QUESTION 1

(a) Describe the main features of amylose visible in Fig. 1.1 [2]

1 Ref to **α (1, 4) glycosidic bonds** between glucose units **;**
2 Ref to **helical** structure, with **6** glucose units per turn **;**

(b) Explain how the structure of amylose makes it suitable for its function. [2]

1 Ref to **large** amylose, thus **insoluble** in water, **does not exert osmotic influence** in the cell ;
2 Ref to **hundreds to thousands** of glucose, thus a **large** source of **carbon ;**
3 Ref to **α (1, 4) glycosidic bonds,** being easily **hydrolysed ;**
4 Ref to amylose being **helical** and thus **compact ;**
5 Ref to **anomeric carbon** involved in glycosidic bond formation, thus **unreactive / chemically-stable ;**

(c) Suggest how double helix structure of amylose is formed. [1]

Ref to via **hydrogen bonds** between adjacent amylose molecules **;**

(d) (i) State **two** way in which the structure of collagen differs from the structure of starch. [2]

	Collagen		Starch	
1 a	**Made up of amino acids**	1 b	**Made up of α-glucose**	**;**
2 a	**Linked by peptide bonds**	2 b	**Linked by α(1,4) glycosidic bonds**	**;**
3 a	**Triple helix** tropocollagen	3 b	**Helical** amylose, highly **branched** amylopectin	**;**
4 a	ref to **unbranched**	4 b	Ref to **branched**	**;**
5 a	Ref to **extensive hydrogen bonds / cross-links / staggered arrangement**	5 b	absent	**;**

(ii) Explain how one of the differences stated in **(d)(i)** allows collagen to perform its function. [2]

1 Ref to glycine-X-Y, **glycine** with **small R group** can **fit in** / **packed tightly** together ;
A: hydroxylproline having OH group for hydrogen bonding
2 Ref to providing high **tensile strength ;**

3 Ref to **extensive hydrogen bonds** within **tropocollagen**, between **NH** group of **Gly** in one α-chain and **CO** group of **another** amino acid in next α-chain **;**
4 Ref to providing high **tensile strength ;**

5 Ref to **covalent cross-links** present within/between tropocollagen, between **CO** end of one molecule and **NH** end of another or ref to **staggered arrangement** stabilised by **hydrophobic interactions ;**

6 Ref to conferring greater **tensile strength ;**

[Total: 9]

QUESTION 2

With reference to Fig. 2.1,

(a) (i) explain why calcium ions do not pass through the phospholipid bilayer. [2]

1 Calcium ions are **water soluble/ hydrophilic;**
2 unable to pass through **hydrophobic core of the phospholipid bilayer** which consists of hydrocarbon fatty acids chains**;**

(ii) state and describe the process by which calcium ions are moved across the membrane. [4]

1 **Active transport;**

Any 3
2 Intracellular Ca^{2+} **binds to the binding sites** of the **calcium pump/ carrier protein;**
R: active site
R: channel protein
3 Upon binding of Ca^{2+}, carrier protein **undergoes conformational change;**
4 Ca^{2+} is transported **against the concentration gradient** from the **cytoplasm** (a region of lower Ca^{2+} concentration) to **outside the cell/ extracellular** (a region of higher Ca^{2+} concentration**;**
5 Ref. to usage of **ATP** as an energy source**;**

*MP1 compulsory for full marks

(b) With respect to the fluid mosaic model, discuss how high temperature affects membrane permeability. [3]

Phospholipids
1 At high temperature, **kinetic energy** of the hydrocarbon chains of the phospholipids **increases**, and **increase thermal agitation/ lateral movements/ AW;**
2 **Overcoming/ weaker hydrophobic interactions** between phospholipids, **increase transient gaps/ pores** between adjacent phospholipids**;**

Membrane proteins
3 Ref. to correct explanation following **denaturation** of membrane proteins at high temperature:
4 Ref. to **increase membrane permeability;**

**Students have to mention effects on both phospholipids and membrane proteins to obtain full marks*

[Total: 9]

QUESTION 3

(a) State the Central Dogma of Molecular Biology. [3]

1 ref. to **unidirectional flow of genetic information** from **DNA** to **RNA** to **polypeptide ;**
A: genetic information being **encoded in DNA**
R: statements wrt cell theory or genetic code
R: discussion of semiconservative replication, i.e. how DNA acts as template in semi-conservative replication

2 ref. to genetic information being **transferred to mRNA** by **transcription ;**
A: RNA

3 ref. to information on mRNA being **used to synthesise polypeptides** by **translation ;**
R: protein

(b) Explain how a molecule of telomerase synthesises additional lengths of DNA. [4]

any four from

1 **template RNA** binds to (part of) region **X / 3' overhang ;**
R: telomerase – it is the RNA template component
R: template DNA – it is the 3' overhang!
R: mere citation of DNA sequence (e.g. TTAGGG) without reference to 3' overhang – these repeats are found all over the place in the telomere

2 **template RNA** and **3' overhang bind** to **active site** of, telomerase / TERT **;**

3 **DNA / free, nucleotides, pair with / bind to,** RNA template via **hydrogen bonds ;**
R: synthesis of primer

4 ref. to **complementary, bases / base pairs ;**

5 (all or none) ref. to **A–T** and **C–G** and **U–A ;**

6 **phosphodiester bonds form**, between (DNA) nucleotides / AW **;**
treat as neutral any *refs.* to likely enzymes, e.g. ligase, etc
R: telomerase catalysing formation of hydrogen bonds between complementary base pairs

7 **telomerase moves**, **in the direction of the arrow / to the right ;**
R: telomerase moving in the 5' to 3' direction – this is the direction of addition of dNTP and you need to contextualise to Fig. 3.2

(c) Explain why the action of telomerase challenges the Central Dogma of Molecular Biology. [2]

1 (template) **RNA acts as a template** rather than DNA **;**

2 (direction) **reverse flow of genetic information from RNA to DNA ;**

I: RNA is not translated to form proteins. Work on the fact at hand about what telomerase does - say explicitly that RNA is used to form DNA and this in opposite to central dogma!

R: ref. to cell theory / ref. to cell being able to overcome Hayflick limit / ref. to preventing telomeres from shortening or sticking together

(d) Suggest why prokaryotes do not have telomerase. [2]

1 prokaryotes have, circular DNA **;** **A:** 'loop of DNA' **I:** plasmid(s)

2 prokaryotes do not have telomeres **;**
A: prokaryotic DNA has no ends
I: ref. to prokaryotes having a smaller genome – it is not relevant to telomeres

R: ref. to prokaryotes not having non-coding regions – they do. Telomere is just one type of non-coding region!
R: ref. to lagging strand – it is not relevant to telomeres.
R: ref. to ssDNA / use host cell polymerase – prokaryotes are living organisms and not viruses
R: simultaneous transcription and translation – we are looking at DNA synthesis!

[Total: 11]

QUESTION 4

(a) Compare the structures of SARS-CoV-2 and influenza virus. [3]

Any 3
1 Both contain **RNA** ;
2 Both have **viral envelope with glycoproteins** on its surface ;
3 There are **8** segments of RNA in influenza but **1** RNA for SARS-CoV-2 ;
4 **HA** glycoprotein is embedded on viral envelope of SARS-CoV-2 whereas **S** glycoprotein is embedded in the viral envelope of COVID-19 ;
R: one type of glycoprotein vs two types of glycoproteins
5 AVP;

(b) Describe how the SARS-CoV-2 virus enters a host cell. [3]

1 *__S glycoprotein__ on the viral membrane **binds to ACE2 and PRS2** receptors on the host cell membrane;
2 The virus enters the host cell by **receptor-mediated endocytosis** ;
3 **forming an endosome/endocytic vesicle**;
4 Ref. to subsequent **viral envelope fusing with vesicle membrane** and **releasing the nucleocapsid into cytoplasm**;
5 AVP;
*Required for full marks

(c) There are at least three variants of the SARS-CoV-2 virus since its discovery in 2019.

Identify and describe one type of variation in viral genomes that may lead to the formation of new strains of the SARS-CoV-2 virus. [3]

1 *Ref. to **antigenic shift / antigenic drift** ;
R: genetic drift

Any 2
2 (for antigenic shift) **Reassortment of viral genome** with that of a different antigenic type results in the formation of a new COVID-19 strain;
or
(for antigenic drift) **Gradual accumulation of minor mutations** results in changes to the genes for the glycoprotein receptors;
MP2 must match MP1

3 Ref. to change of 3D conformation / shape of proteins ;
4 Ref. to lack of proofreading mechanism associated with the enzyme of the virus ;
*required for full marks

[Total: 9]

QUESTION 5

(a) Explain how this mutation causes the HbS to form fibres. [3]

1 ref. to **change in sixth codon** of β-globin gene**, from GAG to GTG ;**
2 resulting in **change of a polar / hydrophilic amino acid / glutamic acid, to a non-polar / hydrophobic amino acid / valine ;**
3 creating a **hydrophobic spot, on surface** of β-globin polypeptide **;**
4 ***HbS molecules stick together** / **polymerise / aggregate into fibres** at low oxygen concentration **;** R: agglutinate

NB: *MP4 is compulsory for full credit

(b) Suggest why PCR may be needed before the extracted DNA can be profiled. [2]

1 extracted **DNA** may be present in, **small amount / minute quantity ;**
2 **PCR, amplifies / replicates / copies / multiplies, DNA ;**

(c)(i) Describe the role of primers in PCR. [2]

1 (primers) **anneal / bind to / flank, specific DNA / DNA of interest ;**
A: hybridize / form hydrogen bonds with DNA of interest at 3' ends, R: reanneal
2 so that **DNA / *Taq* polymerase,** can **replicate / amplify DNA ;**
A: provide a free 3'OH end for DNA / *Taq* pol to extend from

(ii) Explain how the use of two specific primers allows the detection of the normal, sickle cell anaemia and SCT genotypes. [3]

1 (if) **normal primers bind** then**, normal genotype / Hb^AHb^A ;**
2 (if) **mutant primers bind** then**, sickle cell anaemia genotype / Hb^SHb^S ;**
3 (if) **both primers bind** then**, SCT genotype / heterozygote / Hb^AHb^S ;**

R: use of gel electrophoresis / differences in length of fragments for identification of genotypes

[Total: 10]

QUESTION 6

(a) Outline how cancer is caused. [3]

1 Ref. to **accumulation of mutations in cancer-critical genes** in a **single cell lineage ;**
2 Ref. to the **dysregulation of cell cycle checkpoints ;**
3 Ref. to **uncontrolled cell division** / **rate of cell division being greater than rate of cell death ;**

4 Ref. to **activation of telomerase** gene **;**
5 Ref. to the description of the process of **angiogenesis ;**
6 Ref. to the description of the process of **metastasis ;**

Note: Max 1m for MP4 to MP6.

(b) Describe the normal role of the *BRCA2* gene. [3]

1 Ref. to the tumour suppressor gene *BRCA2* coding for the **BRCA2 protein ;**

AND

Any two below:
The tumour suppressor protein / BRCA2 protein:-
2 takes part in the **cell-signaling pathways** to **inhibit the cell cycle ;**
3 **halts cell division if DNA is damaged ;**
4 **triggers DNA repair mechanisms** preventing cells from accumulating DNA damage **;**
5 **initiates apoptosis ;**
6 **maintains cell adhesion ;**
7 **AVP ;**

Note: MP1 is compulsory to attain full marks.

(c) Discuss the extent to which Fig. 6.1 provides evidence that a faulty *BRCA2* allele increases the risk of a person developing cancer. [4]

1 Ref. to the idea that the **overall data** in Fig. 6.1 is **inconclusive / AW ;**

Data that shows *BRCA2* allele **might** increase the risk of a person developing cancer
2 **Individual 3 or 4** may have had the, ***BRCA2*** allele **/** Any **individual from 8 to 11** may **have inherited**, ***BRCA*** allele, **from 3 or 4 ;**
3 Individual **15 has cancer, *BRCA2*** allele **;**
4 Individuals **15, 21 and 23** with cancer in **third generation had a parent** with, ***BRCA2*** allele **;**
5 Individuals **17 and 20** with cancer in third generation **had a parent** with **cancer ;**

Data that shows *BRCA2* allele **might not** increase the risk of a person developing cancer (i.e. data is inconclusive)
6 Individual **8 or 11**, has ***BRCA2*** allele, but **does not have cancer ;**
7 **No evidence / unknown, that individuals** (apart from 15) with **cancer**, have ***BRCA2*** allele **;**
or
Individuals with cancer (apart from individual 15) may have a **different mutation ;**
8 **No children of individual 15**, (known to) have the allele, **have cancer ;**
9 Individuals in **fourth generation / children of** individual **15**, may **develop cancer later in life ;**

Note: MP1 is compulsory to attain full marks. Answers must include a balanced discussion from MP2 to MP5 and MP6 to MP9.

[Total: 10]

QUESTION 7

(a) Explain the term *epistatic gene interaction* in this context. [2]

1 The expression of **tt masks** the **expression of alleles at the M/m locus;**
2 Ref to presence of **T allele being required for expression of red / black hair /ORA ;**
R: MP2 if no ref to effect of M/T alleles on phenotype

(b) A couple with black hair has three children, each with a different hair colour.

Draw a genetic diagram to explain these results. [4]

Let **M** represent the dominant allele for black hair
m represent the recessive allele for red hair
T represent the dominant allele for deposition of pigment
t represent the recessive allele for lack of deposition of pigment

Parental phenotype Both heterozygous black hair parents

Parental genotype MmTt x MmTt

Gametes MT, Mt, mT, mt ;

		Female gametes: MT	Mt	mT	mt
Male Gametes	MT	MMTT	MMTt	MmTT	MmTt
	Mt	MMTt	MMtt	MmTt	Mmtt
	mT	MmTT	MmTt	mmTT	mmTt
	mt	MmTt	Mmtt	mmTt	mmtt

;

offspring genotypic ratio 9 M_T_: 3 mmT_: 3 M_tt: 1 mmtt ;

offspring phenotypic ratio 9 black hair: 3 red hair: 4 (3+1) albino ;

(c)(i) Complete Table 7.1 to show the expected numbers of individuals with each phenotype. [1]

hair colour	observed number of individuals	expected number of individuals
black	579	**540**
red	165	**180**
albino	216	**240**

Note: Award all or none.

(c)(ii) Using the formula above, calculate the χ^2 value for the observed results. Show your working clearly. [1]

χ^2_{calc} = (540-579)^2/540 + (180-165)^2/180 + (240-216)^2/240
= 6.47 ;

(c)(iii) Explain the conclusion that may be drawn from your χ^2 value in **(c)(ii)**. [3]

1 **At df=2, $\chi^2_{calculated}$ = 6.47> $\chi^2_{critical}$ = 5.99 ;**
2 there is **less than 5% probability** that there is **difference between observed and expected results** is **due to chance ;**
3 Thus the distribution of hair types **shows significant difference** from 9:3:4**/ does <u>not</u> follow the predicted ratio of 9: 3: 4/ there is a larger distribution of dark haired individuals at the equator;**

[Total: 11]

<u>QUESTION 8</u>

(a) Explain the roles of proteins involved in the light-dependent reaction of photosynthesis. [2]

Any 2 from:
1 Ref. to **enzymatic role of proteins / protein complexes** that catalyse the **synthesis of NADPH and ATP (either one) / photolysis of water ;** e.g. NADP reductase, ATP synthase complex
2 Ref. to protein complexes with **ability to carry out redox reactions** (electron carriers for accepting / donating electrons) making up the **electron transport chain** ;
A: harness energy from electrons to generate proton gradient
3 Ref. to membrane proteins able to carry out **active transport to pump protons** across the IMM, **generating a proton gradient** for chemiosmosis to occur /AW ;
4 Ref. to **light harvesting complexes / photosystems** with ability to carry pigment for **absorption of light ;**

(b)(i) Describe and explain the pattern of results obtained between 0.25 mol dm^{-3} and 1.25 mol dm^{-3} of sodium hydrogencarbonate solution. [4]

1 *as concentration of sodium hydrogencarbonate solution **increases from 0.25 to 1.00 mol dm^{-3}**, the percentage change in dissolved oxygen **increases <u>gradually</u> from 21 to 31 %;**
2 ***then plateaus / remains constant at 31% thereafter from 1.00 to 1.25 mol dm^{-3} ;**

any 2

3 below 1.0 mol dm^{-3}, **concentration of CO2 is limiting factor, as more CO_2 is used, rate of light independent stage / Calvin cycle / carbon fixation can increase ;**

4 Ref. to **increased frequency of effective collisions** between **Rubisco and RuBP and CO2** as **substrate concentration increases**;

5 above 1.0 mol dm^{-3}, photosynthesis is at a maximum rate because **concentration of CO2, is no longer limiting factor + appropriate reason (e.g. enzymes saturated)** and other factors (such as temperature / light intensity) may be limiting **;**

(ii) Suggest reasons for this negative value. [2]

1 **little / no, photosynthesis** due to **low CO2 concentration ;**

2 ref. to below compensation point, **(aerobic) respiration uses / takes up oxygen, causing oxygen concentration to decrease ;**
A: rate of respiration exceeds rate of photosynthesis hence oxygen concentration decreases ;

(iii) To minimise temperature changes, the student decided to use an LED lamp as a light source. LED lamps release very little heat energy.

Explain the importance of minimising temperature changes in this experiment. [3]

any 3

1 Ref. to keeping temperature as a **controlled variable,** to ensure a fair test / **so CO2 is the only independent variable ;**

2 Ref. to temperature **affects kinetic energy** and hence **rate of photosynthesis / O2 production ;**

3 **low temperature may limit rate /** temperature **becomes limiting ;**

4 **high temperature may denature enzyme(s) ;**

5 **high temperature may causes / increases photorespiration ;**

[Total: 11]

QUESTION 9

(a) (i) State why the two bee species share the first name *Bombus.* [1]

Ref to **same genus ;**

(a) (ii) Describe how it is possible to confirm, over a longer period of time, whether *Bombus pratorum* and *Bombus terrestris* belong to different species. [2]

Any two:

1 Ref to **check if *Bombus pratorum* and *Bombus terrestris* interbreed /AW ;**

2 Ref to **determining if offspring are viable and fertile ;**

3 Ref to **conclusion, i.e. if offspring are infertile, then they are different species (ORA) ;**

(b) (i) Name the process by which new species are formed within the same geographical location. [1]

Sympatric speciation ;
R: adaptive radiation, allopatric speciation, hybridization

(b) (ii) Using Fig. 9.1 and Table 9.1, and the information given, suggest how an ancestral species might have evolved into the two species, *B. pratorum* and *B. terrestris*. [5]

Describe data in Fig. 9.1 and Table 9.1 (Max 2):

D1 Ref to **seasonal / temporal difference in breeding** of males and queens in different populations with **data quoted from Fig. 9.1;**
A: *B.pratorum* has its peak number of workers in June and *B. terrestris* in July

D2 Ref to **behavioural difference** / visit **different types of flowers** / **feed at different times** / **feed on different food types** with **data quoted from Table 9.1;**
A: *B.pratorum* visits flowers of mean depth 7.4mm while *B. terrestris* visits flowers of mean depth 6.3mm

Note: Requires one description each from Fig. 9.1 and Table 9.1.

Note: Deduct 1 mark (either in part a(ii) or b(ii)) if the scientific name is not written correctly based on the binomial nomenclature (i.e. the two parts of the scientific name need to be separately underlined).

Suggest reasons (Max 3):

R1 Ref to **ecological isolation ; A:** behavioral isolation / occupied different ecological niches
R2 Ref to **gene flow restricted ;**
R3 Ref to **mechanism of natural selection,** resulting from **different adaptations** under different selection pressures **;**
R4 Ref to **accumulation of sufficient reproductive isolating mechanisms, genetic diversity and adaptations ;**
R5 Ref to idea of **reproductive isolation ;**
R6 **AVP ;**

[Total: 9]

QUESTION 10

(a) Describe the innate immune response. [2]

1 combats microbes **immediately** upon infection / mediates the **initial protection against infections ;**
2 ref. to **physical barriers** with relevant explanation ;
3 ref. to **non-specific** defence **;**
4 ref. to i**nstructing adaptive immune system** to respond to different microbes ;
5 does not lead to lasting immunity / **no immunological memory** ;
6 ref. to specific **named** cells and molecules involved, e.g. macrophages, chemokines, cytokines, complement system

(b) Explain which immune responses are impaired in Patients A and B [3]

1 Patient A - **innate / innate and adaptive**, Patient B - (only) **adaptive** ;
2 ref. to **non functional** innate immune response that is **unable to prevent the multiplication of microorganism**, leading to **high number / exponential increase of microorganism count** ;
3 ref. to **functional innate** but **non functional adaptive**, hence slow rise at the start, **similar to C**, but microorganism count does not drop, **continues to rise** ;

QUESTION 11

(a) With reference to the information provided, suggest and explain how climate change scientists can estimate atmospheric carbon dioxide concentrations 10 000 years ago. [2]

any two
1 ref. to how carbon dioxide air bubbles is a **good sample / indicator** of atmospheric carbon dioxide levels + **quote appropriate data** – percentage concentration of carbon dioxide in air bubbles from 1959 to 1980 compared to atmospheric percentage carbon dioxide in the same time period **;**
2 ref to **extracting ice samples from different depths of ice sheets** and **determine the age of the ice samples** ;
3 ref to measuring the **concentration of carbon dioxide,** and plot **a graph of percentage concentration of carbon dioxide in the air bubbles of ice ;**
4 **ref to extrapolating to 10,000 years ago, to give an estimate /** a **good sample / indicator** of atmospheric carbon dioxide levels **;**

(b) Use Fig. 11.2 to comment on changes in temperature over the last 800 000 years. [2]

1 **Rise and fall of ratio of ^{1}H to ^{2}H** corresponds with the **rise and fall of percentage concentration of carbon dioxide** over the past 800 000 years **;**
2 **Carbon dioxide** is a greenhouse gas, and an **increased concentration** in the atmosphere would lead to **more heat being trapped**, resulting in the **corresponding rise and fall of temperature** as the concentration of carbon dioxide changes **;**

(c) Explain why the data in Fig. 11.2 do not provide enough evidence to conclude that increased concentrations of greenhouse gases cause climate change. [2]

1 Carbon dioxide is **not the only greenhouse gas** / unable to identify which gas is causing the change **;**
2 ref. to **temperature not the only factor** in climate change **;**
3 ref. to **correlation does not imply causation ;**

[Total: 6]