2022 H2 Paper 3

Section A

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

1(a) Describe the role of insulin in a healthy person. [4]

1. Insulin is a protein hormone secreted by the beta cells of the Islets of Langherhans in the pancreas when glucose levels in blood rises above the norm;
2. It travels through the blood stream to the liver and muscle cell and binds to receptors on the cell surface membrane;
   Cellular responses include:
3. Translocation of glucose transporters from the membrane of cytoplasmic vesicles to the cell surface membrane. This increases glucose intake into cells as it increases permeability of the cell to glucose;
4. Activation of glycogen synthase which catalyses glycogen synthesis from glucose;
5. Increased rate of glycolysis and increased lipid & protein synthesis;
6. Hence bringing blood glucose levels back to norm;

(b) Identify a human disease, **not** including any type of diabetes, that:

(i) is caused mainly by genes [1]

Sickle cell anemia; Haemophilia;

R: colourblindness as it is not considered a disease

(ii) is caused mainly by environmental factors. [1]

Malaria; Dengue; Influenza; Acquired Immunodeficiency Syndrome;

(c) **(i)** Explain how monozygotic twins develop from a single zygote to become individuals that have DNA that is 100% the same. [4]

1. ***Undifferentiated**** zygotic stem cells formed from fertilization of gametes
2. Are capable of undergoing extensive ***proliferation**** via mitosis and ***self-renewal****
3. During interphase, ***Semi-conservative DNA replication**** occurs to produce daughter DNA molecules that are genetically identical.
4. *During **anaphase*** of mitosis, genetically identical sister chromatids are separate equally into opposite poles forming genetically identical daughter cells.*
5. Zygote and cells up to the 8-cell embryo remains ***totipotent* and can differentiate**** into all cell types that make up an organism including ***extra-embryonic tissue**** such as ***placenta****, and hence are able to form entire organism;
6. This is a result of differential switching on of genes which occurs when appropriate molecular signals are received;

(ii) Outline what Table 1.1 shows about the relative influence of genotype and environment on the two types of diabetes. [2]

1. The % of monozygotic twins where both develop a particular form of diabetes is relatively low.
2. this shows that environmentat factors have a significant influence in the development of diabetes, since monozygotic twins are genetically identical,
3. Comparing monozygotic and dizygotic twins, % of sets of twins with both individuals having diabetes are significantly lower in dizygotic twins.
4. This show that genotype have an influcence on developing diabetes.
5. Comparing 2 types of diabetes, higher % of sets of twins with both individuals having diabetes are significantly higher for type 2 diabetes compared to type 1 both mono and dizygotic twins.
6. This implied that genotype might have a greater influence on type 2 than type 1 diabetes.

(d) **(i)** Explain what is meant by a substitution mutation.

Support your explanation by showing an example of a substitution mutation. [2]

1. **Substitution** mutation where a nucleotide/base is replaced by a different nucleotide;
2. An example is when ***thymine**** is replaced by ***adenine**** in the DNA template strand of the ***β globin****gene resulting in ***sickle cell anaemia****;

(ii) The haploid human genome consists of three billion (3×10^9) base pairs. According to one estimate, one SNP occurs every 300 base pairs.

Calculate the expected number of SNPs in a human gamete. [1]

$$\frac{3 \times 10^9}{300} = 10\,000\,000$$

(iii) With reference to Fig. 1.1, evaluate whether the SNPs associated with type 1 diabetes are the same as the SNPs associated with type 2 diabetes. [3]

1. The SNPs associated with type 1 and type 2 diabetes were mostly different as most of them/all but 2 occurred on different chromosomes / at different parts of the chromosome if they were on the same chromosome;
2. With the exception of the SNPs located on chromosome 6 and 16;
3. The SNPs on chromosome 6 were in the same approximate location and were associated with both type 1 and type 2 diabetes, however there were fewer SNPs and also lower degree of association with type 2 diabetes (2 crosses and degree of association between 5 and 10) than type 1 diabetes (more crosses and degree of association ranging from 5 to15)
   A: quoting chromosome 16

(e) Suggest, with reasons, whether Fig. 1.2 indicates a genetic or an environmental cause for the increase in the percentage of people in the USA with diabetes from 1958 to 2015. [2]

Genetic cause

1. The data in Fig. 1.2 shows a steady increase in the percentage of people with diabetes from 0.9% in 1958 to 7.5% in 2015;
2. suggesting that the frequency of alleles associated with diabetes increased;
3. due to improving healthcare over the years allowing with individuals with the SNPs/alleles associated with diabetes surviving and passing them on to their offspring;
   OR

Environmental cause

4. The data showed a gradual increase from 0.9% in 1958 to 3.4% in 1995 and a steep increase from 1995 to 7.5% in 2015;
5. Suggesting that the changes in lifestyle related to the increase in technology and fast food culture might have contributed to the steep rise in percentage of people with diabetes after 1995.

(f) **(i)** Compare the effects of sodium nitrite on the three species of gut bacteria shown in Fig. 1.3. [4]

1. For all three species of bacteria, lower concentration of sodium nitrate has a lower percentage inhibition but as concentration increases, there is a steep increase in the percentage inhibition;
2. 100% inhibition was achieved for *B. coprocola* and *B. longum* at 0.8 mg cm^{-3} and 3 mg cm^{-3} respectively while the highest percentage inhibition of *E. faecalis* was only 95% at 100 mg cm^{-3};
3. 100% inhibition was achieved at lower sodium nitrate concentration for *B. coprocola* at 0.8 mg cm^{-3} than *B. longum* at 3 mg cm^{-3};
4. Very low concentration of sodium nitrate at 0.001 mg cm^{-3} could cause some inhibition of *B. coprocola*, but at least 0.02 mg cm^{-3} cause was required to cause any inhibition of *B. longum* and *E. faecalis*;

(ii) The three species of bacteria in Fig. 1.3 were identified using a molecular method. DNA sequences were obtained and compared to DNA sequences in an online database.

Explain why it is difficult to identify bacterial species without using a molecular method. [2]

1. Bacteria tend to have few morphological features that they can be identified by,
   while molecular methods compares differences in DNA sequence which is more quantitative;
2. The proportion of these 3 bacteria could be very small relative to other bacteria in the gut, but molecular methods like PCR are able to amplify the target sequence of these 3 bacteria so even a small presence can be detected;
3. AVP

(iii) With reference to the three species of bacteria in Fig. 1.3 and Table 1.2, predict **and** explain the possible effects of a gut concentration of 1 mg cm-[3] of sodium nitrite on human health. [4]

1. At 1 mg cm^{-3} of sodium nitrate, 100% of beneficial bacteria *B. coprocola* and *B. longum* growth will be inhibited;
2. only 6.25% of *E. faecalis* will be inhibited, with majority surviving in the gut;
3. individuals will experience an increase in harmful bacteria, *E. faecalis* and will therefore experience gut inflammation and a reduction in protective mucus lining the gut, leaving the individual most susceptible to other pathogens;
4. due to lack of *B. coprocola* to reduce inflammatory disease of the gut and *B. longum* to reduce inflammation and prevent autoimmune response the inflammation will be made worse;

[Total: 30]

2(a) Identify **one** molecule from Fig. 2.1 or Table 2.1 that:

(i) is a fatty acid [1]
arachidonic acid

(ii) breaks an ester bond [1]
phospholipase A2

(iii) has a structural role [1]
phospholipids

(iv) relieves pain. [1]
acetylsalicylic acid (aspirin)

(b) State **and** explain **two** ways in which phagocytes are adapted for their function. [4]

State:

1. Phagocytes contain surface receptors proteins which can recognise the foreign pathogen (or antibody bound to a pathogen);

Explain:

2. Phagocytes like neutrophils have ***Fc receptors**** which can recognise and bind to the Fc region of antibodies that are bound to pathogens (opsonisation);
3. The binding will trigger the cell surface membrane of the neutrophil to extend out and around the pathogen and antibody, engulfing it and trapping it within a phagocytic vesicle;

State:

4. Phagocytes contain major histocompatibility complexes (MHC) which is needed for antigen presentation;

Explain:

5. Some phagocytes like macrophages and dendritic cells are ***antigen-presenting cells*;***
6. They cut up the pathogens and display the short peptides/antigens/epitopes on their surface via binding with the MHC;
7. This allows them to interact with the naïve T cells and activate them;

State:

8. Phagocytes produce digestive (hydrolytic) enzymes which are contained in lysosomes;

Explain:

9. The hydrolytic enzymes are produced at the RER and secreted via the endomembrane pathway in the phagocyte to form lysosomes;
10. When the phagocyte ingests a foreign pathogen into a phagosome, the lysosome will fuse with the phagosome to form the phagolysosome;
11. This will allow the hydrolytic enzymes to digest the foreign pathogen within the vesicle;
12. Idea of antigen presentation or idea of opsonisation accepted;

State:

13. Phagocytes produce and secrete cytokines which are needed to activate naïve T cells;

Explain:

14. The cytokines are produced at the RER and secreted via the endomembrane pathway in the some phagocytes like macrophages to form secretory vesicles;
15. When a complementary TCR of a naïve T cell binds to the peptide:MHC on the surface of the macrophage, it will transduce a signal within the phagocyte;
16. This will lead to a cellular response where the secretory vesicles containing the cytokines will move towards and fuse with the plasma membrane of the macrophage and be released via ***exocytosis****;
17. The cytokines will then diffuse towards the naïve T cells and activate them;

State:

18. Phagocytes have a fluid cell surface membrane which is able to extend to form pseudopodia;

Explain:

19. The composition of the cell surface membrane is made up of more unsaturated phospholipids and fewer cholesterol molecules increasing its fluidity;
20. This allows the membrane to extend outwards forming pseudopodia which is able to engulf and ingest the foreign pathogen;

(c) Plants make salicylic acid from the amino acid phenylalanine.

Complete Table 2.2 to:

- identify **two** different elements, **other than** carbon, that plants need to synthesise phenylalanine
- state how plants obtain these elements for the synthesis of phenylalanine. [2]

element	how the element is obtained
nitrogen	Plants take nitrogen from the soil by absorption through their roots as nitrate ions, nitrite ions, or ammonium ions obtained from fertilisers or from nitrogen-fixing bacteria in the soil;
hydrogen	Plants obtain hydrogen from water in the soil absorbed through their roots. The water undergoes photolysis in plant cells to release the hydrogen ions needed;
oxygen	Plants obtain oxygen from the air during gaseous exchange that enters the plant leaf cells via the stomata/ also oxygen can be obtained when water is broken down or carbon dioxide is broken down;

[Total: 10]

3(a) **(i)** State the number of butterfly species for which Table 3.1 shows that there **must** have been a decrease in their total range. [1]
2 (2nd and 5th columns from the left each had 1 species)

(ii) Calculate the percentage of butterfly species in Table 3.1 that have increased their ranges at one or both of their northern and southern limits.

Show your working and give your answer to 2 significant figures. [2]
(14+7+1+1)/35 = 65.7% = 66% (2 s.f.)

(b) Analyse the extent to which the data in Table 3.1 support the hypothesis that climate warming has caused a change in the distribution of non-migratory species of European butterflies. [4]

Support

1. Of a total of 35 species, a majority of 22 species experienced an overall range shift to the North which would support the hypothesis that climate warming caused the change in distribution of the butterflies;
2. This is because areas north of the northern limit might have been previously too cold for the butterflies but have become more suitable with the 0.5°C increase in temperature;

Does not support

3. However since correlation does not necessarily mean causation, this range shift could have been due to other factors that made the northern areas more habitable for the butterflies;
4. 2 species of butterflies experienced a range shifts to the South (columns 4 and 9 from the left) which would not support the hypothesis that is caused by climate warming since south of Europe is closer to the equator and would be even warmer than their original southern limit;
5. 10 species experienced no overall range shift suggesting that the 0.5°C increase in temperature made no overall impact on their distribution;

(c) Suggest **and** explain how laying an egg at a height of 1 mm above the ground affects the rate of development of the egg compared to an egg laid at a height of 1 m above the ground. [3]

1. At 1 mm above ground, the eggs would experience temperatures ranging from 33°C to 55°C during the day time. (15 +18 and 25 +30 to get the range);
2. At temperatures below the tolerance limit of the eggs at 45°C, the increase in temperature would lead to faster development of the eggs due to increase rate of enzyme reactions;
3. As temperatures increase between 45°C and 55°C there would be an increase in the risk of eggs dying since the maximum temperature is beyond the tolerance limit of the eggs at 45°C;

[Total: 10]

Section B

4(a) Transcription produces precursor RNA molecules that are modified to give the three main types of RNA that are involved in protein synthesis.

Describe the modifications that are needed to give the final functional structures of these three main types of RNA. [14]

Messenger RNA (mRNA)

1. Exists as a single-stranded form, mRNA acts as a ***template**** for translation, i.e. guiding assembly of amino acids into a polypeptide chain.
2. In eukaryotes, pre-mRNA undergoes ***post-transcriptional modification**** to form the mature mRNA.

This includes :

3. ***Capping at 5'**** end of mRNA, addition of a 7-methylguanosine nucleotide to 5'end of pre-mRNA
4. ***Splicing**** of pre-mRNA involves cutting out introns and joining exons by a ***spliceosome****. to form a ***mature mRNA*;***
5. introns are excised and hence non-coding, so the mature mRNA comprises of exons which code for the sequence of amino acids in a protein;
6. Pre-mRNA being cleaved enzymatically at polyadenylation signal at 3'end, and
7. Adenosine monophosphates added by the enzyme poly-A polymerase to form a ***poly-A tail**** at the 3' end of the mRNA.
8. ***Alternative splicing**** Spliceosomes are involved in excision of introns and some exons, and joining of remaining exons giving rise to different combinations of exons;
9. One gene produces ***mature mRNA**** with different combinations of exons, hence giving different proteins/protein isoforms;

Transfer RNA (tRNA)

10. tRNAs bring in **specific amino acids** in a sequence corresponding to **sequence of codons** in mRNA to growing polypeptide.
11. Exists in a single-stranded form that folds back upon itself and held in shape by ***hydrogen bonds**** between ***complementary base pairs**** at certain regions to form a 3D L-shaped structure (in diagrams it is simplified into a 2D cloverleaf structure.)
12. A specific amino acid is covalently attached to ***3'CCA**** stem of a tRNA with a specific ***anticodon**** to form aminocyl-tRNA. This attachment is catalysed by ***aminoacyl-tRNA synthetase****.

Ribosomal RNA (rRNA)

13. Exists in a single-stranded that folds back upon itself and held in shape by ***hydrogen bonds**** between ***complementary base pairs**** at certain regions
14. to form a complex 3D structure comprising of single and double helices.
15. rRNA associates with a set of **ribosomal proteins** to form **2 separate subunit / large and small subunits**;
16. 2 subunits associate on the mRNA during translation to form the functional ribosome.

QWC: mention at least 2 modifications to the 3 RNAs

(b) In a eukaryotic cell, different RNA molecules last for different lengths of time, ranging from several minutes to days.

Discuss reasons why it is beneficial to the cell for different RNA molecules to last for different lengths of time. [11]

Roles of RNA in eukaryotic cells (max 4 marks)

mRNA

1. ***Messenger RNA (mRNA)**** serves as the messenger to carry the genetic information out of the nucleus to the cytoplasm where translation takes place at the ribosomes;
2. It acts as a ***template**** for ***translation**** whereby the sequence of ***codons**** on the mRNA will determine the sequence of amino acids in the corresponding polypeptide chain;

tRNA

3. ***Transfer RNA (tRNA)**** add specific amino acids to the growing polypeptide chain in a sequence corresponding to the sequence of codons in the mRNA;

rRNA

4. ***Ribosomal RNA (rRNA)**** will ***complementary base-pair with mRNA**** to facilitate the binding of the small ribosomal subunit during translation initiation step;
5. rRNA can also ***complementary base-pair with the aminoacyl tRNAs**** at the A-site and P-site of the large ribosomal subunit to coordinate the translation process;

Other RNAs

6. Small nuclear RNA (snRNA) are part of the spliceosomes and are involved in RNA ***splicing**** process where the introns are removed and the exons are joined together;
7. MicroRNA (miRNA) and small Interfering RNA (siRNA) can bind to target mRNAs during ***post-transcriptional gene regulation**** which can lead to degradation or prevent translation of the target mRNA;
8. AVP;

Benefits of varying lifespan of different RNAs

(A) Regulating gene expression and cell differentiation

9. By varying the stability of mRNA molecules, the cell can regulate the expression of specific genes;
10. This will ensure that the proteins they encode are produced at the right times and in the right amounts;
11. Regulating the mRNA turnover numbers controls the protein levels in the cells and prevents protein accumulation, maintaining cell homeostasis;
12. Regulating gene expression will allow for cell specific structures to be produced allowing for cell differentiation to take place;
13. Stable mRNAs can persist in the cells ensuring that the proteins produced from these mRNAs have long term functions in the cells and tissues;
14. while unstable mRNAs are rapidly degraded in the cells ensuring that their protein products are only present for a short period of time;

(B) Growth and development

15. During growth and development, different genes are expressed at different stages;
16. Some genes will produce stable mRNAs that will code for proteins like growth hormones that are required throughout development;
17. Other genes will produce mRNA that is required for a short period of time and is rapidly degraded afterwards, e.g. hormones expressed during puberty that lead to bone growth (growth spurts);

(C) Energy conservation

18. Maintaining stable RNAs that persist for long periods of time requires a lot of energy;
19. By having RNAs with different lifespans, the cells can allocate their resources more efficiently;
20. For example, tRNA and rRNA have an important role in ***protein synthesis**** and hence are synthesized as stable RNAs which require more energy;

(D) Changing environment

21. RNAs are produced in rapid response to a overcome a changing internal/external environment;
22. In plants, stress response genes produce mRNAs with a short lifespan which is quickly expressed and degraded, allowing the plant to adapt to changing environment like heat, cold or nutrient availability;
23. In animals, insulin and glucagon is produced in response to changing blood glucose concentration levels;

(E) Cell cycle

24. Cyclin mRNAs have a short lifespan as the cyclins are produced and degraded cyclically to ensure the cell completes its cell cycle within a fixed timing;
25. The production of proteins that control the cell cycle has to be tightly controlled to ensure that uncontrolled cell division and tumour formation does not arise;

(F) Quality Control

26. RNAs are more prone to degradation if they contain errors in their sequences;
27. This ensures high quality, accurate RNA transcripts are used for protein synthesis and other roles;
28. Specific nuclease enzymes are present in the cell which will breakdown abberant RNA molecules;

(G) Immune response

29. During an immune response, specific mRNAs are produced and degraded rapidly in response to infections;
30. For example, mRNAs coding for granzymes and perforins will be produced in large amounts in the cytotoxic T cells;
31. And mRNAs coding for antibodies will be produced in high numbers in the plasma cells;

QWC: at least 3 different reasons given (including one for short-lived mRNA and one for long-lived mRNA)

[Total: 25]

5(a) The fossil record shows that over geological time evolution has occurred at different rates.

Describe, with examples, factors that may have influenced the rate of evolution over geological time, before the appearance of humans. (do not attempt this question in an exam if you can do Q4) [14]

The rate of evolution over geological time has indeed varied, and several factors can influence the pace of evolutionary change. Before the appearance of humans, there were several key factors that influenced the rate of evolution. Here are some examples:

1. Environmental Changes:
    a) Climate Shifts: Changes in climate, such as ice ages or periods of warming, have had a significant impact on the rate of evolution;
    b) Organisms that can adapt to these new conditions may evolve rapidly to survive, while those that cannot may face extinction eg woolly mammoth;
    c) Geological Events: Geological events like volcanic eruptions, earthquakes, and the formation of new landmasses/islands can alter habitats, leading to selective pressures and driving the evolution of species adapted to these changing environments;
    d) eg. Lord Howe Island was a volcanic island formed off the coast of Australia. The difference in soil condition – volcanic and calcareous soil led to the sympatric speciation of the *Howea* palms ;
2. Predation and Competition:
    a) Interspecies Competition: Intense competition for resources, such as food, territory, or mates, can drive rapid evolution as species develop new adaptations to outcompete others.
    b) For example, the evolution of long necks in giraffes allowed them to access food sources that were out of reach for other herbivores;
    c) Coevolution with Predators: The presence of new predators can drive prey species to evolve defensive mechanisms.
    d) An example is the evolution of defensive structures in prey animals, like the spines on a porcupine;
3. Mass Extinction Events:
    a) Mass extinctions, such as the Permian-Triassic or Cretaceous-Paleogene events, have had profound effects on the rate of evolution. These events wiped out a significant portion of life on Earth, creating opportunities for survivors to rapidly diversify and fill vacant ecological niches;
    b) Mammals, for example, diversified rapidly through adaptive radiation after the extinction of non-avian dinosaurs;
4. Geographic Isolation:
    a) Geographic barriers like mountain ranges or oceans can separate populations of a species, leading to allopatric speciation. Geographically isolated populations may experience different selective pressures, which can result in the evolution of new species.
    b) The classic example is the finches in the Galápagos Islands which exhibited adaptive radiation;
    c) Geographical isolation can be due to continental drift eg primitive marsupials can be found mostly in Australia which was isolated early from the rest of the continents;

5. Genetic Mutations:
    a) The rate of genetic mutations can influence the rate of evolution. Increased mutation rates, due to factors like radiation or chemical exposure, can accelerate the appearance of new traits in populations.
    b) Some mutations may be beneficial eg antibiotic resistance of bacteria to fungal penicillin, while others can be detrimental;
6. Reproductive Strategies:
    a) Different reproductive strategies can influence the rate of evolution. Species with shorter generation times and higher reproductive rates, like insects eg mosquitoes, may evolve more rapidly than species with longer generation times, like elephants;
7. Adaptive Radiation:
    a) When a single ancestral species gives rise to multiple descendant species in a relatively short time, it's known as adaptive radiation.
    b) This can occur when new ecological niches become available, as seen with the diversification of cichlid fish in African lakes;
8. AVP - Symbiosis:
    a) Symbiotic relationships, such as mutualism or parasitism, can drive coevolution between species;
    b) For example, the evolution of flowering plants and their pollinators, like bees, is tightly linked due to mutualistic interactions;

These factors, along with many others, have interacted throughout Earth's history, resulting in the diverse array of life we see today. The rate of evolution has not been constant but has been influenced by a complex interplay of these and other factors over geological time.

Note: Examples given should be those before the appearance of humans.
QWC: At least 3 factors and 2 examples given

(b) Discuss, with examples, how a wide range of different human activities, including science and technology, can affect the evolution of organisms. [11]

Directional selection of Peppered moth (*Biston betularia)*

1. Prior to the industrial revolution, the majority of peppered moths had light-colored wings, which provided camouflage against light-colored lichen covered bark of trees;
2. As industrialization darkened tree trunks due to soot and pollution, darker moths had a selective advantage and were selected for;
3. They survived and reproduced and hence the favourable allele coding for dark colour increased in frequency and the population shifted towards darker forms;
4. This is an example of natural selection in response to human-induced environmental changes;

Artificial selection of domesticated animals/plants

5. Humans have selectively bred domesticated animals and plants for specific traits for many years;
6. For instance, the transformation of wild mustard into *various Brassica crops* such as broccoli, cauliflower, and cabbage over thousands of years is a result of artificial selection;
7. Similarly, dog breeding has led to the development of hundreds of diverse dog breeds with specialized characteristics, from herding to hunting;

Antibiotic resistant bacteria

8. The overuse and misuse of antibiotics in healthcare and agriculture;
9. has led to the evolution of antibiotic-resistant bacteria (such as MRSA:Methicillin-resistant *Staphylococcus aureus*)
10. as bacteria with random genetic ***mutations**** that provide resistance to antibiotics will be selected for in the presence of antibiotics and will survive and reproduce and will increase in numbers;
11. while susceptible strains are eliminated.

Insecticide-resistant insects

12. Genetically-engineered crop plants such as Bt-corn express Bt-toxin, a bio-insecticide, that in harmful to insects (as they kill them by creating pores in their mid-gut membrane) but not humans;
13. The extensive planting of Bt-crops and the overuse of Bt-insecticides has led to Bt-resistant insect species being selected for, surviving and reproducing and increasing in numbers;
14. An example is the diamondback moth which is a crop pest with resistance to Bt-toxin;

Herbicide resistant crops

15. The creation of genetically-engineered herbicide-resistant crops, such as Roundup Ready soybeans;
16. Has led to the evolution of herbicide-resistant weeds;
17. When herbicides are sprayed to kill weeds that grow around Roundup ready soybean plants, weeds that are resistant to the herbicide will be selected for, survive and reproduce and increase in numbers leading to the formation herbicide-resistant weed populations.

Chemical mutagens and ionising radiation

18. Chemical mutagens and ionizing radiation can cause mutations in the DNA of plants and increase their genetic diversity;
19. For example, exposure to chemical mutagens like ethyl methane sulfonate (EMS) can induce mutations in plants such as rice (*Oryza sativa* L.), resulting in novel traits that can be selected for in breeding programs;
20. Ionizing radiation, like X-rays, has been used in the development of new crop varieties, of rice, wheat, barley, cotton etc;

Marker can accept other examples for each category and allocate marks accordingly.

QWC: Examples given from at least 3 different categories.

[Total: 25]

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