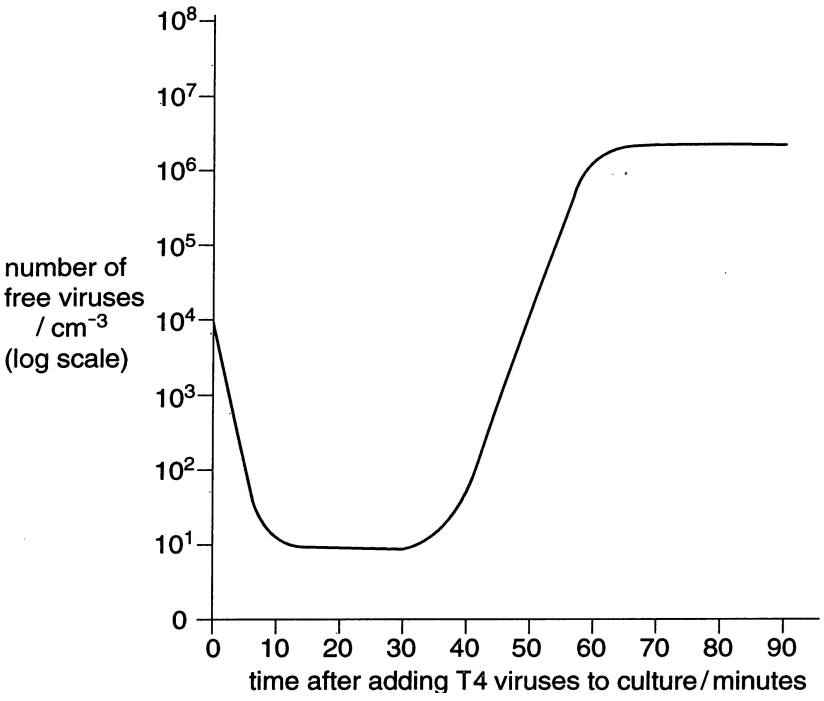

Fig. 5.2

(c) With reference to Fig. 5.2, describe and explain the changes in number of free T4 viruses

(i) in the first 10 minutes; [2]

(ii) between 30 and 60 minutes. [3]

A scientist carried out an investigation using T4 virus and two strains of bacteria: $\mathbf{B}^+$ cells which can grow in media without lysine and $\mathbf{B}^-$ cells which only grow when supplied with lysine. The procedure is shown in Fig. 5.3.

T4 are mixed with $\mathbf{B}^+$ cells

↓

T4 are isolated from the culture and added to $\mathbf{B}^-$ cells

↓

$\mathbf{B}^-$ cells are plated on medium lacking lysine

↓

Growth observed on medium

Fig. 5.3

(d) (i) Explain the observations made by the scientist. [3]

(ii) Suggest **one** other potential benefit of the process mentioned in **(d)(i)** for the recipient bacteria. [1]

[Total: 12]

2017 / H2 / SAJC PRELIM / P2 Q4

QUESTION 10

Researchers have identified a gene that gives bacteria resistance to a type of antibiotics called polymyxins. Despite being discovered around 60 years ago, polymyxins maintained their effectiveness as antibiotics as they were seldom used due to concerns about their toxicity.

In recent years, rampant use of common antibiotics (e.g. penicillin) has led to the emergence of bacterial strains which are resistant to these antibiotics. This has become more and more of a global concern. Polymyxins are now a last line of defense against bacteria because of its previous lack of use.

(a) With reference to the reproductive cycle of bacteriophages, suggest how bacteriophage infections may lead to a spread of antibiotic resistance between bacterial populations.

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……..[3]

Bacteria reproduce by the process of binary fission.

(b) Explain the significance of binary fission in bacteria.

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.....[2]

The process of binary fission involves semi-conservative DNA replication.

(c) State two differences in the formation of the leading and lagging strands during DNA replication.

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……..[2]

2017 / H2 / SAJC PRELIM / P2 Q5

1 Operons in bacteria allow them to regulate their gene expression in response to changes in the
1 environmental conditions.

In order to investigate the function of the regulatory and structural genes of *lac* operon, loss-of-function mutation was induced in the sequences of various genes. The different effects of the mutation on the expression of *lac* genes are shown in Table 5.1.

Table 5.1

Region of DNA sequence in which gene mutation occurs	Allolactose absent		Allolactose present	
	β-galactosidase	transacetylase	β-galactosidase	transacetylase
A	+	+	+	+
B	–	–	–	–
C	–	–	–	+
D	–	–	+	–

(+) indicates the synthesis of functional enzyme
(–) indicates no synthesis of functional enzyme

(a) **(i)** Identify regions **A** and **D**.

A: _____

D: _____ [2]

(ii) Outline the effect of the mutation of region **A** on the expression of *lac* genes.

[2]

Mammals respond to changes in the environmental conditions using different mechanisms. For instance, blood glucose concentration can be regulated by hormones such as insulin and glucagon.

Fig. 5.1 shows the modification of preproinsulin to form insulin in organelles **X** and **Y**.

Fig. 5.1

With reference to Fig. 5.1, outline what happens in organelles **X** and **Y**.

[2]

Fig. 5.2 shows the effect of glucose on a pancreatic cell.

Fig. 5.2

With reference to Fig. 5.2, outline how the pancreatic cell responds to elevated blood glucose levels.

[3]

Mammalian hormones can be synthesized artificially using bacterial cells.

Suggest **one** problem associated with expressing mammalian genes in bacterial cells.

[1]

Compare the advantages of a mammalian response to changes in blood glucose concentration with that of a bacterial response to changes in supply of lactose.

[2]

[Total: 12]

2017 / H2 / VJC PRELIM / P2 Q3

12 Diauxic growth is a two-phase growth response observed in a culture of bacteria of *E.*

coli. This phenomenon (Fig. 3) was discovered by Jacob and Monod who were awarded the Nobel prize for their ground breaking study of how gene expression is regulated in prokaryotic organisms. They studied how glucose and lactose impact the growth of *E. coli*. Substrates X and Y are the two different sugars that are introduced to the bacteria culture medium at the same time, to serve as carbon sources.

Fig. 3

*Note: Optical density, measured in a spectrophotometer, is used as a measure of the concentration of bacteria in a suspension.

(a) **(i)** Identify substrates **X** and **Y**.

X: ----------

Y: [2]

(ii) Using your knowledge of gene expression in bacteria, explain how Fig. 3 supported their conclusion that the *Lac* operon is under dual control.

[4]

(b) On Fig. 3, draw separate graphs to show the change in the concentration of the two substrates over time. Label your graphs clearly. [2]

(c) Eukaryotes are structurally different from prokaryotes and hence exhibit differences in their control of gene expression.

Explain two such differences.

1.

2.

[4]

[Total:12]

Bacteria rely on sugar sources e.g. lactose for survival.

(d) Describe the consequence of mutating the *lacI* gene of the bacterial lac operon, on usage of lactose.

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……[5]

[Q4: 12 marks]