Question 1

Figure 1.1 below depicts the molecular structure of a basic unit of collagen.

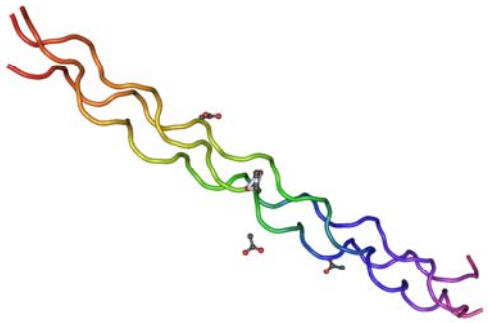

Figure 1.1

(a) State the name given to such a basic unit of collagen. [1]

1. Tropocollagen.

(b) Describe how the monomers of this basic unit are joined together to achieve the final molecular configuration as shown in **Figure 1.1**. [3]

1. Monomers are amino acids
2. Join together via condensation reaction to form peptide bonds with a loss of water molecules forming a polypeptide
3. Three such polypeptides join together via intermolecular hydrogen bonding/ hydrogen bonding between chains between NH and CO groups to form tropocollagen

Collagen is normally found in animal connective tissue where its role is as a structural molecule. **Figure 1.2** shows an electron micrograph of collagen.

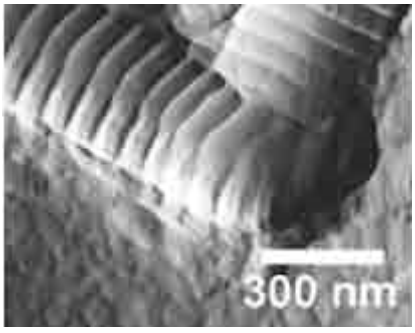

Figure 1.2

(c) Suggest why there is a banded appearance of collagen as shown in **Figure 1.2**. [1]

1. Due to staggered arrangement/ longitudinal displacement of tropocollagen subunits with respect to each other.
2. Association of multiple strands

Another common structural molecule found in nature is cellulose. Cellulose is the main structural molecule in plants.

(d) Compare the structures of cellulose and collagen. [3]

1. Both have intermolecular hydrogen bonding
2. Both associate to form fibrous structures.
3. Both are large structures

4. β-glucose monomer in cellulose vs amino acid monomer in collagen
5. β 1,4 Glycosidic bond in cellulose vs peptide bond in collagen.
6. Cellulose is a straight chain structure while collagen is helical/ helix

At least 1 sim and 1 diff

[Total: 8 marks]

Question 2

The following **Figure 2.1** shows an electron micrograph of several cells.

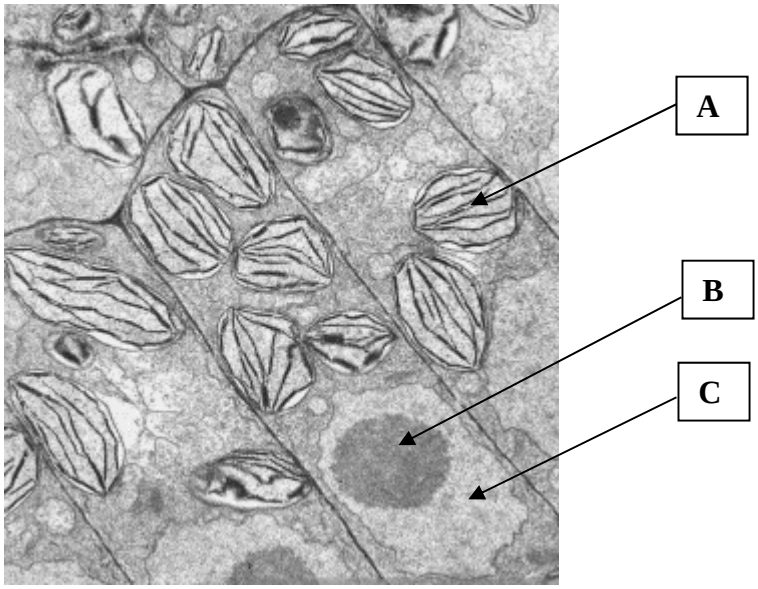

Figure 2.1

(a) Label the organelles **A and C**. [2]

A – Chloroplast
C - Nucleus

(b) Discuss the role of organelle **B**. [3]

1. Contains rRNA genes
2. Involved in the synthesis of ribosomal RNA (rRNA) via transcription,
3. which is a constituent of ribosomes.

4. Also involved in the assembly of rRNA and ribosomal proteins into large and small subunits

[Total: 5 marks]

Question 3

Two recessive traits in mice are crinkly tail and soft coat. A mouse with a crinkly tail and soft coat was crossed to a true-breeding normal mouse. All the F_1 offspring were normal. The F_1 mice were then crossed to mice with crinkly tails and soft coats. The following results were obtained:

104	crinkly tail/ soft coat
102	crinkly tail/ normal coat
97	normal tail/ normal coat
99	normal tail/ soft coat

(a) Using suitable symbols, draw a genetic diagram in the space below, to show the crosses described. [4]

Let T represent the dominant allele for normal tail and t represent the recessive allele for crinkly tail. Let N represent the dominant allele for normal coat and n represent the recessive allele for soft coat.					1
P Phenotype	Crinkly Tail, Soft Coat	x	Normal Tail, Normal Coat		1
P Genotype	ttnn	x	TTNN		
P Gametes	tn	x	TN		
F_1 Genotype F_1 Phenotype	TtNn All Normal Tail, Normal Coat				
F_1 Cross Genotype	Normal Tail, Normal Coat TtNn	x	Crinkly Tail, Soft Coat ttnn		
Gametes	TN tN Tn tn	x	tn		
Punnett square					1
F_2 Phenotype	Normal tail, normal coat	Normal tail, soft coat	crinkly tail, normal coat	crinkly tail, soft coat	1
F_2 phenotypic ratio	1 :	1 :	1 :	1	

Max 3 if first cross is missing

(b) Give a full explanation of these results. [3]

1. Both parents are homozygous and F_1 generation are heterozygous at both gene loci → All the F_1 have normal tail and normal coat.
2. Alleles for normal tail is dominant over the allele for crinkly tail and allele for normal coat is dominant over the allele for soft coat
3. When the F_1 offspring crosses with Crinkly Tail, Soft Coat mice/ test cross/ crossed with homozygous recessive , the phenotypic ratio is 1:1:1:1

[Total: 7 marks]

Question 4

Figure 4.1 shows a series of fossils. This series depicts how land-based amphibians could have evolved from fishes. Tiktaalik hails from the Late Devonian period, about 360 million years ago, and is both chronologically and morphologically intermediate between two other major fossils in this series, the more fish-like *Panderichthys* and the more tetrapod-like *Acanthostega*.

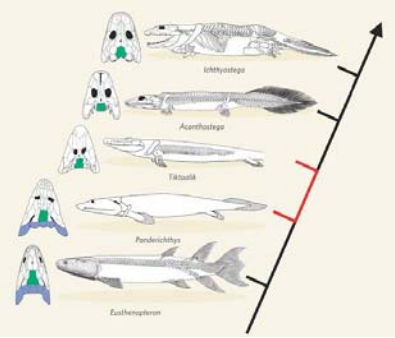

Figure 4.1

(a) Suggest how such fossil records can actually support Darwin's theory of evolution. [2]

1. Similarities amongst group of organisms; suggests a common/ similar ancestor
2. Differences amongst group of organisms; suggests descent with modification/ divergent evolution.

In most respects *Tiktaalik's* body is fish-like: it has fins and gill arches, just like a fish. However, its skull and especially its limbs mark it as a tetrapod ancestor. Species such as *Panderichthys* had true fins, similar to those of modern ray-finned fishes, consisting of an array of long, thin, spindly bones unsuitable for bearing weight. On the other side of the gap is *Acanthostega*, with true limbs – each containing a radius and an ulna, just like our arms, and outfitted with eight true toes.

(b) State the name given to similar structures such as the limbs of *Acanthostega* and *Tiktaalik*. [1]

1. Homology / Homologous structures

(c) It was believed that the environment *Tiktaalik* evolved in was filled with swampy, silty lagoons. These dirty, unclear water masses also tended to have algae covering its surface. Using this information, describe how the amphibian-like *Acanthostega* could have evolved from the species *Tiktaalik*. [4]

- Variation existed within the *Tiktaalik* population; some individuals had the beginnings of true limbs.
- Formed two sub-populations, one on land and one in the swamps (those with fins and gill arches)
- These individuals within the swamps were selected against as the silty water and algae made survival more difficult, eg difficulty breathing. OWTTE/ Those on land selected for as easier to breathe/more food options OWTTE
- Alleles for true limbs passed down to next generation.
- No interbreeding/genetic isolation/reproductive isolation existed between the two sub-populations

[Total: 7 marks]

Question 5

The location of the gene locus responsible for disease X was not discovered until 1985. Samples of DNA were obtained from a family known to have the condition. The gene locus was amplified by polymerase chain reaction and mixed with *Pst*I and *Eco*RI in two separate restriction digests. The results of gel electrophoresis followed by southern blot of both restriction digests are shown in **Figure. 5.1**.

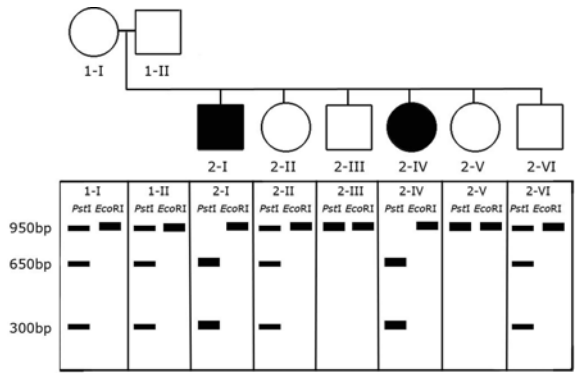

Figure. 5.1

(a) Using the information in **Figure. 5.1**,state and explain which restriction enzyme digest should be used to detect disease X. [3]

1. *Pst*I
2. Digestion with *Pst*I produced two bands of 300bp and 650bp in affected individuals but unaffected individuals showed either a single band of 950bp or three bands of 950bp, 650bp and 300bp.
3. But after digestion with *Eco*RI, all individuals had single 950bp fragments and the affected and unaffected individuals are not differentiated.

This gene locus was amplified by polymerase chain reaction prior to gel electrophoresis and southern blot. The DNA sequence of the gene locus is shown in **Figure. 5.2**.

5' - GGATCCATCCCGATCGAAAGCTAGCTAGGATCC - 3'
3' - CCTAGGTAGGGCTAGCTTTCGATCGATCCTAGG - 5'

Figure. 5.2

(b) Design two 7-base long primers for the sequence to be amplified. [2]
Primer 1: 5' – GGATCCA – 3'
Primer 2: 3' – TCCTAGG – 5'

1. 5' and 3' indicated correctly on both primers- 1m
2. Correct sequence of both primers – 1m

1m awarded if one of the primer has correct sequence and direction indicated.

(c) Contrast between the process of PCR and DNA replication that occurs naturally in cells. [3]

Basis of comparison)	Differences
1. Nature of primers	DNA replication involves RNA primers while PCR requires DNA primers.
2. Location	DNA replication takes place in the nucleus of the cell while PCR is automated/takes place in a thermocycler.
3. Enzymes involved	DNA replication involves DNA polymerase III and DNA polymerase I while PCR involves the enzyme *Taq* polymerase.
4. Proof-reading	In DNA replication, the daughter strands are proofread by DNA polymerase I but there is no proofreading of daughter strands in PCR by *Taq* polymerase.
5. Unzipping of template DNA	In PCR, high temperatures are required for denaturing the strands while in DNA replications, the enzyme helicase unwinds the strands.
6. Synthesis of primers	In DNA replication, primase synthesises the RNA primers, but in PCR, the primers are added in/primase is not involved.

Max 3

The effect of plant diseases on agriculture have recently been in the spotlight. One such disease is the ringspot virus that plagues the papaya agricultural industry. Scientists have developed effective circumventive methods to tackle the problem of the ringspot virus through genetically modifying papaya. To do this, viral genes encoding capsid proteins were transferred to the papaya genome. These viral capsid proteins elicit something similar to an "immune response" from the papaya plant. Thus, the genetically modified papaya plants were resistant to infection by the papaya ringspot virus.

Figure 5.3 below depicts the comparative infection of transgenic and non-transgenic papaya in the 1995 field trail in Kapoho, Hawaii.

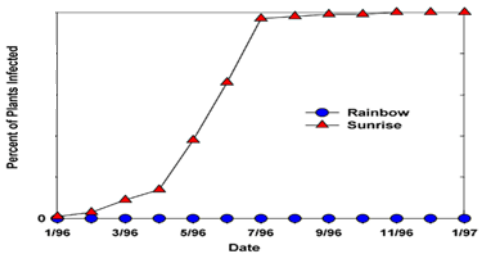

Figure 5.3

(d) With reference to **Figure 5.3**,

(i) Determine the identities of the transgenic and non-transgenic papaya species. [1]

1. Transgenic species: Rainbow + Non-transgenic species: Sunrise.

(ii) Evaluate and justify thoroughly the efficacy of the genetic intervention. [2]

1. Highly effective
2. QF" The percentage of infected Sunrise papaya species increased to from 0% and reached 50% by Nov'96, as compared to the percentage of infected Rainbow species which remained at 0% throughout the year.

It was observed that three years later, the percentage of infected transgenic papaya species increased.

(e) Suggest and explain a possible reason for this phenomenon. [2]

1. Mutation in the ringspot virus genome had occurred,
2. Enables ringspot virus to make new surface glycoproteins that GM papaya is no longer resistant to as immune response is no longer triggered by infection with the ringspot virus.

3. AVP+ explanation

[Total: 13 marks]

Question 6

(a) Outline the main features of the genetic code.[6]

1. Triplet code;
2. transcribed into complementary codons on mRNA which will lead to the synthesis of specific amino acids;
3. Made up of a combination of any of these four bases – adenine, cytosine, guanine or uracil;
4. Code is degenerate that is the same amino acid may be coded for by more than one codon;
5. The code is non-overlapping; each nucleotide in a triplet code is used only once;
6. The code is punctuated with start and stop codons, AUG, UGA, UAG or UAA that signals the beginning and termination of translation;
7. The code is universal, same triplet of bases codes for the same amino acid in all organisms.

(b) Discuss the roles of mRNA and tRNA in protein synthesis. [8]

mRNA: [max 4]

1. mRNA carries genetic information from nucleus to cytoplasm for protein synthesis;
2. Manufactured in the nucleus by transcription;
3. The sequence of bases / nucleotides is complementary to the sequence of bases / nucleotides on the DNA template;
4. A to U, T to A, C to G
5. Each triplet of bases on the mRNA is known as a codon; It codes for a specific amino acid;
6. Hence the specific sequence of codons will determine a specific sequence of amino acids during translation of the protein synthesis in the cytoplasm;

tRNA: [max 4]

1. tRNA carries a specific amino acid to the mRNA;
2. Forms an aminoacyl-tRNA complex/ activated tRNA, catalysed by a specific type of aminoacyl tRNA synthetase;
3. One end of the tRNA structure has the anticodon;
4. A triplet of bases; Complementary to a specific codon on mRNA;
5. Therefore, a specific aminoacyl-tRNA complex will carry the correct amino acid to the ribosome for translation;

(c) Explain the eukaryotic processing of pre-mRNA. [6]

1. Addition of 5' cap;
2. Protects mRNA from degradation by 5' exonucleases
3. assists in ribosomal binding;
4. Splicing removes introns and joins exons to produce a mature mRNA;
5. Alternative splicing may occur, resulting in different combinations mature mRNA from a gene;
6. Addition of poly-A tail to 3' end of mRNA;
7. Allows slower degradation by 3' exonucleases
8. facilitates transport of mRNA from nucleus to cytoplasm;
9. facilitates ribosome binding

Question 7

(a) Discuss the light dependent reactions of photosynthesis. [14]

1. Occurs on the thylakoid membrane
2. Involves cyclic and non-cyclic photophosphorylation
3. Produces ATP and NADPH (reduced NADP) and oxygen a waste product
4. Light energy absorbed by Photosystem II passed from one accessory pigment to another
5. And to special chlorophyll a in the reaction center
6. Electron boosted to higher energy and displaced to primary electron acceptor
7. Electron passed down a series of electron carriers/ ETC, of progressively lower energy levels
8. Energy lost by the electrons is used to pump/ actively transport H+ ions into the lumen/space of the thylakoid
9. Forming electrochemical proton gradient
10. H^+ will diffuse down the gradient into the stroma via the stalked particles/ ATP synthase complex and drive ATP synthase to make ATP (phosphorylation)
11. The electron will enter Photosystem I and passed down the ETC to NADP+, reducing it to NADPH
12. Using Ferrodoxin NADP Reductase (FNR)
13. Photolysis of water using the energy of light
14. Produces H^+, electrons and oxygen and electron replaces electron lost in PSII
15. Similar process occurs for cyclic where light is absorbed by accessory pigments in PSI
16. Electron is passed down the ETC between PSII and PSII and final electron acceptor is PSI
17. Products from cyclic photophosphorylation is ATP only

(b) Outline the ethical and social implications of genetically modified organisms.[6]

1. Organism that has acquired and express one or more genes by recombinant DNA technology. The genes may or may not be from the same species.

Ethical concerns (Max 3):

1. Exploitation of animals for food (+ any 1 elaborated point)
   A. Increased use of growth hormone has harmful effects on the health of animals. Eg the use of bovine somatotrophin in dairy cattle increases the risk of mastitis
   B. Concern whether the animals are biologically capable of withstanding additional stress of increased production of milk, meat and other products
2. Religious concerns or dietary restrictions (+ any 1 elaborated point)
   A. Eg. Religious groups are concerned that GM foods might contain genes from animals prohibited by their religion
   B. Eg. Objections to consumption of plants that have been modified to carry animal genes or vice versa by vegetarians
3. There is concern about the rights of patenting a genetically modified animal or plant. (+ elaboration)
   A. Companies have sought to patent the transgenic animals or plants that they have developed, however, people argue that patenting animals is unethical as it reduces them to the level of objects.

4. Labelling of products on sale to indicate that genetic engineering was involved in their production is not mandatory in some countries (+elaboration)
   A. this deprives consumers from making an informed choice based on their religious, medical (allergies), personal (vegetarians) backgrounds.

Social Concerns (max 3)

1. Release (accidental or otherwise) of GM animals into the wild may result in GM animals outcompeting wild types such that ecological balance is disrupted/severe impacts on the food-chain.
   E.g., larger transgenic salmon may be preferably selected as mates over smaller wild types, thus destabilises ecosystem and hence threatens biodiversity;

2. Introduction of foreign gene(s) may result in production of secondary metabolites that may be toxic to animals themselves and/or livestock/humans that consume them.
3. New proteins in GM animals may be potentially allergenic to humans that consume them.
4. Antibiotic resistance genes may be transferred to bacteria in the gut, increasing the resistance of such bacteria to medicinal antibiotics.
5. AVP