

SUGGESTED RESPONSES FOR P530/1 BIOLOGY PRE-MOCK, MARCH 2026.

ST. MARY'S COLLEGE RUSHOROZA

Item 1 (Construct 1)

Explain the observed effect of tobacco metabolite levels and mutation rate on protein synthesis and ATP concentration, and how this effect contributes to development of lung cancer. Propose realistic ways of reducing exposure to carcinogens and enhancing early cancer detection among the community.

The data shows higher mutation rate in tumour suppressor genes when tobacco metabolite levels are higher ✓. Tobacco smoke contains carcinogens ✓ like some aromatic hydrocarbons and nitrosamines that cause base substitutions, frameshifts, or deletion mutations ✓ during DNA replication. This results in synthesis of faulty/mutated proteins ✓ which lose normal function of activating genes for cell cycle arrest and DNA repair ✓. Cells with damaged DNA continue dividing ✓ instead of undergoing cell death (apoptosis) or senescence ✓. This leads to uncontrolled proliferation of abnormal cells ✓. At the same time, protein synthesis efficiency is severely reduced ✓ because mutations produce faulty mRNA (nonsense or missense mutations) ✓ and abnormal proteins ✓ including defective enzymes ✓ in glycolysis and oxidative phosphorylation ✓. Functioning of ribosomes is also impaired in rapidly dividing cancer cells ✓ due to low energy amounts ✓. ATP concentration reduces because cancer cells shift to aerobic glycolysis (Warburg effect) ✓ even in the presence of oxygen. Mitochondria are damaged by free radicals from tobacco ✓ further reducing rate of oxidative phosphorylation ✓. The resulting low ATP amounts forces cells to divide rapidly while lacking sufficient ATP for normal maintenance and repair ✓, accelerating tumour growth ✓.

Max 15 scores

To reduce exposure to carcinogens among the community;

- Launch community awareness campaigns✓ through radio talk shows, village health team meetings, and school programs✓ explaining tobacco and vehicle emission risks. Simple posters can be used showing structural appearance of lungs before and after smoking✓.
- Advocate for stricter enforcement of the Tobacco Control Act (no smoking in public places, markets, and near schools) ✓ and install roadside air quality monitors to highlight high risk areas✓.
- Partner with NGOs to provide free nicotine patches or counselling at health centres for smokers wanting to quit✓.

Max 5 scores for Any 3 realistic ways, well described/explained

To enhance early detection of cancer among the community;

- Train village health teams to screen high-risk groups✓ like people above the age of 40, smokers and ex-smokers, and those exposed to heavy traffic✓ using symptom checklists that include chronic cough, chest pain, and severe weight loss✓.
- Introduce low-cost annual chest X-rays or sputum cytology at district hospitals✓, funded by government/NGO partnerships/community insurance schemes✓.
- Establish referral systems from community clinics to Mulago or Uganda Cancer Institute✓ for suspected cases for instance, providing free transport vouchers for low-income patients✓.

Max 5 scores for Any 3 realistic ways, well described/explained

Item 2 (Construct 2)

Account for the difference in the yields between native and non-native crops grown in the district, and propose strategies to enhance productivity and resilience.

Native plants in Napak district exhibit Kranz anatomy, a characteristic of C4 plants✓.

Coupled with the thick leaf cuticle, numerous leaf hairs, and many stomata on the lower epidermis, these features are adaptive to the high temperature, low moisture, and shallow soils in the district✓. In Kranz anatomy the bundle sheath cells surround vascular bundles allowing C4 plants✓ to concentrate CO₂ in bundle sheath cells✓, minimising photorespiration✓ that becomes significant in non-native (C3) plants at high temperatures✓. This maintains high photosynthetic efficiency even when stomata partially close to conserve water✓. The thick cuticle and numerous hairs reduce cuticular transpiration✓ and create a boundary layer of humid air around the leaf✓, lowering water loss. Stomata on the lower surface are shaded from direct sun✓, further reducing evaporation of water. These adaptations enable native crops to maintain turgor, continue photosynthesis, and produce higher biomass/yields under drought stress✓.

Non-native crops lack Kranz anatomy a characteristic of C3 plants✓, have thin cuticle, very few hairs, and stomata on both surfaces. Opening of stomata to obtain carbon dioxide in hot dry conditions causes rapid water loss by high transpiration due thin cuticle, very few hairs and many stomata on upper leaf surfaces✓. High temperatures increase photorespiration as oxygen competes with CO₂ in the active sites of RUBISCO✓, reducing net photosynthesis and carbohydrate production✓.

Max 10 scores

Proposed strategies to enhance productivity and resilience

Crop selection✓ by promoting cultivation of native C4 varieties and avoid introducing non-native C3 crop varieties✓.

Apply organic mulches like crop residues and grass✓ to reduce soil evaporation and maintain moisture thus conserving soil water✓.

Use of contour bunds or tied ridges✓ to trap rainwater and reduce runoff on shallow soils✓.

Incorporate farmyard manure or compost annually✓ to increase organic matter, improve water-holding capacity, and supply nutrients✓.

Practise intercropping with legumes like ground nuts, beans and cowpea✓ to fix nitrogen and provide ground cover✓.

Plant native trees (like Acacia) as windbreaks and shade providers✓ to lower temperature and reduce evapotranspiration✓.

Sow at the start of the short rains✓ to maximise soil moisture✓;

Use minimum tillage✓ to preserve soil structure✓.

Non-native C3 varieties be grown in places of the district with high altitude where temperatures are lower and with reduced partial pressures of oxygen✓ to improve their photosynthetic efficiency✓.

Max 15 scores, 2 for each correct and well described response.

Item 3 (Construct 3)

Describe how carbon dioxide is transported in blood, and why this process is vital for the athlete's recovery, by explaining the effect of carbon dioxide concentration on the oxygen-carrying capacity of blood, and how this could have contributed to his collapse. Also explain the importance of the lymphatic system in maintaining his health during and after intense exercise.

Carbon dioxide produced in tissues during exercise is transported to the lungs in three forms: dissolved in plasma✓, bound to amino groups on haemoglobin to form carbaminohaemoglobin✓, and as bicarbonate ions✓. Transport as bicarbonate ions is the form by which the highest amount of carbon dioxide is transported✓, where CO₂ diffuses into RBCs✓ and reacts with water catalysed by carbonic anhydrase to form carbonic acid✓, which dissociates into H⁺ and HCO₃⁻✓. Bicarbonate ions diffuse out into plasma✓ and chloride ions move into the red blood cell✓ to maintain charge balance/electroneutrality✓ while H⁺ are buffered by haemoglobin✓. In the lungs, the process reverses: low CO₂ partial pressure causes HCO₃⁻ to re-enter RBCs✓, combine with H⁺ to form CO₂, which diffuses out into the alveolar space to be exhaled✓.

Max 10 scores

Effect of high CO₂ on oxygen-carrying capacity & collapse

Elevated blood CO₂ lowers pH (respiratory acidosis) ✓ and triggers the Bohr effect: the oxygen-haemoglobin dissociation curve shifts to the right✓ which decreases haemoglobin's affinity for O₂✓, facilitating oxygen unloading to tissues✓, beneficial during exercise. In severe cases, very high CO₂ causes excessive acidosis✓, which impairs enzyme function, reduces muscle contraction efficiency, and causes fatigue, dizziness, and respiratory distress✓. Combined with dehydration (reduced blood volume) and high exercise demand, this contributed to collapse resulting from inadequate oxygen

delivery to brain and muscles✓, leading to hypoxia, hyperventilation failure, and loss of consciousness.

Max 5 scores

Importance of lymphatic system

During intense exercise, capillary filtration increases✓ due to high blood pressure and metabolite accumulation✓, producing excess tissue fluid and lymph✓. The lymphatic system returns this fluid to the blood via thoracic duct✓, preventing oedema and maintaining blood volume✓. It also transports dietary fats (chylomicrons) from the gut✓ and carries lymphocytes/antibodies for immune defence✓ against exercise-induced micro-injuries or infections✓. After exercise, efficient lymph drainage reduces swelling✓ and supports recovery by removing metabolic waste like lactate✓. In the athlete, a functional lymphatic system prevents fluid imbalance✓ and support immune surveillance during recovery✓.

Max 10 scores

Item 4 (Construct 3)

Explain Akello's slow reaction to coaching signals and delayed recovery. Also explain Akello's blood ADH concentration and sweat rate against the normal reference, and propose interventions to prevent collapse and support safe athletic training.

Explanation of slow reaction to coaching signals and delayed recovery

Slow reaction to coaching signals and delayed recovery result from impaired neural impulse transmission and synaptic function✓ caused by heat and dehydration. Impulse transmission speed is reduced because high temperature increases membrane fluidity✓, disrupting voltage-gated Na⁺ and K⁺ channel function✓, slowing depolarisation and action potential propagation✓. Dehydration thickens blood✓, reducing oxygen and

nutrient delivery to nerves✓, further slowing conduction. Synaptic vesicle release rate is low because heat and low ATP impair Ca^{2+} influx✓ and vesicle docking at presynaptic membranes✓. This reduces neurotransmitter release at neuromuscular junctions✓, weakening muscle contraction and coordination✓. Excitatory synapses fire less effectively✓, while inhibitory synapses may dominate due to fatigue✓, causing sluggish responses to sudden signals like, direction changes✓. Delayed recovery occurs because high core temperature denatures proteins and enzymes✓, prolonging metabolic recovery✓, and dehydration reduces blood volume for waste clearance✓.

Max 15 scores

Explanation of ADH and sweat rate

Blood ADH concentration is below the dehydrated reference. This is because, dehydration stimulates osmoreceptors in the hypothalamus to release ADH from the posterior lobe of the pituitary✓, increasing water reabsorption in kidney collecting ducts through aquaporin protein channels✓. Akello's low ADH indicates impaired hypothalamic response or pituitary dysfunction under extreme stress✓, leading to continued water loss and worsening dehydration✓. Sweat rate is severely reduced because dehydration reduces plasma volume✓ and blood flow to skin sweat glands, limiting sweat production✓. This failure to dissipate heat exacerbates hyperthermia and collapse✓.

Max 05 scores

Proposed interventions

Pre-training hydration protocol by drinking water and electrolytes 2 hour before the exercise✓ and sip water at regular intervals during exercise✓.

Gradual exposure to heat for few days✓ to facilitate heat acclimatisation and improve sweat rate and ADH response✓.

Schedule training for cooler hours like early mornings✓ and provide shaded rest areas✓.

Monitor core temperature and heart rate✓ ensuring to stop the exercise if temperature exceeds 39 °C✓.

Immediate post-collapse treatment✓ like rapid cooling using ice towels and fans, rehydration with oral/intra-venous fluids, and medical observation✓.

Max 5 scores

Item 5 (Construct 4)

Explain how human activities have driven ecological succession in this wetland and affected energy flow and ecosystem stability. Evaluate the increased carbon footprint of the degraded site in relation to climate change and propose strategies for effective ecological restoration of this valuable ecosystem.

Human-driven succession and effects on energy flow and stability

Human activities (sand mining and drainage for agriculture) physically remove native sedges and reeds, exposing bare, wet soil and lowering water table✓. This creates pioneer conditions✓ of open, unstable substrate with high light and nutrient pulses from disturbed soil✓. Fast-growing invasive grasses and shrubs (r-strategists) colonise first✓ as they have high seed production, rapid germination, and efficient resource capture✓, outcompeting slower-growing native perennials✓. Succession is arrested at an early seral stage✓ dominated by invasives instead of progressing to a stable climax community of diverse sedges/reeds✓.

Native vegetation has high primary productivity✓ due to efficient photosynthesis thus large biomass✓, while invasives have lower net primary productivity✓ due to poor adaptation to waterlogging✓. Less energy is captured from sunlight and transferred to herbivores and decomposers reducing trophic efficiency✓. Food chains shorten✓ and biomass pyramids become unstable✓ reducing ecosystem stability✓.

Low species diversity reduces resilience as there are fewer redundant species to buffer disturbances like floods or drought✓. Loss of keystone natives like reeds that stabilise soil and provide habitat increases vulnerability to erosion and invasion✓, creating positive feedback loops that results into more erosion and more invasives✓.

Max 16 scores

Evaluation of increased carbon footprint

The degraded wetland has a higher carbon footprint because;

Vegetation removal reduces photosynthesis thus less CO₂ is fixed into biomass✓.

Exposed peat soils undergo oxidation by aerobic microbes, releasing stored carbon as CO₂✓.

Invasives have lower biomass and sequestration capacity than natives✓.

Degraded wetlands contribute to global warming by releasing CO₂ and reducing natural sinks, and this exacerbates temperature rise, rainfall variability, and flooding which are indicators of climate change✓.

Max 4 scores

Proposed restoration strategies

Block drainage canals and build small check dams to re-wet the area and restore natural water levels✓.

Manually remove invasives in phases and replant native sedges/reeds from local nurseries or seed banks✓.

Apply organic mulch and plant cover crops to prevent erosion and rebuild organic matter✓.

Train locals in sustainable reed harvesting for crafts and income; and establish monitoring groups using simple quadrats✓.

Track succession progress with annual biodiversity surveys and carbon stock measurements✓.

Max 5 scores

Item 6 (Construct 4)

As a conservation biologist, describe the step-by-step field methods to estimate population density of papyrus using quadrats in the wetland and of frogs using capture-recapture in the same ecosystem, then analyse the major factors likely affecting population sizes of both species and propose sustainable strategies to reverse the decline.

Step-by-step quadrat method for estimating population density of papyrus

Define the study area which is a representative section of wetland✓ select quadrat size for example 0.5 m × 0.5 m, suitable for papyrus stem density✓; throw quadrats randomly/haphazardly to avoid bias and note the total number of quadrats established/thrown in the selected study area✓; count all living papyrus stems rooted inside each quadrat✓; record data and calculate mean number of stems per quadrat✓; calculate population density as mean stems per quadrat ÷ quadrat area (stems/m²)✓; extrapolate to get total population as population density × total wetland area✓;

Max 7 scores

Step-by-step capture-recapture for frogs

Select study area and make a first capture session by collecting as many frogs as possible✓ and mark them harmlessly for example using visible toe clip or ventral dye pattern✓, record their number, M✓, and release them back into habitat; allow time for mixing of about 3 days✓; and make the second capture session by collecting frogs again, and record the total number of frogs captured in this session, C✓; count how many of the frogs captured in the second capture were marked from the first capture✓ and let this number of re-captured frogs be R✓; estimate population size N using Lincoln index where $N = (M \times C) / R$ ✓; work out population density by dividing N by area sampled (frogs/m² or frogs/ha) ✓.

Max 9 scores

Major factors affecting population sizes

Pesticide bioaccumulation affects papyrus as the plants absorb chemicals through roots and leaves and accumulate in tissues without being broken down or excreted✓, causing damages to cell membranes and inhibiting photosynthetic enzymes✓. Leaves fail to make chlorophyll, stems become stunted and growth rate slows. Fewer viable seeds and rhizomes form and papyrus population density decreases✓.

Pesticide biomagnification affects frogs when they consume contaminated insects, algae, or water with higher toxin levels than in plants✓. Toxins concentrate in fat tissues and organs and cause neurological damage✓. Endocrine function is disrupted. Fertility decreases. Egg development becomes abnormal, immune system weakens and mortality rises causing frog populations to decline rapidly✓.

Reduced water table below the level required for growth of papyrus vegetation, resulting from drainage and sand mining, results in limited nutrient uptake and reduced rate of photosynthesis✓. Plants wilt and reduce available leaf surface area for harvesting light energy lowering rate of photosynthesis further✓. Established rhizomes are destroyed and new shoots fail to emerge thus papyrus population declines✓.

Drainage and sand mining reduce shallow breeding pools and protective vegetation for frogs✓. Predation and desiccation increase, food availability drops and fewer tadpoles survive to adulthood reducing the population of frogs✓.

Over-harvesting affects papyrus because communities cut stems and rhizomes for mats, baskets, roofing, and fuel✓. Removal happens faster than regrowth. Seed production decreases and vegetative spread becomes limited reducing papyrus population density✓.

Over-harvesting affects frog population by reducing their shelter and breeding microhabitats✓. This exposes frogs to predation lowering their survival rate✓.

Competition from invasive grasses and shrubs affects papyrus as invasives grow faster and capture light, space, and nutrients more efficiently✓. They shade out papyrus

seedlings, alter soil moisture through higher transpiration and prevent regeneration of native plants✓.

Competition from invasives affects frogs because invasive-dominated areas have less open water and fewer suitable perches thus reduced breeding and foraging sites✓.

Diseases affect frogs because stressed and toxin-weakened individuals are more susceptible to infections causing some individuals to die✓.

Max 9 scores