VICTORIA JUNIOR COLLEGE
BIOLOGY DEPARTMENT
JC2 PRELIMINARY EXAMINATIONS 2017
HIGHER 2 9744/2 Propose answers

1 Fig.1 shows an electron micrograph of an organelle. There are two distinct group of vesicles (Boxes B and C) associated with this organelle.

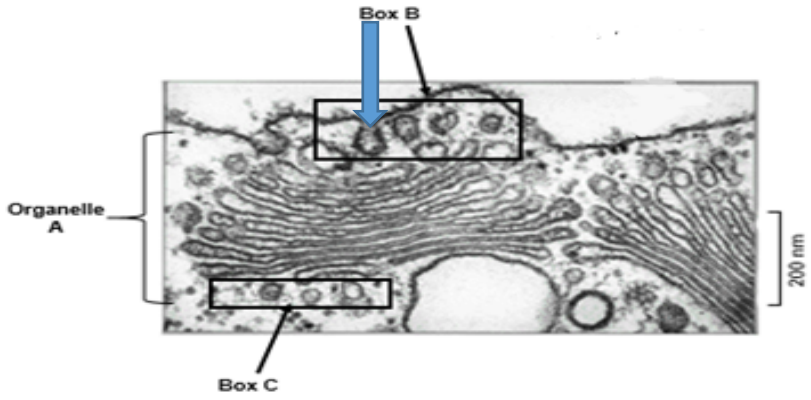


Fig. 1

(a) (i) Identify organelle A. Feature
Golgi body/ golgi apparatus;;

A stack of membranes with swollen ends;;

(ii) Describe the differences in the role of the vesicles that fuse with the forming face and the vesicles that are formed at the maturing face. [4]

- Box C: [2m]
  - vesicles contain proteins and/or lipids;
  - transported from rER and sER;
  - that will undergo chemical **modification** within the golgi body;
  - **examples** of modification: glycolysation, phosphorylation etc

- Box B: [2m]
  - Packaging and transport fn: Vesicles containing modified products will be transported to the cell membrane;
  - where they **fuse** and **release** the products to the outside of the cell/via exocytosis;

(b) Suggest how the lack of E3A expression can lead to a disruption in the structure and function of the Organelle A.

- Lack of gene expression means that the enzyme E3A is not **produced**/ transcribed and translated;;
- Proteins that are tagged by ubiquitin, are meant for **degradation**;;

- These proteins are either **damaged/abnormal/excess**;;
- Removal of these proteins help to maintain the normal functions of the GA (idea of);; (A: reverse argument)

(c) State two characteristics, one in structure and one in chemical property that you would expect to see in ubiquitin protein ligase. [2]

Structure: globular / specific 3D configuartion
Chemical ppty: solubility in water;;

2 (a) Explain the **similarity in the pattern** seen in both HDAC mRNA and HDAC protein. [2]

- HDAC mRNA is the **template** for the **translation** /synthesis of HDAC protein;;
- Decrease in mRNA concentration lead to a decrease in concentration of HDAC protein;;

(b) (i) What information about the gene expression of *RUNX3* can one conclude from the data at the beginning of the experiment? Explain your answer. [3]

There are 2 possible answers to this question.

Possible answer 1

- *RUNX3* gene is silenced/ down regulated;;
  (Note: this last mark is only awarded if student's answer shows that there is an attempt to link *RUNX3* gene expression to HDAC levels shown in Fig 2.1)
- How does HDAC down regulate *RUNX3* expression:
  - Remove acetyl groups from lysine residues of histones;
  - Increase positive charge of histones;
  - Results in negatively *RUNX3* gene being more tightly coiled around histones;
  - Promoter less accessible to transcription factors and RNA polymerase;
- Data: Highest HDAC mRNA and protein;

Possible answer 2

- *RUNX3* gene is upregulated;;
  (Note: this last mark is only awarded if student's answer shows that there is an attempt to link RUNX3 gene expression to HDAC levels shown in Fig 2.1)
- How does RUNX3 **up**regulate HDA
  - RUNX3 TF binds to promoter of **HDAC gene;**
  - Recruits RNA pol or formation of transcription initiation complex for transcription;
  - Up regulation HDAC gene expression (idea of);
  - highest HDAC mRNA and protein concentration;

  A: RUNX3 TF act as activator (attaches to enhancer region); to allow correct positioning of TIC/ stabilise the TIC; through looping mechanism;

(ii) Suggest one way how your answer in (i) can affect the **cell**. [3]

Down regulation of RUNX3:

- *[What is RUNX3]* RUNX3 is a TSG Or TF coded by RUNX3 binds to/activates other TSG;;
- *[what is its function/ function of other genes]* Involved in halting cell cycle/ repair DNA damage/send cells to apoptosis;;
- *[impact –leading to cancer]*Reduced expression leads to accumulation of DNA damage/ cells not able to stop at the appropriate checkpoints/ do not undergo apoptosis, resulting in cancer;;

Upregulation of RUNX3:

- *[What is RUNX3]* RUNX3 codes for the TF for HDAC gene;
- HDAC protein deacetylates/ silence TSG;;
- *[what is its function/ function of other genes]* Involved in halting cell cycle/ repair DNA damage;;
- *[impact –leading to cancer]*Reduced expression leads to accumulation of DNA damage/ cell cycle out of control, resulting in cancer;;
  (Described eg. cells not able to stop at the appropriate checkpoints, leading to uninhibited growth.)

- RUNX3 is a protooncogene or codes for the TF for proto-oncogenes;;
- Results in increase/upregulate expression of genes that promote cell growth and proliferation;;
- *[impact –leading to cancer]* Increased expression leads to increase cell proliferation / cell cycle out of control, resulting in cancer;;

(c) With reference to the data shown in Fig 2, suggest **how** Chemical K can bring about the change in the HDAC mRNA and protein. [2]

- {Change} Decrease HDAC mRNA and protein;

- Any one of the ways below:
  1. Act as a repressor (specific TF) that binds to the silencer;
  2. Prevents TIC assembly;
  3. Down regulate HDAC expression

Or

  4. Breakdown mRNA/Decrease stability of mRNA;
  5. Reduce half life;
  6. Less mRNA and hence less HDAC protein being synthesised;

Or

  7. Cause DNA methylation of HDAC gene;
  8. At CpG regions;
  9. Silence the gene/ recruit histone acetylase;

Or AVP (1 1/2m)

(d) Suggest why HDAC mRNA instead of the HDAC gene was analysed in this experiment. [2]

Answers must provide reason for both HDAC mRNA and HDAc gene.

- Fixed copies/ concentration of the HDAC gene (idea of);;
- Gene may not be expressed/ idea of cannot study expression;;

- Differential expression of the gene can be seen using the mRNA;;
- Chemical K affects transcription and hence its effect can only be seen by observing changes in mRNA concentration;;

3 **(a)** **(i)** Identify substrates **X** and **Y**.[2]

X: glucose;

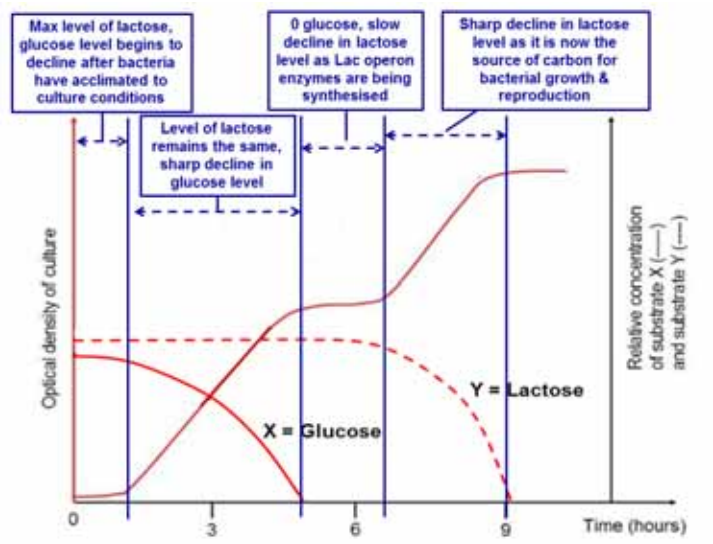
Y: lactose;

(ii) Using your knowledge of gene expression in bacteria, explain how Fig. 3 supported their conclusion that the *Lac* operon is under dual control. [4]

- Evidence #1 – first growth phase: When glucose and lactose are both present, glucose is used preferentially (A! first/ preferred respiratory substrate) for bacteria to grow and reproduce;;
- Lac operon is under negative control and the gene coding for beta-galactosidase that breaks down lactose into glucose and galactose is not expressed;;
- Evidence #2 – second growth phase: when glucose is depleted, lac operon is active and under positive control, so expression of the gene for beta-galactosidase is upregulated;;
- Evidence #3 – Lag phase: bacterial growth levels / plateaus out: time needed for activation of CAP by cAMP when adenylyl cyclase inhibition is removed after glucose is depleted and cAMP levels increase/ time needed for the expression of lac operon;;

(b) On Fig. 3, draw separate graphs to show the change in the concentration of the two substrates over time. Label your graphs. [2]

Answer:



Each curve for glucose and for lactose must show:

- Decreasing trend <u>but with glucose being used first</u> @½ m
- Shape of curve to consist of plateau and linear segments @½ m
- A! decreasing trend for glucose from time 0. (FYI – During the lag phase, bacteria are adapting to growth conditions, so that individual bacteria are maturing and not yet able to undergo binary fission. During the lag phase, synthesis of RNA, enzymes and other molecules occurs. As the cells are metabolising, there is some usage of glucose.)

(c) Eukaryotes are structurally different from prokaryotes and hence exhibit differences in their control of gene expression.

Explain two such differences. [4]

Any two below (note: from perspective of eukaryotic genes):

- Chromatin modelling – acetylation/deacetylation Or methylation/demethylation of CpGs in eukaryotic promoters;; to compact chromatin by wrapping high mw DNA/ large eukaryotic genome around histones to fit into space of nucleus;;
- Post-transcriptional – 5' capping and polyA tail addition;; for protection from exonucleases / facilitate transport out of nucleus through nuclear pores to the cytoplasm;;
- Post-transcriptional – alternative splicing of pre-mRNA occurs;; to produce more than 1 type of mature mRNA/ protein product from one gene / to generate more types / diversity of proteins than no. of genes in genome (to perform all the functions necessary for cell to survive/ in response to different stimuli);;
- Translational - through addition of long polyA tail;; to maintain stability of mature mRNA in the cytoplasm as templates for translation of more protein;;
- Post-translational – protein modification;; to activate/ inactivate proteins in response to appropriate signals/ control activity of synthesised proteins;;
- A! Transcriptional – In eukaryotes, one promoter controls the expression of one gene (instead of several functionally related genes);; because eukaryotic genes are not organised into operons (explanation);;

- A! presence of many control elements distal from gene;; allowing for combinatorial control of expression;;

4 (a) What do you understand by the term pure-breeding? [1]

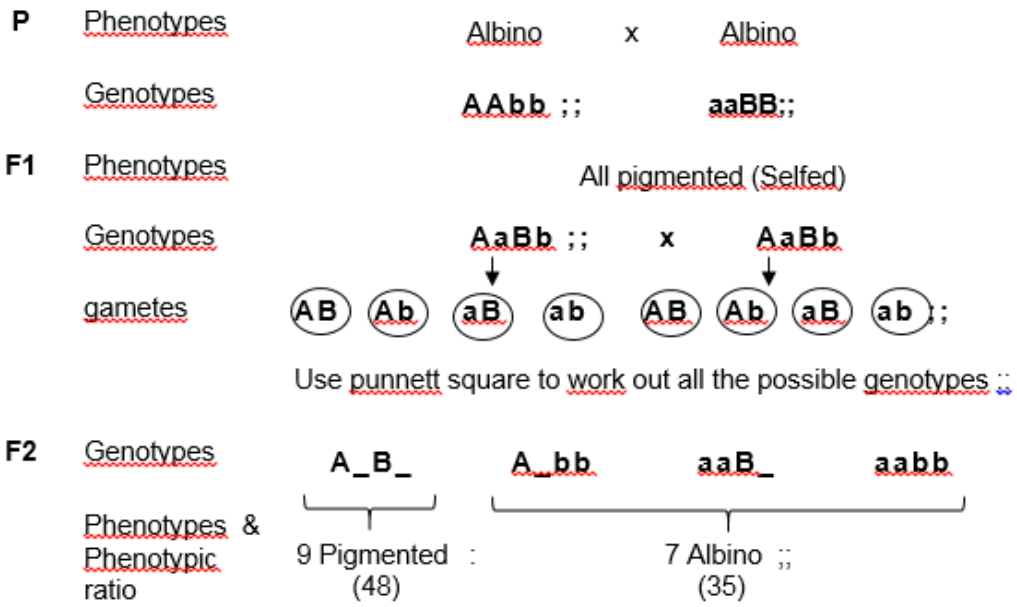
- An organism is said to be pure bred when it is homozygous at the gene loci that is being investigated/under study;;

(b) Using appropriate symbols, draw a genetic diagram to explain the results obtained.

Let A be the dominant allele that codes for an enzyme that converts a precursor to an intermediate pigment (white or albino) and a be the recessive allele that codes for a non-functional enzyme

Let B be the dominant allele that codes for an enzyme that converts the intermediate to a coloured pigment and b be the recessive allele that codes for a non-functional enzyme
At least 1 copy of each dominant allele must be present for the production of coloured pigment.

Genetics Diagram:



5 (a) (i) Account for the decrease in the telomere length of Cell Y. [4]

1) during DNA replication;
2) when the last **RNA primer is removed/excised;**
3) at the **3' end of parental template strand** / **5'end of daughter strand**;
4) it is **not replaced by** corresponding **DNA** sequence;

5) as **DNA polymerase cannot add new nucleotides; without an existing 3'OH end;**
6) idea of resulting daughter DNA strand being shorter than the parental DNA strand;
7) ref to **end replication problem**;

(ii) Explain why there is a limit to the number of times Cell Y can divide (Hayflick's limit). [2]

1) idea of ends of chromosomes **shortening into critical genes** / telomeres **shortening to a critical length**;
2) cells will **halt the cell cycle**;
3) and subsequently cell will **undergo apoptosis**;
4) idea of protecting integrity of genes being passed to daughter cells;
5) idea of preventing accumulation of mutations;

(b) State how Cell X is able to maintain its telomere length. [1]

- presence of an active enzyme **telomerase** to regenerate telomeres;;

(c) (i) With reference to Fig 5, explain how the change in telomere length resulted in Cell Y* after M2. [2]

1) (describe change) telomere length increases slightly then remains constant;
2) failure of cell Y to undergo apoptosis;
3) as the cell can continue to proliferate;
4) idea of mutation;
5) leading to **activation** of telomerase activity / **increased** expression of telomerase which can regenerate length of telomeres;;

(ii) State one external factor that can contribute to the formation of Cell Y*. [1]

- UV radiation/ X ray / ionising radiation;;
- Chemical carcinogens eg. tobacco;;
- Viruses (eg. retroviruses);;

(d) Describe the importance of centromeres in cell division. [3]

1) site where sister chromatids attach to each other;
2) acts as site for specific attachment of kinetochore / kinetochore assembly;
3) Which allows for attachment of microtubules/ spindle fibers;
4) During metaphase / metaphase I / metaphase II;
5) Allow the equal (@proper) separation of sister chromatids and homologous chromosomes;
6) allow genetically identical daughter cells to be formed;
7) prevent non-disjunction / occurrence of aneuploidy or polyploidy;

6 (a) Explain how metformin can be used to decrease the blood glucose level in patients with Type II diabetes. [4]

1) Metformin enters cell via OCT1 / facilitated diffusion through protein channel;
2) Metformin binds to and activates AMPK;

3) Metformin induces decreased ATP:AMP ratio / induces hydrolysis of ATP to AMP;
4) which phosphorylates and activates IRS1/2 and Akt;
5) leading to increased GLUT-4 translocation;
6) by inducing vesicles containing GLUT-4 transporters to fuse with the plasma membrane;
7) increased numbers of GLUT-4 transporters proteins on membrane;
8) allowing increased glucose uptake into the cell;
9) idea of activation of other cellular enzymes (eg. glycogen synthase)

(b) Akt is known to stimulate other cellular responses in the insulin signaling pathway.

Suggest how activation of Akt can lead to different cellular responses. [3]

- **acts as relay protein / secondary messenger** that can **bind to other proteins / enzymes;;** (@ activate other relay proteins)
- that leads to **activation / inactivation of proteins/kinases** that take part in **other signalling transduction pathways/ signal cascades**;;
- leading to **activation of other enzymes** that can **catalyse different cellular reactions**;; (accept specific examples)
- **acts as transcription factors** that can **upregulate/downregulate expression of different genes**;;
- idea of signal amplification;
- idea of activating other kinases in the same signal transduction pathway;

(c) Metformin was found to induce a decrease in NADH oxidation in the mitochondria.

(i) Suggest how metformin can lead to a decrease in the ATP:AMP ratio in the mitochondria. [3]

1) by inhibiting oxidative phosphorylation / chemiosmosis;
2) Reduced electrons being donated to ETC;
3) Resulting in less electron transfer along the ETC;
4) thus lesser energy released;
5) to pump the protons across the inner mitochondrial membrane;
6) lower proton gradient established across the inner mitochondrial membrane; / decreased proton motive force;
7) less ATP generated by ATP synthase;

(ii) Suggest two ways in which ATP can still be produced in the mitochondria. [2]

- **Substrate level phosphorylation** in **Krebs cycle**;;
- Use of **reduced FAD** in **oxidative phosphorylation / oxidation of reduced FAD**;;

7 (a) With reference to Fig7A and 7B, discuss whether these fossils can be used to support Darwin's theory of evolution. [3]

- Explanation of Darwin's theory of evolution – idea of **descent from a common ancestor with modification** to adapt to different environmental conditions/ selective pressures;; (the premise of their discussion)

Can be used:

- Same basic structure of skulls and wing and leg bones indicate shared ancestry;
- Leg bones of giant Hawaii goose is much longer and stouter (idea of) than nene;; (modified to suit a land-bound type of locomotion/ loss of flight)
- Skull and the mandibles show significant differences in size;; (modified to adapt to differences in the types of food they eat/ to different types of food available)

Cannot be used:

- Lack of an 'ancestral' fossil for comparison, so difficult to determine if the 2 sets of bones are "modified" from a common plan;;
- Differences in structure of wing bones are not significant, so inconclusive about modification to adapt to different selective pressures for locomotion (i.e. flight vs flightless);;

(b) Using your knowledge of anatomical homology, explain **how** these differences came about. [5]

- There was existing variation in the population of ancestral birds from East Asia that landed on the two different islands;;
- were subjected to different selection pressures; in the two different islands
- Those that were best adapted to the selective pressure on a particular island were selected for, survived and reproduced;;
- Passing down advantageous genes / alleles to offspring;
- Change in allele frequency over time;
- accumulation of independent mutations;
- With ref to structure of skulls, leg bones:
  - difference in size: e.g. longer leg bones allow the birds to run away from predators faster/ chase after prey faster;;
  - smaller skull - decrease weight for flight/ larger jaw for feeding;;

(c) Explain why molecular data is able to overcome the limitations of this fossil study.[4]

- Definition of molecular data: e.g. DNA and/or proteins;;
- Different species of Hawaiian waterfowl exhibit different bone morphology, as shown by nene and giant Hawaiian goose (idea of closely related species showing distinct morphological features);;
- May be used to confirm that the major phenotypic differences between nene and giant Hawaiian goose may be due to small genetic differences;; (although this sounds like bullet 1, it is not - it illustrates the effect of master regulatory genes such as key TFs)
- Molecular data are unambiguous and objective, side steps the problem of analogous structures/ Overcome the problem of ambiguity between homologous and analogous structures;;
- Or idea of molecular methods are not dependent on subjective judgments / observations) Molecular data being easily converted to numerical form for analysis;;
- A! can use extensive regions of genome (coding and non-coding) OR idea of using many gene/ amino acid sequences for comparison;;
- AVP;;

4 max

(d) Based on the fossils, state one species concept that can be used to determine whether the Hawaiian goose and nene belong to the same species. [1]
Any one
- Genetic (based on DNA analysis of DNA/protein extracted from fossil samples);;
- Ecological (based on structure of mandibles, long legs – clues about the niches they occupy and the competition for similar/ dissimilar resources for e.g. if the mandibles are very similar, they are likely to feed on and thus compete for similar types of food);;

8 The immune response consists of innate and adaptive responses.

(a) What is the importance of the innate immune response? [3]
- Body's first line of defence against pathogens;;
- External mechanisms: physical barriers such as the skin and mucus prevents entry of pathogens;;
- Internal mechanisms: consist of cellular defences, plasma proteins, inflammatory responses that respond immediately to invasion from pathogens to contain (and get rid) the infection;;

(b) Explain the significance of these changes over time. [4]

- Somatic hypermutation;;
- **Point Mutations** produce B cells with membrane Ig having **altered antigen-binding sites;;**
- Producing B cells with <u>higher affinity (B cell) receptors</u> (which will survive, proliferate and mature into plasma cells);;
- In this way, antibodies are generated that have increasingly higher affinity during an immune response;;
- This provides progressively better protection against the pathogen;
- This mechanism is termed **affinity maturation**;;

(c) State how a B cell is able to produce IgM and IgD at the same time. [1]
- **Alternative splicing** of the pre-mRNA;;

9 (a) (i) Describe the pattern of resurgence of dengue shown in Fig.9.1. [2]

- cyclical;;
- QV

(ii) Suggest three possible ways in which climate change can result in the pattern described in part (i). [3]

- Higher temperatures in summer due to climate change leads to faster pathogen development and shorter life cycles for mosquito vectors;;
- Global warming of many regions previously not suitable as habitats for mosquitoes now results in more widespread breeding of the vectors;;
- Climate change resulting in higher precipitation in some areas lead to ponding and more breeding places and also longer breeding seasons for the vector since these pools will take long to dry up with frequent returns of rain;;
- Changes in agricultural practices like crop rotation or choice of crop, planting more rice to take advantage of the ready supply of water from more rain will help in providing more breeding grounds for mosquito vectors;;
- Crop rotation patterns together with higher frequency of extreme weather conditions may culminate to create the cyclical pattern observed in the epidemic outbreaks.
- Climate change resulting in higher wind patterns can also bring vectors to higher regions previously inaccessible to them;;

(b) Suggest why the vector control programme might not have worked as initially intended. [2]

- Climate change resulting in changes in mosquito's phenology, shorter life cycles and more adaptable to wider range of habitats, making vector control methods less effective;;
- A new mutated serotype/strain of Dengue virus emerged which might reproduce faster in the mosquito's salivary glands, extending their period of infection, reducing the impact of vector control;;
- Mosquito populations outside of the homes have become resistant to the pesticides used and are able to survive the thermal fogging treatments and still lay sufficient eggs to replenish their numbers;;
- A shift in dengue virus transmission from the household to other sites, such as schools and workplaces;;

[2 max]

(c) **(i)** Describe two advantages of this strategy. [2]

Advantages

- Biological control (idea of) measures using GM mosquitoes are more target specific than current use of pesticides, which kill off other species of insects like useful honey bees/ natural ecosystem not affected;;

- Even with mating cycles shortened, the self-limiting gene becomes established faster in the population, as the larva die off and adult vector numbers will be drastically reduced and the disease spread impeded;;
- without the use of pesticides, there will be no negative impact on environment, humans etc;;
- Minimal manpower needed to implement and sustain the suppression. Male mosquitoes will live a while to mate with many wild females, unlike the fogging attempts that has to be repeated every few days as mosquitoes evade the fumigated areas and return afterwards.

(ii) Discuss the possible impact of these advantages on the natural ecosystem. [2]

- With the demise of the *Aedes aegypti* species in the community, since the GM mosquitoes are **target specific**, other mosquito species will flourish at their expense and the eventual **extinction** of *Aedes aegypti* might actually be observed in the area tested with GM male releases;;
- Diseases carried by other mosquito species could become the next vector borne disease outbreak if another species succeeds in fulfilling the niche once filled by *Aedes aegypti*
- Without mosquitoes, thousands of plant species would lose a group of pollinators. Adults depend on nectar for energy (only females of some species need a meal of blood to get the proteins necessary to lay eggs).
- Some fishes depend on mosquito larvae for food and so their main food source could be removed without adult laying more eggs in the water
- Many species of insect, spider, salamander, lizard and frog would also lose a primary food source.