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Q6

Each year a large amount of plant material, cellulose, is deposited on the surface of Planet Earth. What are the natural processes this cellulose undergoes before yielding carbon dioxide, water and other end products ?

UPSC Civil Services Mains 2022 · GS III · 10 marks · Environment and Conservation

Conservation, environmental pollution and degradation, environmental impact assessment.

Core demand of the question

- Note that a large mass of plant **cellulose** is deposited yearly
- Explain the natural processes that convert it before carbon dioxide, water and other end products appear

Revision summary

Plants deposit a large annual mass of **cellulose** in litter, wood and roots.

Most animals cannot digest the β -1,4 polymer without microbial cellulases.

Fungi and bacteria hydrolyse **cellulose** to glucose; soil fauna shred and mix.

Aerobic respiration yields carbon dioxide and water; anaerobic guts and wetlands also yield methane.

Humus and soil organic carbon are slower residues, not instant end gases.

Introduction

Land plants lock carbon in **cellulose**-the polymer that makes cell walls. Each year forests, grasslands and crops add a huge mass of that material as litter, roots and wood. It does not sit forever. **Decomposers** and, in part, **herbivores and fire** break **cellulose** into sugars and then into **carbon dioxide, water** and residues such as **humus** and, in wet soils, methane.

Body**What must be broken**

- **Cellulose** is a chain of **glucose** units joined by β -1,4 links. Most animals cannot hydrolyse it; they need **microbes**.
- Lignin and hemicellulose travel with **cellulose** in wood; they slow decay and shape which organisms win.

Natural processes before the end products

- **Mechanical breakdown:** soil fauna (earthworms, termites, millipedes) shred litter, raise surface area, and mix it with microbes.
- **Enzymatic hydrolysis:** fungi (especially **basidiomycetes** and ascomycetes) and bacteria secrete **cellulases** (endoglucanase, exoglucanase, β -glucosidase). The polymer becomes cellobiose and then glucose.

- **Aerobic respiration** of that glucose by microbes (and by animals that host cellulolytic symbionts, such as **ruminants and termites**) yields **CO₂ and H₂O** and energy.
- **Anaerobic pathways in waterlogged soils, sediments and guts: fermentation and methanogenesis** yield **organic acids, CO₂ and CH₄** rather than full oxidation.
- **Humification**: not all carbon becomes gas in one season. Some becomes **humus** and soil organic carbon, a slower pool.
- **Fire and photodegradation** in dry biomes oxidise litter partly to CO₂ without passing through a gut; they are natural but not the forest-floor default.
- **Ruminants and termites** are ecological processors of **cellulose** at landscape scale; their symbionts do the chemistry.

End products in order

- **Immediate: sugars**, then microbial biomass.
- **Terminal under air: CO₂ and water.**
- **Terminal under anoxia: CO₂, methane, and reduced organics.**
- **Residual: humus, charcoal, and mineral-associated organic matter.**

Why it matters for GS-III

- This is the **carbon cycle** on land. Slowing decay (waterlogging, cold, lignin) stores carbon; accelerating it (tillage, drainage) releases CO₂.

Flow diagram

Plant cellulose litter -> Fauna shred
Plant cellulose litter -> Fungal bacterial cellulase
Fauna shred -> Glucose
Fungal bacterial cellulase -> Glucose
Glucose -> Aerobic CO₂ and H₂O
Glucose -> Anaerobic CO₂ CH₄
Glucose -> Humus slow pool

Conclusion

Yearly **cellulose** is dismantled first by shredders and then by microbial cellulases. Glucose is respired to carbon dioxide and water in air, or fermented to methane in wet systems, with **humus** as the slow remainder. The end products named in the question are the last step, not the first.

Facts & figures

Cellulose

β-1,4-linked glucose polymer of plant cell walls; the most abundant biopolymer on land.

Cellulase

Enzyme set (endo-, exo-glucanase, β-glucosidase) secreted mainly by fungi and bacteria.

Ruminants and termites

Animals whose gut symbionts digest cellulose; they process a large share of herbaceous and woody fibre.

Humus

Stabilised soil organic matter left after incomplete decay of litter including cellulose and lignin.

Methanogenesis

Anaerobic microbial path in wetlands and guts that yields methane from fermentation products.

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