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INTERNATIONAL SECONDARY CERTIFICATE EXAMINATION
MAY 2025

BIOLOGY: PAPER II

SOURCE MATERIAL BOOKLET FOR QUESTIONS 1, 2 AND 3
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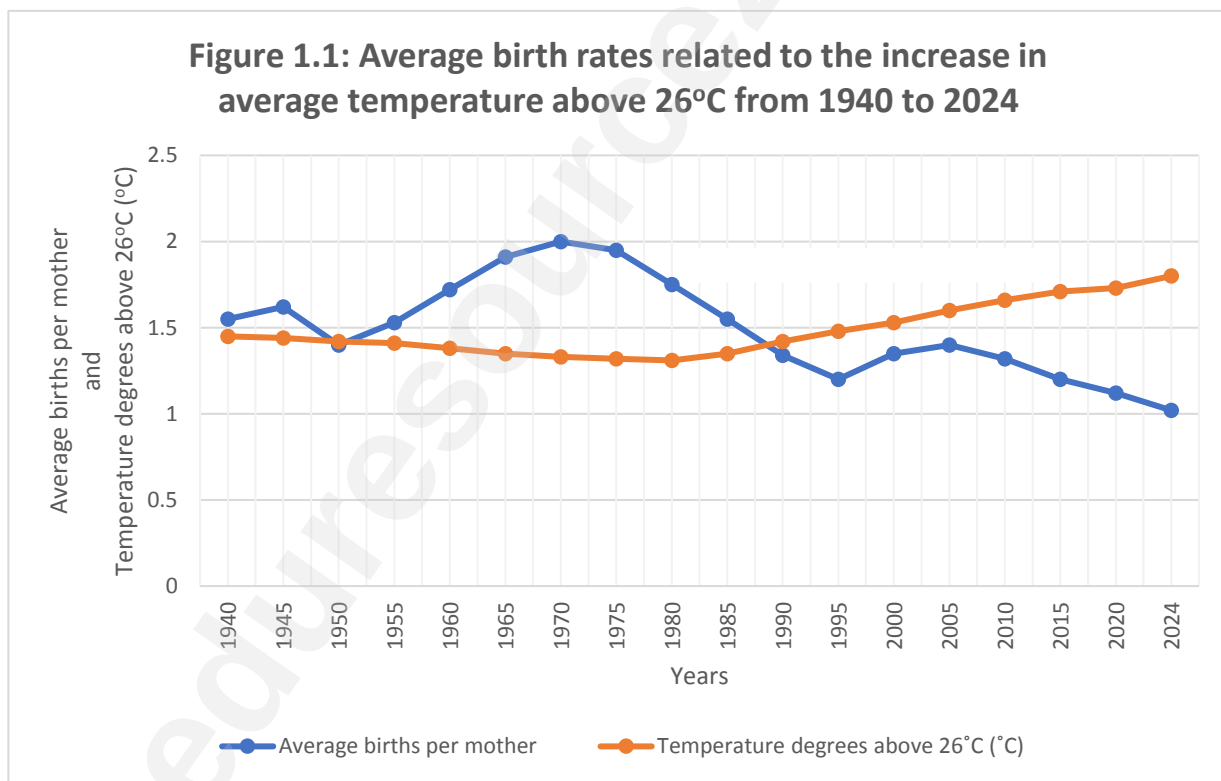
SECTION A**QUESTION 1**

Read the information below on the reproductive systems and fertility of men and women. Use this information as well as your own knowledge to answer Question 1 in the question paper.

Link between temperature and male fertility

Global warming can affect fertility in two ways. Temperature changes can negatively influence reproductive health by affecting sperm motility and menstrual cycles.

In a collaborative study done on the link between climate change and birth rates between 1940 and 2024 in various countries worldwide, the data shows that during warmer summers, birth rates tend to be lower in spring, and the reverse in colder weather. Overall, the rising average temperatures during the last 74 years showed a decline in average birth rates, as shown in Figure 1.1 below.



[Adapted from: <<https://www.weforum.org/agenda/2015/11/how-does-climate-change-affect-fertility/>>, <https://www.nber.org/system/files/working_papers/w21681/w21681.pdf?utm_campaign=PANTHEON_STRIPPED&utm_medium=PANTHEON_STRIPPED&utm_source=PANTHEON_STRIPPED>]

The effect of climate change on reproduction in mammals

Climate change can potentially affect the reproductive cycles of all mammals. The following are some of the main effects of climate change:

1. **Temperature changes:** Many mammals rely on seasonal cues to regulate reproduction. Changes in temperature can alter the timing of breeding seasons. This may disrupt menstruation cycles for species that depend on specific environmental conditions to reproduce.
2. **Food availability:** Climate change affects ecosystems, leading to shifts in the availability of food. A lack of proper nutrition can delay or suppress menstruation cycles in mammals as reproductive processes often depend on energy reserves.
3. **Habitat loss:** Changing climates may force mammals into new habitats where they experience stress due to competition or environmental unsuitability. Stress is known to affect hormone levels, which can disrupt menstruation cycles.
4. **Photoperiod changes:** Some species rely on day length (photoperiod) to trigger reproductive cycles. Climate-induced shifts in weather patterns may shift traditional reproductive cues from their normal seasons, confusing the reproductive timing.
5. **Hormonal and gamete changes:** As temperatures increase, external stress can influence hormone levels within mammals, and in turn this increases the chances of abnormal gamete development.

[Adapted from: <<https://www.frontiersin.org/research-topics/66110/the-impact-of-climate-change-on-reproduction-and-sex/>> & <<https://www.weforum.org/agenda/2015/11/how-does-climate-change-affect-fertility/>>]

Effect of climate change on sperm cell production

1. Rising temperatures also have an impact on the formation and development of sperm cells and egg cells. In men, increased temperatures around the testes can cause a condition called 'teratozoospermia' (a condition in which a man has a high percentage of abnormally shaped sperm). This means that a significant number of a man's sperm are the wrong size, shape, or structure to successfully fertilise an egg cell. This condition is often seen among men who wear tight pants, take frequent hot baths, or work frequently with their computers on their laps.
2. The increase in average environmental temperature can also increase the immediate surface temperature of the body, leading to an increase in the temperature in and around the testes.

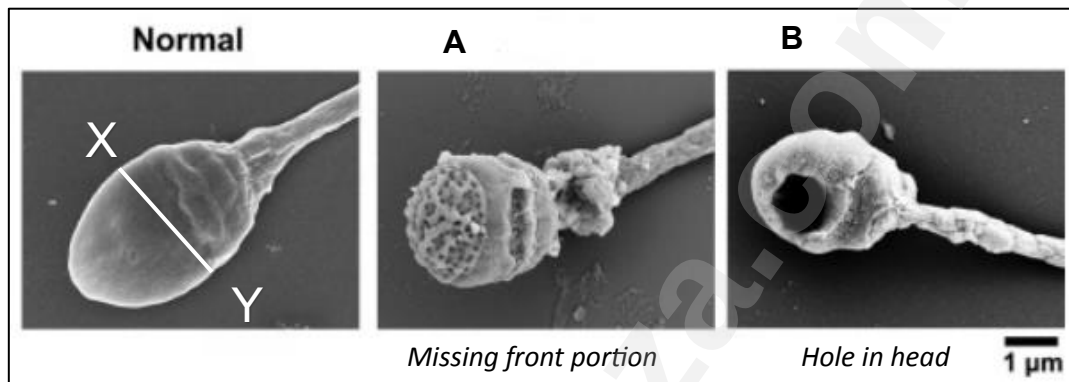
[Source: <<https://vidafertility.com/en/teratozoospermia-2/>>]

Below are three images of sperm cells: A normal sperm cell (*Normal*) and two mutated sperm cells (*A and B*), that could develop as a result of high temperatures around the testes.

Sperm cell A: Cell is missing the front portion of its head.

Sperm cell B: A very large hole in the head of the sperm cell.

Figure 1.2: Micrograph images of different sperm cells



[Source: <<https://www.sciencedirect.com/science/article/pii/S2095927322004455#s0140>>]

Temperature change effects on female reproduction

1. Heat stress can also disrupt development and functioning of the egg cell. Evidence has shown that high temperatures can affect the egg cell and the follicle surrounding it by affecting the development of the follicle. These follicular changes could impact the actual growth of a follicle or the secretion of the pituitary hormones that control development of a follicle.
2. Studies on many different mammals contribute to these theories. In lactating cows, heat stress reduced the secretion of a hormone (**Hormone A as seen in figure 1.3 on page vi**). This decreased the number of times ovulation occurred in the cows. The decrease of another hormone (**Hormone B as seen in figure 1.3 on page vi**) resulted in less follicles developing to maturity.
*lactating – the process of making milk

[Adapted from: <<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2781849/>>]

The menstrual cycle of humans and cows

Menstruation is an important reproductive process in mammals, as it prepares the female body for the possible implantation of a fertilised egg cell. Humans and cows have similar menstrual cycles, except that, instead of a 28-day cycle in humans, cows have a shorter cycle of 21 days. Figures 1.3 and 1.4 that follow show the differences between the human menstrual cycle and the cow menstrual (oestrus) cycle.

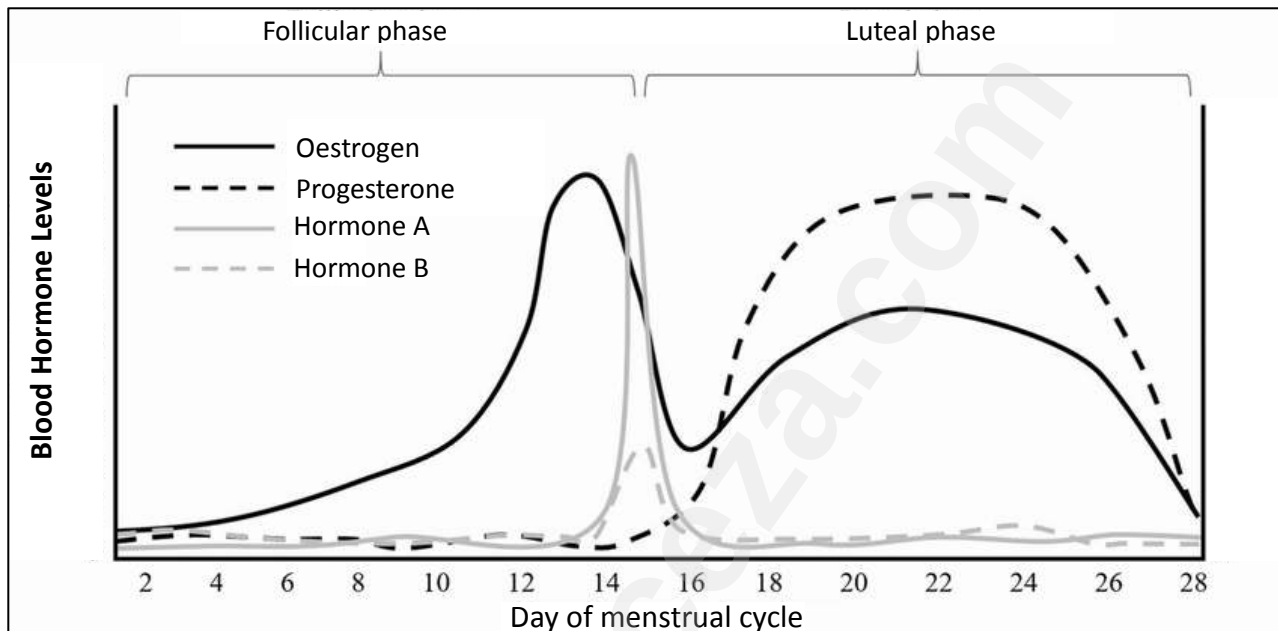
The cow's oestrous cycle (as shown in Figure 1.4 on page vi) is similar to the human female menstrual cycle, but it prepares the cow for pregnancy in a slightly different way. It lasts about 21 days and has four main phases:

1. **Phase 1** (Days 18–21): This is similar to the follicular phase in humans. Follicles in the ovary develop, and oestrogen levels rise, preparing for ovulation.
2. **Phase 2** (Day 0): This is the 'heat' phase when the cow is ready to mate. It is similar to ovulation in humans, and it lasts 8–30 hours. The egg is released during this time.
3. **Phase 3** (Days 1–4): This is similar to the early luteal phase. After ovulation, a structure called the corpus luteum forms and starts producing progesterone, which helps prepare the uterus for pregnancy.
4. **Phase 4** (Days 5–17): Similar to the luteal phase in humans. If the cow isn't pregnant, the corpus luteum breaks down, progesterone levels decrease, and the cycle starts over again.

[Adapted from: <<https://www.fda.gov/animal-veterinary/product-safety-information/cattle-estrous-cycle-and-fda-approved-animal-drugs-control-and-synchronize-estrus-resource-producers>>]

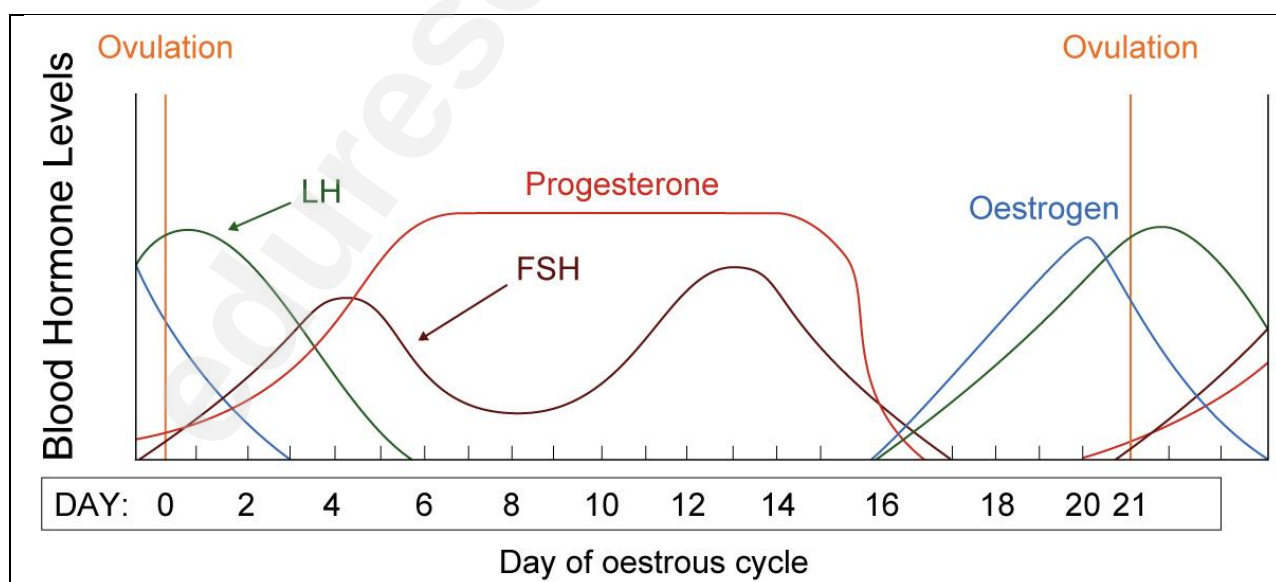
Figures 1.3 and 1.4 compare the human menstrual cycle with the cow oestrus (menstrual) cycle.

Figure 1.3: Graph showing reproductive hormone levels during the menstrual cycle of a human



[Source: <https://www.researchgate.net/figure/Graphical-representation-of-oestrogen-progesterone-luteinising-hormone-LH-and_fig1_35083056>]

Figure 1.4: Graph showing reproductive hormone levels during the oestrus (menstrual) cycle of a cow

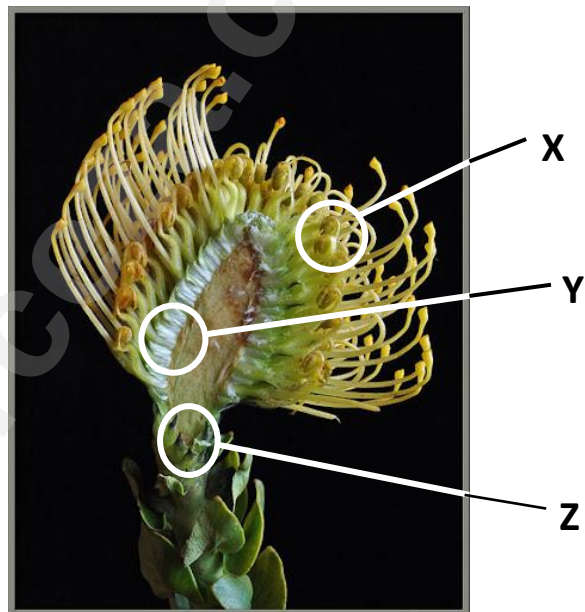


[Adapted from: <<https://www.chegg.com/homework-help/questions-and-answers/2-speckttacular-begger-ovulated-1-26-today-2-4--would-speckttacular-begger-estrous-cycle-gra-q108398259/>>>]

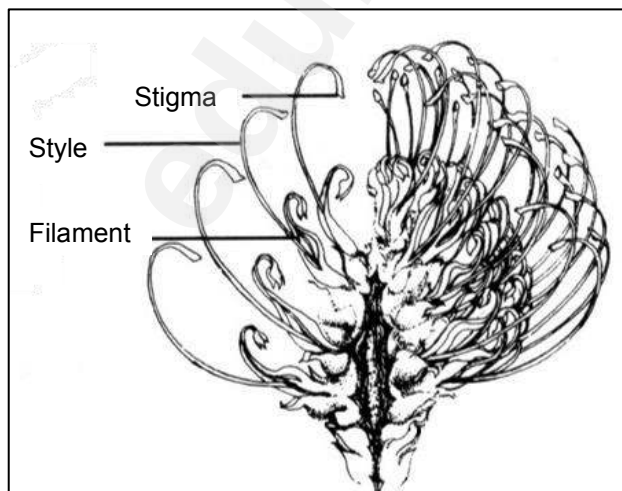
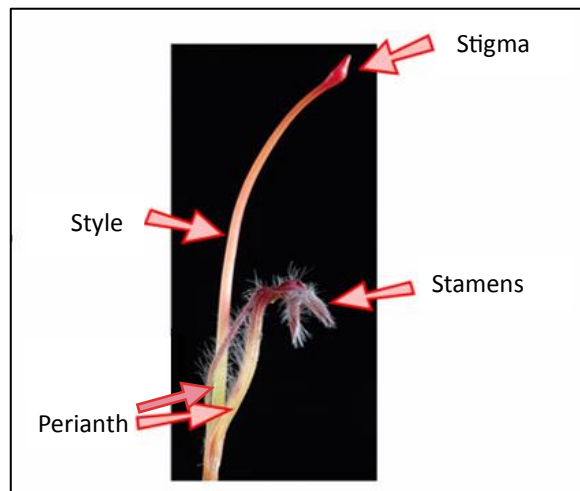
QUESTION 2

Read the information on the South African protea flower below. Use this information as well as your own knowledge to answer Question 2 in the question paper.

The composite flower of the Yellow Pincushion Protea consists of a number of smaller flowers called florets.

Flower structure of the Yellow Pincushion Protea (*Leucospermum cordifolium*)**Figure 2.1:** External structure of the pincushion protea flower**Figure 2.2:** Longitudinal section of the pincushion protea flower

[Source: <<http://www.microscopy-uk.org.uk/mag/artaug10/bj-protea2.html>>]

Figure 2.3: Detailed structure of pincushion protea flower**Figure 2.4:** Parts of one floret in the protea pincushion flower

[Adapted from: <<https://www.proteaatlas.org.za/flowerh.html>>]

***Perianth:** The outer parts of the flower, consisting of sepals and petals.

The Benefit of Fire in the Western Cape Province

Fynbos, a unique and diverse ecosystem found in the southwestern Cape of South Africa, is characterised by its distinctive flora, including the prominent Protea family. Proteas rely on fire for their survival as they need fire to complete their reproductive cycle.

There are many different species of proteas, but they all share a similar characteristic. They contain dormant flower buds within their thick woody stems. These buds can remain inactive for decades, but when a fire occurs, it stimulates them to germinate. The buds then mature and grow into flowers. Once fertilised, inedible nuts develop from the ovary of the flower around the seeds. These seeds also need fire to develop and germinate.

Protea species depend on brush fires occurring at least every 10–20 years to grow and develop well. Fires kill invasive species not able to survive the flames.

Unfortunately, invasive plants have started growing in the protea's environment. For example, the Australian acacia was introduced into South Africa to be cultivated for timber and now grows in the proteas' natural environment. Another example is grape cultivation for wine that resulted in many protea species and fynbos plants being cleared to make way for vineyards.

A way to preserve the declining fynbos populations is to conserve the area where the protea plants grow. This area was declared a registered UNESCO site in 2004 which means that this area is legally protected for its scientific significance. Other ways of preserving fynbos plants are either to keep the seeds in a seed bank or make the seeds readily available to the public. By people planting more seeds, protea plants will spread to more areas and reduce their endangered status.

[Adapted from: <<https://www.bbc.com/travel/article/20190304-south-africas-flammable-floral-kingdom>>]

Ways in which to cultivate proteas

Proteas can be propagated using different methods, with the choice depending on the purpose of propagation and what particular characteristics the plant may have.

There are three main ways of propagating plants: From seeds, cuttings, or by grafting.

1. Growing proteas from seeds

Seed propagation is the method most widely used. Seeds develop by sexual reproduction in plants and can lead to new cultivars and varieties of proteas. It is also a cheaper method as many protea seeds are readily available. Propagation from seeds also promotes genetic variation.

Even though protea seeds may come from a visually attractive, and fast-growing protea plant, these traits are not guaranteed to be present in the offspring, as cross-pollination may have occurred, and unfavourable alleles may be expressed. Seed propagation also takes longer than cuttings and grafting, as pollination must first occur to produce seeds. These seeds also have to germinate and grow to reach maturity. Pollination, fertilisation and germination are processes that require large amounts of energy expenditure.

2. Growing proteas from cuttings

Some protea species do not produce a lot of seeds and cuttings may be a better choice for propagating new plants. Cuttings are a form of cloning, and the offspring will be identical to the parent plant. Using cuttings can also be an easier and cheaper option than growing seeds. If cuttings are taken from a mature plant, the new plant will start flowering more quickly.

Initially, using cuttings for propagation of new plants may require expensive equipment and infrastructure. Cuttings might also lead to the reproduction of unfavourable genetic characteristics present in parent plants, e.g. susceptibility to diseases.

3. Growing proteas by grafting

If a protea is a weak plant and has difficulty growing, part of it can be grafted onto another stronger protea plant. A grafted plant can grow faster than a plant grown either from seeds or cuttings. The grafted protea will still grow even if it is grafted onto another plant with different growing conditions outside of the protea's normal conditions.

There are, however, some problems in propagating protea plants through grafting methods. If a healthy protea is grafted onto a weaker plant, it may affect the health of the stronger plant. If the plant onto which the protea is grafted cannot successfully provide the protea with the correct amount of nutrients, it will wither and die.

[Adapted from: <<https://plantinfo.co.za/articles/propagation-by-seed-versus-propagation-by-cuttings/>>, <<https://growproteas.com/reasons-for-grafting/>>]

Pollinators of the protea flower

Cape Sugarbird (*Promerops cafer*)

The Cape sugarbird is found throughout most of the Fynbos biome of South Africa. The staple food of the sugarbird is nectar; however, it will also eat spiders and insects. The characteristic strong winds of the Western Cape may make feeding off protea heads difficult, but the Cape sugarbird has adapted to this with the development of sharp claws.



Breeding of the Cape sugarbird takes place from April to July. The female builds a nest during five to ten days without the male, and the nest is placed in the protea bushes. Sugarbirds usually breed only in one male-female pair. The female then lays one to two eggs, and she incubates the eggs alone for seventeen days. The hatched chicks are protected by the mother, but both adults feed them on a diet of nectar and insects. The chicks leave the nest eighteen days after hatching but still depend on the adults for food for another eighteen to twenty-one days. After this period the parents chase them from the territory.

[Sources: <<https://www.inaturalist.org/taxa/13442-Promerops-cafer/>>, <<https://www.oiseaux-birds.com/card-cape-sugarbird.html/>>]

Protea Beetle (*Trichostetha fascicularis*)

The protea beetle is a very small beetle with metallic-green wing cases with a black head and thorax which has two vertical stripes. They are found everywhere where proteas grow as the adult beetles feed on the pollen and nectar of the protea flowers.



When reproducing, the female beetle will lay clusters of eggs of anywhere between 60 to 100 eggs, in soil or plant debris. These eggs will hatch into larvae, from where the larvae will look for food, grow, cocoon and develop into mature Protea Beetles. Many of these larvae will not survive, as they are a food source for many animals in their surroundings, including birds and rodents.

[Sources: <<https://www.inaturalist.org/taxa/423694-Trichostetha-fascicularis/>>]

SECTION B**QUESTION 3**

Read the information below. Use this information as well as your own knowledge to answer Question 3 in the question paper.

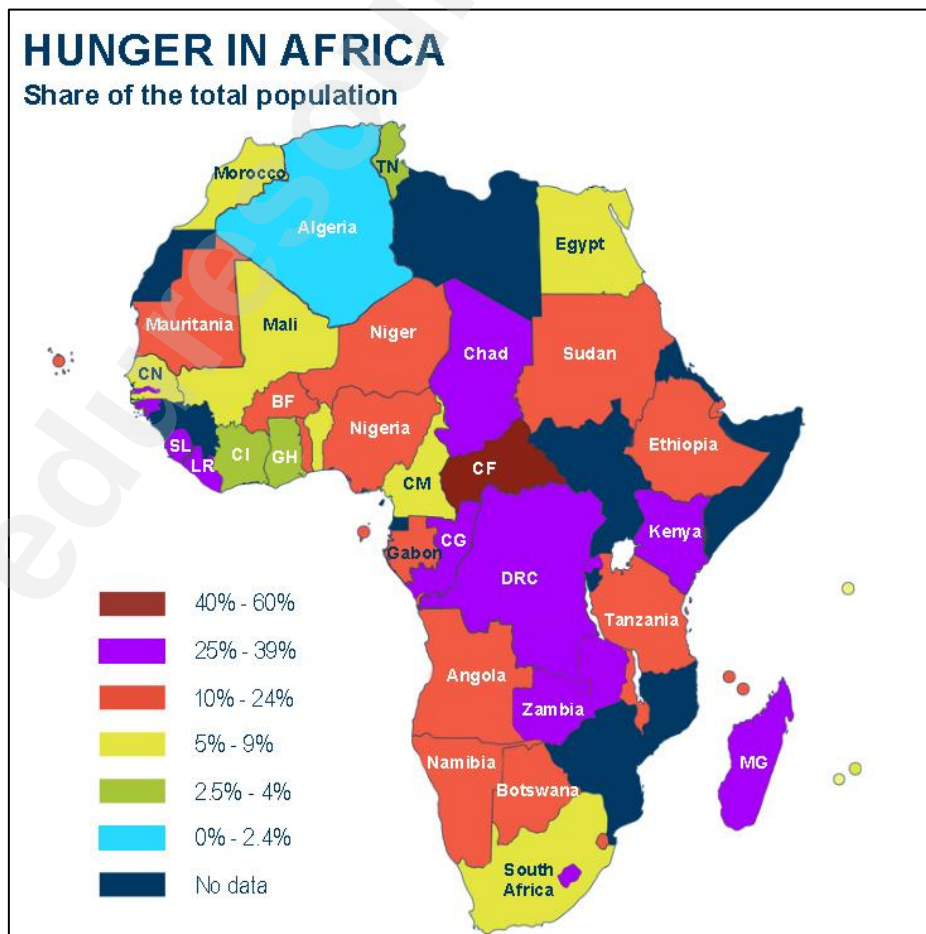
SOURCE A – Africa's hunger and food crisis

A severe food crisis is intensifying across Africa, driving millions of people into a heightened risk of hunger and starvation. Fuelled by a combination of factors, including the war in Ukraine, regional conflicts, extreme weather events, and the ongoing effects of the COVID-19 pandemic, hunger threatens the lives and wellbeing of vulnerable communities and people.

Fast facts:

- More than 1 billion people in Africa struggle to afford a healthy diet.
- 30% of children suffer from stunted growth due to malnutrition.
- An estimated 20% of the population is undernourished in Africa.
- Approximately 868 million people experience moderate to severe food insecurity in Africa.

[Source: World Vision, a global humanitarian organization (2024). <<https://www.worldvision.org/hunger-news-stories/africa-hunger-famine-facts/>>]

Diagram showing hunger in Africa

[Source: Ukrainska Pravda – a Ukrainian news website (2023). <<https://www.pravda.com.ua/en/articles/2023/08/1/7414161/>>]

In 2020, in Eastern Africa, where food scarcity is already a problem, a locust pest consumed approximately the same amount of food as 35 000 people could eat in a day. So it is important to genetically modify crops that could efficiently reduce crop loss due to pests.

I agree, but only eleven out of the fifty-four African nations have approved the cultivation of GM crops so far.



[Source: ScienceDirect, a website publishing peer-reviewed articles. (2022) <<https://www.sciencedirect.com/science/article/abs/pii/S0956713522003863>> & National Library of Medicine, also publishing scientific articles. (2024) <<https://pmc.ncbi.nlm.nih.gov/articles/PMC11042066/>>]

SOURCE B – Genetically Modified (GM) food crops as a solution to the hunger problem

A sustainable food system delivers food security and nutrition for all people in such a way that it:

- has a positive or neutral impact on the natural environment;
- is accessible to every member of society; and
- is profitable throughout.

These factors are seen as sustainable if they can be reached now and maintained in the future.

[Adapted from: Food and Agricultural Organization of the United Nations. (2018) <<https://openknowledge.fao.org>>]

Dietary benefits of GM crops

Crops can be genetically altered to supplement the diets of people with dietary deficiencies. In 2004 a strain of Golden Rice was developed that satisfies 50% of a person's daily Vitamin A needs per 250 ml consumed per day. The GM rice crop is also durable and can grow in relatively infertile regions of the world, especially sub-Saharan Africa.

[Source: University of Michigan article, written by a Masters in Public Health candidate. (2018) <<https://sph.umich.edu/pursuit/2018posts/gmos.html>>]

Top 10 GM Foods Grown in Zambia



Maize



Soy



Cotton



Papaya



Rice



**Rapeseed
(Canola)**



Potatoes



Tomatoes



**Dairy
products**



Peas

[Source: EcoJesuit, an organisation that connects Jesuit religious practitioners with people and ecology (2013). <<https://www.ecojesuit.com/gmos-and-zambia/>>]

Uses of GM crops

Maize:

Maize is the most commonly grown crop around the world, and most of it is genetically modified. Most GM maize is created to resist insect pests or tolerate herbicides. *Bacillus thuringiensis* (Bt) maize is a GM maize that produces proteins that are toxic to certain insect pests but not to humans, pets and livestock. GM Bt maize reduces the need for spraying harmful insecticides and prevents insect damage to crops.

Soybean:

Most GM soybeans are used as food for animals, predominantly for poultry and livestock, and are also used in the making of soybean oil. Soybeans are a very good source of protein, and it is a staple crop in Japan and China.

Canola:

GM canola is used mostly to make cooking oil and margarine. Most grown GM canola is engineered to be resistant to herbicides that farmers use to control weeds that compete with their crops in their fields.

[Adapted from: U.S. Food & Drug Administration (FDA), an organisation that regulates food and medicinal products in the USA (2024). <<https://www.fda.gov/food/agricultural-biotechnology/gmo-crops-animal-food-and-beyond/>>]

GM crops not as promising as they seem

"Green Revolution" Farming was a concept introduced in the 1960s and was a popular idea to bring seeds of a variety of crop plants into countries with unmet food needs. The technology of the Green Revolution involved bio-engineered seeds that worked in conjunction with chemical fertilisers and heavy irrigation to increase crop yields. Initially it was seen as a triumph for both science (as it overcame environmental obstacles) and ethics (as it addressed critical global issues of hunger and poverty), but later on it was branded as a source of economic, social, and environmental harm. The new seeds required huge amounts of groundwater, an excessive use of chemicals, and a sixfold rise in fertiliser use per hectare as they were not indigenous to these countries.

Another concern was that the companies that sell the GM seeds, also sell the herbicides for use on these GM crops. This raised a concern about corporate control, where the corporations selling the seeds force the farmers to buy their herbicides only, influencing the price of the seeds and herbicides to benefit the corporations. To poverty-stricken countries, as found on the continent of Africa, this can be destructive to the local communities, as they would not have the funds for these seeds and herbicides. These herbicides can also be applied excessively without proper knowledge. This can harm nearby indigenous plants by killing off non-resistant species, leading to further reduction in biodiversity and also affecting their reproduction cycles.

[Adapted from: Oxford Academic, an online library containing scientific journals (2023) <<https://academic.oup.com/book/51726/chapter/419833700/>> & Non-GMO Project, a project committed to building and preserving the non-GMO food supply (2021). <<https://www.nongmoproject.org/blog/how-do-gmos-affect-biodiversity/>>]

SOURCE C – Importance of indigenous plant species

There are many advantages to a local ecosystem in growing indigenous plants.

Plants are home to a large number of animals, birds, insects, and invertebrates that are essential to sustaining ecological balance in the environment. Exotic plants support approximately 20% fewer invertebrates than indigenous species. This is due to specialisation, where certain invertebrates can only eat plants that have co-evolved with them. Exotic plants disturb the biodiversity of local ecosystems.

Indigenous plants are also low maintenance, because they are naturally adapted to the soil conditions and climate of local environments. They also help to conserve water, as the majority of indigenous varieties are drought resistant which means that they will not need to be watered as often in the summer.

Examples of some indigenous crop plants which are important staple foods and the areas where they grow naturally:

1. Rice (China)
2. Wheat (Europe, North America, and parts of Asia)
3. Maize (Americas and parts of Africa)
4. Potatoes (Europe and parts of the Americas)
5. Sorghum (North Africa and South Asia)

Exotic plants, even genetically engineered plants, will still be more detrimental to their immediate environment than the equivalent indigenous plants.

[Source: The Oxfordshire Gardener, a website for avid gardeners (2020). <<https://theoxfordshiregardener.co.uk/the-importance-of-native-planting/>>]

Can indigenous crops solve the hunger crisis?

GMOs can be seen as the solution to Africa's food crisis. However, some argue that the solution has been there all along, in the form of indigenous plants.

A 2010 study highlighted that, in most cases, indigenous plants contained much higher concentrations of key nutrients, such as vitamins A and C, than non-indigenous varieties.

With predictions of global climate change causing weather patterns to become more unpredictable, indigenous plants that have spent thousands of years adapting to Africa's already intense climate could offer a much more reliable food source in the face of such dramatic changes.

While indigenous plants only make up a tiny fraction of total agricultural sales in Africa and may not be able to solve Africa's food crisis overnight, they may offer a cheaper solution in the future.

They will need to be introduced to the public as healthy nutritional alternatives to conventional crops so that they can gain popularity and become familiar foods to local communities.

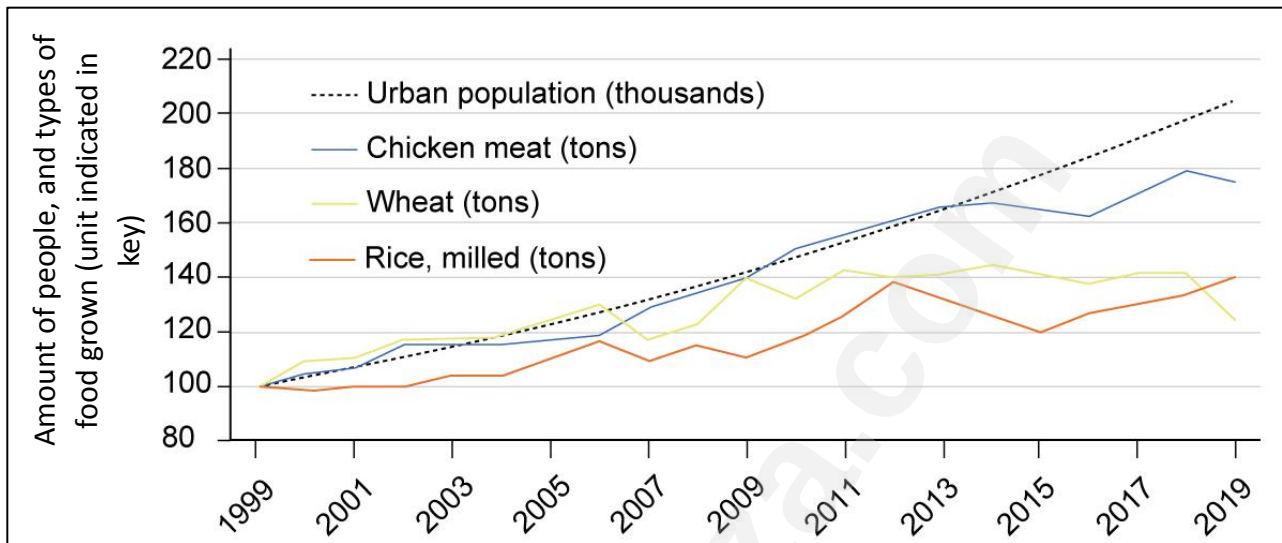
[Source: The Borgen Project, a private organisation fighting for issues in poor countries (2015).
<<https://borgenproject.org/native-crops-africas-food-crisis/>>]

SOURCE D – GMO crops designed for Africa**Commercialising Genetically Modified Crops for Africa**

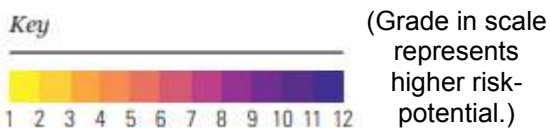
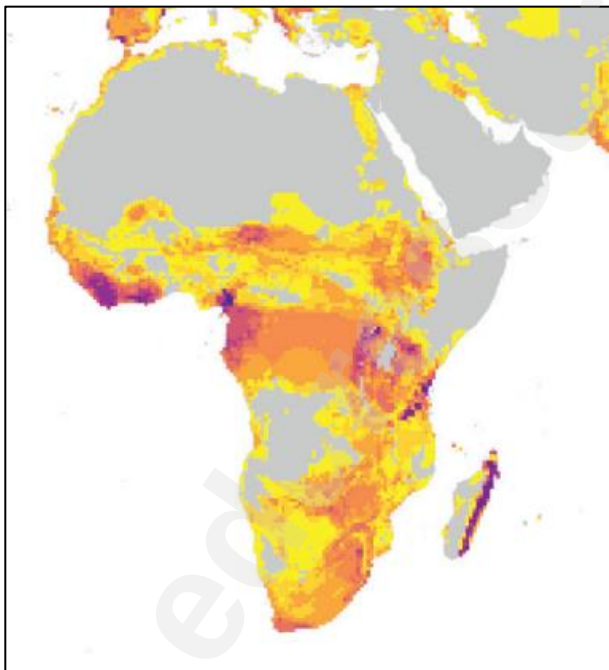
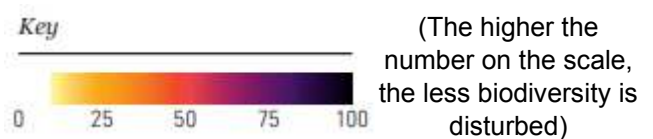
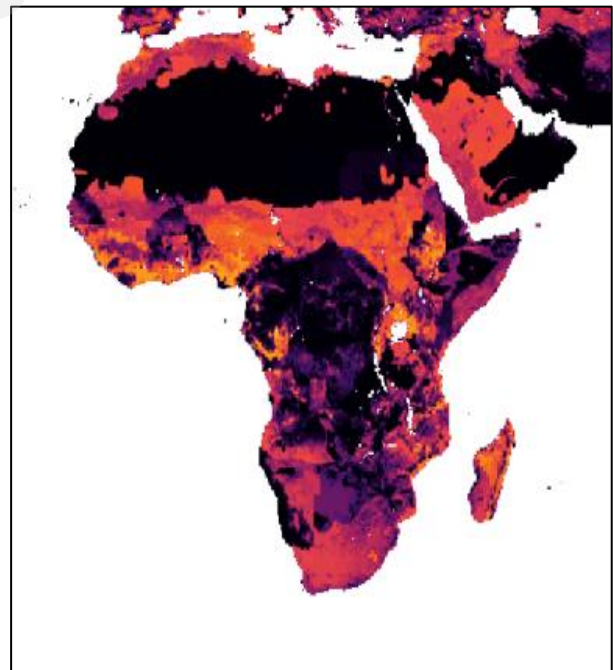
The African continent has been home to GM crops for the past 27 years, beginning in 1996 with insect-resistant GM maize grown in South Africa. Drought-resistant maize has also been engineered to be able to grow in areas with lower rainfall. Bt cotton (named after the pest it is modified to ward off: *Bacillus thuringiensis*), is another example of a crop engineered to be pest resistant, although this change adds no nutritional value to the cotton plant.

Since the introduction of GM crops into Africa, several other GM crops have been developed on the continent, including cowpea, soybean, rice, and canola. These crops have been modified to increase agricultural productivity by delivering desirable traits, like pest resistance, herbicide tolerance, and improved nutritional qualities, and are perfect for the African continent.

[Source: The Breakthrough Institute, an organisation fighting for good use of the plant's resources (2023).
<<https://thebreakthrough.org/issues/food-agriculture-environment/commercializing-genetically-modified-crops-in-africa>>]

SOURCE E – Comparing aspects of population growth and biodiversity in Africa**Graph A:** Comparing population growth with locally grown food supply.

[Source: Economic Research Service – US Department of Agriculture (2023).
<https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=105712>]

Map B: The number of species at risk**Map C:** Disturbance of biodiversity

Map D: Agricultural land.

Key: Darker areas show agricultural land.

[Sources: National Geographic, a nature-based organisation.
<<https://www.nationalgeographic.com/foodfeatures/land-grab/africa-animation/africa-scroll-index.html>> and
WWF – Living Planet Report, a report on wildlife conditions all over the planet (2022).
<https://wwflpr.awsassets.panda.org/downloads/lpr_2022_full_report_1.pdf>]

SOURCE F – GMOs and the reproduction of indigenous species

If we grow GM crops, will they cross breed with other plants?

GM crops may cross breed with closely related plants. This includes non-GM varieties of the same species. Regulators for the approval of GM crops have judged that GM crops do not pose a risk in terms of cross breeding with indigenous plant species.

But, if a GM crop cross breeds with a closely related plant, the wild relative may acquire characteristics that make it spread more rapidly, making it more invasive.

[Source: The Royal Society, an independent scientific academy of the UK (2016).
<<https://royalsociety.org/news-resources/projects/gm-plants/if-we-grow-gm-crops-will-they-cross-breed-with-other-plants/>>]

GM crops interfering with reproductive strategies of plants.

GM crops, which may become invasive species, may displace indigenous species through competition, alter the structure and composition of natural plant communities, and sometimes also hybridise with indigenous species.

Where indigenous plants may have adapted to certain conditions as part of their reproductive strategy, these invasive species may outcompete these plants, disrupting their reproductive strategies, leading to a decline in the number of indigenous species in the area.

[Source: Introduction to Conservation Biology textbook, regularly updated college textbook (last updated 2024).
<https://bio.libretexts.org/Courses/Fresno_City_College/Introduction_to_Conservation_Biology/11%3A_Pollution_Overharvesting_Invasive_Species_and_Disease/11.00%3A_Invasive_Species/>]

SOURCE G – Future of GMO crops

The continued success of GM crops in many African countries, including South Africa, shows that GM technology is valuable for dealing with food security and sustainability issues.

It is hard to predict where the next big plant disease that could harm important food crops will come from. For now, the arguments against using GM crops are mostly guesses without strong evidence. This suggests that GM crops are currently the best option for addressing Africa's food security crisis.

[Source: National Library of Medicine, a collection of scientific journals (2020).
<<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7553747/>>]