2019 Paper 1 Q1

1. **(D)**
   - Focus of the question includes size, as it asks for the *smallest* structure to represent life.
   - It is true that definitions of life include ability to carry out metabolism (**1**) like anabolic and catabolic reactions; contain genetic material (**2**), of which DNA is useful for both storing of genetic information as well as being template for transcription. However, these 2 features can also be found in structures like mitochondrion and chloroplast, which are much smaller than cell.
   - Likewise, not all organisms are multicellular and needs tissues and organs (**4**). For example, prokaryotes are generally unicellular.
   - Other features that identify cell as the smallest unit of life (**3**) include communication, gaining nutrition, excretion, and reproduction.

2019 Paper 1 Q4

4. **(B)**
   - (**1**) is at least partially correct as thermophilic enzyme optimum activity is reached at about 75% of enzyme unfolding [but not beyond 75% enzyme unfolding]. The unfolding could have expressed activator / active site in thermophilic enzyme.
   - (**3**) is not supported as the psychrophilic enzyme started losing enzyme activity even before enzyme unfolding occurs. Likewise, mesophilic and thermophilic enzyme activity began to drop even before enzyme unfolds to 100%.
   - The psychrophilic enzyme took about 15 ºC (from 40 to 55 ºC) to unfold completely (**2**).

2019 Paper 1 Q7

7. **(D)**
   - Totipotent stem cells (**D**) can give rise to all cell types of human. Ethics is breached as the resultant human life cannot give consent to the genetic modification procedure.
   - Pluripotent stem cells (**C**) can give rise to all human cell types too except the extraembryonic tissue like umbilical cord, placenta, and amniotic sac.
   - Using induced pluripotent stem cells (iPSC) (**A**) has its own ethical issues, but may attract less ethical implications with regard to no embryo destruction.
   - Genetically modifying multipotent stem cells (**B**) like blood haematopoietic stem cells have the least ethical implication, as this practice is usually used for therapeutic purposes (e.g. treating blood disorders), instead of permanently affecting a potential human life.

Note

- (**C**) may be an alternative answer too.
- Stem cells from *very early human embryos* could refer to zygotic up to the 16-cell morula stem cells (formed 3–4 days after fertilization), which are still totipotent (**D**), or the pluripotent stem cells from inner call mass of blastocyst (formed 5–7 days post-fertilization).
- But as the focus of the question is also on *ethical concern*, genetic modification of blastocyst may be more likely to be one that cause such concern as the pluripotent stem cells are physiologically closer towards human life development than totipotent stem cells.

2019 Paper 1 Q9

9. **(A)**
   - In *antigenic drift* (**A** & **B**), lack of proof reading ability of RNA-dependent RNA polymerase in influenza facilitates mutations to antigens, resulting in viruses using new antigens to evade host immune system with potentially injurious effect.
   - Thus, H3N2 (**A**) can mutate via antigenic drift to form a new H antigen (e.g. H4) that the human immune system has never encountered.
   - Even though H2N2 (**B**) can also be formed within pigs via antigenic drift, it would not harm human health as significantly as (**A**) due to earlier exposure of humans to H2N2 from *1958-1970*. This early exposure produces antibodies to protect humans against H2N2 that they may encounter in future.
   - *Antigenic shift* is the random assembly of RNA genomic segments between more than 1 type of virus to give rise to novel genetic combinations, resulting in viruses with new antigenic combinations (e.g. H7N10) to infect host cell and evade host immune system with potentially more deadly effect than antigenic drift. Even though there is low risk of virus transmission from birds to humans directly, the novel virus strain from birds can still infect humans using pigs as intermediary. However, N10 antigen is not found in any of the species over the years studied from the question.

- Antigenic drift, instead of antigenic shift (**D**), is more well-known to occur in human cells. Even if antigenic shift occurs in humans, different assortments of H2N2 with either H1N1 or H3N2 strains still cannot give rise to a dangerous strain, with a combination of both H and N antigen that are totally foreign to the *present day* humans (who are currently exposed to H1N1 and H3N2).

2019 Paper 1 Q12

12. **(D)**
    - mRNA with no poly(A) tail may be broken down (**1**) to account that those mRNA stored contain Poly(A) tail attached (**bullet pt. 2**). However, the mechanism in this statement is not explicitly supported from the findings.
    - Poly(A) tail is only added to mRNA after the gene is transcribed (**bullet pt. 2**) and lengthened when required during later development (**bullet pt. 3**), thus supporting the notion that Poly(A) tail is not encoded by DNA of the gene (**2**).
    - It is shown that lengthened poly(A) tail (**3**) can activate translation (**bullet pt. 1**) for embryonic development (**bullet pt. 3**).

2019 Paper 1 Q25

25. **(D)**
    - Continual increase in skeleton size over the usually warm weathers (paragraph 4) shows that small skeleton size (**D**) are not selected for in such climate.
    - Continual increase in beak size over the usually warm weathers (paragraph 4) refutes that stable (**A**) or smaller (**B**) beak sizes are selected for in such climate.
    - Shorter wing length (**C**) is selected for in both cold (paragraphs 2 and 3) and the usually warm weathers (paragraph 4).

2019 Paper 1 Q28

28. **(B)**
    - As pertussis *is easily transmitted*, vaccination *at an age of about three months* can reduce infection for newborns.
    - Vaccination can provide direct immunity protection to the vaccinated individual, as well as herd immunity to those that cannot be vaccinated due to medical (such *as people with reduced immunity*) or philosophical reasons.
    - However, increasing vaccination in local children alone of only one small area cannot bring about the eradication of a pathogen, considering the wide flow of visitors and migrants entering Singapore from other bigger regions.

Note

- Disease eradication is distinctly different from elimination.
- Eradication refers to the reduction to zero (or a very low defined target rate) of new cases in a defined geographical area. Elimination refers to the complete and permanent worldwide reduction to zero new cases of the disease.

2019 Paper 2 Q1

1. (a) [Any 3 of the following]:
    1. **cell surface membrane**
    [REJECT: cell membrane]
    2. **chromosome / DNA**
    [REJECT: bacterial genome]
    3. **cell wall**
    4. **septum**

    (c) • Both **plasmid** and **nucleoid** bacteria chromosome undergoes theta (θ)-mode of **semi-conservative DNA replication** using both **parental DNA strands** as **template**, where adenine base pairs with thymine, and cytoside base pairs with guanine.
    • Mesosomes attach nucleoid bacteria chromosome to plasma membrane. Each nucleoid bacteria chromosome is separated towards opposite poles of cell as cell elongates.

Note

Candidates need to link named nutrients, with effect of its lack on named cell processes.

2019 Paper 2 Q2

2. (c)

Feature	*Details*
Orientation of monomer	• Alternate beta glucose subunits are rotated 180 deg with respect to each other.
Structural shape	• The polymer shape exists as long, **straight** [REJECT: imprecise terms e.g. linear] chain.
Bonds between molecules	• Due to the chain form, **OH groups** on glucose subunits project outwards to allow interchain **hydrogen bonding cross-linking**, which leads to microfibril formation. • Microfibril assemble to form increasingly complex structures of macrofibrils through hydrogen bonding.

(d) [Any 3 of the following]:

1. **Cellulose synthase** that catalyzes intracellular cellulose monomers into **cellulose microfibril**, is only located at the **cell surface membrane**, not inside the cell.
2. Huge space required for the **large** cellulose molecule formation can disrupt other biochemical processes (e.g. vesicle movement) within cell.
3. Migration of big cellulose chains from inside to outside of cell will lyse **cell surface membrane**.
4. **Cellulose is needed outside the cell** to help maintain cell shape. Cellulose's **insolubility** in **water** prevents it from being dissolved in the extracellular **aqueous** environment.
5. [Alternative valid point]

2019 Paper 2 Q3

3. (a) • Transcription and translation can occur together as there is no nuclear membrane/envelope separating **RNA polymerase** and **ribosome**.
    • As no mRNA **post-transcriptional modifications** are required, the mRNA transcribed by **RNA polymerase** is translated by ribosome into polypeptide even before transcription is completed.

2019 Paper 2 Q4

4. (a) • X: **double stranded DNA**
    [REJECT: Vague responses e.g. head / genome]
    • Y: **contractile tail sheath**
    • Z: **tail fibre**

Common Mistake

- Describing transcription and translation of the viral proteins, rather than viral genome replication.

2019 Paper 2 Q5

5. (b) • The bottom DNA strand of row 1 sequence, is used as **template** by **RNA polymerase in transcription**.
    • Based on **complementary base-pairing** during transcription, **DNA sequences** of **G, C, A,** and **T base pairs** with **C, G, U,** and **A** on **mRNA** respectively. This results in change in mRNA sequence from GAG to GUG at the second codon.
    • The resultant different **codon** read by **ribosome** during **translation**, caused a missense mutation as **Glu** (**glutamic acid / glutamate**) is replaced with **Val** (valine) in the polypeptide chain [REJECT: amino acids were 'formed' or 'produced' by DNA triplets].

Common Mistake

- Giving full name of amino acids, when it is not required for this question.
- Many of those who chose to provide the full name for the changed amino acid referred to glutamine, rather than glutamic acid / glutamate.

(c)
- The resultant different **codon** caused **glutamic acid's hydrophilic R group** to be replaced with **valine's hydrophobic R group**.
- The adult haemoglobin (**HbA**) changes to mutated haemoglobin (**HbS**), where the valine amino acid now replaced glutamic acid at exposed binding site of **beta globin chain** of HbS molecule.
- At **low oxygen** concentration, the **three-dimensional conformation** of beta globin chain of HbS molecules' tertiary structure would change and would **polymerise into fibres**.

Common Mistake

- Confusing effect on haemoglobin with effect on red blood cell e.g. haemoglobin becomes sickle shaped.

Exam Tips

- To avoid misunderstanding questions or overlapping answers over related sections, scan all parts of the structured or essay question before writing.

(d)
- The haemoglobin polymerisation resulted in change from biconcave **red blood cells** used for effective transport of oxygen, to transformation into **sickle shape**.
- The less flexible sickle shaped cells block the **narrow blood capillaries**, and have a shorter life as they get trapped at spleen. The lowered blood and oxygen [REJECT: no oxygen] flow to tissues results in anaemia and organ damage.

2019 Paper 2 Q6

6. (c) [Any 3 of the following]:
   1. Environment in the form of **diet** and chemicals (pheromones from queen bee), can serve as specific **transcription factors** to regulate gene expression of egg development.
   2. Offspring designated to become queen bees are fed predominantly with **royal jelly**. Whereas larvae designated to become worker bees [missed by most] are only given royal jelly for the first 3 days, and fed pollen, nectar and honey henceforth[2].
   3. These transcription factors include **activator** and **repressor** proteins, which bind to **enhancer** and **silencer** respectively. **Enhancer-activator** complex can upregulate transcription by forming **transcription initiation complex**, while **silencer-repressor** complex has the opposite effect.
   4. This transcriptional control allows **activation** and **inactivation** of selected **genes**, so that the proportion and types of proteins formed will determine physiological development of the bee type.

   REJECT:
   - Reference to natural selection or the need to replace dead queens.

2019 Paper 2 Q7

7. (a)
- **Oxygen**, the **final electron acceptor**,
- accepts **electrons** carried by the **electron transport chain** (ETC) and **hydrogen protons** to form **water**.
- The electron flow along the ETC generates a **proton reservoir** (in intermembrane space) for **chemiosmosis** to produce ATP via oxidative phosphorylation.

REJECT:
- Unnecessary detail about chemiosmosis.

(b)
- Aerobic **respiration** is more efficient in generating ATP compared to anaerobic respiration, as there is net gain of **38 ATP** per molecule of glucose oxidised, compared to only **2 ATP per molecule of glucose** oxidized from anaerobic respiration via **substrate level phosphorylation**.
- Without **oxygen**, the 2 **NADH** generated during glycolysis cannot pass their electrons along the **electron transport chain**, to produce ATP via oxidative phosphorylation.
- During anaerobic respiration, the 2 NADH generated during glycolysis, is regenerated to 2 **NAD+** during conversion of **pyruvate to ethanol**. Incomplete breakdown of glucose caused energy to still be trapped in ethanol.

[2] *(n.d.). https://www.science.org.au/curious/earth-environment/what-it-takes-make-queen-bee#:~:text=After%20three%20days%2C%20those%20larvae,the%20remainder%20of%20their%20lives. Accessed 2 Jul 2020.*

(d)
- ATP is an **allosteric <u>inhibitor</u>** that binds to **non-active site of PFK**.
- This allosteric binding changes **three-dimensional conformation** of PFK's active site, such that PFK can no longer bind to F6P substrate, thus lowering rate of PFK enzymatic activity.
- At increasing [REJECT: 'high' only] F6P substrate concentration, there is a higher chance of F6P substrate to **effectively collide** with PFK to form **E-S complexes** to form reaction **products**.

[SUPPORTING INFORMATION]: **PFK and ATP**

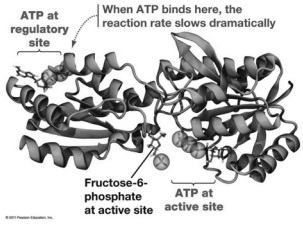

Figure 7 ATP as both activator and inhibitor for PFK

Source: <u>https://www.istitutogreppi.edu.it/sites/default/files/page/2017/16%20Phosphofructokinase%201.pdf</u>. Accessed 15 Nov 2019.

- PFK1 has two sites with different affinities for ATP which is both a **substrate** and an **inhibitor**. This may explain the competitive-like PFK inhibition curve by high levels of ATP.

2019 Paper 2 Q8

8. (c) [Any 2 of the following]:
   - No **<u>needles</u>** are needed [REJECT: vague terms e.g. less invasive]
   - Oral insulin administering allows for a more gradual decline in blood glucose due to more gradual absorption of insulin into blood, as its takes 7.5 hours to reach blood glucose homeostatic set point of 80-100 mg dm^{-3}, whereas insulin injection causes a sharp reduction of blood glucose, as its takes only 2 hours to reach the blood glucose homeostatic set point. This sharp drop in blood glucose can cause physiological symptoms such as mood swings.
   - Oral insulin administering allows for a more sustained period of 2 hours at blood glucose homeostatic set point of 80-100 mg dm^{-3}, whereas insulin injection causes blood glucose to increase less than half hour after reaching the blood glucose homeostatic set point.

(d)
- Binding of insulin to extracellular ligand binding site on the **tyrosine kinase receptor** on liver cell, results in **three-dimensional conformational change** causes **dimerization** of the receptors, and **auto-cross phosphorylation** of **tyrosine amino acid residues** by tyrosine kinases in opposite homodimer.
- **Signal transduction** is **amplified** within cell (e.g. addition of phosphates can convert a protein like protein kinases, from an inactive form to an active form) in a **phosphorylation cascade** to create **second messengers**.
- Second messenger may serve as transcription factors to trigger **cellular response** e.g. by translocating **glucose transporter** onto plasma membrane of target cell, to increase cellular uptake of glucose by facilitated diffusion.

2019 Paper 2 Q9

9. (a) [Any 3 of the following]:
   1. Although descended from a **common ancestor**, varying **environmental factors** of the islands present **different <u>selection pressures</u>**.
   2. **<u>Favourable adaptations</u>** that are **<u>selected for</u>** will have a **selective advantage** and enable their owners to have higher **reproductive success**, and thus **pass down alleles that code for these advantageous traits** to their offspring resulting within **populations**.
   3. The resultant **<u>change in allele frequency</u>** within each population leads to formation of the 4 ecomorph types. This displays **descent with modification**.
   4. Reproductive isolation mechanisms such as **geographical** isolation due to the sea around the islands, disrupt **gene flow** and cause sufficient genetic changes to be accumulated to form different species on different islands through **adaptive radiation**.

(b) (i)
- Sea/ocean causes **<u>geographical isolation</u>** to **<u>disrupt gene flow</u>** between organisms in island those from other islands/mainland, thus causing **allopatric speciation**.

- Based on **Founder effect**, **genetic drift** occurs when a new population on the island is based on pioneer individuals that first arrived at island. The **gene pool** of the pioneers that landed on Puerto Rico and Cuba [or quote other appropriate data], are different from each other and gene pool of original population the pioneers came from, thus facilitating speciation. This accounts why **different islands have different species** [often missed].

(ii) [Any 2 of the following]:
- Within the island of Jamaica [or quote other appropriate data], **sympatric speciation** can occur, where new species can be formed from organisms sharing same geographic range.
- Due to different niches in the environment (e.g. vegetation size for camouflaging) serving as different **selective pressures**, **offspring** from the organisms with selected types of **genetic variation** from [named processes in meiosis; gene/chromosomal mutation] are selected for.
- The **alleles that code for these adaptive traits** (e.g. large toepads to move well in tree canopy) are passed on the next generation. Over multiple generations this results in development of distinct subpopulations that eventually they can no longer **interbreed** to produce **viable** and **fertile** offspring and hence new species are formed through such **adaptive radiation**.

(c)
- **Genetic drift** has a greater effect in smaller than bigger islands, as smaller islands generally have a smaller **gene pool** due to less niches, and also a smaller **population** size of the various lizard species.
- Severe storms that serve as a **Bottleneck effect** in genetic drift, can randomly remove most or all of the lizards on the smallest islands, thus significantly reducing the gene pool. If lizards that survive or pioneer the island after the storms have alleles coding for short legs [or quote other appropriate data], then their offspring in the subsequent generations will also inherit the same alleles coding for similar leg length.
- Larger islands have a bigger gene pool due to more niches, and also a bigger population size of the various lizard species. Thus there is a higher chance of at least a few representative individuals from the various lizard species surviving the storms, to preserve the original gene pool richness.

REJECT:
- Vague responses outlining the process of natural selection on large islands, and then simply stating that this did not occur on small islands

2019 Paper 2 Q10

10. (a)
- Sea urchin density seems to increase with increasing August sea temperature, with high number of observations in 0.2 m^{-2} sea urchin density between 12.0 to 12.3°C, to as high as 0.9 m^{-2} sea urchin density at 12.4°C.
- Although August sea temperature has been showing general trend of increase since 1950 of 11.5°C, it was only between recent years of 1995 to 2010 that the temperature reaches 12.3°C to facilitate sea urchin invasion.

Common Mistake
- Quoting temperature range from beginning to end of the study without identifying the specific temperature range within which sea urchin numbers increase.
- No references to years.

(b) [Any 3 of the following]:
1. There is a general trend that sea urchin density seems to increase with increasing August sea temperature over the years, up to as high as 0.9 m^{-2} sea urchin density.
2. Fig. 10.3 shows that **increased sea urchin density results in increased grazing** of **kelp** [missed by most],
3. because as sea urchin density increases from 1.0 to 6.8 m^{-2}, percentage kelp cover tends to decrease to 0%.

4. As kelp cover is also used as habitat / food by other **marine species**, **reduction in percentage kelp cover** can also lower **marine biodiversity** [missed by most].

OR

5. The gradually increasing August sea temperature over the years due to climate change, may not significantly impact kelp forests.
6. Even though there is a general trend that sea urchin density seems to increase with increasing August sea temperature over the years, up to as high as 0.9 m^{-2} sea urchin density, most of the sites in Fig. 10.3 still show percentage kelp cover at 100% at that sea urchin density. Percentage kelp cover only reaches 0% in most sites from about 1.5 m^{-2} sea urchin density and above.
7. Moreover, the trend of increasing sea urchin density with increasing August sea temperature may not always be valid, as the data in Fig. 10.2 shows unequal number of sampling observations at the various temperatures, with most observations done over 12.0 to 12.3 ºC.
8. Furthermore, Fig. 10.2 only shows observations till 12.5 ºC. There is no conclusive evidence that increasing August sea temperature beyond 12.5 ºC, can allow sea urchin to thrive and reach higher sea urchin density of 1.5 m^{-2} and above to significantly reduce kelp cover.

2019 Paper 2 Q11

(b) • Rate of bacteria death decreased over time in culture media, as bacteria number decreased from 10^7 to 50 per cm^3 at 0 to 4 hours.
• Penicillin effect on bacteria slows down from 4 to 5 hours, as bacteria number remains constant at 50 per cm^3 [missed by some].

2019 Paper 3 Q1

1. (a) (i) • Phylogeny

Common Mistake
• Phenology

(ii) 1. Use **polymerase chain reaction** to selectively amplify loci containing **variable / short number tandem repeats** and other unique genetic sequences that can distinguish the plant species.
2. Use the appropriate and **same restriction enzymes** to digest DNA flanking the tandem repeats or the other unique genetic sequences to obtain **RFLP fragments**.
3. Use **gel electrophoresis** to separate RFLP fragments based on size, where gel contains **pores** to provide molecular sieve to separate RFLP fragments based on molecular size, such that the distance travelled by a **DNA band** is inversely proportional to its molecular size.
4. Perform **Southern Blot** using radioactively-labelled **probes** complementary in sequence for tandem repeats specific to non-GM grain, followed by **autoradiography** using X-ray film [or other appropriate visualization methods], to obtain the DNA profile.

Common Mistake
• Not thinking broadly across syllabus in approaching question.
• Discussion on how this information should be analyzed or the principles underpinning such analysis.
• Describing only a particular molecular method in excessive detail, instead of combination of different methods to obtain the required information.

(iii) [Any 2 of the following:]
1. Organisms grouped together lower down the taxonomic ranks (e.g. kingdom, phylum, class, order, family, genus, species) have more similarities. Therefore, simply having a common trait of curcumin production is insufficient to place them in the same genus.
2. Some plants have more similarities in both phenotypic, genotypic, and ecological niche traits that placed

them under the same genus (e.g. *Curcuma longa and Curcuma zanthorrhiza* are placed under the same genus as they have many more similarities such as molecular homology other than curcumin production).

3. To be the same genus but still different species, they must have sufficient number of similar characteristics to be the same genus, but other characteristics distinct enough to be considered as different species.
4. [Alternative valid point]

Common Mistake

- Referring biochemical trait like curcumin as a morphological trait.
- Referring to inability to interbreed [only relevant when considering whether organisms belong to the same species, not to the same genus].

(iv)
- The **common ancestor** of these 2 families contained **genes** on curcumin production, which are only passed to members of these groups over generations.
- The 5 species from these 2 families of plants that can make curcumin, contain specific DNA sequences (e.g. **alleles**) that allow for its transcription and the corresponding translation process to synthesize curcumin.
- [Alternative valid point]

Common Mistake

- Selection pressure arguments that only these two families live in environments where curcumin is selected for [Not supported by Fig. 1.1, which shows that most members of the two families do not produce curcumin].

(b) (i)
- In G1 phase, increasing curcumin concentration from both 0 and 40 μmol dm^{-3} causes percentage of cancer cells to increase from 20 to 76%.
- In G2 phase, increasing curcumin concentration from both 0 and 40 μmol dm^{-3} causes percentage of cancer cells to decrease from 74 to 17%. This shows that increasing curcumin concentration has a greater effect in keeping cancer cells in G1 phase, and preventing them from entering S phase.
- There do not seem to be significant difference in effect of curcumin concentration on cells entering G2 phase, as across the 4 different curcumin concentrations, as percentage of cells in G2 phase range closely from 6-9% over these concentrations. In fact, both 0 and 10 μmol dm-3 of curcumin resulted in the same 6% of cells in G2 phase [Or quote other appropriate data]

Common Mistakes

- Not addressing each of the three phases separately.
- Omitting trends and their meaning.
- Omitting judgement as to whether curcumin in a given phase makes the percentage of cancer cells higher or lower.
- Mistaking the Y-axis label of percentage as absolute amount of cancer cells.
- Not appreciating that cells that enter G2 must pass through earlier phases (i.e. S phase) too [Thus, all cells that have entered into S phase is 24% (17% S + 7% G2 phases) under 40 μmol dm^{-3} of curcumin].

(ii) 3. Cancer cells thus will be slowed in its progression to result in cancer in the body, as cancer cells need to proliferate uncontrollably to form a **tumour**.

4. Curcumin inhibits cell cycle progression by up-regulating cyclin-dependent kinase (CDK) inhibitor[3]. Without active CDK to complex with cyclin, there is no activated CDK to **phosphorylate** and activate other proteins to advance the **cell cycle** past **G1 checkpoint** [Alternative molecular mechanisms in Fig. 1.3].

Common Mistake

- Mitosis occurs during S phase of interphase.
- Confusing DNA replication with nuclear division.

(iii) [Any 3 of the following:]

1. Curcumin upregulates **p53** expression (e.g. via increasing stability of p53 protein[4]).
2. In presence of mutation, p53 protein acts a **tumour suppressor gene** protein.
3. It naturally stops **cell division** upon detection of DNA mutation, triggers **DNA repair**, and activates **apoptosis** of cancer cells. These protective activities help prevent **uncontrolled cell proliferation** that give rise to cancer.

4. [Alternative molecular mechanisms in Fig. 1.3]

REJECT: Writing about a molecule that was not in Fig. 1.3 (e.g. ras).

[SUPPORTING INFORMATION]: **Curcumin and p53**

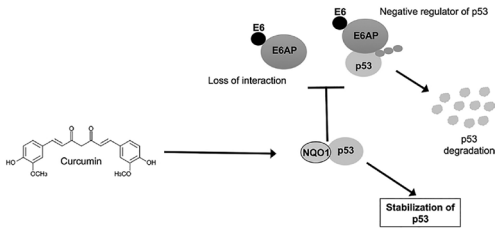

Figure 1.1 Curcumin promotes p53 stability

Source: Patiño-Morales, C. C., Soto-Reyes, E., Arechaga-Ocampo, E., Ortiz-Sánchez, E., Antonio-Véjar, V., Pedraza-Chaverri, J., & García-Carrancá, A. (2020). Curcumin stabilizes p53 by interaction with NAD(P)H:quinone oxidoreductase 1 in tumor-derived cell lines. Redox Biology, 28, 101320. doi:10.1016/j.redox.2019.101320

(c) (i) 1. Curcumin reduces amount of activated **PhK** required to activate **NFκB**.

2. Without NFκB serving as **transcription factors**, the **200 genes** involved in scar formation cannot be activated for scar tissue formation.

3. Scar formation in another pathway requires white blood cell (WBC) to release **FGF** and **TGFβ1** growth factors that cause **fibroblasts** to proliferate and differentiate into scar tissue.

4. Scarring is also disrupted when curcumin reduces amount of activated **TNFα**. Without TNFα, **white blood cells were no longer attracted to or accumulated at the burn site**.

REJECT:

- Simply quoting data from Fig. 1.4 instead of describing the decrease or stopping of each event in Fig. 1.4 in a logical stepwise progression.
- Curcumin reduces amount [instead of activity] of PhK and TNFα.

(iii) 3. Benefit of such **signal transduction** using phosphorylation includes [Any 1 of the following]:

- **Signal amplification**.
- Ability to **regulate the response**.
- **Specificity** in activating gene of interest.
- Ability of a molecule reaching a cell membrane to activate genes in the nucleus.
- Activation of many cells **simultaneously** and for a single signal molecule to trigger numerous cellular reactions at once.

4. Phosphatase removes phosphate group from a molecule via **hydrolyzing** the **phosphoester bond** using a **water** molecule. Its antagonistic function to kinase thus regulates cellular responses during homeostasis.

Common Mistake

Poor knowledge of phosphatase

[SUPPORTING INFORMATION]: **Kinase and Phosphatase**

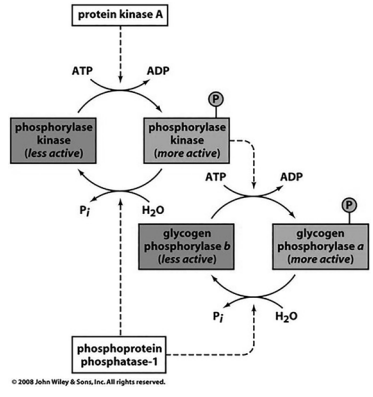

Figure 1.2 Antagonistic functions of kinase and phosphatase

Source: Biochemistry MT2: 05Control of Glycogen Metabolism. (n.d.). Retrieved from https://quizlet.com/16415778/biochemistry-mt2-05control-of-glycogen-metabolism-flash-cards/

[3]*Park, M., Kim, E., Park, I., Lee, H., Woo, S., Lee, J., ... Hong, S. (2002). Curcumin inhibits cell cycle progression of immortalized human umbilical vein endothelial (ECV304) cells by up-regulating cyclin-dependent kinase inhibitor, p21WAF1/CIP1, p27KIP1 and p53. International Journal of Oncology. doi:10.3892/ijo.21.2.379*

[4]*Patiño-Morales, C. C., Soto-Reyes, E., Arechaga-Ocampo, E., Ortiz-Sánchez, E., Antonio-Véjar, V., Pedraza-Chaverri, J., & García-Carrancá, A. (2020). Curcumin stabilizes p53 by interaction with NAD(P)H:quinone oxidoreductase 1 in tumor-derived cell lines. Redox Biology, 28, 101320. doi:10.1016/j.redox.2019.101320*

2019 Paper 3 Q2

2. (a) (i) • **Oligopotent**

(b) (iii) • **Somatic hypermutation**

REJECT #2b: clonal selection, clonal expansion and affinity maturation [QN asks for *specific genetic process*]

(c) (i) [Any 4 of the following:]

Crossing-over

1. During **prophase I**, **chiasmata** allows **recombination** of genetic material between **non-sister chromatids** of **homologous chromosomes** by **crossing over between** these **non-sister chromatids**. It may break established genetic linkage groups and produce new ones.

Independent assortment of chromosomes

2. During **metaphase I**, pairs of homologous chromosomes undergo **<u>independent assortment</u>** by arranging themselves **randomly** on the cell equator. **Anaphase I** that follows then separates the chromosomes towards opposite poles of cell.
3. Orientation of the **non-identical sister chromatids** at **metaphase II** determines which cross-over combination of alleles goes to which pole. **Anaphase II** that follows then separates the daughter chromosomes [REJECT: sister chromatids] towards opposite poles of cell.
4. Thus the genetic sequences (e.g. alleles) separate in certain combinations among the gametes.

Non-disjunction [Often missed]

5. Non-disjunction in **anaphase I** and **anaphase II** results in failure of separation of homologous chromosomes and **sister chromatids**.
6. Thus non-disjunction during **anaphase I** affects chromosome numbers of all daughter cells; non-disjunction during **anaphase II** affects chromosome numbers in 2 or all of the 4 daughter cells

REJECT:

- Independent assortment occurred during anaphase I.
- Not qualifying the name of a stage with a number to show whether reference was being made to meiosis I or meiosis II.
- Misnaming independent segregation as 'independent separation'.
- Incomplete descriptions for crossing-over and independent assortment.

(ii) • Stage I of Fig. 2.1 (Somatic recombination) resulted in shortening of the chromosome due to deletion of genes from the VDJ domains, whereas **crossing-over** and **independent assortment** in meiosis can still result in chromosome of the same length.

- Stage I of Fig. 2.1 takes place within **1** chromosome, while meiosis requires **2 homologous chromosomes** to occur.
- [Alternative valid point]

! Common Mistake

- Recombinase enzymes only important in somatic recombination.
- Somatic recombination involves alternative splicing of mRNA.
- Not understanding random nature of somatic recombination.

2019 Paper 3 Q3

3. (a) *Comparing population*

1. There seems to be a general trend that as human population increases, contribution to carbon dioxide (CO_2) emissions also increases.
   For example, China and United States of America (USA) both have a similar percentage share of global economic wealth of 15 and 17% respectively, yet China produced a much higher 23% global CO2 emissions compared to USA's 14%, due to China's bigger 19% share of global human population compared to USA's 4%.
2. This could be caused by the need to **<u>generate more energy for rearing livestock</u>** and heating [or other appropriate examples] in order to support a greater population, thus requiring **<u>burning</u>** of **<u>more</u> fossil <u>fuel</u>** that subsequently releases more CO_2.

Comparing economic wealth

3. There also seems to be a general trend that CO_2 emissions increases with increasing economic wealth.
   For example, China and India both have a similar percentage share of global population of 19 and 17% respectively, yet China produced a much higher 23% global CO_2 emissions compared to India's 6%, due to China's bigger 15% share of global economic wealth compared to India's 6%.
4. This could be caused by the need to **generate more energy for** higher **personal electrical** consumption and **transport** [or other appropriate examples] reflective of wealthier population, thus requiring **burning** of **more fossil fuel** that subsequently releases more CO_2.

Genetics Tips

Answering Strategy

- *Pay close attention to question demand.*
  Due to question requirement to explain how, explaining the mechanisms (e.g. more fuel are burned to generate more electricity) should be included instead of only references to data.
- *Source data for effective comparison.*
  Identify the factor responsible for the observation or anomaly. In this case, one should compare China with India or Russia with USA, as these pairs of countries have similar population sizes but different shares of global economic wealth.

(b) 1. In **light-dependent reactions**, specific wavelengths from light cause photoactivation of **photopigment** molecules in PS I and II for eventual formation of **NADPH** and **ATP**, which are both required for reactions in the Calvin cycle. Calvin cycle can sequester gaseous carbon dioxide from the air, and is an active process in young trees.

2. **In carbon fixation, ribulose bisphosphate carboxylase oxygenase catalyses carboxylation of RuBP (a 5 carbon compound) by carbon dioxide.**

3. **This reaction gives rise to an unstable a 6-carbon intermediate, which is split to form two 3-C molecules called 3-phosphoglycerate (PGA).**

4. ATP and NADPH are required for reduction of PGA to **triose phosphate**, and **ATP** is also used in **regeneration of ribulose bisphosphate (RuBP)**.

5. 3 rounds of **Calvin cycle** yield a TP that leaves the cycle to form other organic compounds (e.g. glucose). The **carbon atoms from carbon dioxide are stored long term in cellulose, starch and other macromolecules** [missed by most].

REJECT:

- Carbon dioxide gas / glucose are stored in plants.
- Describing carbon cycle in which stored glucose is then respired, releasing the carbon dioxide.

2019 Paper 3 Q4

4. (a) *Nuclear envelope structure*

1. Nuclear envelope is made up of **2 phospholipid bilayers**. Nuclear envelope contains proteins and enzymes near **nuclear pores**[5].
7. Membranes allow **compartmentalization**, which facilitates **optimum** conditions for promoting required reactions within that section of organelle.
   - For example, nuclear envelope allows mRNA to undergo post-transcriptional modification (e.g. RNA splicing) before being translated, by keeping ribosomes outside nucleus.

Roles of membrane's biomolecules (Proteins as receptors)

8. **Proteins** and **glycoproteins** can serve as **receptors** on **cell surface membrane**, to bind to and respond to **signal molecules**.
   - For example, nuclear envelope contain receptor proteins at nuclear pores to control migration of substances into and out of nucleus.

Roles of membrane's biomolecules (Proteins as transporters)

9. **Transport / carrier proteins** provide hydrophilic channels / pores to transport hydrophilic (e.g. charged, polar) solutes via **facilitated diffusion**, down the solute's **concentration gradient**.

10. Carrier proteins shuttle substances by changing **3-dimensional conformation** and **charge**.
11. Some carrier proteins are coupled to ATPase and ATP hydrolysis to facilitate substance transport.
12. Transport proteins are specific for translocation of substances (e.g. aquaporins facilitating water passage; glucose transporters transport glucose).

Roles of membrane's biomolecules (Proteins to maintain membrane structure)

13. Membrane proteins attached to cytoskeletal and extracellular matrix elements helps maintain cell shape, to provide animal cells with stronger structural framework and coordinate extracellular and intracellular changes.
14. [Alternative valid point]

Genetics Tips

Answering Strategy: Contextual answering

Identify the theme or key case study in the structured / essay question, and write concepts and examples closely linked to them.
In this case, limit discussion of membranes to the nuclear membranes, and not cell membranes of other organelles.

REJECT:

- Nuclear envelope consists of a single phospholipid bilayer [instead of two].
- Equating the nucleus double membrane to just one bilayer of phospholipids.
- Referring nuclear pores as small and passive transient openings.

(b) Gene expression

1. Nuclear envelope provides **compartmentalization** to create suitable environment for gene expression.
2. Nuclear envelope contains proteins and enzymes near nuclear pores. Nuclear pores regulate **movement** of substances **in and out of the nucleus**.
    - Raw materials like nucleotides are imported into nucleus for nuclear activities like DNA replication and transcription.
    - Mature mRNA is exported out of nucleus for translation by ribosome.
9. Nuclear envelope must reform around chromosomes at **telophase I and II** to form the nucleus, so as to facilitate gene expression e.g. for centriole replication during Interphase II.

Common Mistake

- No named examples of molecules transported across nuclear envelope.
- Reference to breakdown and formation of nuclear envelope during mitosis or meiosis, without clear attribution to role for the nuclear envelope.

2019 Paper 3 Q5

5. (a) 7. Different combinations of at least 20 different types of amino acids give rise to different **polypeptide primary structure** of amino acid residue sequences and length.
8. Each amino acid residue of primary structure has a different R group, which contains functional group to confer varying physical and chemical properties. They form bonds like **hydrogen bond**, **ionic bond**, **hydrophobic interaction**, and **disulphide bond** to influence shape and function of secondary, and **3-dimensional conformation** and **charge** of **globular** tertiary and quaternary structures.
11. The **alpha-1,4 glycosidic bonds** between **alpha-glucose** molecules form a helical structure, while the high numbers of **alpha-1,6 glycosidic** bonds allow extensive branching of the **polysaccharide** polymer.
15. Transcription occurs in **nucleus** for eukaryotes. Transcription uses **4** different types of **ribonucleotides** of ATP, UTP, CTP, GTP as monomers, to form **polyribonucleotide** [often missed].

[5]*Nuclear pores regulate migration of substances into and out of the nucleus.*
[6]*Van der Waals forces = A weak attractive force between atoms or nonpolar molecules caused by a temporary change in dipole moment arising from a brief shift of orbital electrons to one side of one atom or molecule, creating a similar shift in adjacent atoms or molecules.*
[7]*Capping enzyme complex is formed in three sequential reactions catalyzed by RNA triphosphatase, RNA guanylyltransferase, and RNA guanine-N7 methyltransferase.*
[8]*Link, J., Jahn, D., Schmitt, J., Göb, E., Baar, J., Ortega, S., Alsheimer, M. (2013). The Meiotic Nuclear Lamina Regulates Chromosome Dynamics and Promotes Efficient Homologous Recombination in the Mouse. PLoS Genetics, 9(1), e1003261. doi:10.1371/journal.pgen.1003261.*
Ding, X., Xu, R., Yu, J., Xu, T., Zhuang, Y., & Han, M. (2007). SUN1 Is Required for Telomere Attachment to Nuclear Envelope and Gametogenesis in Mice. Developmental Cell, 12(6), 863-872. doi:10.1016/j.devcel.2007.03.018

17. Transcription is catalyzed by **RNA polymerase** using **condensation reaction**, with **phosphodiester** bond formed between 2 monomers to form **RNA**.
18. Only one strand (non-coding strand) of DNA is used as **template**, and reading of template is from **3' to 5' direction**.
19. **DNA** replication starts at **origin of replication**. Enzyme **helicase unzips** DNA molecule, such that **hydrogen bonds between the bases are broken**.
20. **Topoisomerases** reduce the strain in DNA during uncoiling, and **single-stranded DNA Binding Proteins** (SSBP) bind to each parental strand to prevent the strands from winding back. **Two separating parental strand each acts as a template** for synthesis of new daughter strand.
21. **Primers** are formed in **5'to 3' direction** by **primase** using ribonucleotides. Due to **anti-parallel nature** of DNA, **DNA polymerase** adds **free deoxyribonucleotides** also in 5' to 3' direction, to the 3' end of the growing polynucleotide chain, by reading template strand from 3' to 5' direction. **Phosphodiester bonds** are formed between adjacent deoxyribonucleotides using free nucleotides ATP, GTP, CTP, TTP.
22. DNA polymerase uses **complementary base pairing** with adenine binding to thymine and guanine to cytosine **between deoxyribonucleotides** between opposite DNA strands, such that ratio of **purine** (adenine, guanine) to **pyrimidine** (thymine, cytosine) is 1:1.
23. One new **leading strand** is synthesized continuously towards **replication fork**, while the other **lagging strand** is synthesized in short segments of **Okazaki fragments** away from replication fork.
24. **DNA polymerase** removes the primer and replaces them with deoxyribonucleotides. Enzymes **ligase** anneals fragments with phosphodiester bonds to form one continuous strand.
25. [Alternative valid point]

Common Mistake

- Failure to write a balanced essay covering all types of polymers.
- Reference to triglycerides and phospholipids [which are not polymers].

(b) 3. Each amino acid residue of primary structure has a different R group, which contains functional group to confer varying physical and chemical properties. They form bonds like **hydrogen bond, ionic bond, hydrophobic interaction**, and **disulphide bond** to influence **folded** shape and function of secondary, and **3-dimensional conformation** and **charge of globular** tertiary and quaternary structures.

12. To stabilize transmembrane receptor, such as **G-protein linked receptor** (GPLR) protein, on **cell surface membrane**, specific amino acid residues are needed to form bonds for the stability.

2014 Paper 1 Q8

8. **(C)**
   - In semi-conservative replication, both parental DNA strands are used as template to synthesize the new strand. In the first generation, 100% of DNA molecules will have one ^{14}N and one ^{15}N strand. In the following generation, only 50% of DNA molecules will have one ^{14}N and one ^{15}N strand, while the other 50% of DNA molecules will have two ^{14}N strands.

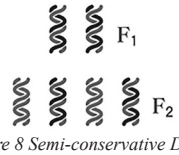

Figure 8 Semi-conservative DNA replication

Source: http://csls-text3.c.u-tokyo.ac.jp/large_fig/c_fig07_01.html