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TOPICAL REVISION ITEMS

CELL BIOLOGY

1. Researchers in Mbale District compared lung tissue samples from long-term smokers and non-smokers to understand why smokers often experience shortness of breath, fatigue, and persistent coughing. Some samples were obtained from individuals who had been working in poorly ventilated areas and had diets low in antioxidants.

Observation	Non-smoker	Smoker
Elastic fiber content (%)	95	40
Collagenase enzyme activity (%)	100	180
Alveolar wall thickness (µm)	2	5
Number of alveoli per mm^2	120	70
Vital capacity (L)	4.8	2.9

Task:

(a) Explain how enzyme activity and connective tissue changes contribute to reduced lung efficiency.

(b) Suggest physiologically supported strategies to prevent or reverse such damage.

RESPONSE

(a) Explain how enzyme activity and connective tissue changes contribute to reduced lung efficiency.

- *In smokers, increased **collagenase enzyme activity** (100% to 180%) causes excessive breakdown of connective tissue proteins in the lung, especially components that support the alveolar walls. High collagenase activity weakens the structural framework of the lungs and contributes to tissue destruction.*
- *Reduced **elastic fibre content** (95% to 40%) lowers the elasticity of lung tissue. Elastic fibres normally allow alveoli to stretch during inhalation and recoil during exhalation. When elastic fibres are lost, recoil becomes poor, air remains trapped in the lungs, and less fresh air enters during the next breath, reducing gaseous exchange efficiency.*
- *Increased **alveolar wall thickness** (2 µm to 5 µm) increases the diffusion distance for gases. Oxygen takes longer to move from alveolar air into the blood, while carbon dioxide also diffuses out more slowly. This reduces the rate of gaseous exchange and causes shortness of breath and fatigue.*
- *Reduced **number of alveoli per mm^2** (120 to 70) lowers the total surface area available for gaseous exchange. With less surface area, less oxygen enters the blood at a time, so body tissues receive less oxygen for **aerobic respiration**, leading to low energy production and tiredness.*
- *The reduction in **vital capacity** (4.8 L to 2.9 L) shows that smokers can move less air in and out of the lungs. This means less oxygen reaches the alveoli and less carbon dioxide is removed, worsening persistent coughing and breathlessness.*
- *Poor ventilation and low antioxidant diet worsen the damage because inhaled smoke and pollutants increase production of harmful oxidants, which damage lung cells and connective tissue. Low*

antioxidant intake reduces protection against this oxidative damage, so tissue destruction increases further.

(b) Suggest physiologically supported strategies to prevent or reverse such damage.

- ***Stopping smoking*** *removes the main source of toxic chemicals and oxidants; this reduces further stimulation of collagenase activity and slows destruction of elastic and connective tissues in the lungs.*
- ***Improving ventilation in working areas*** *lowers inhalation of smoke, dust, and harmful gases; this reduces irritation of lung tissues and limits further thickening and damage of alveolar walls.*
- ***Eating an antioxidant-rich diet*** *provides substances such as vitamins C and E that neutralise harmful free radicals; this protects lung cells and connective tissue from oxidative damage.*
- ***Regular physical exercise*** *improves breathing efficiency and strengthens respiratory muscles; this helps improve ventilation and may increase functional use of the remaining healthy alveoli.*
- ***Early medical screening and treatment*** *allows detection of declining lung function before severe damage occurs; timely management can reduce inflammation and slow progression of lung disease.*
- ***Using protective masks in polluted environments*** *reduces entry of harmful particles into the lungs; this protects alveoli and connective tissues from continued irritation and injury.*
- ***Avoiding long-term exposure to indoor smoke and poorly ventilated spaces*** *helps maintain normal gaseous exchange surfaces and reduces additional stress on already damaged lungs.*

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2. Medical students at Mulago Hospital examined epithelial samples from residents living near Kampala's Northern Bypass, where traffic pollution is heavy. Residents reported frequent coughing and throat irritation. The polluted zone had visibly darker dust deposits and frequent temperature inversions at night, reducing air movement.

Parameter	Control (Suburban Area)	Polluted Zone
Ciliated epithelial cell density (cells/mm^2)	320	110
Mucus viscosity (Pa·s)	0.8	2.3
Lysozyme enzyme activity (%)	100	40
Alveolar macrophage count	1200	600
Bacterial colonies per sample	5	25

Task:

(a) Explain how structural and enzymatic changes in the respiratory epithelium impair its function.

(b) Propose and justify community and biological strategies to reduce damage and restore respiratory health.

RESPONSE

(a) Explain how structural and enzymatic changes in the respiratory epithelium impair its function.

- *Reduced* ***ciliated epithelial cell density*** *(320 to 110 cells/mm^2) lowers the effectiveness of the* ***mucociliary escalator****; fewer cilia beat to move mucus upward toward the pharynx; this leads to accumulation of dust, pathogens, and pollutants in the airways, causing irritation and persistent coughing.*

- *Increased **mucus viscosity** (0.8 to 2.3 Pa·s) produces thicker, less mobile mucus; highly viscous mucus resists ciliary movement; trapped particles and microorganisms are not cleared efficiently, leading to airway blockage and reduced airflow.*
- *Reduced **lysozyme enzyme activity** (100% to 40%) weakens chemical defense in mucus; lysozyme normally breaks down **bacterial cell walls (peptidoglycan)**; low activity allows bacteria to survive and multiply on epithelial surfaces.*
- *Reduced **alveolar macrophage count** (1200 to 600) lowers **phagocytic activity** in the alveoli; fewer macrophages engulf and destroy pathogens and particulate matter; this increases risk of infection and inflammation in lung tissues.*
- *Increased **bacterial colonies per sample** (5 to 25) indicates successful microbial proliferation; accumulation of bacteria leads to infection, triggering inflammation and further damage to epithelial cells.*
- *Temperature inversion reduces air movement; pollutants remain concentrated near the ground; continuous exposure increases epithelial irritation, damages cilia, and denatures enzymes, worsening impairment of respiratory defense mechanisms.*
- *Overall, impaired clearance (cilia + mucus), reduced enzymatic defense (lysozyme), and weakened immune response (macrophages) lead to accumulation of pollutants and pathogens, causing coughing, irritation, and reduced respiratory efficiency.*

(b) Propose and justify community and biological strategies to reduce damage and restore respiratory health.

- ***Reducing vehicle emissions** lowers release of particulate matter and toxic gases; decreases damage to epithelial cells and preserves cilia structure and function.*
- ***Improving urban air flow (tree planting and proper planning)** enhances air circulation; reduces pollutant accumulation during temperature inversion; limits exposure of respiratory tissues.*
- ***Wearing protective masks** reduces inhalation of dust and microorganisms; protects epithelial surfaces and maintains normal mucociliary function.*
- ***Promoting antioxidant-rich diets** supplies molecules that neutralise pollutants-induced **free radicals**; protects epithelial cells and enzymes such as lysozyme from oxidative damage.*
- ***Hydration and humidified air intake** reduce mucus viscosity; improves ciliary movement and enhances removal of trapped particles.*
- ***Medical screening and early treatment** detects infections early; supports immune function and prevents severe epithelial damage.*
- ***Public awareness and behavioural change** reduces exposure time in highly polluted zones; supports long-term protection of respiratory health.*

3. A clinic investigated how smoking and chemical exposure affect respiratory health. Samples from a smoker and a healthy non-smoker were analysed. The smoker also reported frequent dehydration and poor dietary habits.

Tissue Type	Cilia Density (per mm^2)	Goblet Cells (per mm^2)	Mucus Thickness (μm)	Oxygen Uptake Rate (mL/min)
Healthy	280	80	5	200
Smoker	100	200	15	90

Task:

(a) Explain how structural changes in epithelial tissue impair its function.

(b) Suggest five public-health or lifestyle strategies to reduce tissue damage and promote recovery.

RESPONSE

(a) Explain how structural changes in epithelial tissue impair its function.

- *Reduced **cilia density** (280 to 100 cells/mm^2) lowers efficiency of the **mucociliary escalator**; fewer motile cilia beat to move mucus toward the pharynx; particles and microorganisms accumulate in airways, causing irritation and persistent coughing.*
- *Increased **goblet cell density** (80 → 200 cells/mm^2) leads to excessive mucus secretion; hyperplasia of goblet cells increases mucus production beyond clearance capacity; this contributes to airway obstruction.*
- *Increased **mucus thickness** (5 to 15 µm) produces highly viscous mucus; thick mucus resists ciliary movement and traps debris; blockage of bronchioles reduces airflow to alveoli.*
- *Reduced **oxygen uptake rate** (200 to 90 mL/min) results from poor ventilation and obstruction of airways; less oxygen reaches alveoli, lowering the diffusion gradient for gas exchange.*
- *Smoking and chemical exposure damage epithelial cells through toxic substances; this leads to loss of cilia, increased mucus production, and disruption of epithelial integrity.*
- *Frequent dehydration reduces water content of mucus; increases viscosity further; impairs ciliary function and clearance efficiency.*
- *Poor diet reduces availability of nutrients and antioxidants; weakens epithelial cell repair and maintenance; increases susceptibility to damage and infection.*

(b) Suggest five public-health or lifestyle strategies to reduce tissue damage and promote recovery.

- ***Stopping smoking** removes exposure to toxic chemicals; allows regeneration of ciliated epithelial cells and restores mucociliary clearance.*
- ***Reducing exposure to environmental pollutants** limits further damage to epithelial tissues; preserves cilia structure and normal mucus production.*
- ***Maintaining adequate hydration** lowers mucus viscosity; improves ciliary movement and enhances removal of trapped particles.*
- ***Consuming a balanced antioxidant-rich diet** supports repair of epithelial cells; protects tissues from oxidative damage caused by pollutants.*
- ***Improving ventilation in living and working environments** reduces inhalation of concentrated pollutants; protects respiratory surfaces and improves oxygen availability.*

4. A medical investigation explored why diabetic patients experience delayed wound healing after skin burns. Samples were collected from two patients one with controlled glucose levels and another with poorly managed diabetes. The diabetic patient also had reduced physical activity and poor hydration habits.

Observation	Normal Skin	Diabetic Burn Skin
Epidermal cell division rate (cells/day)	240	80
Collagenase activity (%)	100	40
Fibroblast density (per mm^2)	1200	700
Capillary density	Normal	Sparse
Blood glucose (mmol/L)	4.8	10.5

Task:

(a) Analyse how enzyme activity and tissue organisation influence wound repair.

(b) Suggest measures to improve recovery in diabetic patients.

RESPONSE

(a) Analyse how enzyme activity and tissue organisation influence wound repair.

- *Reduced **epidermal cell division rate** (240 to 80 cells/day) slows replacement of damaged skin cells; fewer cells are produced by **mitosis** to cover the wound surface; this delays re-epithelialisation and prolongs wound closure.*
- *Reduced **collagenase activity** (100% to 40%) interferes with normal tissue remodelling; collagenase normally breaks down damaged or excess collagen during healing; low activity causes poor removal of old extracellular material, slowing formation of organised new tissue.*
- *Reduced **fibroblast density** (1200 to 700 per mm^2) lowers synthesis of **collagen fibres**, glycoproteins, and other extracellular matrix components; fibroblasts are needed to rebuild connective tissue and provide structural support for the healing area; fewer fibroblasts therefore delay wound strength and repair.*
- ***Sparse capillary density** reduces blood supply to the damaged tissue; less **oxygen**, water, and nutrients reach the wound; this lowers **aerobic respiration** and **ATP production** in repairing cells, slowing cell division, protein synthesis, and tissue regeneration.*
- *High **blood glucose** (4.8 to 10.5 mmol/L) impairs normal healing by damaging small blood vessels and reducing efficiency of circulation; excess glucose also disrupts cell function and increases risk of infection, which further delays tissue repair.*
- *Poor hydration reduces tissue water content; this lowers transport of dissolved nutrients and wastes, reduces cell efficiency, and slows metabolic reactions required for healing.*
- *Reduced physical activity worsens circulation; poor blood flow further limits oxygen and nutrient delivery to the wound, contributing to delayed repair.*

(b) Suggest measures to improve recovery in diabetic patients.

- ***Good blood glucose control** maintains a near-normal internal environment; reduces damage to capillaries and cells; improves tissue repair and lowers infection risk.*
- ***Adequate hydration** supports transport of nutrients, oxygen, and wastes in tissue fluids; improves cell metabolism and promotes faster healing.*
- ***Regular controlled physical activity** improves blood circulation; increases delivery of oxygen and nutrients to the wound; supports tissue regeneration.*
- ***Balanced protein-rich diet** provides amino acids for synthesis of collagen and other repair proteins; supports fibroblast activity and rebuilding of damaged tissues.*
- ***Proper wound care and infection control** prevent microbial growth; reduces inflammation and protects newly forming tissues from further damage.*
- ***Medical monitoring of diabetic patients** allows early correction of poor glucose control and delayed healing signs; improves recovery outcomes.*
- ***Adequate rest and tissue protection** reduce repeated injury to the healing area; allows mitosis, fibroblast activity, and tissue remodelling to continue effectively.*

5. A team of students at Gulu University investigated why some individuals experience bloating and fatigue after heavy meals. They compared intestinal enzyme activity and tissue features in two groups: one consuming a balanced diet rich in fruits and fiber, and another eating mostly fatty, processed foods.

Parameter	Balanced Diet Group	High-Fat Diet Group
Lipase activity (%)	100	50
Villi height (µm)	500	250
Goblet cell count (per mm^2)	60	120
Absorption rate (mg/min)	150	70
Intestinal mucus thickness (µm)	5	15

Task:

(a) Explain how differences in enzyme activity and tissue structure affect digestion and absorption.

(b) Suggest dietary and physiological strategies to maintain healthy intestinal function.

RESPONSE

(a) Explain how differences in enzyme activity and tissue structure affect digestion and absorption.

- *Reduced **lipase activity** (100% to 50%) lowers hydrolysis of lipids into **fatty acids and glycerol**; fewer enzyme–substrate complexes form; incomplete digestion of fats leads to accumulation of undigested lipids, causing bloating and reduced nutrient availability.*
- *Reduced **villi height** (500 to 250 µm) decreases the surface area for absorption; shorter villi contain fewer **epithelial absorptive cells (enterocytes)** and fewer microvilli; this reduces diffusion and active transport of nutrients into the bloodstream.*
- *Increased **goblet cell count** (60 to 120 per mm^2) leads to excessive mucus secretion; hyperplasia of goblet cells produces more mucus than required for lubrication.*
- *Increased **intestinal mucus thickness** (5 to 15 µm) forms a thicker barrier over epithelial cells; this increases the diffusion distance for digested nutrients; slows absorption of glucose, amino acids, and fatty acids.*
- *Reduced **absorption rate** (150 to 70 mg/min) reflects combined effects of low enzyme activity and reduced absorptive surface; fewer nutrients enter circulation, leading to reduced **ATP production** during cellular respiration and resulting in fatigue.*
- *High-fat processed diets alter intestinal environment; may disrupt enzyme secretion and damage epithelial structure; this further reduces digestive efficiency and absorption capacity.*
- *In contrast, a balanced diet supports normal enzyme production, maintains villi structure, and ensures efficient digestion and absorption of nutrients.*

(b) Suggest dietary and physiological strategies to maintain healthy intestinal function.

- ***Consuming a balanced diet rich in fibre** maintains normal intestinal structure; supports healthy villi development and efficient nutrient absorption.*
- ***Reducing intake of fatty processed foods** prevents suppression of digestive enzymes such as lipase; improves efficiency of lipid digestion.*
- ***Adequate hydration** maintains optimal mucus consistency; prevents excessive thickness and allows efficient diffusion of nutrients.*
- ***Including fruits and vegetables rich in vitamins** supports epithelial cell maintenance and repair; preserves villi structure and enzyme function.*
- ***Regular meal patterns** promote consistent enzyme secretion; improves coordination of digestion and absorption processes.*
- ***Engaging in physical activity** enhances gut motility; improves mixing of food with digestive enzymes and increases absorption efficiency.*
- ***Maintaining healthy gut microbiota (e.g., through diet)** supports digestion and protects intestinal lining; improves overall nutrient absorption.*

6. In a rural health study, medical interns investigated why some farmers exposed to pesticide residues developed fatigue and yellowish eyes. Liver tissue samples were analysed for enzyme activity and structure. Many farmers lacked protective gear and drank untreated water from nearby irrigation canals.

Parameter	Control (Unexposed)	Exposed Farmers
Catalase activity (%)	100	45
ALT enzyme level (U/L)	30	95
Liver cell density (cells/mm^2)	500	280
Mitochondrial density	Normal	Reduced
Blood bilirubin (mg/dL)	0.8	2.5

Task:

(a) Explain how pesticide exposure affects enzyme function and tissue structure in the liver.

(b) Propose biologically sound strategies to prevent or reverse such damage in farming communities.

RESPONSE

(a) Explain how pesticide exposure affects enzyme function and tissue structure in the liver.

- *Reduced **catalase activity** (100% to 45%) lowers breakdown of **hydrogen peroxide (H_2O_2)** into water and oxygen; accumulation of reactive oxygen species causes **oxidative stress**; damages cell membranes, proteins, and DNA in hepatocytes.*
- *Increased **ALT enzyme level** (30 to 95 U/L) indicates leakage of **alanine aminotransferase** from damaged liver cells; ALT is normally intracellular; elevated levels reflect loss of membrane integrity and hepatocyte injury.*
- *Reduced **liver cell density** (500 to 280 cells/mm^2) shows loss of hepatocytes due to toxic effects; fewer functional cells reduce metabolic activities such as detoxification, protein synthesis, and bile production.*
- *Reduced **mitochondrial density** lowers capacity for **aerobic respiration**; decreased activity of the **electron transport chain** reduces **ATP production**; insufficient ATP limits active processes such as detoxification and biosynthesis.*
- *Increased **blood bilirubin** (0.8 to 2.5 mg/dL) results from impaired breakdown and excretion of haemoglobin derivatives; damaged liver cells cannot effectively conjugate and excrete bilirubin; accumulation causes yellowish eyes (**jaundice**).*
- *Pesticide residues disrupt enzyme structure by binding to active sites or denaturing proteins; this reduces enzyme–substrate interactions and slows detoxification pathways.*
- *Consumption of untreated water increases toxin intake; lack of protective gear increases exposure through skin and inhalation; together intensify liver damage.*

(b) Propose biologically sound strategies to prevent or reverse such damage in farming communities.

- ***Use of protective gear during pesticide handling** reduces absorption of toxic chemicals through skin and inhalation; protects liver from excessive toxin load.*
- ***Treatment of drinking water** removes pesticide residues; reduces ingestion of harmful substances that damage liver cells.*

- ***Reducing pesticide exposure (safe application practices)*** *lowers toxin entry into the body; preserves enzyme function and hepatocyte integrity.*
- ***Consumption of antioxidant-rich diets*** *provides molecules that neutralise reactive oxygen species; protects liver cells and enzymes such as catalase from oxidative damage.*
- ***Regular medical screening (liver function tests)*** *allows early detection of elevated ALT and bilirubin levels; enables timely intervention to prevent severe damage.*
- ***Adequate hydration*** *supports transport and excretion of metabolic wastes and toxins; improves liver detoxification efficiency.*
- ***Education on safe farming practices*** *promotes correct pesticide use and handling; reduces long-term exposure and protects community health.*