H

Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME

BIOLOGY CLASS 2bi2 __ / 2IPbi2 __

REGISTRATION NUMBER

BIOLOGY

9648/01

Paper 1 Multiple Choice

15 September 2016

1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your Biology class, registration number and name above and on the Answer Sheet provided.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

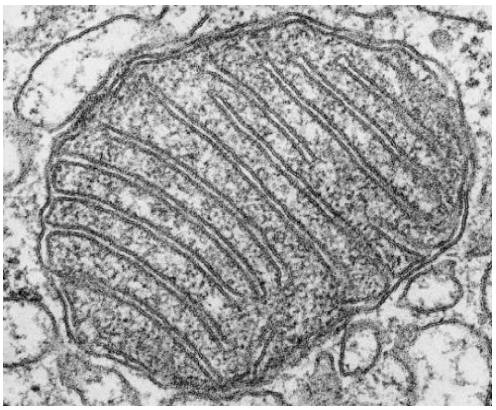
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **23** printed pages.

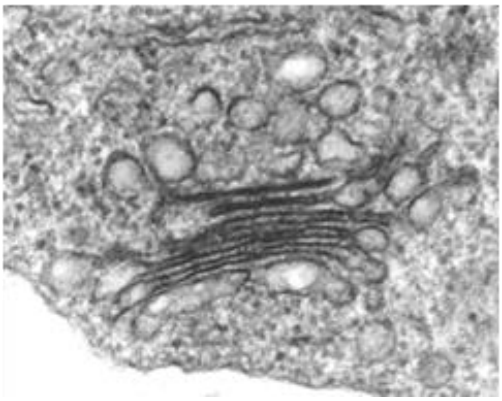
[Turn over

1 The electron micrographs, which are taken at different magnifications, show four different organelles that can be found in different eukaryotic cells.

1



2



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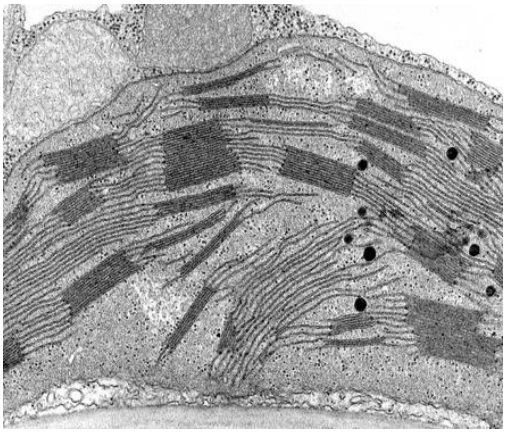


Which organelle(s) contain(s) nucleic acids?

A 4 only

B 1 and 4 only

C 1, 3 and 4 only

D 1, 2, 3 and 4

2 Which statements about membrane fluidity are correct?

1 The less unsaturated the fatty acid chains of the phospholipids, the more fluid the membrane is.

2 The greater the amount of cholesterol in the membrane, the less fluid the membrane is at high temperatures.

3 The longer the hydrocarbon tails of the phospholipids, the more fluid the membrane is.

4 The lower the temperature, the less fluid the membrane is.

A 1 and 3

B 2 and 4

C 1, 2 and 3

D 2, 3 and 4

3 The following statements describe three orders of structure of the insulin molecule.

1 The molecule consists of two polypeptide chains joined and folded around one another.

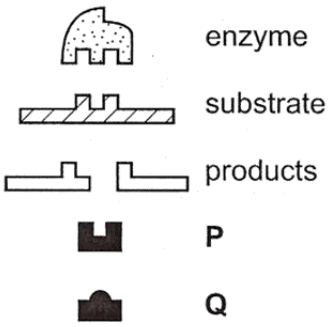
2 The sequence and number of amino acids in each polypeptide chain are known.

3 The amino acids in each chain are coiled into a helix and held in position by hydrogen bonds.

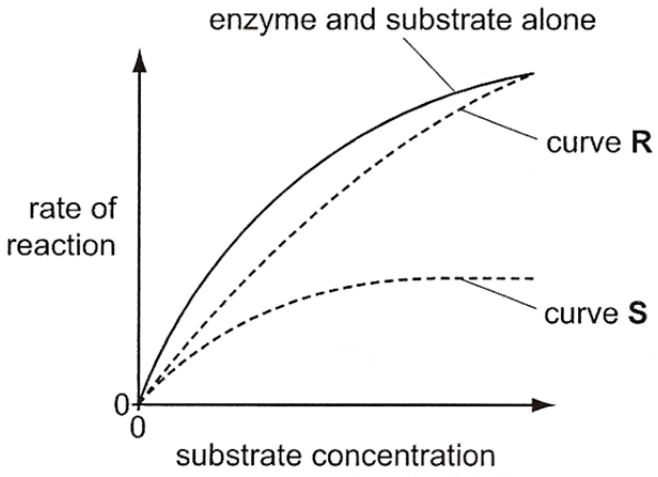
Which order is described by each statement?

	1	2	3
A	primary	secondary	tertiary
B	quaternary	primary	secondary
C	quaternary	primary	tertiary
D	secondary	tertiary	primary

4 The diagram shows an enzyme molecule with its normal substrate and products. P and Q are other molecules that can bind to the enzyme.



The graph shows the effect of P and Q on the rate of reaction of the enzyme at different substrate concentrations.



Which statement correctly describes the activity of the enzyme?

A P is a competitive inhibitor that binds to the active site, resulting in curve R.

B P is a non-competitive inhibitor that distorts the shape of the enzyme, resulting in curve S.

C Q is a competitive inhibitor that distorts the shape of the enzyme, resulting in curve R.

D Q is a non-competitive inhibitor that binds to the active site, resulting in curve S.

5 How does the second meiotic division differ from mitosis?

A Chiasmata form between the chromatids of a bivalent in the second meiotic division but not in mitosis.

B Each chromosome replicates to form two chromatids during metaphase in the second meiotic division but not in mitosis.

C Exchange of genetic material occurs between chromatids in the second meiotic division but not in mitosis.

D The separating chromatids of a pair differ genetically in the second meiotic division but not in mitosis.

6 Suppose a cell with 14 chromosomes divides mitotically and one of the two new cells has 13 chromosomes and the other has 15 chromosomes.

At which phase of the cell cycle could an error have occurred and resulted in the unequal number of chromosomes in the two new cells?

A anaphase

B interphase

C prophase

D telophase

7 The following DNA sequence of the coding strand, which is complementary to the mRNA, is taken randomly from a bacterial genome.

3’ TTACGCTTCGAAATAGGAATATCATAGGCT 5’

This DNA sequence is cloned into a plasmid, which is introduced into a suitable host.

The table shows the mRNA codons for some amino acids.

arg	CGA, CGG, AGA, AGG	leu	CUU, CUC, CUA, CUG
asp	GAU, GAC	lys	AAA, AAG
ile	AUU, AUC, AUA	phe	UUU, UUC
met	AUG	ser	UCA, UCG, AGU, AGC
stop	UAG, UGA, UAA	tyr	UAU, UAC

What are the first four amino acids of the polypeptide generated from this DNA sequence?

A met-arg-ser-lys

B met-arg-ser-phe

C met-ile-phe-leu

D met-tyr-lys-asp

8 What is true about the regulation of gene expression in both prokaryotes and eukaryotes?

1 involves histone modifications

2 involves helicase to separate the DNA so that transcription can take place

3 involves binding of specific transcription factors to enhancers or silencers that are some distance from the gene(s) to be transcribed

4 involves binding of a protein that can regulate transcription of several genes at the same time

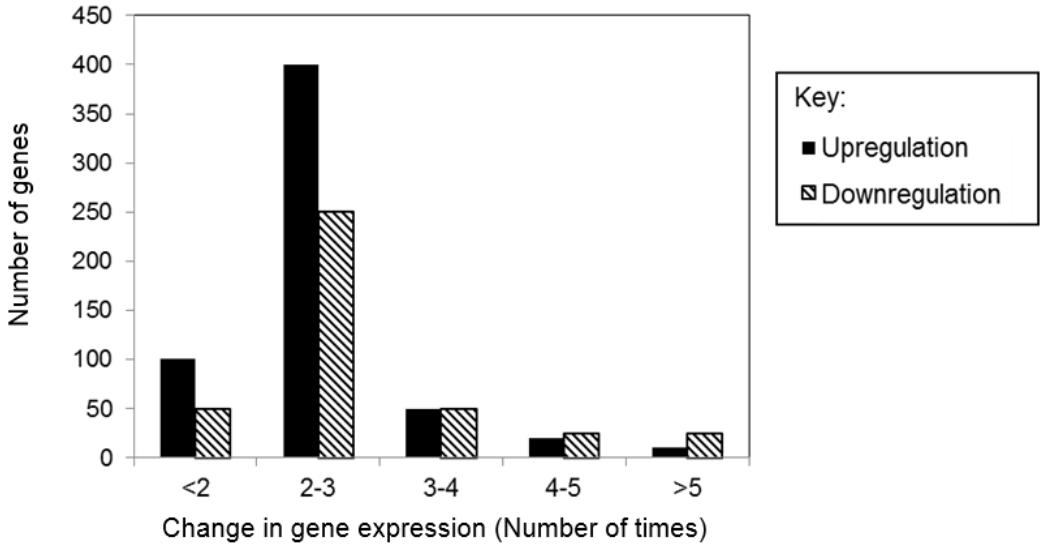
A 4 only

B 2 and 3 only

C 3 and 4 only

D 1, 2 and 4 only

9 The graph shows the changes in gene expression in the liver cells of a group of mice after oxygen deprivation for four minutes.



What can result in all the observed changes?

A activation of specific transcription factors

B alternative splicing of mRNA

C increase in activity of histone acetyltransferase

D methylation of cytosine at the promoters of the genes

10 Which statement best defines an oncogene?

A An oncogene codes for a cell cycle control protein.

B An oncogene codes for a mutated form of a protein that forms part of a signal transduction pathway.

C An oncogene codes for a protein that prevents the cell from undergoing apoptosis.

D An oncogene is a dominantly expressed mutated gene that gives a cell a growth advantage.

11 A scientist is studying a strain of bacteria whose genes are commonly transferred to other bacteria.

What could serve as evidence that the genes are transferred through specialized transduction?

A Cells that are treated with calcium ions show a higher rate of gene transfer.

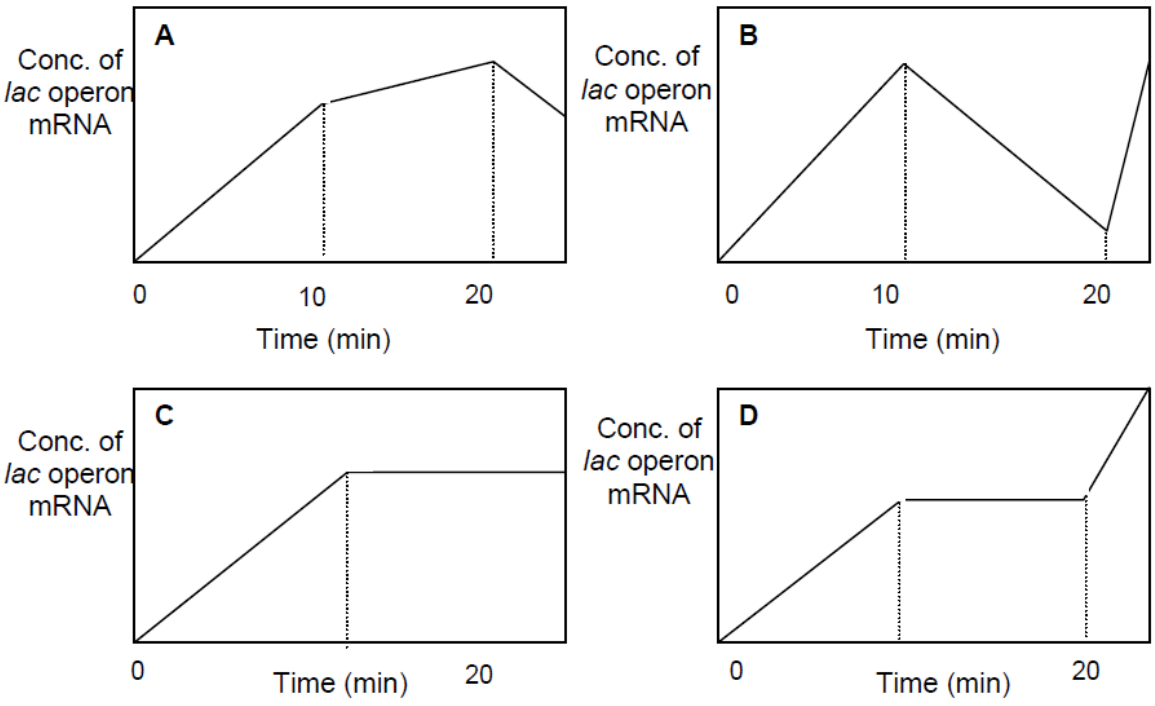
B F plasmid is always transferred from donor cell to recipient cell.

C Only certain genes are transferred in the process.

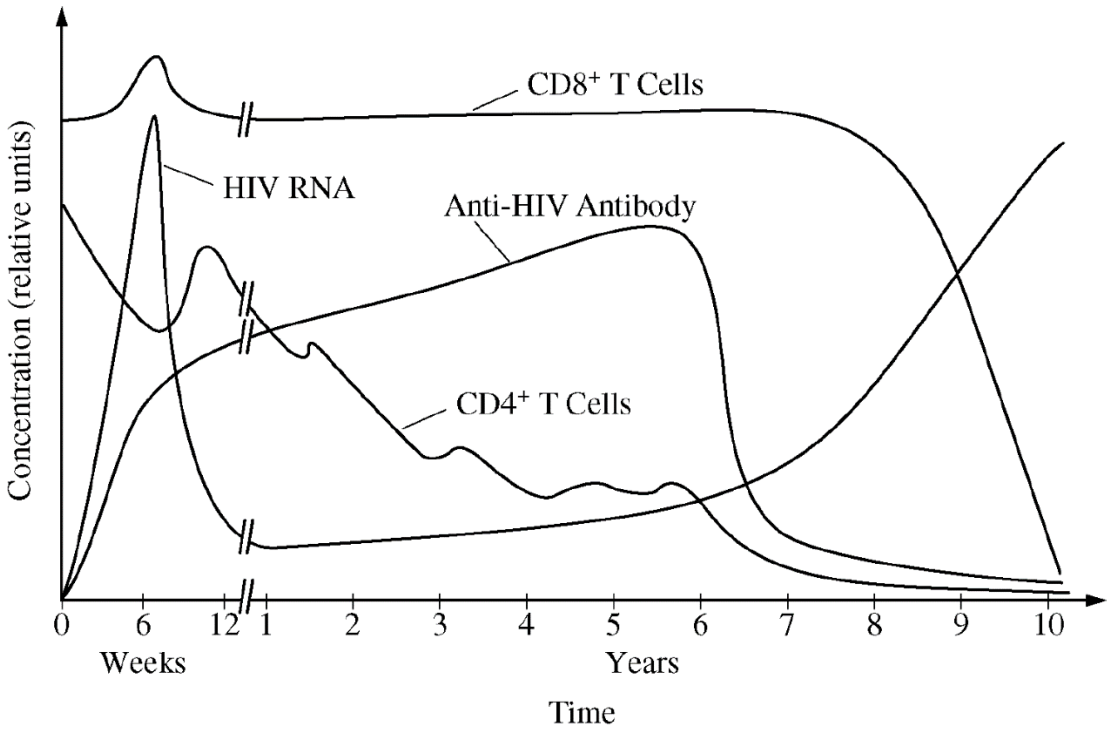
D The strain of bacteria is often infected by a virulent phage.

12 IPTG is an analogue of lactose that binds to the *lac* repressor in the same fashion as allolactose. However, it cannot be metabolized by β-galactosidase. *E. coli* cells, which were grown in the absence of lactose and glucose, were initially supplemented with IPTG. After 10 minutes, glucose was added to the cells. 10 minutes later, cAMP was added to the cells.

Which graph best represents the amount of *lac* operon mRNA during the time course of the experiment?



13 The graph shows the relationship among serum concentrations of human immunodeficiency virus (HIV) RNA, anti-HIV antibody, $CD4^+$ and $CD8^+$ T-cells over a ten-year period following infection of an individual by the virus.



What is the primary explanation for the drop in serum concentration of HIV-RNA during 6- to 12- week period following infection?

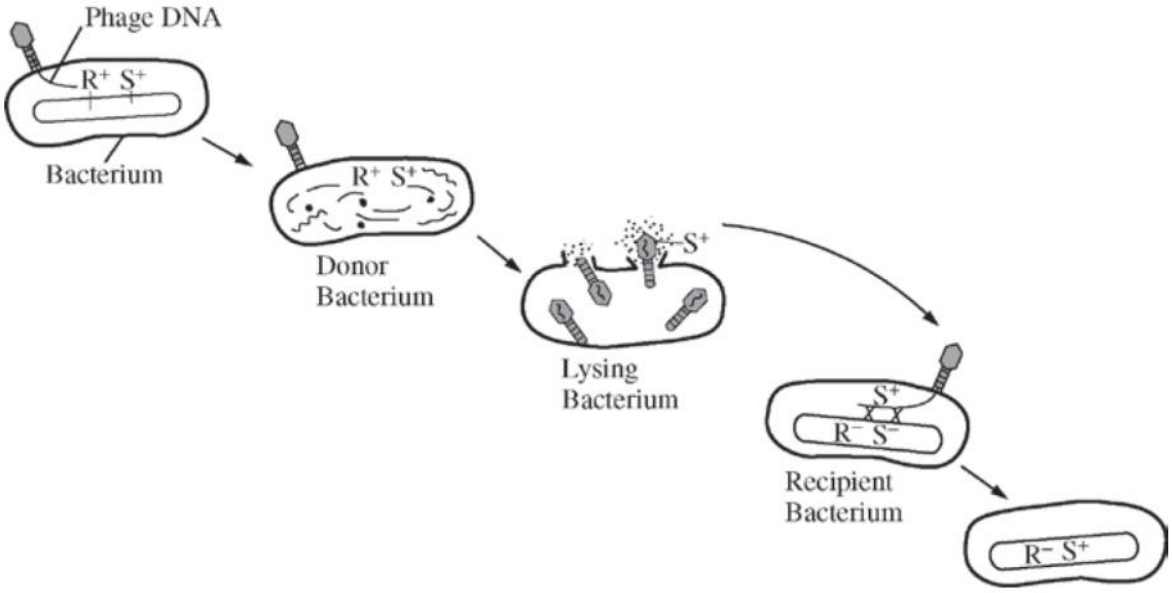
A The viruses enter host cells via endocytosis to evade the immune system.

B The viruses have a protein that accelerates viral replication.

C The viruses that are actively replicating are eliminated by the immune system.

D The viruses undergo rapid mutation.

14 The diagram shows several steps in the process of bacteriophage transduction in bacteria.



Which statement explains how genetic variation in a population of bacteria results from this process?

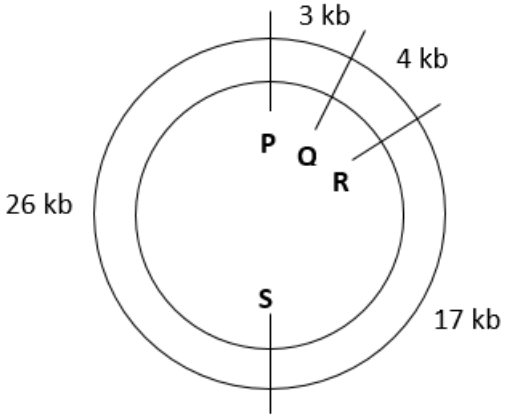
A Bacterial proteins transferred from the donor bacterium by the phage to the recipient bacterium recombine with genes on the recipient's chromosome.

B DNA of the recipient bacterial chromosome undergoes recombination with DNA introduced by the phage from the donor bacterium, leading to a change in the recipient's genotype.

C The phage infection of the recipient bacterium and the introduction of DNA carried by the phage cause increased random point mutations of the bacterial chromosome.

D The recipient bacterium incorporates the transduced genetic material coding for phage proteins into its chromosome and synthesizes the corresponding proteins.

15 The diagram shows a plasmid with the positions of four restriction sites P to S indicated.



Copies of the plasmid were cut using two different restriction enzymes at a time, and the resulting fragments were separated by gel electrophoresis.

The diagram shows the results following gel electrophoresis of three samples.

Length of fragment (kb)	Restriction enzymes used		
	***Bal*I and *Eco*RI**	***Pvu*II and *Ava*I**	***Pvu*II and *Eco*RI**
40			
30			
20			
10			

Which row correctly matches the four restriction enzymes to their respective restriction sites on the plasmid?

	P	Q	R	S
A	*Ava*I	*Eco*RI	*Pvu*II	*Bal*I
B	*Bal*I	*Ava*I	*Eco*RI	*Pvu*II
C	*Eco*RI	*Pvu*II	*Bal*I	*Ava*I
D	*Pvu*II	*Bal*I	*Ava*I	*Eco*RI

16 The statements are about the preparation and application of DNA libraries.

1 A cDNA library allows the study of the functions of introns of specific genes.

2 A genomic library enables detection of genes that, in the host, have no detectable level of expression.

3 Alternative splicing can be studied using a cDNA library.

4 The preparation of a genomic DNA library requires restriction enzyme, reverse transcriptase and DNA ligase.

Which statements are correct?

A 1 and 4 only

B 2 and 3 only

C 1, 2 and 4 only

D 2, 3 and 4 only

17 A sample of DNA was treated separately with two different restriction enzymes. The products of digestion were then run on a gel and stained with ethidium bromide.

Which of the following statements cannot account for the difference in the number of bands seen on the gel?

1 The two enzymes have active sites that are of different shapes.

2 One of the enzymes produces blunt ends while the other produces sticky ends.

3 Ethidium bromide binds with greater affinity to double stranded DNA than single stranded DNA.

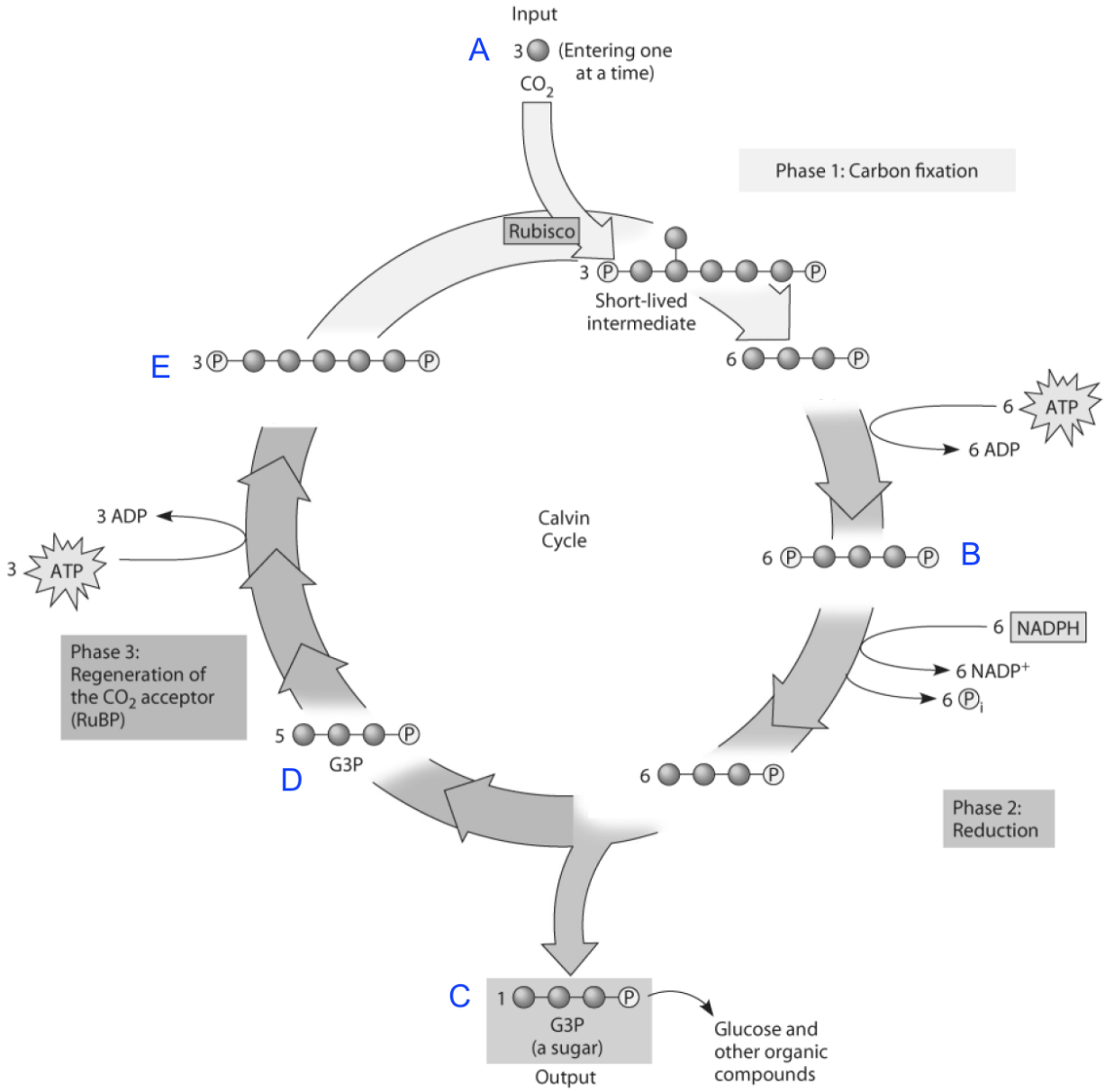
A 1 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

18 The diagram shows some molecules that are involved in the Calvin cycle.



If ATP used by a plant is labelled with radioactive phosphorus, in which molecules would the radioactivity be measurable after one "turn" of the Calvin cycle?

A A and B only

B A, C and D only

C B, D and E only

D B, C, D and E only

19 Which statement about the Krebs cycle is correct?

A Oxygen is used to oxidise the acetyl group carbons of acetyl-CoA in the Krebs cycle.

B Oxygen is not used in the Krebs cycle, so the cycle can occur in anaerobic conditions.

C The Krebs cycle produces the water that is formed during the complete oxidation of glucose.

D Three molecules of NADH and one molecule of $FADH_2$ are produced in one turn of the Krebs cycle.

20 Which statement correctly describes the role of lactate dehydrogenase?

A Lactate dehydrogenase catalyses the oxidation of pyruvate to lactate to regenerate NAD+.

B Lactate dehydrogenase catalyses the reduction of pyruvate to lactate to regenerate NAD+.

C Lactate dehydrogenase catalyses the oxidation of pyruvate to lactate to regenerate NADH.

D Lactate dehydrogenase catalyses the reduction of pyruvate to lactate to regenerate NADH.

21 In humans, hair colour is determined by the pigment produced by hair follicle cells. The genes determining pigment colour are found on chromosome 15.

Which statement is true?

A Chromosome 15 in liver cells also contains genes determining pigment colour.

B Chromosome 15 in liver cells contains genes that are different from that of chromosome 15 in hair follicle cells as liver cells do not produce hair.

C Hair follicle cells do not contain homologous chromosomes of chromosome 15 as the cells only undergo mitosis.

D Homologous chromosomes of chromosome 15 in hair follicle cells contain the same genes but at different loci.

22 A strain of toad has only one nucleolus in the nucleus of each cell instead of the usual two. When such toads are mated, approximately one quarter of the offspring have two nucleoli per nucleus, one half have one nucleolus per nucleus, and one quarter have no nucleoli at all.

What is the most likely explanation of these results?

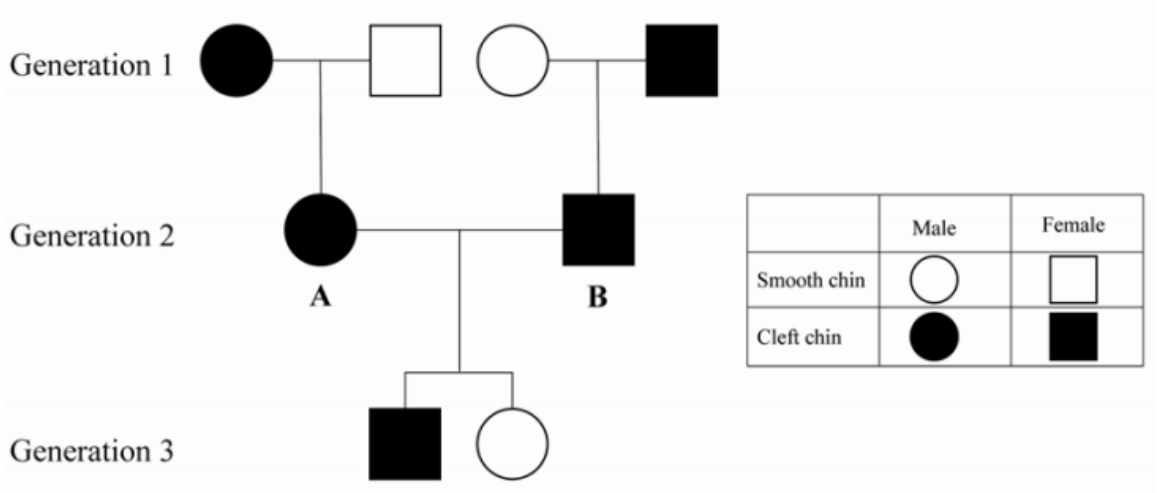
A The allele for the inheritance of two nucleoli per nucleus is dominant.

B The allele for the inheritance of two nucleoli per nucleus is recessive.

C The possession of one nucleolus per nucleus is due to the effect of crossing over.

D The possession of one nucleolus per nucleus is due to the heterozygous condition.

23 The pedigree diagram shows the chin types in a family.



Which statement correctly describes the cleft chin allele and the smooth chin allele?

A Both alleles are codominant.

B Both alleles are linked on the X chromosome.

C The cleft chin allele is dominant over the smooth chin allele.

D The smooth chin allele is epistatic to the cleft chin allele.

24 The rate of divergence of different proteins is shown in the table below.

Protein	Amino acid substitutions per site per billion years
fibrinopeptide	8.3
lysozyme	2.0
α-globin	1.2
insulin	0.44
cytochrome *c*	0.3
histone H4	0.01

What may be concluded from the data about the neutral theory of molecular evolution?

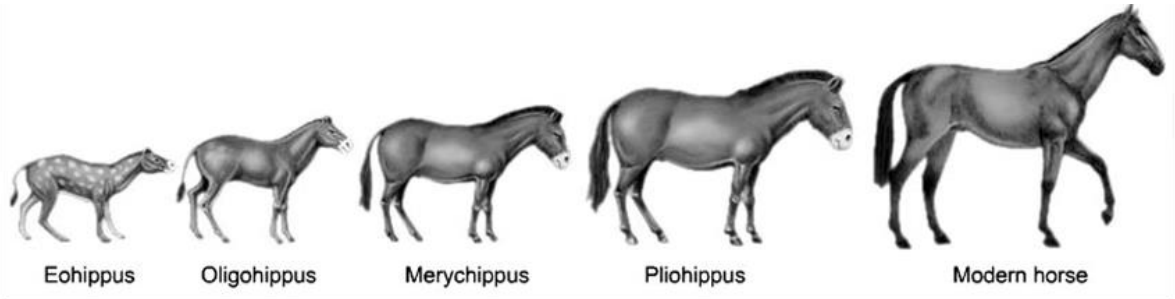
A All of these proteins are found in a common ancestor of all Earth's known living organisms before they started evolving at the molecular level.

B Genetic drift could play a greater role in the evolution of the gene for fibrinopeptide resulting in greater number of amino acid substitutions per site per billion years.

C Some essential proteins allow for fewer amino acid substitutions per site than others in order to maintain the same function.

D The rate of neutral mutations that result in the amino acid substitutions for all proteins is the same.

25 The diagram suggests the evolution of horses beginning from the Eophippus 58 million years ago.



Fossil records show that the ancestor of the modern horse is believed to have had relatively short legs. According to Darwinian views, what best explains the evolution of horses?

A acquired characteristics

B directional selection

C disruptive selection

D stabilising selection

26 When organochlorine insecticides such as DDT were in widespread use, mosquitoes in malarial regions developed resistance more rapidly than houseflies in Britain.

What could account for the difference in the rate of development of resistance against organochlorine insecticides?

A More insecticides were used in Britain.

B More insecticides were used in malarial regions.

C Mosquitoes have fewer random mutations when exposed to insecticides.

D Mosquitoes have more random mutations when exposed to insecticides.

27 Which process involves one stem cell giving rise to two distinct daughter cells: one copy of the original stem cell as well as a second daughter cell programmed to differentiate into a non-stem cell?

A asymmetric replication

B differentiation

C potency

D self renewal

28 Which is not a source for stem cells?

A bone marrow

B early embryos

C egg cells

D umbilical cord blood

29 Which is a reason why gene therapy involving the delivery of a normal allele of a proto-oncogene is not likely to be successful in the treatment of cancer?

A The proto-oncogene has many alleles controlling the production of the normal protein.

B The delivery of the normal allele of the proto-oncogene is likely to cause the cell cycle to stop.

C The normal allele for the proto-oncogene is not expressed in the presence of the dominant mutated allele.

D The normal allele of the proto-oncogene codes for a protein that will allow the formation of a tumour.

30 The adenoviral vector is used to introduce the normal CFTR allele into patients with cystic fibrosis (CF). The main procedures involved in the treatment are listed below.

- Genes for replication are removed from the vector to prevent respiratory infections caused by adenoviruses.
- Genes that causes the vector to elicit immune response are removed from the vector.
- After treatment, patients are screened to ensure that replication of adenoviral vectors is not occurring in their system.
- Patients are screened to ensure that shedding airway cells contain the normal CFTR allele

What limits the effectiveness of this type of gene therapy for CF?

A The adenoviral vector always causes infections in young and old patients.

B The adenoviral vector delivers the normal CFTR allele to the airway cells that are gradually shed.

C The adenoviral vector multiplies and make more copies of the normal CFTR allele.

D The adenoviral vector will cause immune response in patients undergoing this treatment.

31 Which of the following is/are reason(s) for scientists to employ the method of plant cloning?

1 introduction of animal genes into plants
2 create large changes at a rapid pace
3 large scale production of pharmaceutical drugs
4 selective breeding is too slow

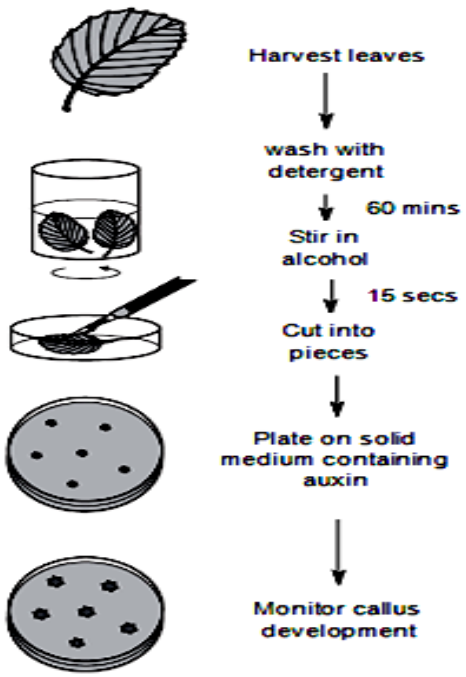
A 3 only

B 1, 3 and 4 only

C 2, 3 and 4 only

D 1, 2, 3 and 4

32 Callus tissue is produced using leaves by the technique shown in the diagram below. Using this, a student investigated the effect of two different concentrations of auxin on the volume of callus material produced. The table shows the results obtained over five days.



time (day)	volume of callus tissue (cm^3)	
	low concentration of auxin added	high concentration of auxin added
0	1.0	1.0
1	1.3	1.7
2	1.9	4.1
3	3.0	8.3
4	3.9	10.6
5	5.4	12.9

Which of the following statements about the experiment is / are true?

1 The leaves are disinfected and sterilised by washing with detergent and stirring in alcohol.

2 The leaves are wounded in order for callus tissue to form.

3 The concentration of auxin affects the volume of callus tissue formed.

4 Continued subculturing at three- to four-week intervals of small cell clusters taken from callus tissue can maintain the callus cultures for long periods of time.

A 3 only

B 1 and 3 only

C 1, 2 and 3 only

D 1, 2, 3 and 4

33 Which statements are possible issues of concern over the creation of genetically modified farmed animals?

1 Genetic engineering may result in the creation of new proteins that are harmful to the organisms that produce or consume them.

2 Cross species gene transfer may compromise the genome integrity of the species involved.

3 Over production of certain gene products may cause undue stress to the genetically modified farmed animals.

4 Some genetically modified food products may not be acceptable to certain groups of people.

A 1 and 4 only

B 2 and 3 only

C 1, 3 and 4 only

D 1, 2, 3 and 4

34 Scientists are concerned about the escape of genetically modified mosquitoes into the wild.

What is the most likely reason for this concern?

A The genetically modified mosquitoes may not survive in the wild.

B The mutation rate of the genetically modified mosquitoes will increase.

C The genetically modified mosquitoes may replace the wild mosquitoes population.

D The growth rate of the genetically modified mosquitoes will be affected.

35 Which statement best describes homeostasis?

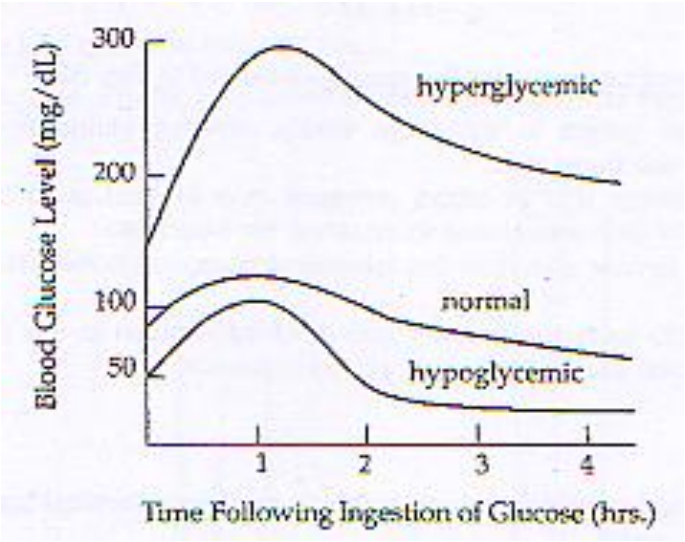
A achieving independence from fluctuating internal conditions

B altering the external environment to accommodate the body's needs

C keeping the body in a fixed and unaltered state

D maintaining a near-constant internal environment

36 The graph shows the blood glucose levels for normal, hyperglycaemic and hypoglycaemic individuals. The values in the graph represent averaged data from 10 subjects for each condition.



A glucose tolerance test was administered to evaluate the glucose levels in the blood of experimental subjects. Subjects were asked to fast for 12 hours before they were administered glucose at time 0 and then had blood samples drawn to assess the blood glucose levels. Glucose concentration was monitored every 30 minutes for a total of five hours. If the blood concentration exceeded 130 mg / dl, the subject was considered hyperglycaemic. Typically, hyperglycaemic patients exhibit symptoms such as thirst, increased appetite, and weight loss.

Why would a physician prescribe a diet consisting of several small meals to hypoglycaemic individuals?

A to cause the liver to convert more glucose to glycogen

B to cause the pancreas to release more glucagon

C to maintain a steady blood glucose concentration

D to rapidly decrease the blood glucose concentration

37 What is the first event that happens to insulin receptor after binding to insulin?

A Binding of insulin activates the receptor's cytosolic tyrosine kinase domain.

B Binding of insulin causes the receptors to dimerise.

C Binding of insulin causes the receptor to recruit a tyrosine kinase from the cytosol.

D Binding of insulin causes tyrosines in the receptor's C-terminal tail to become phosphorylated.

38 Which enzyme is activated by cyclic AMP in the signal transduction pathway after glucagon binds to its receptor?

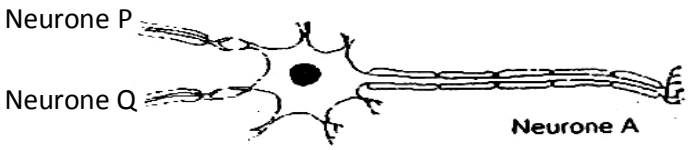
A adenylyl cyclase

B phosphorylase kinase

C protein kinase A

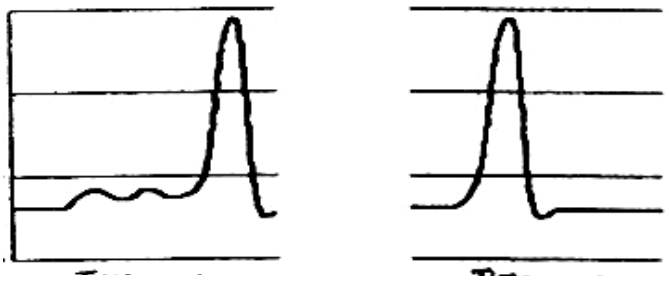
D protein kinase B

39 The diagram shows the effect of impulses from neurones P and Q on the production of an action potential in neurone A.



Action potentials in neurones P and Q

Membrane potential in neurone A / mV



Which of the following best describes X and Y?

	X	Y
A	EPSP	IPSP
B	IPSP	EPSP
C	spatial summation	temporal summation
D	temporal summation	spatial summation

40 Certain drugs act at the synapses and affect the action of neurotransmitters.

The table shows the effects of four different drugs.

drug	effect
1	competes with acetylcholine at the receptor sites
2	inhibits the enzyme acetylcholinesterase
3	inhibits the opening of voltage-gated sodium ion channels
4	uncontrolled release of acetylcholine

Which combination of drugs will reduce the possibility of the formation of an excitatory postsynaptic potential?

A 1 and 3

B 2 and 4

C 1, 3 and 4

D 2, 3 and 4

- **End of paper -**

Senior High 2
Preliminary Examination
Higher 2

BIOLOGY

9648/01

Paper 1 Multiple Choice

15 September 2016

1 hour 15 minutes

ANSWERS

1	C	11	C	21	A	31	D
2	B	12	B	22	D	32	D
3	B	13	C	23	C	33	D
4	A	14	B	24	B	34	C
5	D	15	B	25	B	35	D
6	A	16	B	26	B	36	C
7	B	17	C	27	A	37	B
8	A	18	D	28	C	38	C
9	A	19	D	29	C	39	D
10	D	20	B	30	B	40	A

H

Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME

BIOLOGY CLASS 2bi2____ / 2IPbi2__

REGISTRATION NUMBER

BIOLOGY

9648/02

Paper 2

26 August 2016

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and Biology class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Sections A - D
Answer **all** questions in the spaces provided on the question paper.

Section E
Answer any **one** question on the answer paper provided.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	(Total: 23)
1	/ 12
2	/ 11
Section B	(Total: 19)
3	/ 7
4	/ 12
Section C	(Total: 19)
5	/ 12
6	/ 7
Section D	(Total: 19)
7	/ 7
8	/ 12
Section E	(Total: 20)
9 or 10	/ 20
Total	**/ 100**

This document consists of **24** printed pages.

Section A

Answer **all** the questions in this section.

1 Many bacteria can digest cellulose using a group of enzymes called cellulases. Cellulases **A** and **T** were extracted from two different bacteria, *Agrobacterium tumefaciens* and *Thermotoga maritima*, respectively.

Fig. 1.1 shows the results of an investigation into the effect of temperature on the activity of each enzyme.

L represents the lowest temperature at which activity of each enzyme was detected.
H represents the highest temperature at which activity of each enzyme was detected.

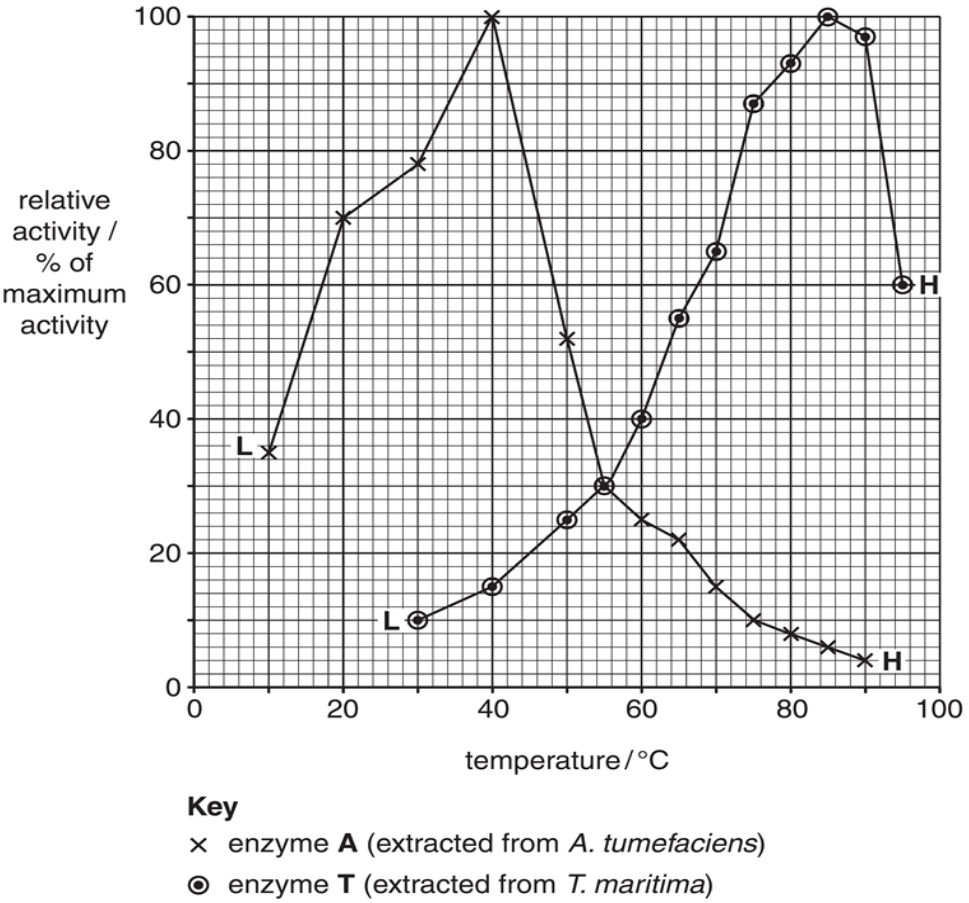


Fig.1.1

(a) With reference to Fig. 1.1, describe two differences in the results for the two enzymes, **A** and **T**. [2]

.....

.....

.....

[2]

(b) With reference to Fig. 1.1, explain the effect of increasing temperature on the relative activity of enzyme **T**.

[3]

(c) Suggest a structural feature of enzyme **T**, which helps to explain the results obtained in the investigation.

[2]

Fig. 1.2 shows the structure of small sections of DNA and messenger RNA (mRNA) in the nucleus of *Agrobacterium tumefaciens* during transcription of the gene coding for cellulase.

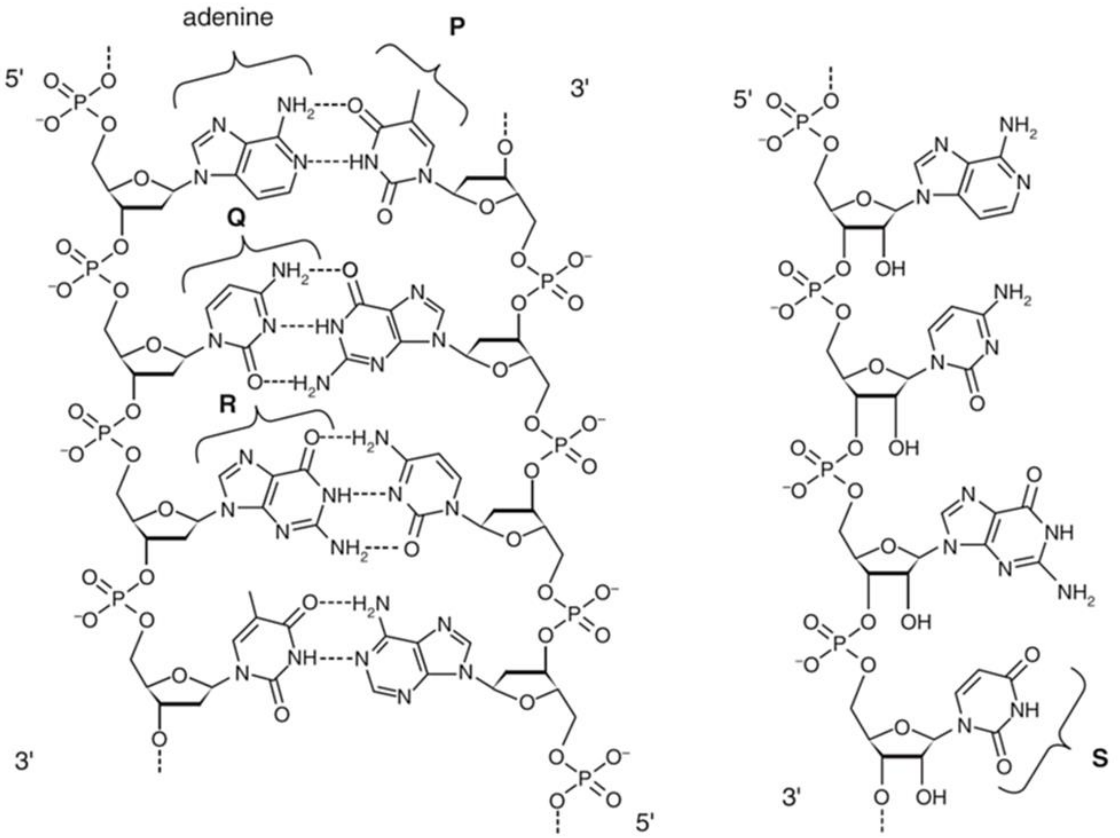


Fig. 1.2

(d) Name the bases **P** to **S**.

P: .....

Q: .....

R: .....

S: ..... [2]

(e) Describe how messenger RNA coding for cellulase is synthesised in *Agrobacterium tumefaciens*.

[3]

[Total: 12]

2 Fig. 2.1 shows the main steps involved in the synthesis of preproinsulin to insulin in the pancreatic β-cell. The preproinsulin is synthesised into the lumen of organelle **A** as proinsulin.

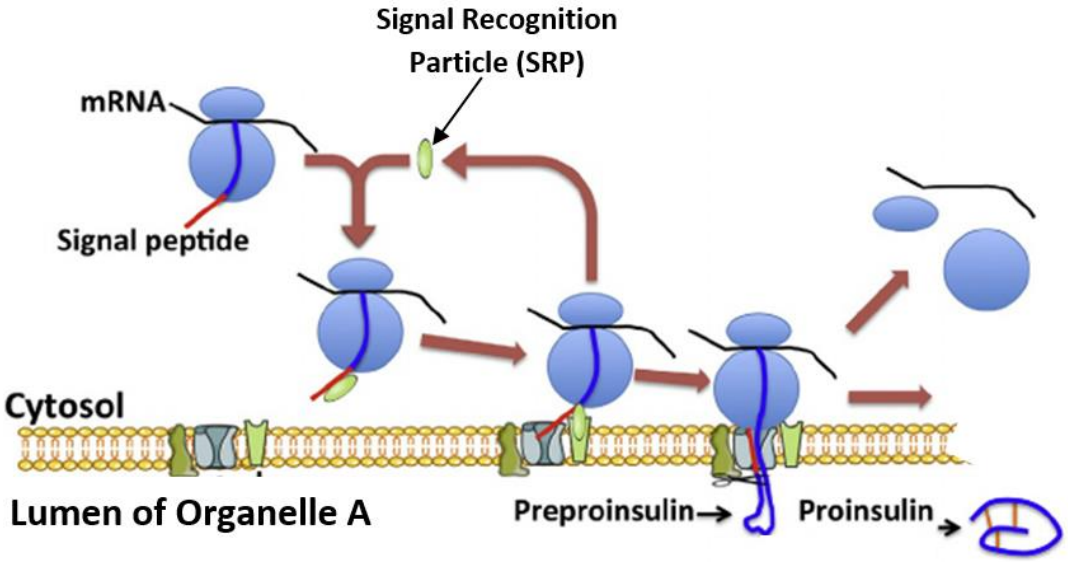


Fig. 2.1

The proinsulin is then be transported to organelle **B** where it is further processed to form insulin.

Fig. 2.2 shows the conversion of proinsulin to insulin in organelle **B**.

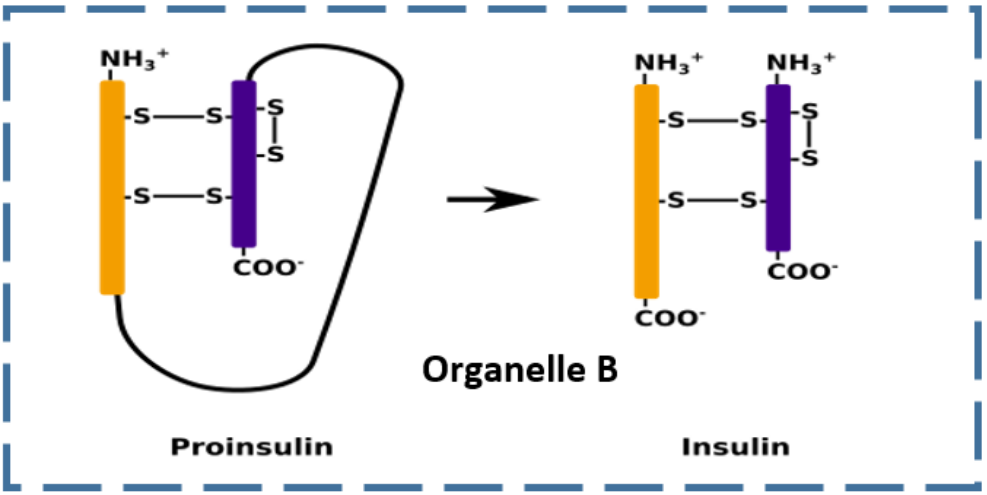


Fig. 2.2

(a) Name the organelles labelled **A** and **B**.

organelle **A:** .....

organelle **B:** ..... [1]

(b) State the role of rRNA in insulin synthesis.

[2]

(c) Insulin is released by pancreatic β-cell. Outline the route taken by proinsulin.

[2]

The synthesis of insulin is regulated at the transcriptional levels in β-cell.

Fig. 2.3 shows the binding of three β-cell-specific transcriptional factors, Pdx-1, MafA and NeuroD1 E47 in response to high glucose levels in β-cell.

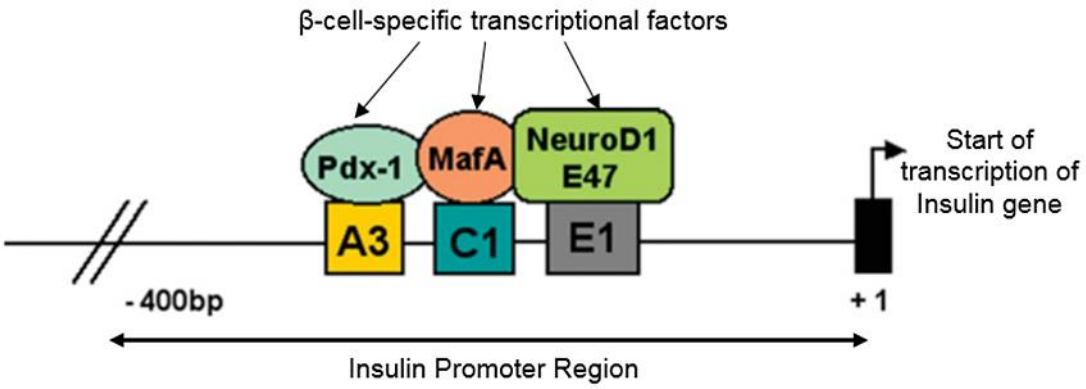


Fig. 2.3

(d) Explain how β-cell-specific transcriptional factors will lead to high level of insulin gene expression.

[2]

(e) It has been found that insulin promoters differ widely in efficiency among individuals. Strong promoters cause frequent initiations of transcription while weak promoters have low frequency of initiations of transcription. Explain what may have caused the difference in efficiency of the insulin promoters.

[2]

(f) Explain why gene mutations do not always produce mutated insulin protein whereas mutations of the splicing sites involved in RNA splicing will produce mutated insulin.

[2]

[Total: 11]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section B
Answer **all** the questions in this section.

3 Fig. 3.1 shows the life cycle of a water flea.

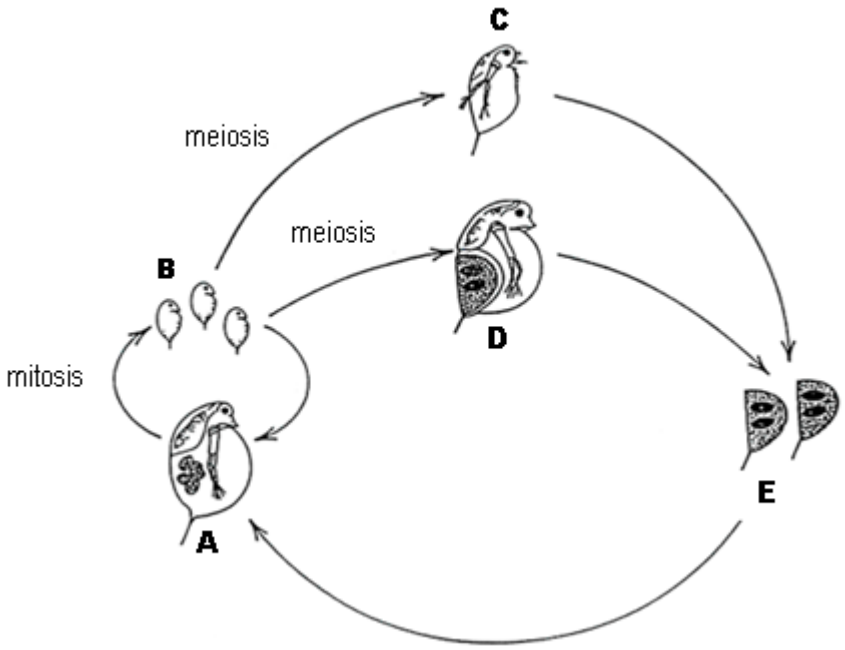


Fig. 3.1

In favourable conditions, all the animals in a population are females (**A**). These females produce eggs by mitosis, which develop into young females (**B**) without being fertilized. In unfavourable conditions, eggs produced by meiosis develop directly without fertilization into either males (**C**) or females (**D**). The eggs produced by the females (**D**) are fertilized by the sperms from the males (**C**), then released in protective egg cases (**E**) which enable them to survive unfavourable conditions. When favourable conditions return, these eggs develop back into females (**A**).

(a) The females at stage **A** of the life cycle have 18 chromosomes.

Complete the table to show the number of chromosomes at the other stages of the life cycle.

stage of life cycle	chromosome number
A	18
B	
C	
D	
E	

[1]

(b) Explain why the eggs from **D** and the sperms from **C** must be produced by mitosis.

[2]

(c) Explain why females **A**, developed from fertilized eggs **E**, are genetically different from each other.

[3]

(d) Give an example of a favourable condition in which females will develop from eggs formed via mitosis.

[1]

[Total: 7]

4 Cattle were found to have three different coat colours: brown, white and roan. Roan cattle have both brown and white patches. When two roan cattle were crossed, a ratio of 1:2:1 was obtained for brown, roan and white coat colour respectively. A separate gene on X chromosome in cattle code for a disease called Agnathia. The absence of a normal allele causes a deformity in the lower jaw.

(a) Construct a genetic diagram to show the expected ratio when brown carrier cows are crossed with normal jawed white bulls.

[5]

(b) State the mode of inheritance of the two traits. Explain how you arrive at your answer.

.....

.....

.....

..... [2]

(c) When a geneticist carried out a cross between brown carrier cows and normal jawed white bulls, he obtained the following phenotypes.

normal jawed, roan cows	55
normal jawed, roan bulls	37
deformed jawed, roan bulls	28

Fig. 4.1 shows the table of probabilities.

df	probability				
	0.10	**0.05**	**0.02**	**0.01**	**0.001**
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.69	13.28	18.47
5	9.24	11.07	13.39	15.09	20.52

Fig. 4.1

The formula for the chi-square statistic used in the chi square test is as follows:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

where O = observed value;
E = expected value.

With reference to Fig. 4.1, carry out a chi-square test to support your explanation in (b). Show your workings clearly in the space below.

[3]

(d) In some cases, the environment may affect the phenotype.

Give one named example to illustrate such an environmental effect.

.....

.....

.....

..... [2]

[Total: 12]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section C
Answer **all** the questions in this section.

5 Hepatitis C virus (HCV) is an enveloped, positive-strand RNA virus within the family Flaviviridae. HCV undergoes reproductive cycles similar to other enveloped viruses, such as influenza virus and dengue virus.

Fig. 5.1 shows a model of a HCV particle.

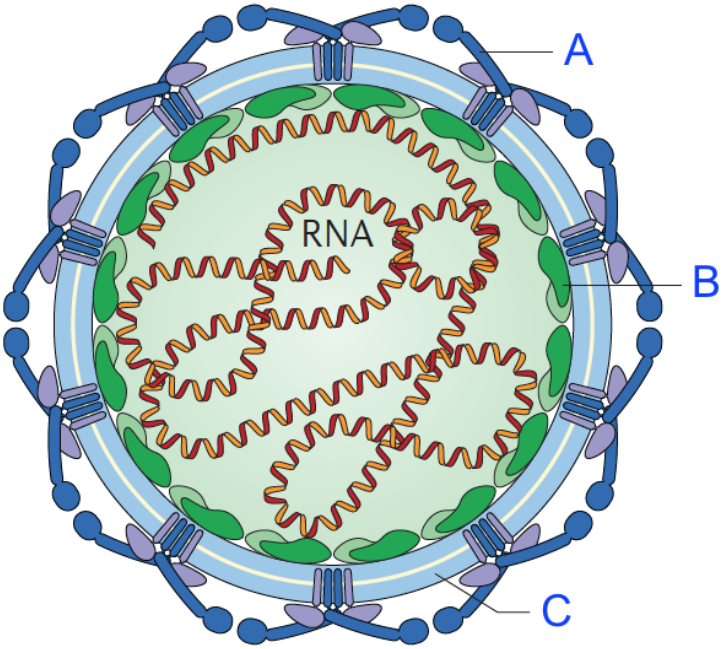


Fig. 5.1

(a) Identify the labelled structures **A**, **B** and **C**.

A: .....

B: .....

C: ..... [2]

(b) Explain why HCV is considered an obligate parasite.

.....

.....

..... [2]

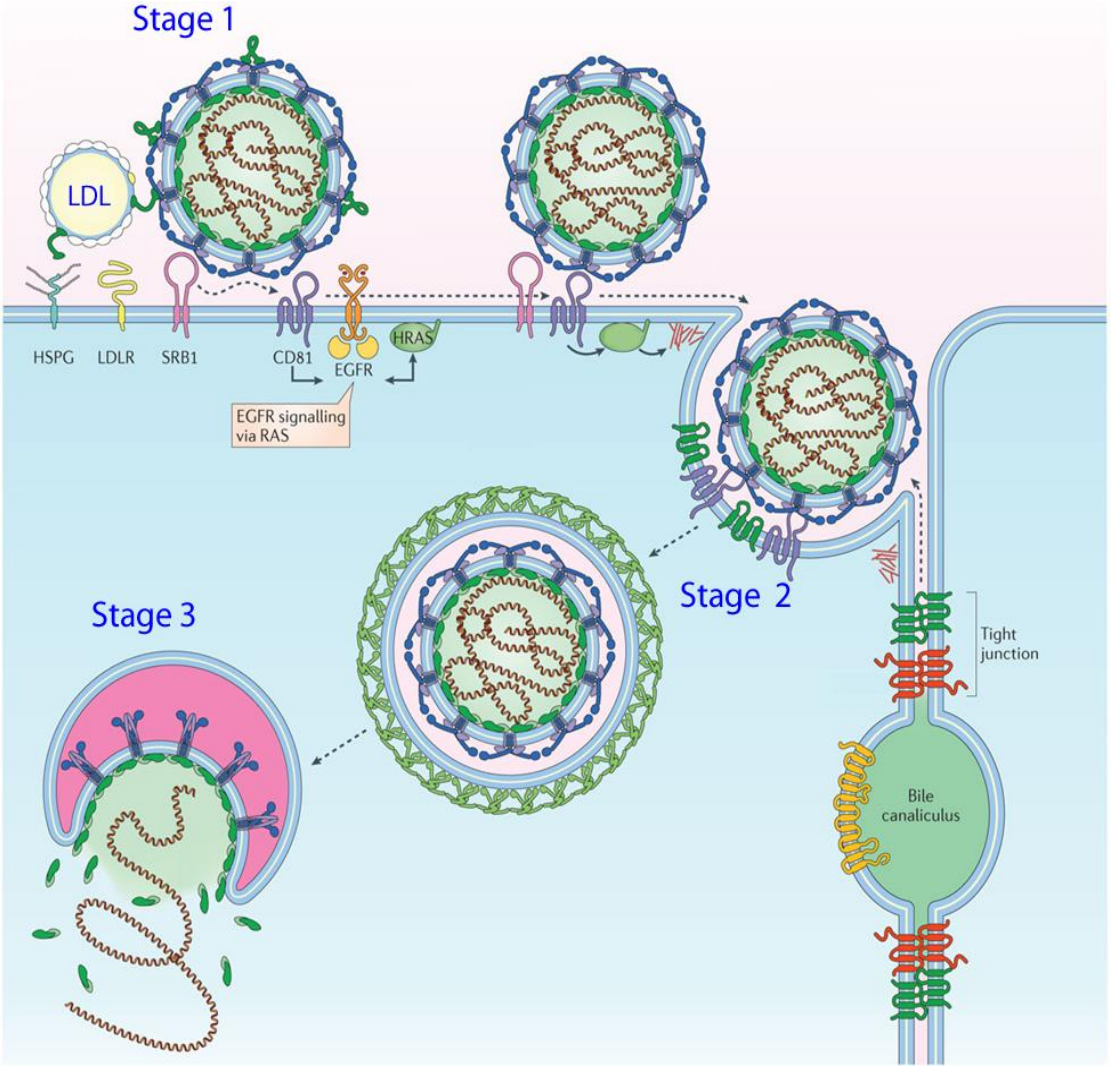


Fig. 5.2

(c) With reference to all labelled stages in Fig. 5.2, describe how HCV gains entry into its host cell.

.....

.....

.....

.....

.....

..... [3]

Fig. 5.3 shows the positive-strand RNA genome of HCV genome.

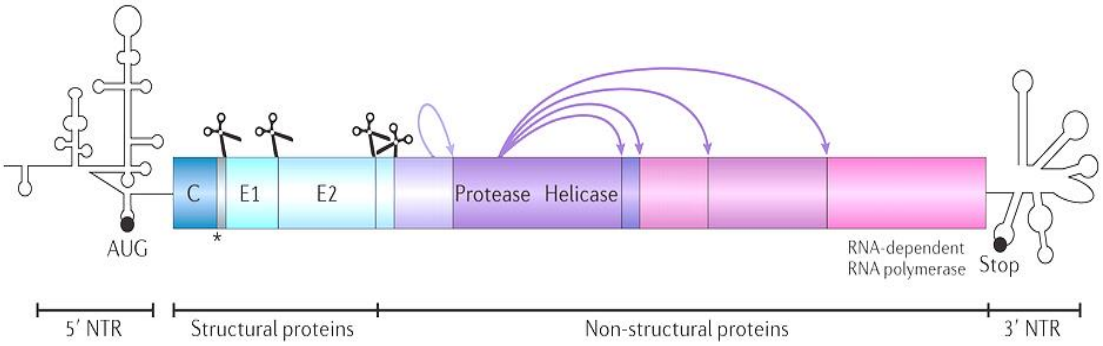


Fig. 5.3

(d) With reference to Fig. 5.3, describe the role of HCV genome in the infection process.

[2]

Hepatitis B virus (HBV) and HCV are known to be two major causative agents of hepatocellular carcinoma. Studies have shown that HBV DNA can be integrated during the early stages of infection. The integration of viral DNA is associated with deletions in portions of the host chromosomes. Many of these chromosomal segments contain known genes such as p53.

(e) Explain how HBV infection may lead to cancer.

[3]

[Total: 12]

6 **(a)** Human newborns and hibernating mammals contain large amounts of brown adipose tissue ('body fat').

Fig 6.1 shows the electron micrograph of a brown adipocyte. Brown adipocytes are characterised by the presence of numerous vacuoles and organelle **X** throughout the cell.

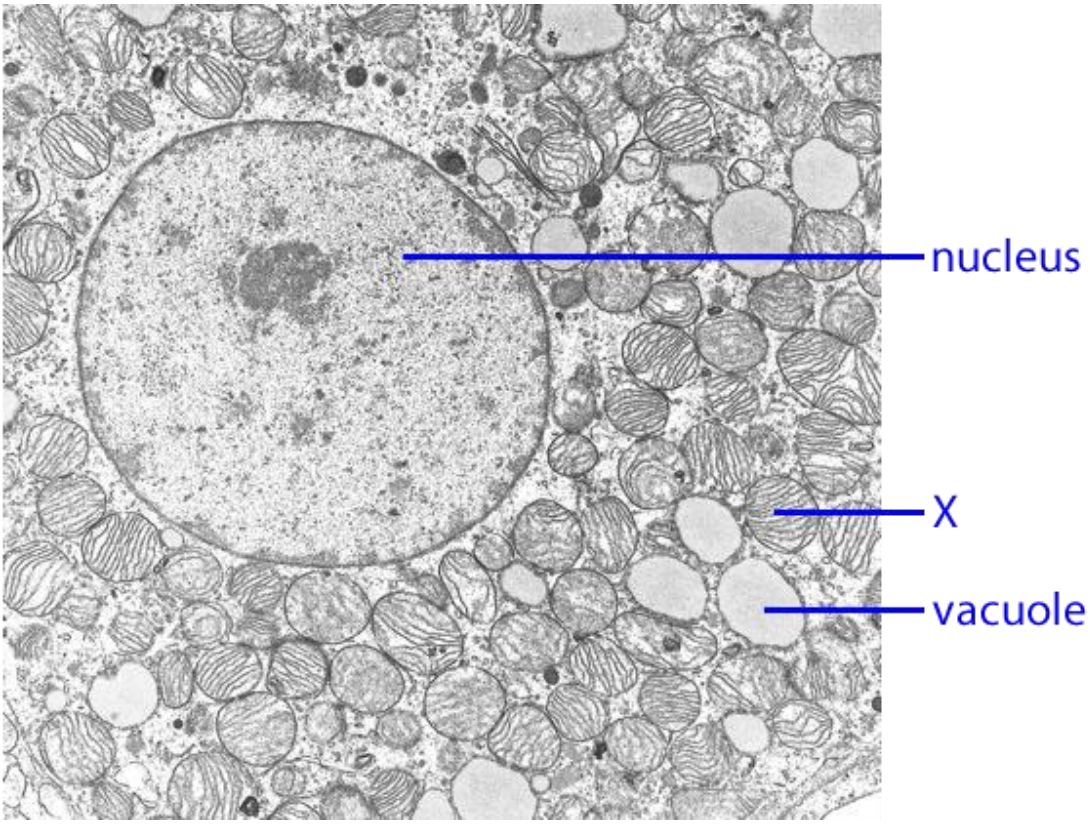


Fig. 6.1

(i) Identify organelle **X**.

.....[1]

(ii) Suggest the role of the numerous vacuoles found in brown adipocytes.

.....[1]

(b) Fig. 6.2 shows the schematic representation of a series of protein complexes found on the inner membrane of organelle **X**.

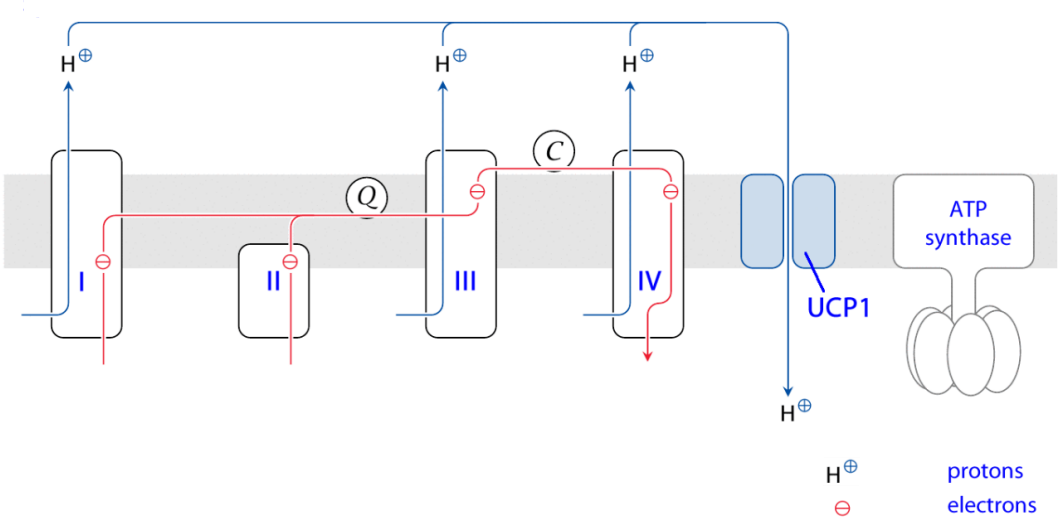


Fig. 6.2

(i) Oxygen is required to sustain the process illustrated in Fig. 6.2.
With reference to Fig. 6.2, describe the role played by oxygen.

.....

..... [1]

(ii) Brown adipocytes contain a unique protein, UCP1, which is not found in organelle **X** in any other cell type.

Evaluate the impact of UCP1 on the normal functioning of the process illustrated in Fig. 6.2 and suggest the physiological significance of brown adipose tissue.

.....

.....

.....

..... [2]

(c) In other cell types, NADH and $FADH_2$ are used to drive ATP synthesis by ATP synthase. Using relevant information from Fig. 6.2, suggest and explain why more ATP is produced from NADH.

.....

.....

.....

..... [2]

[Total: 7]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section D

Answer **all** the questions in this section.

7 The cardiac action potential is a specialised action potential with unique properties necessary for the electrical conduction system of the heart. The cardiac muscle cells share many things in common with nerve cells.

Fig. 7.1 shows the five phases of a cardiac action potential. Each of which is characterised with their respective changes in membrane potential.

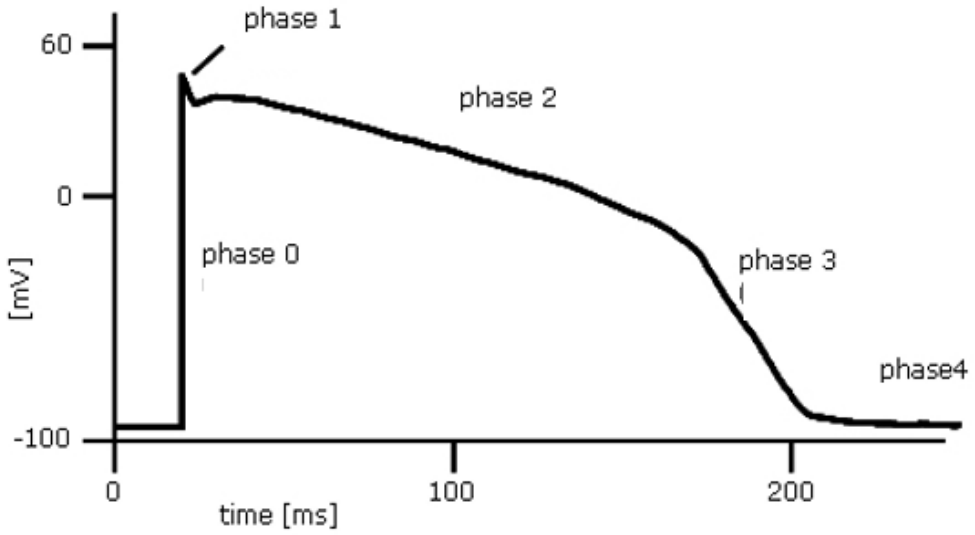


Fig. 7.1

The table shows the relative concentrations of ions inside and outside of the cardiac muscle cells.

element	ion	extracellular	intracellular
sodium	Na^+	135 – 145	10
potassium	K^+	3.5 – 5.0	155
chloride	Cl^-	95 – 110	20 – 30
calcium	Ca^{2+}	2	10^{-4}

(a) Estimate the resting potential for the cardiac action potential shown in Fig. 7.1.

.....

[1]

(b) Using the information from the table, explain how the resting potential can be produced in the heart muscles using sodium and potassium ions.

[3]

(c) Compare phase 2 of the action potential of a cardiac muscle cell with that of a nerve cell.

[1]

(d) Cardiac arrhythmia refers to any abnormal electrical activity in the heart. As a result, the heart may beat too fast. Calcium channel blockers such as Verapamil are often used to treat this condition.

Suggest and explain the action of Verapamil in controlling this symptom of arrhythmia.

[2]

[Total: 7]

8 The table shows the amino acid differences in the cytochrome b protein between various vertebrates.

	Human	Elephant	Platypus	Ostrich	Starling	Crocodile	Lungfish	Coelacanth	Goldfish	Shark
Human		26	40	43	41	47	83	70	68	71
Elephant			45	45	48	50	84	72	63	74
Platypus				54	52	51	89	74	70	76
Ostrich					26	36	91	75	68	73
Starling						47	91	77	67	70
Crocodile							85	78	70	77
Lungfish								90	94	86
Coelacanth									83	78
Goldfish										88
Shark										

Fig. 8.1 shows the phylogenetic tree based on differences between the cytochrome b proteins.

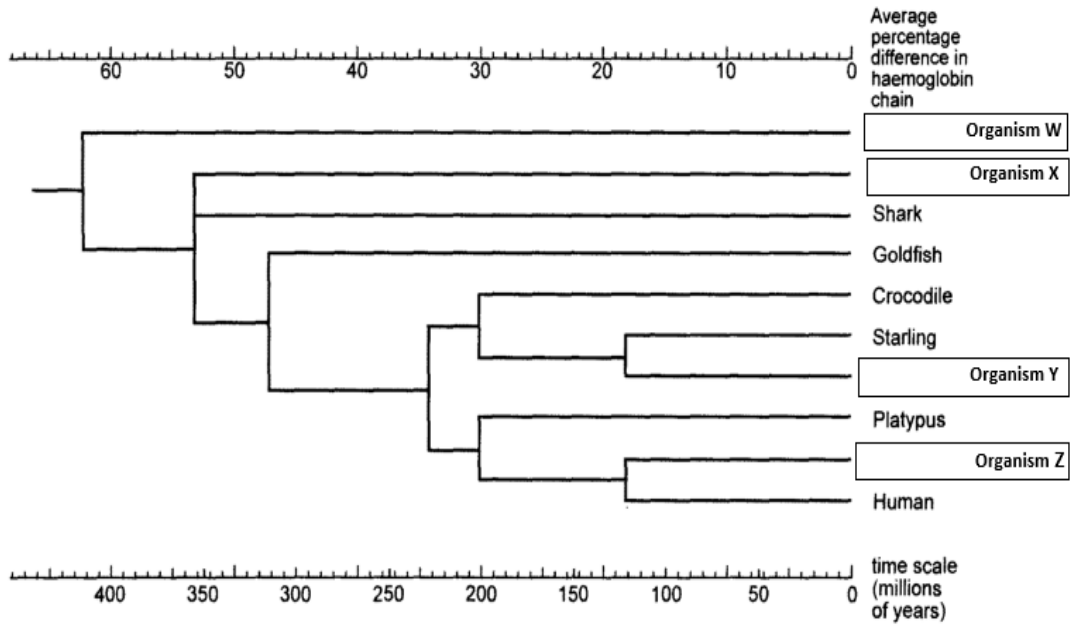


Fig. 8.1

(a) Using information from the table and Fig. 8.1, identify organisms **W** to **Z**.

W: .....

X: .....

Y: .....

Z: ..... [2]

(b) Explain how differences in amino acid sequences in the cytochrome b chain allow the establishment of the phylogenetic tree.

[3]

(c) Explain the difference between classification and phylogeny.

[2]

(d) Suggest why homology still features prominently in evolutionary studies despite the advantages that molecular evidence can confer.

[2]

(e) Explain the role of neutral mutations in evolutionary studies.

[3]

[Total: 12]

Section E

Answer **one** question.

Write your answers on the separate answer paper provided.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

9 **(a)** Compare the role of nervous system and endocrine system as communication systems within organisms. [6]

(b) Explain the meaning of the term homeostasis with specific reference to the control of raised blood glucose concentration in humans. [8]

(c) Describe the cell signalling pathway that glucagon initiates in order to regulate blood glucose concentration. [6]

[Total: 20]

10 **(a)** Compare the structural and regulatory genes in prokaryotes. [6]

(b) Explain the roles of the operator and activator binding site in the *lac* operon. [8]

(c) Describe how the molecular structure of phospholipids is related to their function in the plasma membrane. [6]

[Total: 20]

- End of paper -

H

Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME **ANSWERS**

BIOLOGY CLASS 2bi2____ / 2IPbi2__

REGISTRATION NUMBER

BIOLOGY

9648/02

Paper 2

26 August 2016

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and Biology class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Sections A - D
Answer **all** questions in the spaces provided on the question paper.

Section E
Answer any **one** question on the answer paper provided.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	(Total: 23)
1	/ 12
2	/ 11
Section B	(Total: 19)
3	/ 7
4	/ 12
Section C	(Total: 19)
5	/ 12
6	/ 7
Section D	(Total: 19)
7	/ 7
8	/ 12
Section E	(Total: 20)
9 or 10	/ 20
Total	**/ 100**

This document consists of **28** printed pages.

Section A

Answer **all** the questions in this section.

1 Many bacteria can digest cellulose using a group of enzymes called cellulases. Cellulases **A** and **T** were extracted from two different bacteria, *Agrobacterium tumefaciens* and *Thermotoga maritima*, respectively.

Fig. 1.1 shows the results of an investigation into the effect of temperature on the activity of each enzyme.

L represents the lowest temperature at which activity of each enzyme was detected.
H represents the highest temperature at which activity of each enzyme was detected.

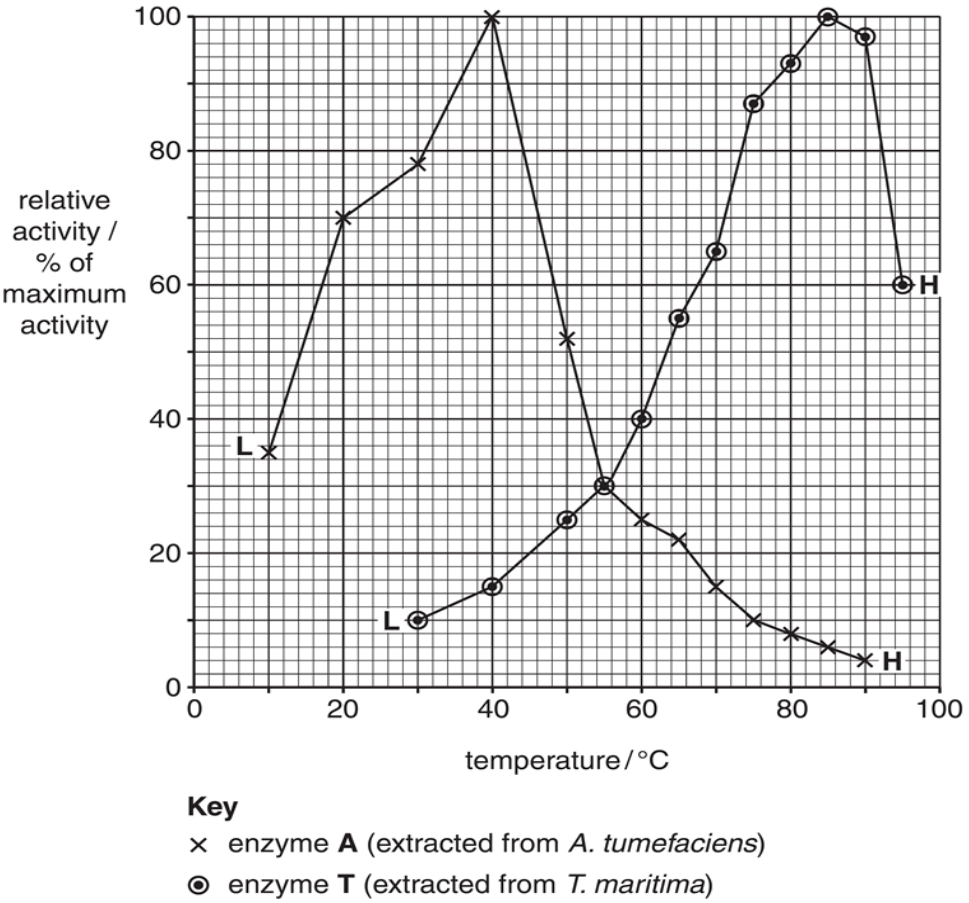


Fig.1.1

(a) With reference to Fig. 1.1, describe two differences in the results for the two enzymes, **A** and **T**. [2]

1. **Optimum temperature for enzyme A (40°C) is lower than that for enzyme T (85°C).**
   (Accept: "enzyme A optimum temperature is lower than enzyme T by 45 °C")
   (Accept: "maximum activity of enzyme A is at a lower temperature than T)

2. **Temperature range for enzyme A (10–90°C / spans 80°C range) is greater than that for enzyme T (30-95°C / spans 65°C range).** [2]

3. **Difference in shape of curve before or after optimum**
   E.g. before optimum, enzyme A has a steep increase, whereas enzyme T has a more gradual increase.
   E.g. after optimum, enzyme T has a steep decrease, whereas enzyme A has an initial steep decrease followed by a subsequent less steep gradient (Accept: enzyme A has a gradual decrease).

4. **Lowest temperature for enzyme A (at 10°C) as compared to lowest temperature for enzyme T (at 30°C)**

5. **Highest temperature for enzyme A (at 90°C) as compared to highest temperature for enzyme T (at 95°C)**

6. **Enzyme A works better at lower temperatures (10-55°C) as compared to enzyme T, which works better at higher temperatures (55-95°C).**

@ 1mark each, max 2

(b) With reference to Fig. 1.1, explain the effect of increasing temperature on the relative activity of enzyme **T**.

To *explain* the effect,

1. **As temperature increases from 30°C to 95°C, increase in <u>kinetic energy of enzyme and substrate molecules</u>, hence increasing the <u>rate of effective collisions</u> between them.**

2. **This facilitates the formation of <u>more enzyme-substrate (ES) complexes</u> resulting in an increase in relative activity.**

3. **However, as the temperature <u>increases beyond the optimum temperature of 85°C</u>, the enzyme molecules start to vibrate violently with the excess kinetic energy. As a result, the <u>weak (non-covalent) intramolecular bonds break.</u> These bonds maintain the secondary and tertiary structures/ specific 3D conformation of the enzyme. Enzyme becomes <u>denatured</u>.**

[3]

(c) Suggest a structural feature of enzyme **T**, which helps to explain the results obtained in the investigation.

1. **Enzyme T contains many <u>cysteine</u> amino acid residues (that maintain the tertiary structure by forming disulphide bonds).**

2. **<u>Higher temperature required</u> to break the <u>many/multiple disulphide bonds</u> within enzyme T (cysteine R-groups form covalent disulphide bonds)** [2]

Fig. 1.2 shows the structure of small sections of DNA and messenger RNA (mRNA) in the nucleus of *Agrobacterium tumefaciens* during transcription of the gene coding for cellulase.

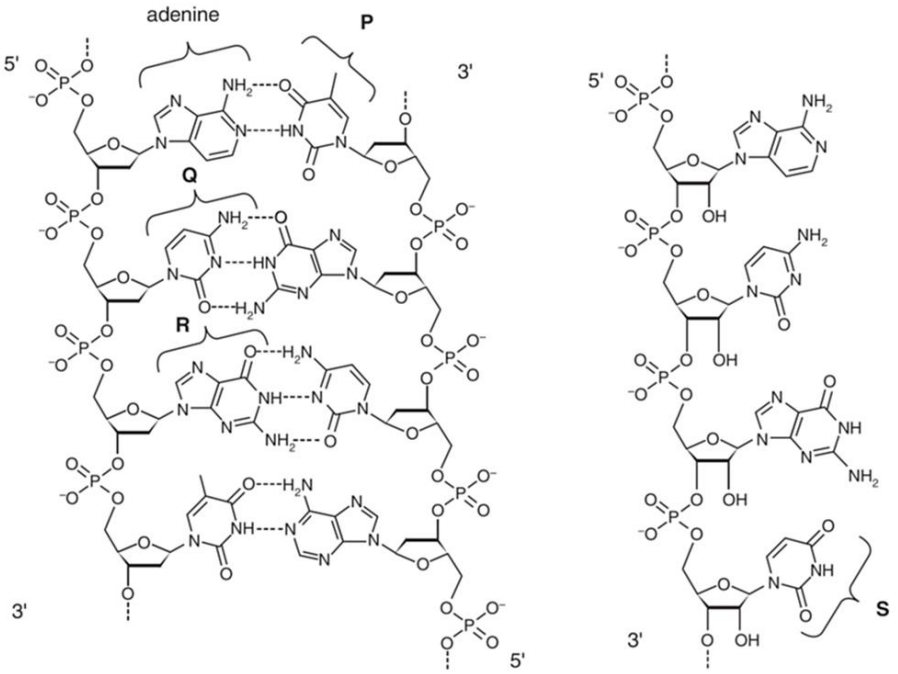


Fig. 1.2

(d) Name the bases **P** to **S**.

P: Thymine , Q: Cytosine , R: Guanine , S: Uracil

(all 4 correct – 2 mark, 2-3 correct – 1 mark) [2]

(e) Describe how messenger RNA coding for cellulase is synthesised in *Agrobacterium tumefaciens*.

1. **<u>RNA polymerase</u> (with the aid of Sigma factor) binds to cellulose gene <u>promoter</u> (Pribnow box), causing the DNA double helix to <u>unzip (separate)</u>** [3]
2. **<u>One</u> of the two DNA strands serves as <u>template strand</u>**
3. **<u>Free ribonucleotides / free ribonucleoside triphosphates / rNTPs</u> form <u>complementary base pairing</u> with bases/deoxyribonucleotides on the template DNA strand**
4. **RNA polymerase catalyses <u>formation of phosphodiester bonds</u> (between ribonucleotides via condensation reactions)**
5. **Template DNA strand is read from 3' to 5' direction, and mRNA is synthesized from 5' to 3' direction**
6. **Transcription ends when RNA polymerase transcribes a <u>terminator</u> sequence**

@1 mark each, max 3

[Total: 12]

2 Fig. 2.1 shows the main steps involved in the synthesis of preproinsulin to insulin in the pancreatic β-cell. The preproinsulin is synthesised into the lumen of organelle **A** as proinsulin.

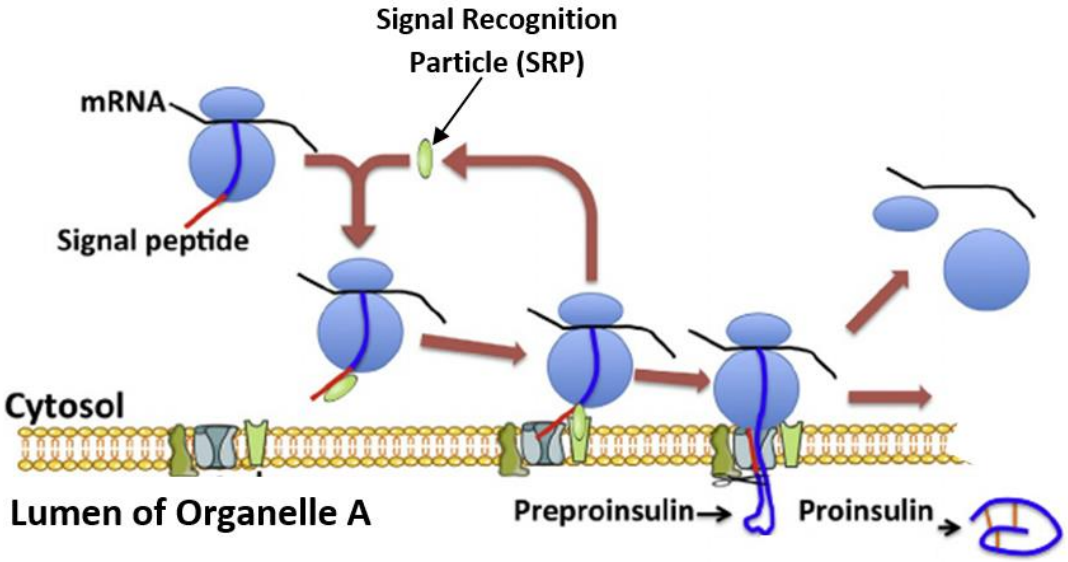


Fig. 2.1

The proinsulin is then be transported to organelle **B** where it is further processed to form insulin.

Fig. 2.2 shows the conversion of proinsulin to insulin in organelle **B**.

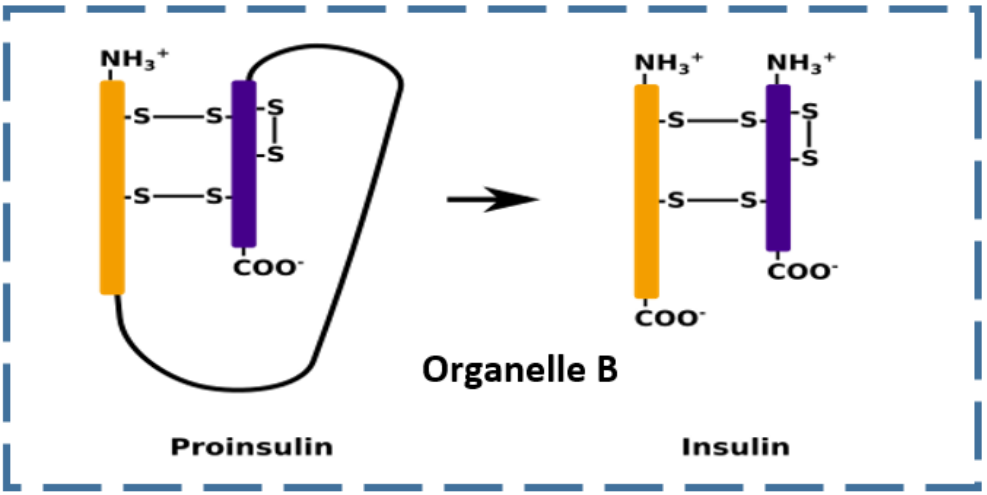


Fig. 2.2

(a) Name the organelles labelled **A** and **B**.

Organelle A: **Rough Endoplasmic reticulum (Must spell in FULL)**

Organelle B: **Golgi apparatus / Golgi body** [1]

(b) State the role of rRNA in insulin synthesis.

1. **rRNA along with ribosomal proteins forms the structural component of ribosome (large and small sub-unit).**
2. **rRNA is responsible for catalytic function of ribosome in the formation of peptide bond between amino acids (found at the large sub-unit).**
3. **rRNA in the small ribosomal subunit binds to 5' end of mRNA sequence during protein translation.**
4. **rRNA at the A site binds to the amino-acyl tRNA while the rRNA at the P site binds to the peptidyl-tRNA.**

OWTTE

*** Any 2 of the above**

[2]

(c) Insulin is released by pancreatic β-cell. Outline the route taken by proinsulin.

1. **From Rough ER, a transport vesicle takes the proinsulin to the Golgi apparatus (GA).**
2. **After chemical modification and packaging, a secretory vesicle pinched/buds off from GA.**
3. **The transport of secretory vesicles (aided by microtubules-the cytoskeletal elements) in the cytoplasm, until they fuse to the plasma membrane.**
4. **Secretory vesicle fuses with the cell surface membrane before releasing insulin by exocytosis.**

[2]

* 3 points to get 2 marks. Pt 4 is crucial to talk about.

The synthesis of insulin is regulated at the transcriptional levels in β-cell.

Fig. 2.3 shows the binding of three β-cell-specific transcriptional factors, Pdx-1, MafA and NeuroD1 E47 in response to high glucose levels in β-cell.

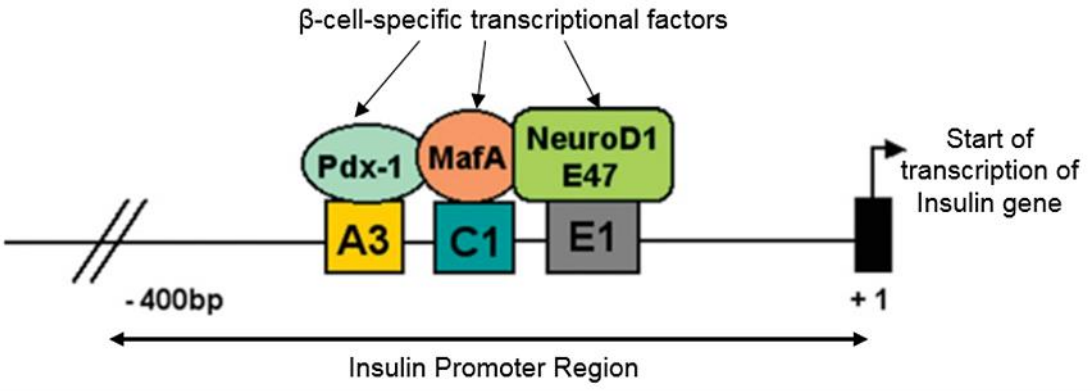


Fig. 2.3

(d) Explain how β-cell-specific transcriptional factors will lead to high level of insulin gene expression.

[2]

1. **β-cell-specific transcriptional factors are activators that bind to the enhancer region found in the insulin promoter region.**

2. **Binding of β-cell-specific transcription factors will lead to <u>increase in the formation of transcription initiation complex</u> / <u>helps RNA polymerase, transcription initiation factors to bind to promoter region with greater affinity</u>.**

3. **β-cell-specific transcriptional factors act as activators and <u>lead to chromatin remodelling / changes in chromatin structure</u> to increase rate of transcription. E.g. via histone acetylation *to allow greater accessibility to RNA polymerases for transcription to occur.***

   E.g of changes:
   - ***a. <u>Aacetylation of histone tails / addition of acetyl groups</u> catalyzed by histone acetyltransferase***
   - ***b. Cause, the chromatin structure becomes <u>less compact and</u> <u>allow access to RNA polymerase</u> to insulin gene promoter sequence. Transcription can take place.***

Any 2 of the above point

(e) It has been found that insulin promoters differ widely in efficiency among individuals. Strong promoters cause frequent initiations of transcription while weak promoters have low frequency of initiations of transcription. Explain what may have caused the difference in efficiency of the insulin promoters.

1. **Gene mutation / base substitutions in the insulin promoter sequence result in changes in the base sequence of the promoter**

2. **This change will cause the structure of the promoter to be of less complementary to the DNA binding site of the RNA polymerase and affects the binding of the RNA polymerase to the promoter sequence / Resulting in a promoter which initiates transcription less strongly;**

Other accepted answers:

- **Promoter region found in tightly coiled region of DNA molecule, affects accessibility by RNA polymerases- Level of supercoiling of the DNA affects accessibility to RNA polymerase.**
- **Methylation of the promoter regions, which affects the binding by RNA polymerases.**

[2]

(f) Explain why gene mutations do not always produce mutated insulin protein whereas mutations of the splicing sites involved in RNA splicing will produce mutated insulin.

[2]

Why gene mutations do not always produce mutated insulin:

1. **Gene mutations that involve substitution may result in the same amino acid being coded for and due to the degenerate code/ same amino acid can be coded for by different codons.**
2. **Gene mutation could occur at the intro region instead of exons.**

Why mutations at RNA splicing sites will produce mutated insulin:

Mutation at the splice site will affect the binding of spliceosome, and will affect the removal of introns & exons, hence giving rise to a mutated protein with loss of function.

Example of the kind of mutations at RNA splicing sites and the outcome:

An example of mutation at RNA splicing sites *(any one)*	Effect of such mutation (i.e. production of mutated collagen) *(any one)*
Different combinations of exons being produced	**Different primary sequences of amino acids resulting in different protein (mutated protein)**
An exon is lost/ wrong excision of exons	**Large number of bases and hence amino acids is lost/ as above**
Introns not removed by spliceosome	**Introns translated and became additional amino acids, this will lead to change the protein structure**

[Total: 11]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section B

Answer **all** the questions in this section.

3 Fig. 3.1 shows the life cycle of a water flea.

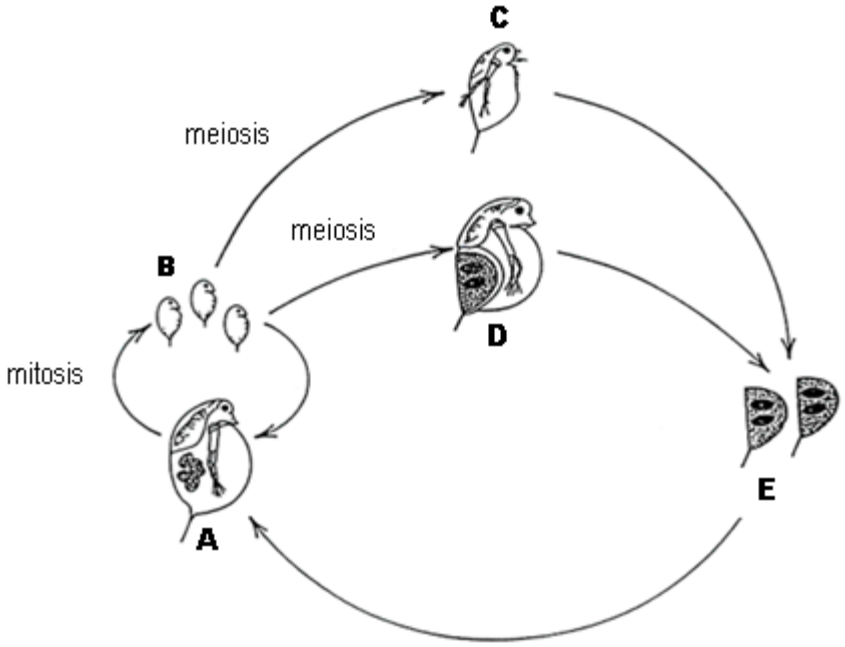


Fig. 3.1

In favourable conditions, all the animals in a population are females (**A**). These females produce eggs by mitosis, which develop into young females (**B**) without being fertilized. In unfavourable conditions, eggs produced by meiosis develop directly without fertilization into either males (**C**) or females (**D**). The eggs produced by the females (**D**) are fertilized by the sperms from the males (**C**), then released in protective egg cases (**E**) which enable them to survive unfavourable conditions. When favourable conditions return, these eggs develop back into females (**A**).

(a) The females at stage **A** of the life cycle have 18 chromosomes.

Complete the table to show the number of chromosomes at the other stages of the life cycle.

stage of life cycle	chromosome number
A	18
B	**18**
C	**9**
D	**9**
E	**18**

[1]

(b) Explain why the eggs from **D** and the sperms from **C** must be produced by mitosis.

1. **Since C and D (developed from unfertilised eggs from B) are haploid, mitosis ensures that the haploid chromosome number is preserved / the eggs and sperms are haploid.**

2. **Thus, when the haploid sperm and haploid egg fuse, the original diploid chromosome number is restored.** [2]

(c) Explain why females **A**, developed from fertilized eggs **E**, are genetically different from each other.

(Any 3)

1. **C and D developed from eggs that are produced by meiosis in B.**

2. **Crossing over between non-sister chromatids of homologous chromosomes at prophase 1 of meiosis**

3. **Independent assortment of homologous chromosomes at metaphase 1 of meiosis**

4. **Independent assortment of non-identical chromatids at metaphase 2 of meiosis**

5. **Random mating between C and D**

6. **Mutations can occur at any time.** [3]

(d) Give an example of a favourable condition in which females will develop from eggs formed via mitosis.

(Any 1)

- **Presence of water in a previously dry pond**
- **Reasonably high temperature (~20°C)**
- **Abundant food source**
- **Lack of competition**
- **Stable environment**
- **Few or no predators**
- **Appropriate photoperiod**
- **Water of optimal pH**
- **Suitable salinity**
- **(any other valid point)** [1]

[Total: 7]

4 Cattle were found to have three different coat colours: brown, white and roan. Roan cows have both brown and white patches. When two roan cattle were crossed, a ratio of 1:2:1 was obtained for brown, roan and white coat colour respectively. A separate gene on X chromosome in cattle code for a disease called Agnathia. The absence of a normal allele causes a deformity in the lower jaw.

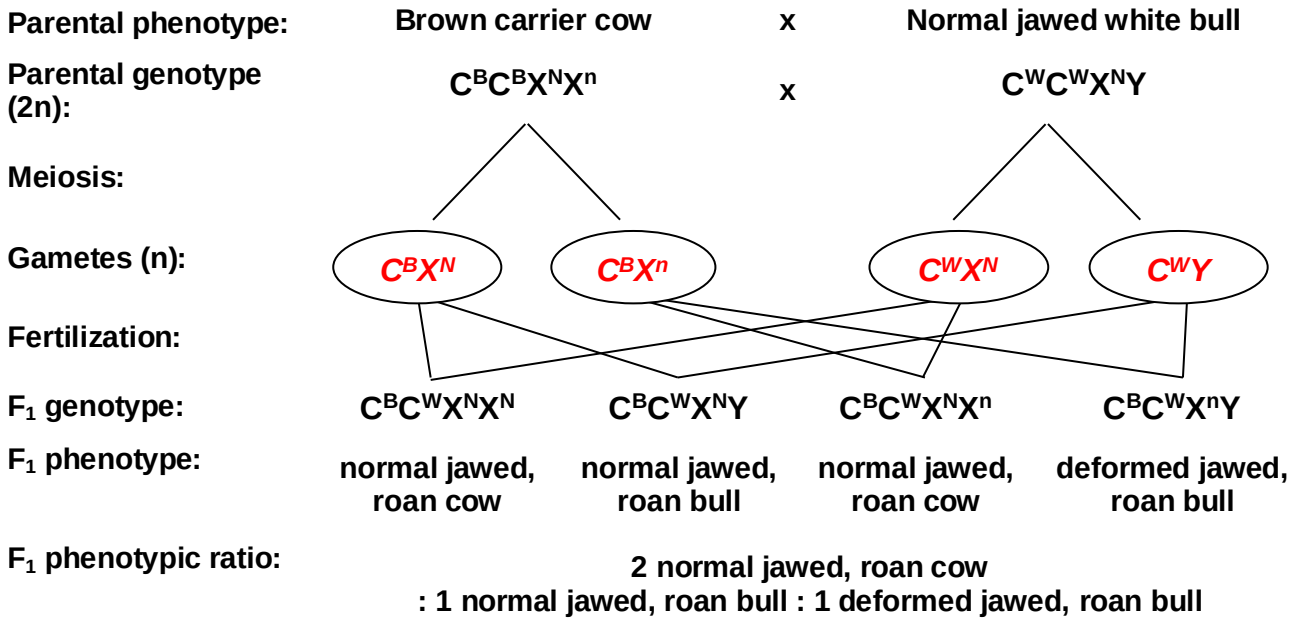
(a) Construct a genetic diagram to show the expected ratio when brown carrier cows are crossed with normal jawed white bulls.

Let C^B represent the codominant allele for brown coat.

Let C^W represent the codominant allele for white coat.

Let X^N represent the X-linked dominant allele for normal jaw.

Let X^n represent the X-linked recessive allele for deformed jaw.



Both parental phenotypes and genotypes are correct (with appropriate use of symbols). [1]

All possible gametes from each parent are correct. [1]

Genetic diagram correctly shows 4 possible combinations of gametes. [1]

The phenotypes of all F_1 genotypes are correct. [1]

Expected F_1 phenotypic ratio is correct. [1]

[5]

(b) State the mode of inheritance of the two traits. Explain how you arrive at your answer.

- **agnathia: X-linked / sex-linked recessive**
- **gene is on X chromosome AND absence of normal allele causes it**
- **coat colour: codominance**
- **roan cattle have both brown and white patches (intermediate phenotype)**

Award 1 m if mention any 2 of the above
Award 2 m if mention all of the above [2]

(c) When a geneticist carried out a cross between brown carrier cows and normal jawed white bulls, he obtained the following phenotypes.

normal jawed, roan cows	55
normal jawed, roan bulls	37
deformed jawed, roan bulls	28

Fig. 4.1 shows the table of probabilities.

df	probability				
	0.10	**0.05**	**0.02**	**0.01**	**0.001**
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.69	13.28	18.47
5	9.24	11.07	13.39	15.09	20.52

Fig. 4.1

The formula for the chi-square statistic used in the chi square test is as follows:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$ where O = observed value; E = expected value.

[3]

With reference to Fig. 4.1, carry out a chi-square test to support your explanation in (b). Show your workings clearly in the space below.

Null Hypothesis: H_0: There is no significant difference between observed and expected data. i.e. the observed data follows a 2:1:1 distribution. Any difference is due to chance.

Phenotype	Ratio	(O)	(E)	$(O-E)^2/E$
Normal jawed, roan cows	2	55	60	0.42
Normal jawed, roan bulls	1	37	30	1.63
Deformed jawed, roan bulls	1	28	30;	0.13;
		$\Sigma_{(O)} = 120$	$\Sigma_{(E)} = 120$	$X^2_{cal} = 2.18$;

Correct working for calculation of chi-square statistic (i.e. 2.18) [1]

Use correct df (i.e. 2) and probability (i.e. 0.05) in Fig. 4.1 to determine critical chi-square value (i.e. 5.99) [1]

State / Accept the null hypothesis [1]

(d) In some cases, the environment may affect the phenotype.

Give one named example to illustrate such an environmental effect. [2]

- **(valid character) e.g. fur colour / synthesis pf black pigment**
- **(type of organism) e.g. Himalayan rabbit**
- **(change in environment) e.g. exposure to heat**
- **(corresponding change in phenotype) e.g. white fur formed instead of black fur / no synthesis of black pigment**

[Total: 12]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section C

Answer **all** the questions in this section.

5 Hepatitis C virus (HCV) is an enveloped, positive-strand RNA virus within the family Flaviviridae. HCV undergoes reproductive cycles similar to other enveloped viruses, such as influenza virus and dengue virus.

Fig. 5.1 shows a model of a HCV particle.

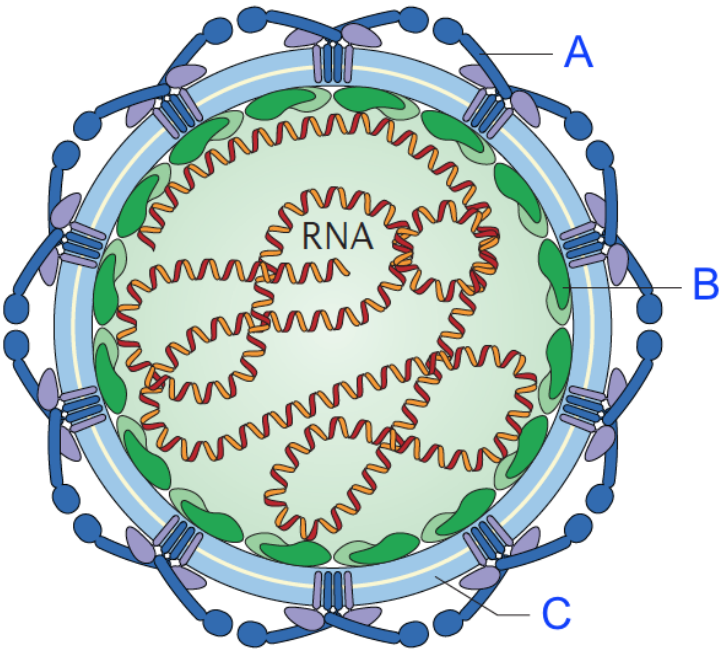


Fig. 5.1

(a) Identify the labelled structures **A**, **B** and **C**.

A: glycoprotein/ envelope glycoprotein

B: capsid/ capsomere

C: envelope [2]

(b) Explain why HCV is considered an obligate parasite.

1. **HCV can only survive and reproduce in living host cells.**
2. **HCV uses host cell's machinery and resources to replicate and assemble new viral particles.** [2]

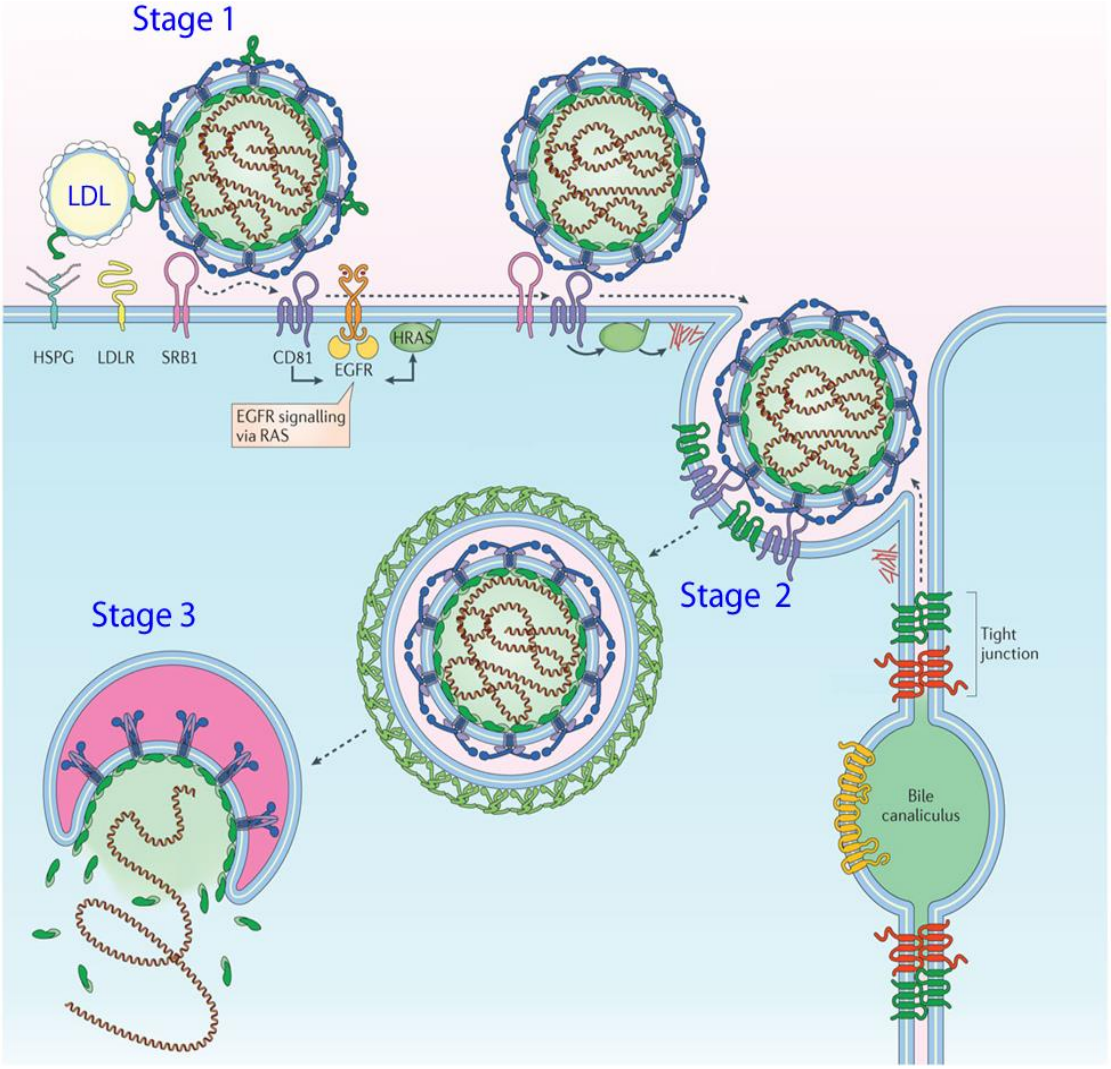


Fig. 5.2

(c) With reference to all labelled stages in Fig. 5.2, describe how HCV gains entry into its host cell.

1. **HCV binds to SRB1/ CD81 in stage 1.**

2. **Host cell membrane invaginates and HCV enters host cell through receptor-mediated endocytosis in stage 2.**

3. **Low pH within endosome stimulates fusion of viral envelope with endosome membrane, exposing capsid to digestion by cellular enzymes, releasing viral RNA into the cytoplasm in stage 3.** [3]

Fig. 5.3 shows the positive-strand RNA genome of HCV genome.

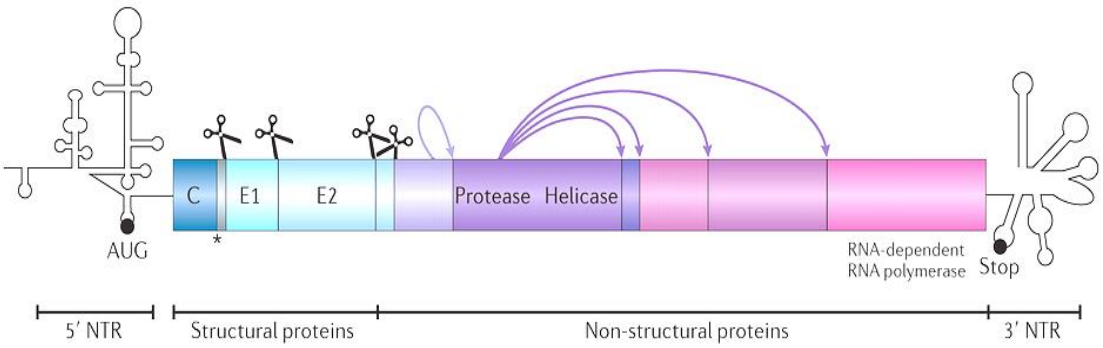


Fig. 5.3

(d) With reference to Fig. 5.3, describe the role of HCV genome in the infection process.

1. **Positive-stranded RNA is translated into a polyprotein by host ribosomes and cleaved into individual proteins.**

2. **RNA-dependent RNA polymerase coded by viral genome synthesizes a negative-sense RNA intermediate which is used as a template for synthesizing**

[2]

Hepatitis B virus (HBV) and HCV are known to be two major causative agents of hepatocellular carcinoma. Studies have shown that HBV DNA can be integrated during the early stages of infection. The integration of viral DNA is associated with deletions in portions of the host chromosomes. Many of these chromosomal segments contain known genes such as p53.

(e) Explain how HBV infection may lead to cancer.

1. **p53 is a tumour suppressor gene, which bring about inhibition of cell cycle and activation of DNA repair genes when DNA damage is detected.**

2. **Deletion of p53 results in loss of function mutation of p53, allowing DNA damage to accumulate in cells.**

3. **As cells accumulate 4-6/ more mutations in key regulatory genes, including appearance of <u>at least 1 active oncogene</u>, they become cancerous.**

[3]

[Total: 12]

6 **(a)** Human newborns and hibernating mammals contain large amounts of brown adipose tissue ('body fat').

Fig 6.1 shows the electron micrograph of a brown adipocyte. Brown adipocytes are characterised by the presence of numerous vacuoles and organelle **X** throughout the cell.

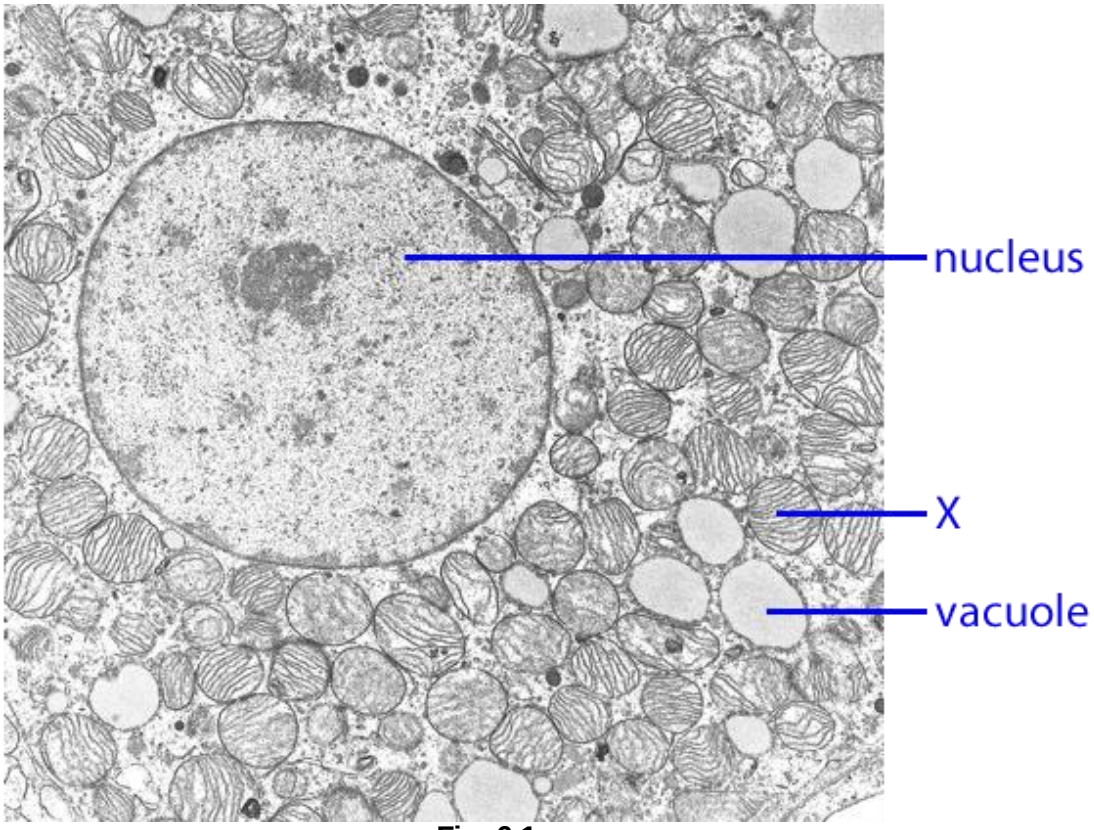


Fig. 6.1

(i) Identify organelle **X**.

mitochondrion [1]

(ii) Suggest the role of the numerous vacuoles found in brown adipocytes.

They store lipids / triglycerides / fats. [1]

(b) Fig. 6.2 shows the schematic representation of a series of protein complexes found on the inner membrane of organelle **X**.

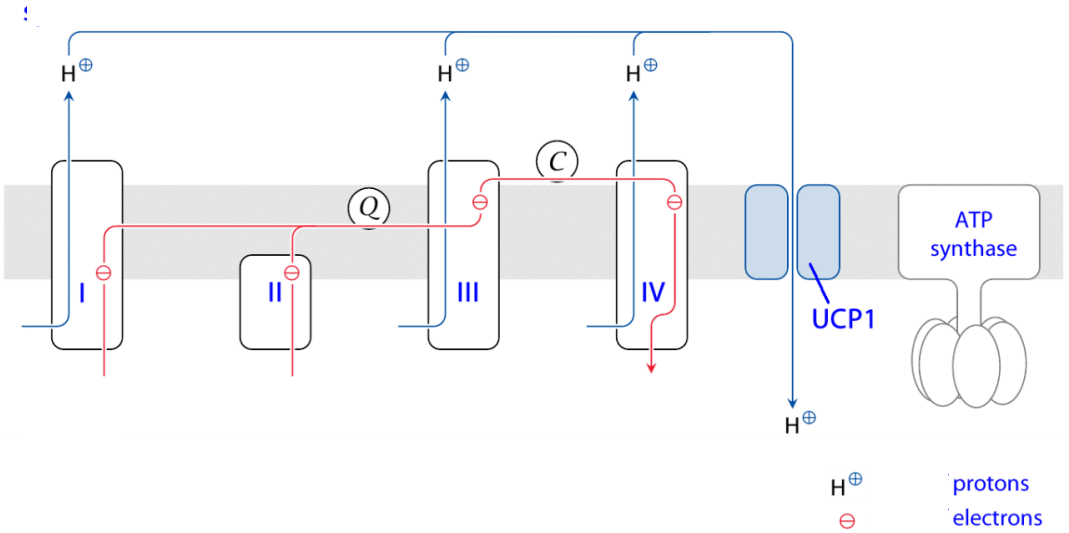


Fig. 6.2

(i) Oxygen is required to sustain the process illustrated in Fig. 6.2.
With reference to Fig. 6.2, describe the role played by oxygen.

Oxygen serves as the final electron acceptor, receiving electrons from complex IV to form water. [1]

(ii) Brown adipocytes contain a unique protein, UCP1, which is not found in organelle **X** in any other cell type.

Evaluate the impact of UCP1 on the normal functioning of the process illustrated in Fig. 6.2 and suggest the physiological significance of brown adipose tissue.

1. **As UCP1 allows protons to leak back into the matrix without passing through the ATP synthase, no ATP will be synthesized from the NADH and $FADH_2$.**

2. **The energy released from the spontaneous flow of protons through UCP1 is lost as heat, which helps to keep the organisms warm.** [2]

(c) In other cell types, NADH and $FADH_2$ are used to drive ATP synthesis by ATP synthase. Using relevant information from Fig. 6.2, suggest and explain why more ATP is produced from NADH.

1. **NADH and $FADH_2$ donates electrons to complex I and II respectively, the energy released from transfer of electrons through the complexes is used to pump protons across the inner membrane.**

2. **Because NADH started with Complex I, it had more chances to pumps more protons across the gradient, which powers the ATP synthase and gives us 3 ATP per molecule of NADH, while $FADH_2$ produces 2 ATP during the ETC because it gives up its electron to complex II, bypassing complex I.** [2]

[Total: 7]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section D

Answer **all** the questions in this section.

7 The cardiac action potential is a specialised action potential with unique properties necessary for the electrical conduction system of the heart. The cardiac muscle cells share many things in common with nerve cells.

Fig. 7.1 shows the five phases of a cardiac action potential. Each of which is characterised with their respective changes in membrane potential.

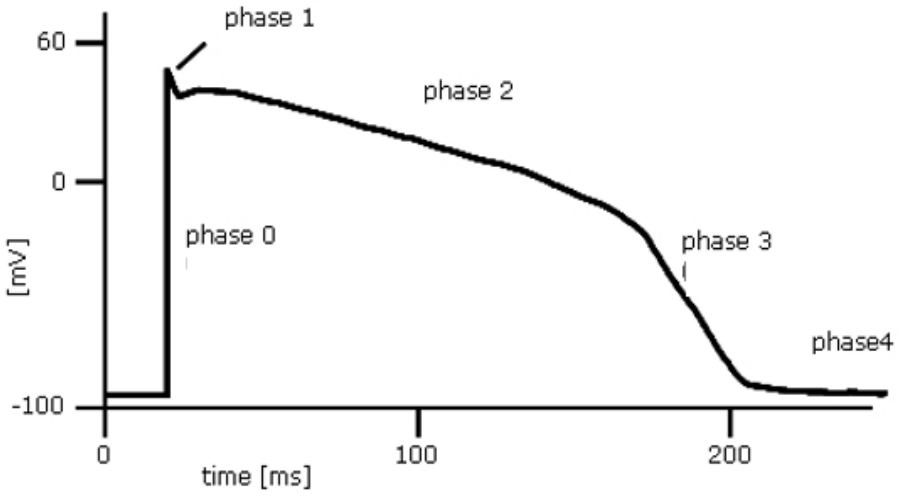


Fig. 7.1

The table shows the relative concentrations of ions inside and outside of the cardiac muscle cells.

element	ion	extracellular	intracellular
sodium	Na^+	135 – 145	10
potassium	K^+	3.5 – 5.0	155
chloride	Cl^-	95 – 110	20 – 30
calcium	Ca^{2+}	2	10^{-4}

(a) Estimate the resting potential for the cardiac action potential shown in Fig. 7.1.

Between (-90 mV to -95 mV) [1]

(b) Using the information from the table, explain how the resting potential can be produced in the heart muscles using sodium and potassium ions.

- **[Na+] outside the cell > [Na+] inside the cell while [K+] outside the cell < [K+] inside the cell**
- **Possible involvement of a protein pump: Requires energy in the form of ATP for movement of ions against concentration gradient**
- **More Na+ pumped out than K+ pumped in → Nett loss of +ve ions from inside the cell thus inside –ve 90mv**

[3]

(c) Compare phase 2 of the action potential of a cardiac muscle cell with that of a nerve cell.

- **The fall in membrane potential in a nerve cell is more drastic/ shows a steeper gradient/ faster rate/ longer time in** **OR**
- **Nerve cell only shows Phase 3/ Phase 2 is absent in nerve cells.**

[1]

(d) Cardiac arrhythmia refers to any abnormal electrical activity in the heart. As a result, the heart may beat too fast. Calcium channel blockers such as Verapamil are often used to treat this condition.

Suggest and explain the action of Verapamil in controlling this symptom of arrhythmia. [2]

- **Interrupts inflow of Ca2+ during plateau phase to prolong the refractory period/ depresses Phase 2 and 3**
- **Reduces the rate of heart contraction → heart rate declines**

[Total: 7]

8 The table shows the amino acid differences in the cytochrome b protein between various vertebrates.

	Human	Elephant	Platypus	Ostrich	Starling	Crocodile	Lungfish	Coelacanth	Goldfish	Shark
Human		26	40	43	41	47	83	70	68	71
Elephant			45	45	48	50	84	72	63	74
Platypus				54	52	51	89	74	70	76
Ostrich					26	36	91	75	68	73
Starling						47	91	77	67	70
Crocodile							85	78	70	77
Lungfish								90	94	86
Coelacanth									83	78
Goldfish										88
Shark										

Fig. 8.1 shows the phylogenetic tree based on differences between the cytochrome b proteins.

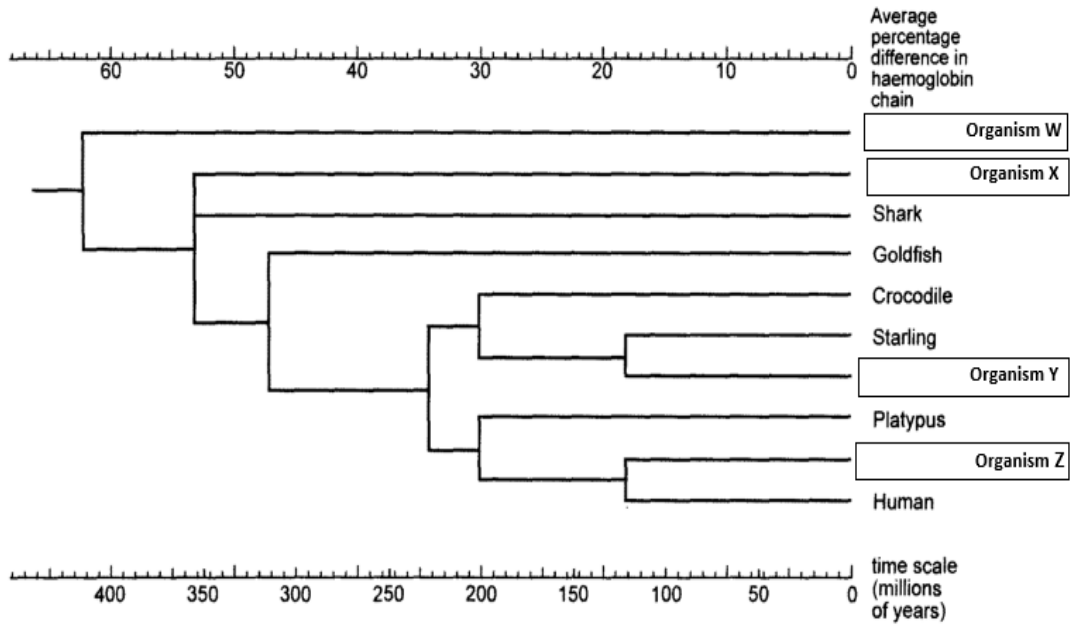


Fig. 8.1

(a) Using information from the table and Fig. 8.1, identify organisms **W** to **Z**.

W: lungfish

X: coelacanth

Y: ostrich

Z: elephant [2]

(b) Explain how differences in amino acid sequences in the cytochrome b chain allow the establishment of the phylogenetic tree.

- **% of aa difference in Hb chain indicates relatedness;;**
- **few difference indicates recent common ancestor / large difference indicates early divergence** OWTTE
- **provides quantitative data to construct phylogenetic tree**

[3]

(c) Explain the difference between classification and phylogeny.

- **classification refers to grouping organisms based on similar characteristics**
- **characteristics may be analogous and not homologous**
- **phylogeny involves grouping organisms based on evolutionary relationship**
- **similarity is due to inheritance from common ancestry**

[2]

(d) Suggest why homology still features prominently in evolutionary studies despite the advantages that molecular evidence can confer.

- **easier to use / often requires observation rather than machines**
- **DNA / protein not always available e.g. in fossils**

[2]

(e) Explain the role of neutral mutations in evolutionary studies.

- **constant rate of mutation**
- **act as molecular clock**
- **genetic differences act as an indicator of time / period of divergence**
- **genetic differences act as an indicator of speciation event** OWTTE

[3]

[Total: 12]

9 (a) Compare the role of nervous system and endocrine system as communication systems within organisms. [6]

Similarities

S1. Both systems communicate through use of signalling molecules that bind to specific receptors on effector cells.

S2. They function in response to stimuli

Differences

D1. Nervous system transmit information in the form of electrical impulses along an axon and in the form of chemical signals known as neurotransmitters across a synapse. Endocrine system transmit information in the form of chemical signals known as hormones only.

D2. Signals are transmitted via specific neural pathways consisting of communicating neurons in the nervous system. In contrast, signals are transported by the circulatory system via bloodstream.

D3. Transmission of signals via nervous system is rapid, where transmission of nerve impulses to effector cells bringing about response is completed in milliseconds. Transmission of signals via endocrine system is slow, which may take minutes to days for hormones to be produced and carried by blood to target organs for response to occur.

D4. Communication through nervous system results in localized responses from the target cell(s) that are post-synaptic to the motor neurons. In contrast, endocrine system results in responses that may be widespread as various tissues/ organs can respond to a single hormone.

D5. The response brought about by nervous system is immediate and short-lived, while the response brought about by endocrine system is slow and long-lasting.

D6. Communication via nervous system results in "all or none" response, where the magnitude of action potential is the same regardless of the strength of the stimuli. Whereas communication through endocrine system can bring about graded response.

D7. The control of response in nervous system may be voluntary or involuntary, while the control of response in endocrine system is always involuntary.

(b) Explain the meaning of the term homeostasis with specific reference to the control of raised blood glucose concentration in humans. [8]

1. **Homeostasis is the maintenance of a constant internal environment.**
2. **One of the principles underpinning homeostasis is self-regulation, in that the control mechanism is triggered by the parameter that is being regulated.**
3. **Another principle of homeostasis is negative feedback, whereby deviation from set/reference point triggers response which counteracts/ reverses the deviation, restoring the parameter to set/reference point.**
4. **The set/reference point for blood glucose level is 90mg glucose/100cm^3.**
5. **The rise in blood glucose level from set point is the stimulus that triggers the control mechanism to reduce blood glucose level back to set point.**
6. **The rise in blood glucose level is detected by the alpha and beta cells of the Islets of Langerhans in the pancreas (detector).**
7. **Beta cells are triggered to secrete insulin into bloodstream,**
8. **Alpha cells are signalled to stop glucagon secretion.**
9. **Insulin is transported via bloodstream to target cells, such as liver cells (effector). Insulin binds to receptors and acts to bring about responses that restore the set point.**
10. **One response is increased fusion of vesicles containing glucose-carrier/glucose-transporter proteins with the plasma membrane so as to increase rate of uptake of glucose in the effector cells.**
11. **These cellular responses result in a decrease in blood glucose level back to the set point of 90mg glucose/100cm^3 of blood. This is negative feedback regulation of blood glucose level.**
12. **As blood glucose level return to the set point, beta cells will no longer be triggered to secrete insulin, hence insulin level in the blood decreases.**

(c) Describe the cell signalling pathway that glucagon initiates in order to regulate blood glucose concentration. [6]

1. **Glucagon binds to extracellular binding site of G protein-coupled receptor (GPCR) on the plasma membrane of liver cells.**

2. **Binding of glucagon triggers a change in 3D conformation in the GPCR, resulting in the release of GDP followed by binding of GTP, thus activating G protein.**

3. **(a) Activated G protein dissociates from receptor and diffuses along the plasma membrane to bind to and activate adenylyl cyclase.; (b) Adenylyl catalyses the conversion of many cyclic AMP (cAMP) from ATP.;**

4. **cAMP acts as second messenger to activate enzymes such as protein kinase A.**

5. **Protein kinase A activate other enzymes by phosphorylating them, triggering a phosphorylation cascade that help to amplify the initial signal and bring about the necessary cellular responses.**

6. **For example, glycogen phosphorylase brings about increased glycogenolysis by catalysing the breakdown of glycogen to glucose-1-phosphate which is then converted to glucose and transported out of the liver cell into the bloodstream to increase blood glucose level back to the set point.**

7. **Another cellular response is increased activity of enzymes involved in gluconeogenesis (synthesis of glucose from non-carbohydrate sources) forming more glucose to increase availability of glucose for cellular respiration**

[Total: 20]

10 (a) Compare the structural and regulatory genes in prokaryotes. [6]

(Maximum 2 marks for similarities)

- **Both do not contain introns.**
- **Both are transcribed by RNA polymerase.**
- **Both are on the same chromosome.**
- **(any other valid point)**

(Maximum 5 marks for differences)

	Point of comparison	Structural gene	Regulatory gene
1	Codes for?	Codes for a protein or RNA molecule that forms part of a structure or has an enzymatic function	Codes for a specific protein product that regulates the expression of the structural genes
2	Gene product interacts with DNA?	May not interact with DNA	Yes, e.g. the operator of the operon
3	Example?	*lacZ* = β-galactosidase gene *lacY* = permease gene *lacA*= transacetylase gene	*lacI* = *lac* repressor gene *trpR* = *trp* repressor gene gene for Catabolite Activator Protein (CAP)
4	Expression?	Regulated as in *lac* operon	Constitutive
5	Location?	Related structural genes found within operon	Regulatory genes exist singly outside operon (*lacI* is near *lac* operon) (gene for CAP is not anywhere near *lac* operon)
6	Presence of promoter/operator?	Both promoter and operator upstream of structural genes	Only promoter precedes it
7	Type of mRNA formed?	Polycistronic	Monocistronic

(b) Explain the roles of the operator and activator binding site in the *lac* operon.

[8]

(Any 8)

1. **An operon is a unit of genetic function consisting of a promoter, an operator, and a coordinately regulated cluster of related (structural) genes whose products function in a common pathway.**
2. **Regulated / Controlled / Switched off and on / Transcribed together as a unit to produce a single <u>messenger RNA</u> (mRNA)**
3. **The operator can lie within the promoter or between the promoter and the structural genes. / The activator binding site can lie within or upstream of the promoter.**
4. **The operator is a binding site for the *lac* repressor.**
5. **Binding of *lac* repressor to the operator will deny the RNA polymerase access to the promoter and hence inhibit transcription.**
6. **Presence of the inducer allolactose / lactose inactivates the *lac* repressor by changing its conformation such that it can no longer bind to the operator, and transcription can be carried out / RNA polymerase can bind to the promoter.**
7. **The activator binding site is the binding site for Catabolite Activator Protein (CAP) / cAMP-CAP complex.**
8. **Low level of glucose leads to high level of cAMP in the cell, which results in high level of cAMP-CAP complex / activated CAP.**
9. **Binding of cAMP-CAP complex / activated CAP to the activator binding site will stimulate transcription / switch the *lac* operon on by increasing the affinity of RNA polymerase for the promoter.**
10. **Both the operator and activator binding site allow the expression of the lactose metabolizing enzymes to be responsive to changes in the environment (e.g. glucose and lactose concentrations) / prevent the waste of energy and resources.**

(c) Describe how the molecular structure of phospholipids is related to their function in the plasma membrane. [6]

(Any 6)

- **Each phospholipid consists of a phosphate group, a glycerol backbone and two fatty acid chains.**
- **Each phospholipid is amphipathic / contains both a hydrophilic region and a hydrophobic region within the same molecule.**
- **Hydrophilic phosphate heads are on the outside of the bilayer, in contact with the surrounding aqueous medium.**
- **Hydrophobic fatty acid chains point towards the interior of the bilayer, away from the surrounding aqueous medium.**
- **Major component of the plasma membrane / Form a bilayer**
- **Selectively permeable to solutes due to presence of hydrophobic core in the bilayer**
- **Determine the fluidity of membrane**
- **The more unsaturated fatty acid chains are, the more fluid the membrane is.**
- **Kinks in unsaturated fatty acid chains prevent close packing of the phospholipids and decrease the interaction between adjacent fatty acid chains.**
- **Phospholipids with shorter fatty acid chains are more fluid.**
- **Shorter chain length reduces the tendency of the hydrocarbon tails to interact with one another.**
- **Some types of phospholipid can be split to produce products that function as second messengers in signal transduction.**

[Total: 20]

- End of paper -

H

Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME

BIOLOGY CLASS 2bi2____ / 2IPbi2__

REGISTRATION NUMBER

BIOLOGY 9648/03

Paper 3 **31 August 2016**

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your Biology class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Sections A - C
Answer **all** questions in the spaces provided on the question paper.

Sections D - E
Answer **all** questions on the answer paper provided.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or id you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 14
2	/ 14
3	/ 12
4	/ 12
5	/ 20
TOTAL	**/ 72**

This document consists of **11** printed pages.

[Turn over

Section A

Answer the question in this section.

1 In a maternity ward at a local hospital, a mix-up involving three couples and three babies caused a lot of confusion. Based on phenotypic characteristics, the nurses were unable to correctly identify the parents of the babies. In order to solve the case, a scientist was called in to carry out a DNA test to identify the parents of the babies. The test was based on the principle that different individuals have a different number of repeating units at a particular locus in a chromosome.

Chromosome 13 was isolated from the DNA samples that were obtained from the three couples and three babies and used for further analysis. The sequence below shows a segment of chromosome 13, which was used in the analysis where (TTAGGAT) is the repeating unit and n is the number of repeats.

5' …GCTAAGTATTGCTCAAGA… (TTAGGAT)n…GATAAATAACTGGCTAGTA…-3'
3' …CGATTCATAACGAGTTCT… (AATCCTA)n… CTATTTATTGACCGATCAT…-5'

Fig. 1.1 shows the results of the DNA test obtained from each individual.

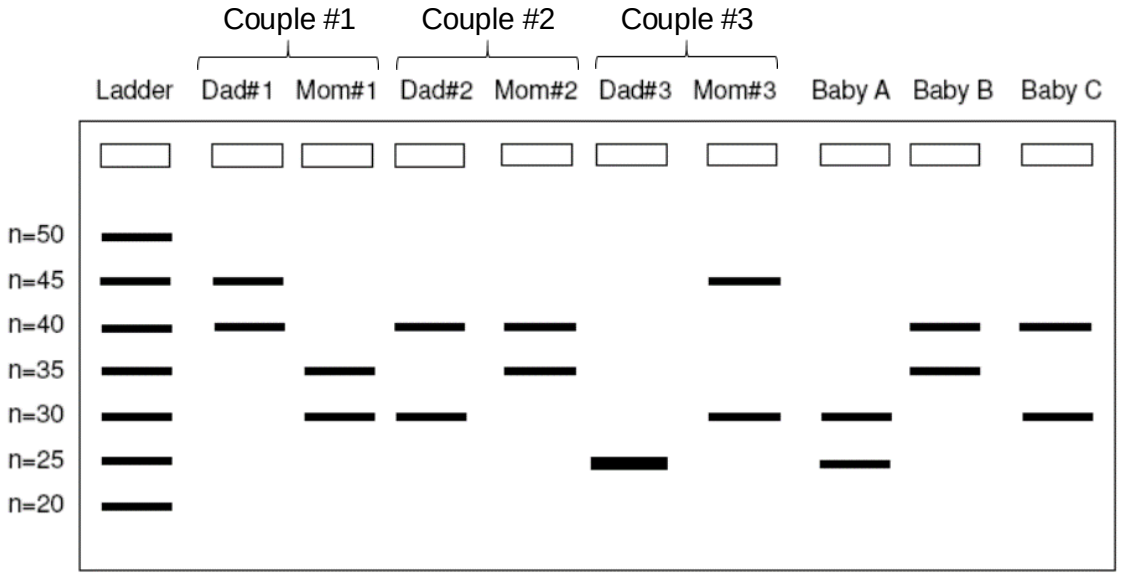


Fig.1.1

(a) Describe how the DNA bands in the gel could be made visible.

.....

.....

[1]

(b) State the purpose of the DNA ladder.

.....

.....

[1]

(c) Explain how gel electrophoresis is used to separate fragments of DNA.

[5]

(d) Explain the banding pattern of Dad #3.

[3]

(e) Identify the couple that Baby A belongs to.

[1]

(f) Explain why the results shown in Fig. 1.1 could not confirm which couple that Baby B belongs to.

[2]

(g) Suggest an alternative DNA test to identify the couple that each of the three mixed up babies belongs to.

.....[1]

[Total: 14]

Name: _____ Class: 2bi2___ / 2IPbi2___	14

Section B

Answer the question in this section

2 Haemophilia is an X-linked recessive disorder that impairs the body's ability to form blood clots. There are two main types, haemophilia A and haemophilia B, resulting from deficiencies in clotting factors VIII and IX respectively.

Both *ex vivo* and *in vivo* gene therapy approaches are undergoing clinical trials.

(a) (i) Explain why gene therapy approach for treatment of haemophilia is possible.

.....

..... [1]

(ii) Distinguish between *ex vivo* and *in vivo* gene therapy approaches.

.....

.....

.....

..... [2]

Haematopoietic stem cells (HSC) are ideal vehicles for *ex vivo* gene therapy application.

(b) (i) Describe the normal function of HSC.

.....

..... [1]

(ii) Explain why HSC are ideal vehicles for *ex vivo* gene therapy application.

.....

.....

.....

.....

..... [3]

The liver is an ideal target for *in vivo* gene therapy application. As a major organ and central metabolic hub, it receives an abundant blood supply through sinusoids with highly permeable walls, which facilitates easy access of blood-borne particles to the hepatocytes. Hepatocytes are long-lived and robust protein factories that can efficiently release their products into the blood circulation. Both viral and non-viral vectors have been and continued to be investigated.

(c) Use of non-viral vectors for gene therapy has met with low success rate.

Describe one method of non-viral vector delivery and explain why the method has achieved low success.

[3]

(d) Many ongoing clinical trials are focused on the application of adeno-associated viral (AAV) vectors, which are found to remain as episomes within the nucleus.

Explain an advantage and a disadvantage of the use of such adeno-associated viral vectors compared to retroviral vectors.

[2]

(e) Somatic cell nuclear transfer (SCNT), also known as therapeutic cloning, involves the replacement of an egg nucleus with a somatic cell nucleus. As the oocyte develops into a blastocyst, cells from the inner cell mass can be isolated and purified to serve as a source of pluripotent stem cells.

Explain why such an approach cannot be used to treat patients with haemophilia.

.....

.....

.....

..... [2]

[Total: 14]

Name: _____ Class: 2bi2___ / 2IPbi2___

12

Section C

Answer the question in this section.

3 The success of culturing callus is low due to the difficult task of removing contaminants. It has proven more challenging for plants taken from the wild in tropical countries. In Sumbawa, Indonesia, plant tissue samples were sampled at three different times of the year. They were grown in medium containing no fungicide or antibiotic.

Table 3.1 shows the results.

Table 3.1

explant	time of year	number of explants	number of cultured explants with no fungal or bacterial contamination	percentage of cultured explants with no fungal or bacterial contamination
leaf disc	April	153	12	8
	August	322	16	5
	January	332	30	9
shoot tip	April	194	116	60
	August	191	122	64
	January	211	156	74

(a) Describe and explain the results of using the two types of explant.

[3]

(b) Besides using the appropriate explant, suggest how the number of contaminated samples could be reduced when using wild plant samples.

[1]

(c) Explain, with relevant examples, how genetic engineering has helped to increase the quantity of crops for farmers.

[3]

(d) Describe two disadvantages of plant tissue culture.

[2]

(e) In several countries including China, Korea and the United States, human DNA has already been put into eggs from both rabbits and cows.

Discuss the ethical concerns of conducting such experiments.

[3]

[Total: 12]

Section D

Answer the question in this section on the answer paper provided.

4 Planning Question

You are required to plan, but not carry out, an investigation into the effect of increasing concentration of glucose on rate of respiration of yeast.

Yeast synthesizes ATP through two major biochemical pathways: aerobic respiration and fermentation. During both aerobic respiration and fermentation, yeast cells break down glucose molecules within the cell to release energy, and some of this energy is captured and stored in the ATP's high-energy phosphate bonds. The breakdown of glucose also releases carbon atoms, which become available for biosynthetic reactions, enabling the yeast to grow and reproduce by budding. The rest of the carbon ends up in the by-products of these reactions.

You are to use methylene blue in your investigation. Methylene blue acts as an artificial electron acceptor during respiration, which changes from blue to colourless as a result of its reduction in the enzymatic reaction.

Your plan should have a clear and helpful structure to include:

- a description of the method used including the scientific reasoning behind the method,
- an explanation of the dependent and independent variables involved,
- relevant, clearly labelled diagrams,
- how you will record your results and ensure that they are as accurate and reliable as possible,
- proposed layout of results tables and graphs with clear headings and labels,
- the correct use of technical and scientific terms,
- relevant risks and precautions taken.

Your planning must be based on the assumption that you have been provided with the following equipment and materials, which you must use:

- yeast suspension,
- 10% glucose solution,
- distilled water,
- access to tap water,
- thermostatically controlled water bath,
- methylene blue,
- stopwatch,
- a variety of different sized beakers, test-tubes, boiling tubes, measuring cylinders or syringes for measuring volumes.

[Total: 12]

Section E

Answer the question in this section on the answer paper provided.
Begin each part of the question on a new piece of answer paper.

5 Free-response question

Your answers:

- should be illustrated by large, clearly labelled diagrams, where appropriate,
- must be in continuous prose, where appropriate,
- must be set out in sections **(a)**, **(b)**, etc., as indicated in the question.

(a) Describe the goals, benefits and ethical concerns of human genome project. [8]

(b) Explain the significance of genetic engineering in improving food quality. [6]

(c) Discuss the social and ethical implications of genetically modified crop plants. [6]

[Total: 20]

--- End of Paper ---

Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME

BIOLOGY CLASS 2bi2____ / 2IPbi2__

REGISTRATION NUMBER

BIOLOGY 9648/03

Paper 3 **31 August 2016**

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

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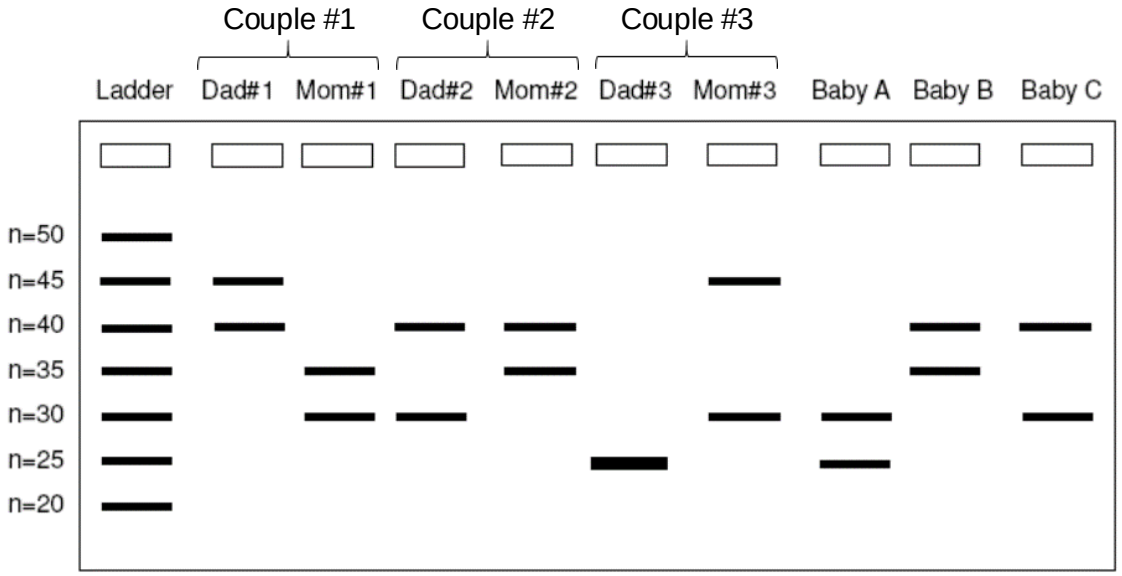

Fig.1.1

(a) Describe how the DNA bands in the gel could be made visible.

Staining with ethidium bromide and viewing under UV light
OR
Staining with methylene blue [1]

(b) State the purpose of the DNA ladder.

Each band serves as a comparison / reference for the size / number of repeats present in the individuals tested. [1]

(c) Explain how gel electrophoresis is used to separate fragments of DNA.

1. **Because all DNA molecules are negatively charged, regardless of the length or source, the rate of DNA migration and separation through an agarose gel depends on the size / molecular length of the DNA molecule.**

2. **An agarose gel is submerged in a buffer solution containing ions that will conduct electricity.**

3. **DNA samples are loaded into small depressions in the gel called wells, which are close to the negative electrode / cathode.**

4. **A direct current is applied through electrodes at opposite ends of the gel.**

5. **The negatively charged DNA molecules move toward the positive electrode / anode, with shorter DNA molecules moving faster and further than the longer ones.** [5]

(d) Explain the banding pattern of Dad #3.

(Any 3)

1. **Only one band corresponding to n=25**

2. **Band is twice as thick as the other bands**

3. **Homozygous for the locus being examined**

4. **25 repeats on both copies of chromosome 13** [3]

(e) Identify the couple that Baby A belongs to.

Couple #3 [1]

(f) Explain why the results shown in Fig. 1.1 could not confirm which couple that Baby B belongs to.

(Any 2)

1. **Each band in Baby B's DNA fingerprint would match the band in either the mum's or dad's DNA fingerprint.**

2. **The band corresponding to n=40 in Baby B's DNA fingerprint can be found in Dad#1, Dad#2 and Mom#2, whereas the band corresponding to n=35 in Baby B's DNA fingerprint can be found in Mom#1 and Mom#2.**

3. **Hence, Baby B could belong to either Couple #1 or Couple #2.** [2]

(g) Suggest an alternative DNA test to identify the couple that each of the three mixed up babies belongs to.

Analysis of Restriction Fragment Length Polymorphism (RFLP) or other Short Tandem Repeats (STR) [1]

[Total: 14]

Name: _____ Class: 2bi2___ / 2IPbi2___	14

Section B

Answer the question in this section

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(a) (i) Explain why gene therapy approach for treatment of haemophilia is possible.

[1]

(ii) Distinguish between *ex vivo* and *in vivo* gene therapy approaches.

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Haematopoietic stem cells (HSC) are ideal vehicles for *ex vivo* gene therapy application.

(b) (i) Describe the normal function of HSC.

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The liver is an ideal target for *in vivo* gene therapy application. As a major organ and central metabolic hub, it receives an abundant blood supply through sinusoids with highly permeable walls, which facilitates easy access of blood-borne particles to the hepatocytes. Hepatocytes are long-lived and robust protein factories that can efficiently release their products into the blood circulation. Both viral and non-viral vectors have been and continued to be investigated.

(c) Use of non-viral vectors for gene therapy has met with low success rate.

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Explain why such an approach cannot be used to treat patients with haemophilia.

[2]

[Total: 14]

2 Haemophilia is X-linked recessive disorder that impairs the body's ability to form blood clots. There are two main types, haemophilia A and haemophilia B, resulting from deficiencies in clotting factor VIII and IX respectively.

Both *ex vivo* and *in vivo* gene therapy approaches are undergoing clinical trials.

(a) **(i)** Explain why gene therapy approach for treatment of haemophilia is possible. [1]

1. Haemophilia is caused by single defective gene.

(ii) Distinguish between *ex vivo* and *in vivo* gene therapy approaches. [2]

1. In *ex vivo* gene therapy, the therapeutic gene is introduced into target cells extracted from patient, and the altered cells are injected back into the patient.
2. In *in vivo* gene therapy, the therapeutic gene is introduced directly into target cells/tissues in the patient's body.

Haematopoietic stem cells (HSC) are ideal vehicles for *ex vivo* gene therapy application.

(b) **(i)** Describe the normal function of HSC. [1]

1. HSC normally differentiates to give rise to many types of blood cells, such as red blood cells, white blood cells and platelets.

(ii) Explain why HSC are ideal vehicles for *ex vivo* gene therapy application. [3]

1. HSC can undergo indefinite self-renewal, hence they can multiply indefinitely, thus sustaining the gene therapy treatment.
2. HSC are unspecialised

3. HSC have potential to differentiate, they can be stimulated to differentiate to produce the therapeutic gene product
4. HSCs multiply themselves >106 fold during haematopoietic reconstitution
5. HSCs can be manipulated to secrete biotherapeutic molecules such as FVIII directly into the bloodstream
6. HSCs can induce a state of immune tolerance or nonresponsiveness to the therapeutic transgene product

Accept:
A1. Given that HSCs are derived from patient, there is lower risk of immune rejection.

Reference: Spencer et.al. (2016). State of the art; gene therapy of haemophilia
HSCs are ideal cellular vehicles for gene therapy applications since they can (i) self-renew, (ii) multiply themselves >106 fold during haematopoietic reconstitution, and (iii) secrete biotherapeutic molecules such as FVIII directly into the bloodstream. Another critical property of HSC-directed gene therapy is the ability to induce a state of immune tolerance or nonresponsiveness to the therapeutic transgene product, which in the case of haemophilia A is a single protein, FVIII, that is known to possess a higher degree of immunogenic potential.

Reject:
(R!) HSCs can be isolated/ culture easily
(R!) lower risk of tumor formation compared to using pluripotent cells

The liver is an ideal target for *in vivo* gene therapy application. As a major organ and central metabolic hub, it receives an abundant blood supply through sinusoids with highly permeable walls, which facilitates easy access of blood-borne particles to the hepatocytes. Hepatocytes are long-lived and robust protein factories that can efficiently release their products into the blood circulation. Both viral and non-viral vectors have been and continue to be investigated.

(c) Use of non-viral vectors for gene therapy has met with low success rate.

Describe one method of non-viral vector delivery and explain why the method has achieved low success. [3]

Naked DNA method
L1. Therapeutic DNA is injected directly into target tissues.
L2. Target cells take up DNA randomly
L3. Poor transfection efficiency
L4. Not integrated into genome, hence transient expression

Liposomes
N1. Therapeutic DNA is encapsulated in anionic liposome.
N2. Mixing of liposomes and target cells result in fusion, thus introducing gene into target cell
N3. Poor transfection efficiency
N4. Not integrated into genome, hence transient expression

Molecular conjugates
M1. Therapeutic DNA is coupled to a targeting molecule.

M2. Targeting molecule binds to specific cell surface receptor and induces endocytosis and transfer of DNA into cells.
M3. Molecular conjugate often remain trapped in endosome resulting in poor gene transfer
M4. Not integrated into genome, hence transient expression.

(d) Many ongoing clinical trials are focused on the application of adeno-associated viral (AAV) vectors, which are found to remain as episomes within the nucleus.

Explain an advantage and a disadvantages of use of such adeno-associated viral vectors compared to retroviral vectors. [2]

Advantages:
A1. AAV vectors does not result in integration of therapeutic DNA into host genome unlike retroviral vectors hence less likely to cause insertional mutagenesis.
A2. AAV vectors readily infects both dividing and non-dividing cells, unlike retroviral vectors which can only infect dividing cells

Disadvantages
D1. AAV vectors does not result in integration of therapeutic DNA into host genome unlike retroviral vectors hence expression may be transient.
D2. AAV vectors can only accept smaller insert size, up to 4.5kb, compared to retroviral vectors which can accepts to larger insert size of up to 8 kb.
D3. AAV vectors require helper virus to infect target cells, while retroviral vectors do not.

Reject:
Advantage:
1. AAV vectors have higher transfection efficiency. (A!)
2. AAV vectors can target specific tissues and organs, which is not the case for retroviral vectors. (A!)
3. AAV vectors elicits lesser immune response (A!)
4. AAV vectors less likely to regain viral properties than retroviral vectors (A!)

Disadvantage
5. AAV vectors have lower transfection efficiency. (A!)
6. Less familiarity with AAV vectors, thus potential danger of AAV vectors is unknown. (R!)
7. DNA insert in AAV vectors is not inserted into cell genome, hence level of DNA expression is significantly lower. (A!)
8. Repeated therapy cycles may be needed hence more costly.

(e) Somatic cell nuclear transfer (SCNT), also known as therapeutic cloning, involves the replacement of an egg nucleus with a somatic cell nucleus. As the oocyte develops into a blastocyst, cells from the inner cell mass can be isolated and purified to serve as a source of pluripotent stem cells.

Explain why such as approach cannot be used to treat patients with haemophilia. [2]
1. All somatic cells from the patient will contain the defective gene.
2. The resulting pluripotent cells isolated from inner cell mass from such a procedure will contain the same genetic defect, hence remain unable to produce the necessary clotting factors.
3. If a donor cell nucleus containing a functional gene is used for SCNT, the stem

cells may contain antigens that cause them to be rejected by the immune system.

[Total: 14]

Name: _____ Class: 2bi2___ / 2IPbi2___

12

Section C

Answer the question in this section.

3 The success of culturing callus is low due to the difficult task of removing contaminants. It has proven more challenging for plants taken from the wild in tropical countries. In Sumbawa, Indonesia, plant tissue samples were sampled at three different times of the year. They were grown in medium containing no fungicide or antibiotic.

Table 3.1 shows the results.

Table 3.1

explant	time of year	number of explants	number of cultured explants with no fungal or bacterial contamination	percentage of cultured explants with no fungal or bacterial contamination
leaf disc	April	153	12	8
	August	322	16	5
	January	332	30	9
shoot tip	April	194	116	60
	August	191	122	64
	January	211	156	74

(a) Describe and explain the results of using the two types of explant.

Using shoot tip had higher rate of success;

Where for example in April, using shoot tip explant produced 60% cultured

explants with no contamination compared to the 8% of uncontaminated explants that

were produced when leaf discs were used; (A! any appropriate comparison of values

in the months of august or January) OR

Explant taken during January had a higher success rate with 8% for leaf disc

and 74% for shoot tip;

Shoot tip contains meristematic cells which are actively dividing; [3]

Use antibiotics/fungicide;

Use of dilute sodium hypochlorite/ bleach to sterilise wild plant samples; [1]

(b) Besides using the appropriate explant, suggest how the number of contaminated samples could be reduced when using wild plant samples.

(c) Explain, with relevant examples, how genetic engineering has helped to increase the quantity of crops for farmers.

Any relevant technology;

Change;

Benefit to farmers;

E.g. Super Salmon àpromotor for AFP plus beside the gene coding for growth;

Gene will be activated all year round due to cold environment and growth hormone

year round;

Salmon can grow twice as fast with same amount of feed; [3]

(d) Describe two disadvantages of plant tissue culture.

Contamination of cultures poses the greatest problem to commercial tissue culture as

it can cause very high losses in a short time;

Micropropagation is tedious and costly as it requires much labour (e.g transfer of

plantlets from the laboratory to the soil), trained personnel with specialized skills,

sophisticated facilities and organization, sterile laboratory conditions and special

nutrient media. This may not be economical for crops with low financial returns like

carrots;

Plants produced from calli may undergo genetic changes to produce genetic off-types.

For example, bananas can produce a lot of genetic off-types in culture. Most of these

changes are undesirable;

The limited genetic pool and genetic uniformity of plants cultured make them vulnerable to new diseases or drastic changes in the environment;

[Any two points] [2]

(e) In several countries including China, Korea and the United States, human DNA has already been put into eggs from both rabbits and cows.

Discuss the ethical concerns of conducting such experiments.

Humans should not be tampering with nature by creating living organisms which may be objectionable by certain religious groups;

Crossing the species barrier and violating the genetic integrity of the organism;

The research may not be justified if it is not to address the urgent needs of mankind only the desires of mankind;

Exploitation of animals in the process/ Lack of concern for their welfare;

Slippery slope that may lead to human cloning; AVP [3]

Section D

Answer the question in this section on the answer paper provided.

4 Planning Question

You are required to plan, but not carry out, an investigation into the effect of increasing concentration of glucose on rate of respiration of yeast.

Yeast synthesizes ATP through two major biochemical pathways: aerobic respiration and fermentation. During both aerobic respiration and fermentation, yeast cells break down glucose molecules within the cell to release energy, and some of this energy is captured and stored in the ATP's high-energy phosphate bonds. The breakdown of glucose also releases carbon atoms, which become available for biosynthetic reactions, enabling the yeast to grow and reproduce by budding. The rest of the carbon ends up in the by-products of these reactions.

You are to use methylene blue in your investigation. Methylene blue acts as an artificial electron acceptor during respiration, which changes from blue to colourless as a result of its reduction in the enzymatic reaction.

Your plan should have a clear and helpful structure to include:

- a description of the method used including the scientific reasoning behind the method,
- an explanation of the dependent and independent variables involved,
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- how you will record your results and ensure that they are as accurate and reliable as possible,
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- the correct use of technical and scientific terms,
- relevant risks and precautions taken.

Your planning must be based on the assumption that you have been provided with the following equipment and materials, which you must use:

- yeast suspension,
- 10% glucose solution,
- distilled water,
- access to tap water,
- thermostatically controlled water bath,
- methylene blue,
- stopwatch,
- a variety of different sized beakers, test-tubes, boiling tubes, measuring cylinders or syringes for measuring volumes.

[Total: 12]

Mark Scheme (details)

The independent variable in this experiment is the glucose concentration while the dependent variable is average time taken for methylene blue to decolourise.

the likely outcome of the experiment/Trend

As glucose concentration increases, the average time taken for blue colour of methylene blue to disappear decreases. [1]

ikely outcome of the experiment

- When glucose concentration increases, more hydrogen atoms are removed from glucose molecules by enzymes called dehydrogenases and passed to hydrogen acceptor NAD+ and FAD (co-enzyme) [1]

Method of measuring rate of respiration/rational of experiment

- Methylene blue mimic the action of NAD+ and FAD
  Methylene blue turns from blue to colourless when it is reduced by hydrogen. [1]
- Respiration rate is measured by average time taken for methylene blue to turn from blue to colourless **[1]**

1. **Procedure** Set up a thermostatically controlled water bath at 37 ˚C.

2. Using **dilution** to obtain at least five known glucose solution concentrations; and placed them in separate labelled test-tubes.

   Concentration stated 0.1% - 10% (any reasonable range). Final volume stated. **[1]**

es	Volume of **10%** glucose / cm^3	Volume of distilled water / cm^3	Concentration of glucose solution / %

3. Label 6 boiling tubes A – E and F (control). Using a 5 cm^3 syringe, add 5 cm^3 of each glucose solution concentration to A – E and 5 cm^3 of distilled water to F.

4. Label another 6 boiling tubes A1 – F1. Using a 5 cm^3 syringe, add 5 cm^3 of yeast suspension to A1 – F1.
   Use the same concentration of yeast suspension from the same stock for each reading and repeat as it affects the rate of respiration. This ensures initial concentration of the respiratory enzymes is kept constant. **(Controlled variable)**

5. Using another 5 cm^3 syringe, add 3cm^3 of pH buffer to A1 – F1. Changes in pH may affect the active site configuration and therefore enzyme activity. Addition of pH buffer will keep pH constant. **(Controlled variable)**

6. Leave boiling tubes A – F and A1 – F1 in the thermostatically controlled water bath for 5 min **(equilibration/acclimatization time)** using stopwatch to time. **[1]**

   Temperature must be kept constant as it affects enzyme activity, hence the rate of respiration. **(Controlled variable)**

7. Pour contents from A into A1, B into B1, C into C1, D into D1, E into E1 and F into F1.

8. **Add 3 drops of methylene blue into each tube and shake/stir each tube to mix the contents and place them back into the water bath. [1] (key step)**
   The same amount and concentration of methylene blue used ensures consistency in the time taken for complete decolourisation. (**Controlled variable)**

   Any 2 controlled variables – [1]

9. **Start the stopwatch and note the time taken for the blue colour to disappear from each tube. [1] (Method to measure)**

10. Repeat steps 1 to 9 to obtain a total of three readings, using freshly prepared yeast suspension, glucose solution and methylene blue each time. **(Reliability of results)**

11. Repeat the entire experiment (steps 1 to 10) twice using fresh yeast suspension, glucose solution and methylene blue of a different batch, to ensure reproducibiltity of results.
    Replicate + Repeat [1]

12. Plot a graph of rate of respiration / s^{-1} against glucose concentration / %. **[1] (with correctly plotted graph)**

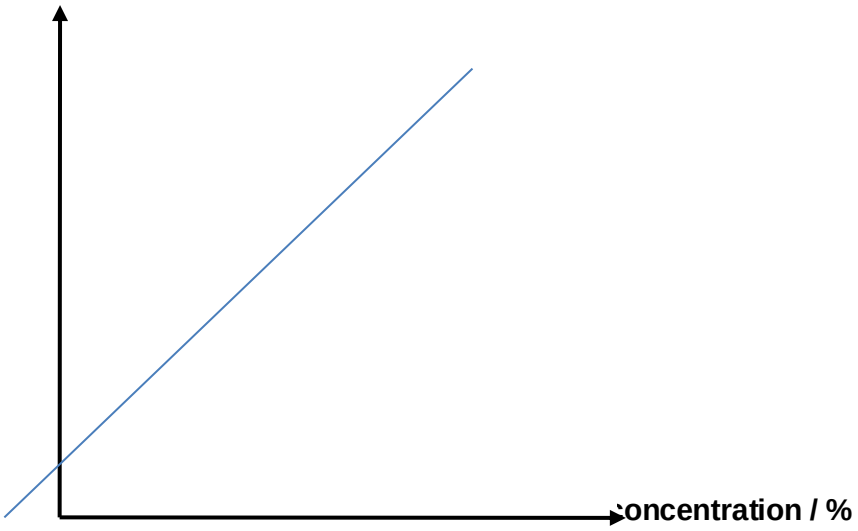
Control

A control (test tube F) is set up which has 5 cm^3 of distilled water instead of glucose added to it and subjected to the same conditions as the rest of the tubes. To show that the colour change of methylene blue is due to the oxidation of glucose by yeast enzymes**. [1]**

Table showing rate of respiration with varying glucose concentration [1]

Glucose ncentration / %	Time taken for blue colour to disappear / s				Rate of respi s^{-1}
	Reading 1	ading 2	eading 3	Average	

Graph of AVG rate of respiration/s^{-1} against glucose concentration / %.



Safety Precaution

- Methylene blue can be a skin irritant – Wash under running water when in contact with skin.
- Water bath may be hot and may scald. Wear gloves when handling beaker of hot water. [1] for 2 precautions

Fully Labelled Diagram [1]

Section E

Answer the question in this section on the answer paper provided.
Begin each part of the question on a new piece of answer paper.

5 Free-response question

Your answers:

- should be illustrated by large, clearly labelled diagrams, where appropriate,
- must be in continuous prose, where appropriate,
- must be set out in sections **(a)**, **(b)**, etc., as indicated in the question.

(a) Describe the goals, benefits and ethical concerns of human genome project. [8]

(b) Explain the significance of genetic engineering in improving food quality. [6]

(c) Discuss the social and ethical implications of genetically modified crop plants. [6]

9 (a) Describe the goals, benefits and ethical concerns of Human Genome Project. [Total: 20] [8]

Goals of Human Genome Project: [Any 2 of the]

1. To determine the sequences of all the 3 billion DNA base pairs in the human genome and to store them in databases accessible to the public.
2. To identify and sequence all the 20,000 to 25,000 genes in the human DNA.
3. Using the gene sequences obtained, to construct a detailed genetic linkage map and physical map of the human genome to understand genetic basis of diseases.
4. The Project also aimed to sequence the genomes of several other organisms that are important to medical research, such as the mouse and the fruit fly.
5. Develop new tools to obtain and analyse the data and to make this information widely available. Computer programs or software would be developed and improved to analyze the data because the data are difficult to interpret without such programs. (OWTTE)
6. Develop genetic tests/screening for diseases and develop more efficient methods for DNA sequencing and sequence analysis and the transfer of these technologies to industry. (OWTTE)
7. Address the ethical, legal and social issues (ELSI) that may arise from the project.

[Max 3 of the above with elaboration]

Benefits of Human Genome Project (HGP) – Max 3 Marks

State + describe one example within category (include explanation to get full mark)

1. **Advancement in Genetic testing / Molecular Medicine** [8]

a) The HGP has allowed for discovery of genes/alleles/ associated with human diseases/ understanding genetics basis of disease; this allows for improved diagnosis of disease / genetic testing.
b) Earlier detection of genetic predispositions to disease (eg. breast cancer, cystic fibrosis, Alzheimer's disease).
c) It also allows scientists to design drugs to target a specific gene/protein.

2. Personalised Medicine / Pharmacogenomics

a) The HGP allows scientists/doctors to know which genes/alleles affect a person's response to a drug since genetic differences affect the way we react to the same drug.
b) It is now possible to tailor drugs/treatments to fit patient's genome for greater efficacy / avoiding dangerous side effects;

3. Improvement in Gene therapy

a) Since we are able to have a understanding which genes/alleles are associated with which diseases, It is possible to use gene therapy to treat certain diseases since gene sequences are now readily available via databases,

4. Risk assessment of individuals upon exposure to toxic agents

a) The HGP has allowed for **discovery of genes/alleles associated** with resistance/susceptibility to radiation/carcinogens. Individuals' genome can be used as a means of risk assessment to evaluate health risks of individuals who may be exposed to radiation or carcinogens. This will help to reduce the likelihood of heritable mutations.

5. Anthropology, Evolution, and Human Migration
a) study **evolution through germline** mutations in lineages
b) study population migration through matrilineal line based on female genetic inheritance or patrilineal line through Y chromosome mutations

6. Energy and Environmental Applications
a) Use microbial genomics research to create new energy sources (biofuels)
b) Use microbial genomics research to develop environmental monitoring techniques to detect pollutants
c) Use microbial genomics research for safe, efficient environmental remediation

7. Advancement in Agriculture, Livestock Breeding (GMO)
a) Creation of Disease-, insect-, and drought-resistant crops. E.g. BT corn,
b) Creation of healthier, more productive, disease-resistant farm animals.

Ethical Concerns – 3 Marks

1. Privacy and confidentiality of genetic information. [Elaboration with one point from below]

a) The issue of who owns genetic information – whether the individual has

complete control over who has access to his genetic information, or is access controlled by the company/researcher who carries out the genome sequencing, or even controlled the government.

b) Fairness in the use of genetic information by insurers, employers, courts, schools, adoption agencies, and the military, among others.
c) The issue of whether insurers / employers / courts / schools / adoption agencies / military may request for and have access to personal genetic information to discriminate people based on their genomes.

2. Psychological impact and stigmatization due to an individual's genetic differences.

a) It is unclear how personal genetic information affects an individual and society's perceptions of that individual
b) Will the genomic information lead to discrimination and affect members of minority communities

3. Reproductive issues including adequate informed consent for complex and potentially controversial procedures, use of genetic information in reproductive decision making, and reproductive rights.

a) There is an issue of whether healthcare personnel are properly counseling parents about the risks and limitations of genetic technology (eg. with regards to the reliability of the genetic test, or whether the detected condition can be treated, and to help patients anticipate and deal with options to deal with the disease, if present, and whether relatives should be informed of the condition so that they can decide whether to test for the condition as well).
b) To-be parents may have to make difficult decisions of whether to terminate pregnancy due to presence of genetic disorder (especially one for which there is currently no cure or treatment for).

4. Uncertainties associated with gene tests for susceptibilities and complex conditions (e.g., heart disease) linked to multiple genes and gene-environment interactions.

a) The issue of whether testing should be performed when no treatment is available/treatment is extremely expensive and the patient cannot afford it, as diagnosing such a condition could lead to more anxiety and frustration.
b) The issue of whether parents have the right to have their children tested for adult-onset diseases, as there is potential for conflict between a parent's choice and a child's welfare (eg. a parent refuses to consent to a test that is clearly in their child's best interest, or a parent who decides to pursue a genetic "enhancement" that involves significant risks for a child, or that may limit a child's life prospects)
c) There is also the related issue of who has the right to determine whether newborns or others who are incapable of valid consent (eg. mentally incapacitated) should undergo genetic screening.
d) The genetic tests may only indicate a probability and not a certainty of a particular polymorphism/allele being associated with a disease or condition. (There is difficulty in interpreting a positive result because some people who carry a disease-associated mutation never develop the disease.) Hence the genetic tests may not be reliable.

(b) Explain the significance of Genetic Engineering in improving food quality.

Define Genetic Engineering [1]
Define genetic engineering:
the application of recombinant DNA technology to introduce genetic material/ foreign genes in order to alter the hereditary traits/ genetic makeup of a cell, organism, or population;

Genetically Modified Organism: Refers to an organism that has acquired one or more genes by artificial means. The genes may or may not be from the same species. OR
Transgenic organism: to describe organisms that had been genetically engineered to express a foreign gene from another species.

Improving Food Quality + Explain briefly [max 2 Marks each]

1. Improved Quality and Yield in Plants e.g. **Bt corn [2]**

- Development of plants resistant to insects / pests. E.g. BT corn express Bt toxins from the Bt toxin gene (Bt toxin gene is isolated from Bacillus thuringiensis and genetically engineered into corn crops).
- Growers use Bt corn as an alternative to spraying insecticides for control of corn borer. Consequently, farmers use less pesticides because BT corn express their own insecticidal proteins.
- This gene crystal proteins (Cry proteins) which acts as insect stomach poisons that must be eaten to kill the insect. Once eaten, the insect's own digestive enzymes activate the toxic form of the protein.
- The Cry proteins bind to specific receptors on the intestinal lining and rupture the cells causing death of the organism within 2 or 3 days.
- Bt maize has revolutionized pest control and many farmers have benefited financially.
- As this toxin is lethal to the pest but harmless to other animals, this Bt corn allows farmers to control pest infestations in order to reduce crop losses.

Others:
Development of Frost Resistance Plants. E.g. Frost-resistant Strawberries, edible vaccines
- *Development of crops with frost resistance. E.g. frost-resistant strawberries can be made by inserting the gene for antifreeze proteins from winter fishes into strawberry crops using recombinant DNA Technology.*
- *Development of bananas that contains human vaccines against infectious diseases such as hepatitis B*

2. Improved quality e.g. golden rice [2]

- Modification of crops by allowing them to produce additional vitamins / minerals. E.g. Golden rice has been genetically engineered to produce beta-carotene a pre-cursor of vitamin A. Production of golden rice will help to provide nutritionally enriched foods particularly to those in developing countries.
- Vitamin A deficiency is the leading cause of preventable blindness in children and increases the risk of disease and death from severe infections.
- Rice grain, which serves as a food staple for much of the world do not contain vitamin A naturally.

- It was discovered that **geranyl geranyl diphosphate (GGPP)** found in rice seed can be a precursor to carotenoid production. **Beta-carotene** and other carotenes are natural **precursors** (inactive form) **of vitamin A.**
- Thus it is possible to genetically engineer a new breed of rice variety, **golden rice** which can **express the enzymes** necessary for the **conversion of GGPP to beta-carotene**.
- To engineer **golden rice**, genes coding for **phytoene synthase** (obtained from plant) and **phytoene desaturase** (obtained from bacteria) must be introduced into the rice plant cells. These enzyme-coding genes catalyze the biosynthesis of beta-carotene from precursor GGPP in the endosperm (edible part of the grain)
- A bacterium, ***Agrobacterium tumefaciens***, containing a **Ti plasmid**, was used to introduce all the **enzyme-coding genes**. OR another way of introducing DNA into plant cells is through DNA coated particles that are literally shot through the cell wall using a modified gun. This is commonly referred to as the use of a 'gene gun'.

3. Improved yield e.g. GM salmon [2]

- Production of GM salmon that grow and reach market size twice as fast as non-transgenic salmon for greater production of fish meat.
- Recombinant DNA composed of an **antifreeze promoter** from an ocean pout and a **growth hormone gene** from a Pacific Chinook salmon is synthesized. Fusing of a strong gene promoter such as the ocean pout antifreeze promoter leads to enhancement in the expression of the gene construct.
- The recombinant DNA is then introduced into fertilized eggs of Atlantic salmon. Subsequent selection and breeding led to development of the genetically modified salmon.
- Due to the year-round production of growth hormone (due to the antifreeze promoter), this allows for continuous feeding and growth of the GM salmon.
- The GM salmon is able to grow quicker in size while feeding more efficiently (less feed is consumed to reach a larger size).

Others:

Improving the nutrient and quality of food. E.g.

- *Pharming of animals to produce vaccines or drugs for therapy / medicine. E.g. genetically engineering goats to produce anti-thrombin in their milk.*
- *For increase quality of meat, pigs have been genetically engineered to produce higher content of omega-3 fatty acid.*

(c) Discuss the social and ethical implications of GM crop plants.

[6]

Social Implications [Max 3 Marks]

1. Cost Savings for famers and cheaper foods for consumers {social}

a) Growth of pest-resistant plants means that lesser crops are lost due to insect damage / diseases spread by insect vectors, therefore resulting in higher yield.
b) Lesser insecticide / pesticide is used, therefore the farmers can save more money.
c) Growth of herbicide-resistant plants means that farmers can spray herbicides to kill weeds without harming the crops. This results in reduction in competition from weeds, resulting in higher crop yield.
d) Savings for famers translate into cheaper foods for consumers.

2. Malnutrition and reduce mortality rate {social}

a) Enhanced quality of crop (e.g. Golden rice, expression of beta-carotene in endosperm in rice, which is converted into Vitamin A in the body when eaten) which helps to keep people healthy and to prevent malnutrition.
b) Doing so will have a positive impact on public health, improving economic productivity, and individual well-being.

3. Rise of super-weeds lead to increase in expenses for Farmers {social}

a) There is a risk of transgene transfer to closely-related non-crop species. For e.g. for herbicide-resistant GM crops, the use of herbicides can lead to the rise of super-weeds that are resistant to herbicides as weeds are grown alongside herbicide-resistant GM crops, due to crossing with the closely related GM plant;
b) Herbicide acts as a selection pressure when a grower continues to use only one particular herbicide without any other herbicide modes of action, or doesn't use any other cultural practices. The resistant weed type continues to survive, mature and produce seed. Subsequent populations of the resistant biotype will continue to increase, reducing crop yields.
c) Farmers would then have to resort to heavy / excessive usage of herbicide, which persist in the environment (i.e. runoff of chemicals into waterways), affecting the ecosystem.

4. Big biotechnology companies will monopolise the seed market, poor farmers not able to afford such seeds (Widening the gap between the rich and poor)

a) GM suppliers could make farmers buy new seed every year. E.g., when farmers purchase a patented seed variety from Monsanto, they sign an agreement that they will not save and replant seeds produced from the seed they buy from Monsanto.
b) Concerns that a few big biotechnology companies will dominate the world seed market.
c) There are also concerns that GM crops might prove too expensive for poor farmers in developing countries to cultivate, thus widening the gap between the rich and poor.

d) Using gene from animals in plant food foods may pose ethical or religious problems.
e) Increasing dependence of developing nations on industrialized nations as the GM crops / seeds may be too expensive for the poor famers in developing countries;

5. Increase in antibiotic-resistance genes found in crops and gut bacteria

Concerns over effects in agriculture of crops interbreeding with closely related species making them resistant. E.g., there is a possibility that bacteria in our guts could pick up antibiotic-resistance genes found in any GM food. If this transfer occurs, it might exacerbate the already worrisome spread of disease-causing bacteria that are resistant to antibiotics.

Ethical Issues: Max 3 Marks

1. GM crops may have long-term effects on humans which are yet unknown. The FDA currently does not require safety assessments of GM foods to be done, in part due to the difficulty of conducting long term feeding trials.
2. There are concerns whether genetically modified foods would be acceptable to various religions or vegetarians. E.g. a vegetarian might not feel comfortable eating strawberries bearing antifreeze proteins from a winter fish / a person observing kosher dietary laws might be offended to know that a tomato he / she has eaten carried a gene isolated from pigs.
3. There are calls for GM food products to be labelled so that consumers can make informed choices. Currently, in the United States, food labeling of GM food is optional / voluntary, so consumers do not know they are consuming GM foods.
4. Critics argue that raising GM crops is an uncontrolled experiment with unknown consequences to the surrounding ecosystems, such as causing “genetic pollution” from the out-crossing of transgenic / GM organisms with wild populations. This mixing of genes and the formation of hybrids result in changes in the gene pools, causing a loss in biodiversity. This might lead to reduction in biodiversity and changes. Cite study showing reduced survival of Monarch caterpillars fed on milkweed dusted with Bt maize pollen.
5. Some critics oppose to GMOs on religious grounds, arguing that the act of altering genetic material goes against Nature and raises the idea of “playing of” god.

--- End of Paper ---