**QUESTION 1**

**(a)** Explain why scientists keep the protoplasts in a solution that has the same water potential as the cell. [2]

*any two:*
1 to prevent, lysis or to prevent, shrinking
2 ref. to no net movement, of water (occurs)
3 prevent movement of water, by osmosis

**(b)** The cellulose microfibrils visible in Fig. 1.2 will form cellulose fibres. Each cellulose molecule is a polymer of β-glucose.

**(i)** Define the term *polymer*. [1]

a macromolecule, that is made up of many monomers

**(ii)** Explain how the structure of a cellulose molecule allows for the formation of the cellulose microfibrils and fibres. [3]

*cellulose chain max 2*
1 monomers joined by β(1,4) glycosidic bonds
2 adjacent, monomers, rotated through 180°
3 straight chain

*cellulose microfibril and fibres max 2*
4 parallel molecules, of cellulose
5 hydrogen bonds form, between the OH groups of neighbouring chains
6 (as such) formation of cross links
7 microfibrils associate with other non-cellulose polysaccharides, and are arranged in larger bundles to form macrofibrils
8 many macrofibrils bundle together to form a cellulose fibre
9 *idea that* between adjacent cellulose molecules, beginnings and ends in different places

**(c)(i)** Explain why the mAb ZAC-3 produced against the core polysaccharide and lipid A components will not act against the O-polysaccharide of the LPS molecules. [2]

*any two:*
1 (mAbs) specific / different, antigen-binding sites
2 (each mAb has) specific / different, 3D conformation
3 ZAC-3 has complementary shape to core polysaccharide and lipid A
Or
2D6 complementary shape to O-polysaccharide

**(ii)** The results of the tests showed that both mAbs were effective in causing agglutination (clumping) of bacteria and in preventing their motility. This suggests they may be useful for preventing cholera and for treating the disease.

Justify the claim that mAb 2D6 and mAb ZAC-3 are useful for preventing cholera and for treating the disease. [3]

*any three:*
*general points*
1 *(agglutination / motility prevented, so)* bacteria less able to, colonise intestine
2 less / no, choleragen released
3 bacteria passed out in faeces not able to cause disease in others
4 ref. to phagocytosis more effective
*prevention / treatment*
5 (to prevent disease) needs to be given, at early stages
6 passive immunity
7 *idea that* in addition to immune response (so increased effect)
8 ref. to quicker recovery (if a person has cholera)
9 useful when, there is antibiotic resistance / antibiotics cannot be given

*specific mAb*
10 mAb ZAC-3 may be more effective for cholera caused by, wider range of *V. cholerae*
11 mAb ZAC-3 may be useful if exact form of *V. cholerae* not known
12 AVP

[Total: 11]

**QUESTION 2**

**(a)** Name the structures labelled **X** and **Y** in Fig. 2.1 [2]

X = 3' CCA stem
Y = anticodon

**(b)** Compare the structure of **Z** with the structure of DNA. [3]

Similarities:
S1 double-stranded
S2 hydrogen bonds between complementary bases
S3 sugar-phosphate backbone
S4 phosphodiester bonds

Differences:
D1 deoxyribose in DNA and ribose in RNA
D2 thymine as a base in DNA and uracil as a base in RNA
D3 Z is single-stranded but DNA is double-stranded

**(c)** With reference to Fig. 2.1, explain how tRNA acts as an adaptor molecule for translation. [4]
1 translate base sequence into amino acid sequence
2 3' CCA stem as attachment site for amino acid
3 anticodon determine specific amino acid attached
4 anticodon forms complementary base pairs with codon

**(d)** Suggest why each amino acid can be carried by more than one type of tRNA. [1]
1 idea of induced fit model
2 active site of aminoacyl-tRNA synthetase can bind to slightly different anticodons

[Total: 10]

**QUESTION 3**

**(a)** Suggest why the structural genes in *trp* operon are transcribed together. [1]

ref. to structural genes under control of one promoter

**(b)** *trpR* is a regulatory gene located upstream of the *trp* operon. Describe the differences between the functions of *trpR* and *trpE*. [2]

1 *trpR* codes for regulatory protein, while *trpE* codes for structural proteins
2 repressor protein regulates expression of structural genes, while enzyme is involved in synthesis of amino acid tryptophan

**(c)(i)** On Fig. 3.2, draw the positions of RNA polymerase and the repressor molecule when tryptophan is present. [2]

1 repressor with bound tryptophan, attached to operator
2 RNA polymerase not bound to promoter / blocked by repressor

**(c)(ii)** Explain the significance of your answer in **(c)(i)**. [3]

1 tryptophan binds to inactive repressor protein, to activate repressor protein which will bind to operator
2 prevents binding of RNA polymerase to promoter, which stops expression of structural genes
3 *trp* operon is repressed when tryptophan level is high

**(d)** Describe **and** explain the population growth curve shown in Fig. 3.3. [4]

1 *E. coli* population increases initially, then levels off, increases again, then levels off again
2 glucose was metabolised to provide ATP, and when glucose was depleted there is no available ATP
3 plateau because delay in lac operon structural gene expression before lactose was hydrolyzed
4 lactose used as respiratory substrate before lactose was depleted / run out hence second plateau

[Total: 12]

**QUESTION 4**

**(a)** State what is meant by *recessive mutation* in this context. [2]

1 both copies of *TYR* gene must be mutated
2 mutation resulted in non-functional tyrosinase / no tyrosinase
3 (normal) allele mask the effect of recessive (mutant) allele

**(b)** Explain how an insertion mutation in the *TYR* gene can lead to a lack of melanin in a person with albinism. [4]

1 frameshift
2 change in primary structure
3 change in specific 3D conformation
4 may introduce stop codon
5 shortened polypeptide / no tyrosinase produced
6 tyrosinase becomes non-functional
7 tyrosine not converted to DOPA / DOPA not converted to dopaquinone
8 dopaquinone not formed to produce melanin

**(c)** Describe the role of PCR primers in this context. [1]

flanking exon 2, thus providing free 3' OH group for extension

**(d)** Discuss if PCR followed by gel electrophoresis can detect all types of mutations in exon 2 of the *TYR* gene. [3]

1 no, cannot detect base substitutions
2 mutant exon 2 remains 216 bp
3 (amplified) mutant exon 2 and normal exon would not appear as separate bands

[Total: 10]

**QUESTION 5**

**(a)(i)** Identify the phase of nuclear division that cell **B** is undergoing. [1]

Metaphase

**(a)(ii)** Describe two observable differences between cell **B** and the cell at prophase. [2]

| cell **B** | cell at prophase |
|---|---|
| **1** absence of nuclear envelope | presence of nuclear envelope |
| **2** chromosomes aligned at metaphase plate | chromosomes not aligned at metaphase plate |
| **3** chromosomes being fully condensed | chromosomes not fully condensed yet |

**(b)(i)** State the cell cycle checkpoint that determines if cell **B** can proceed to the phase shown by cell **A.** [1]

M checkpoint

**(b)(ii)** Discuss the significance of the cell cycle checkpoint identified in **(b)(i)**. [2]

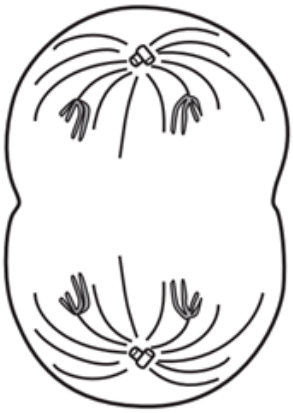
1 check if there is successful attachment of microtubules to the kinetochores of chromosomes
2 ensure successful separation of DNA to daughter cells

**(c)(i)** Table 5.1 describes some of the events that take place during four of the different stages of meiosis in an animal cell.

Complete Table 5.1 by:
- outlining the behaviour of the spindle fibres during anaphase I
- identifying the stage of meiosis in which spindle fibres re-form the spindle in daughter cells
- drawing a diagram to show telophase II.

You do not need to add labels to your diagram showing telophase II. [4]

Table 5.1

| stage of meiosis | spindle fibres | diagram |
|---|---|---|
| anaphase I | shorten, pulling (homologous) chromosomes to opposite poles |  |
| prophase II | re-form spindle in daughter cells |  |
| telophase II | disassemble | 1 four daughter cells / nuclei<br>2 two single chromosomes inside a (re-forming) nuclear envelope |

**(c)(ii)** Explain the need for a reduction division during meiosis. [2]

1 to produce gametes that are haploid / have half the number of chromosomes
2 to restore diploid condition upon fertilization
3 to prevent doubling of chromosome number / polyploidy / having too many chromosomes or allowing chromosome number to remain constant from generation to generation

[Total: 12]

**QUESTION 6**

**(a)** Explain the meaning of the term *autosomal linkage*. [2]

**1** ref. to genes on same chromosome

**2** ref. to not sex chromosome

**(b)(i)** A chi-squared ($\chi^2$) test was carried out to determine if the observed results fit the expected phenotypic ratio of 9:3:3:1.

Calculate the value of $|^2$ and the number of degrees of freedom, using these formulae.

Show your working. [3]

**1** calculate expected number of individuals in each class = 225:75:75:25

**2** calculate $\chi^2$ = 189

**3** calculate $\nu$ = 3

**(b)(ii)** Use Table 6.2 and your answers to **(b)(i)** to explain how the observed results support the fact that this is an example of autosomal linkage. [3]

1 ref. to correct comparison of $\chi^2_{calc}$ and $\chi^2_{crit}$

2 ref. to significant difference between observed and expected results

3 ref. to any valid explanation / observation for difference

**(c)** Draw a genetic diagram to show the results of the test cross shown in Fig. 6.1 on page 22. [5]

F1 Test cross: full band and rays × broken band and no rays

Genotypes: $\frac{FR}{fr}$ . $\frac{fr}{fr}$

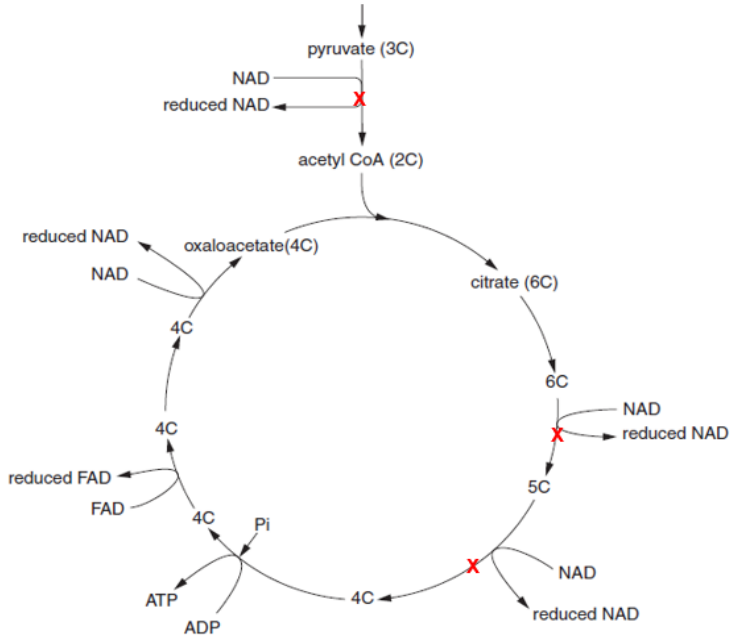
Gametes: FR, fr, Fr, fR (from F1) ; fr (from parent)

| | | Male gametes: FR | Male gametes: fr | Male gametes: Fr | Male gametes: fR |
|---|---|---|---|---|---|
| Female gametes | fr | $\frac{FR}{fr}$ | $\frac{fr}{fr}$ | $\frac{Fr}{fr}$ | $\frac{fR}{fr}$ |

| Offspring phenotype | full band and rays | broken band and no rays | full band and no rays | broken band and rays |
|---|---|---|---|---|
| Observed number of offspring | 215 | 210 | 30 | 32 |
| | parentals | | recombinants | |

[Total: 13]

**QUESTION 7**




**(a)** State precisely the name and location of the preceding process that forms pyruvate. [2]

process: glycolysis
location: cytoplasm

**(b)** Label on Fig 7.1 the **three** stages where decarboxylation reactions occur with the letter **X**. [1]

all 3 X labelled correctly

**(c)** Outline how ATP is synthesised in the Krebs cycle. [2]

1 substrate level phosphorylation
2 coupling of dephosphorylation of substrate to phosphorylation of ADP

**(d)** Describe **and** explain the role of the coenzymes NAD and FAD in aerobic respiration. [4]

1 ref. to electron carriers
2 in glycolysis, NAD is reduced
3 in the link reaction, NAD is reduced
4 in the Krebs cycle, both NAD and FAD are reduced
5 NADH / $FADH_2$ deliver electrons to the electron transport chain
6 resulting in the production of ATP and the regeneration of NAD/ FAD

**(e)** Describe the differences between the process of chemiosmosis in mitochondria and the process of chemiosmosis in chloroplasts. [3]

| | mitochondria | chloroplasts |
|---|---|---|
| 1 | oxidative phosphorylation | photophosphorylation |
| 2 | inner mitochondrial membrane | thylakoid membrane |
| 3 | reduced NAD/ FAD donate electron | photolysis of water donate electron |
| 4 | protons being pumped from matrix to intermembrane space | protons being pumped from stroma to thylakoid space |
| 5 | protons diffusing back from intermembrane space to matrix | diffusing back from thylakoid space to stroma |
| 6 | oxygen is the final electron acceptor | NADP is the final electron acceptor |

[Total: 12]

**QUESTION 8**

**(a)** With reference to the data in Table 8.1, explain the isolating mechanisms that prevent gene flow between *M. lewisii* and *M. cardinalis* populations. [5]

1 Both species have different types of pollinators / altitude / petal colour / flower length to nectar distance
2 The two species of *Mimulus* cannot exchange pollen
3 Ref. to geographical isolation

4 Both species are reproductively isolated
5 ref. to pre-zygotic isolation, and, appropriate elaboration

**(b)(i)** Suggest, with reasons, what prediction can be made about the chromosome numbers of *M. lewisii* and *M. cardinalis*. [2]

1 The two species have the same number of chromosomes
2 Hence meiosis can occur in offspring

**(b)(ii)** Explain how the reduced production of seeds by the inter-species (F1) hybrids can act as a post-zygotic isolating mechanism. [3]

1 F1 have fewer offspring
2 hence are outcompeted
3 resulting in hybrid breakdown

[Total: 10]

**QUESTION 9**

**(a)** Describe **two other** defense mechanisms that **prevent** *Mycobacterium tuberculosis* in inhaled air from entering cells of the gas exchange system. [2]

1 ref. to production of mucus
2 ref. to cilia on epithelial cells

**(b)(i)** Explain how binding to RNA polymerase allows rifampicin to kill mycobacterial cells. [2]

1 ref. to mRNA not synthesized so polypeptides not synthesized
2 ref. to proteins required for metabolism not produced

**(b)(ii)** Suggest why rifampicin does **not** affect human cells. [1]

1. pathogen and humans have slightly different RNA polymerase
2. rifampicin unable to cross cell surface membrane / enter nucleus

[Total: 5]

**QUESTION 10**

**(a)** Using the data in Fig 10.1, explain how climate change affects plant distributions. [3]

1 ref. to 53 species of plant experience an upward shift in mean elevation
2 climate change leads to increased temperature / decreased precipitation
3 ref. to range shifts upwards where there is decreased temperature and increased precipitation which is now within tolerable limits

4 ref. to 11 plant species experienced no change to mean elevation
5 changes are still within tolerable limits

6 ref. to 19 plant species experienced a downhill shift in mean elevation
7 increased competition in the communities located at high altitudes

**(b)** Suggest why it would be difficult for the scientists to conclude that the changes in mean elevation for the plant species were due to climate change. [2]

**1** ref. to difficulties in determining cause-effect
**2** historical data had to be used / may not be as accurate / reliable
**3** incomplete data

[Total:5]