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ITEM ONE: CYTOLOGY

A biotechnology research centre in Uganda is investigating the causes of abnormal cell division in maize plants that show stunted growth and poor grain formation. Samples are taken from the root tips of both normal and affected plants and examined under a light microscope after appropriate staining.

The scientists observe that in the affected plants, some cells contain unusually large nuclei, irregular chromosome numbers, and poorly developed organelles. Further biochemical tests reveal that protein synthesis and energy production are significantly reduced in these cells.

To understand the problem, the researchers compare the cell structure, cell cycle behaviour, and organelle function of normal cells with those of the abnormal cells.

Task

(a) Distinguish between prokaryotic and eukaryotic cells, giving two structural differences relevant to this investigation.

(b) Describe the structure of the nucleus and explain how abnormalities in nuclear structure can affect cell function.

(c) Explain the role of mitochondria and ribosomes in normal cells and relate their malfunction to the observed reduction in energy production and protein synthesis.

(d) Describe the stages of mitosis observed in root tip cells and explain how errors during mitosis can result in cells with abnormal chromosome numbers.

(e) Explain how the cell cycle is regulated and suggest two possible reasons why regulation may fail in the affected maize cells.

(f) State two techniques that could be used to improve the clarity of chromosomes during microscopic examination and explain the importance of each.

ITEM TWO: GENETICS

A medical research team at a regional hospital in Uganda is studying the inheritance of a genetic disorder that affects blood clotting in certain families. The disorder is more common in males than females and often appears in individuals whose parents show no symptoms.

Blood samples are collected from several generations within affected families, and pedigree charts are constructed. Laboratory analysis reveals that the disorder is controlled by a single gene located on one of the sex chromosomes.

In a related study, plant breeders are also investigating the inheritance of seed colour and seed shape in beans to improve crop yield and resistance to disease.

Task

(a) Define the terms gene, allele, and genotype, giving one example relevant to the disorder described.
(b) Using genetic principles, explain why the blood disorder is more common in males than in females.
(c) With the aid of a genetic cross, show how two phenotypically normal parents can produce an affected male child.
(d) Distinguish between autosomal inheritance and sex-linked inheritance, giving one example of each.
(e) In beans, yellow seed colour (Y) is dominant over green (y), and round seed shape (R) is dominant over wrinkled (r).
Two heterozygous plants are crossed.
Determine the phenotypic ratio of the offspring.
(f) State two applications of genetics in medicine or agriculture and explain one ethical concern associated with genetic studies.