Degradation of organic matter

Our natural resources, 10 hp, fall-08

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Eukaryote

- Animals
- Plants
- Fungi
- Protists (micro-organisms)

Brown algae (plant-like protist)
www.lanesville.k12.in.us/lcsyellowpages/Ticket/Carl/protists.html

Chlamydospires of *Ustilago maydis*
www.plant.uga.edu

*Amanita muscaria*
www.usask.ca/biology/fungi
Eukaryote

• Definition: organisms whose cells are organized into complex structures by internal membranes and a cytoskeleton
• The nuclei contain genetic information which is organized into discrete chromosomes and contained within a membrane-bounded compartment.
• Contain complex organic compounds (molecules containing carbon atoms)
Organic compounds

Methane: the simplest organic molecule

\( \text{O} = \text{C} = \text{O} \)

Carbon dioxide is NOT defined as an organic compound

Lignin – a complex organic compound found in wood and in cell walls of plants
Ecosystems consist of nonliving (abiotic) and living (biotic) components.

[Diagram showing a tree as a producer, with arrows indicating the flow of oxygen, carbon dioxide, and water. Other components include soil decomposers and soluble mineral nutrients.]
Producers: Basic Source of All Food

Most producers capture sunlight to produce carbohydrates by photosynthesis:

$$6 \text{ CO}_2 + 6 \text{ H}_2\text{O} + \text{ solar energy} \rightarrow \text{ C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2$$
Consumers: Eating and Recycling to Survive

- Consumers (heterotrophs) get their food by eating or breaking down all or parts of other organisms or their remains.
  - Herbivores
    - Primary consumers that eat producers
  - Carnivores
    - Primary consumers eat primary consumers
    - Third and higher level consumers: carnivores that eat carnivores.
  - Omnivores
    - Feed on both plant and animals.
Degradation/decomposition of organic matter

Highly complex organic compounds/structures

Smaller organic compounds, minerals, water, carbon dioxide, etc.
Microorganisms – the decomposers!

- **Scavengers** eat dead animals or plants
  - Examples are flies, wasps, cockroaches, worms, etc...
- **Decomposers** take over after the scavengers!
  - Examples are fungi, bacteria, etc...
Figure 3-13, p. 61
# Biomass under 1 m² of land

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Weight (gram)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>1.000</td>
<td>$10^{15}$</td>
</tr>
<tr>
<td>Fungi</td>
<td>400</td>
<td>-</td>
</tr>
<tr>
<td>Earthworms</td>
<td>120</td>
<td>$10^{3}$</td>
</tr>
<tr>
<td>Nematodes</td>
<td>12</td>
<td>$10^{7}$</td>
</tr>
<tr>
<td>Springtails</td>
<td>5</td>
<td>$5\times10^{4}$</td>
</tr>
<tr>
<td>Eriophyidae mites</td>
<td>1</td>
<td>$5\times10^{3}$</td>
</tr>
</tbody>
</table>
Microorganism-assisted decomposition

Straight hydrocarbon chains are easier to degrade than branched hydrocarbon chains, which are easier to degrade than aromatic hydrocarbon chains, which are easier to degrade than chlorinated hydrocarbon chains.

Size is of course also important!
DECOMPOSITION

AEROBIC

• Access to oxygen (microorganisms use oxygen as electron acceptor)
• Relatively FAST process

ANAEROBIC

• No access to oxygen (microorganisms use nitrate, sulfate, etc as electron acceptor)
• Relatively SLOW process
What is oxidation and reduction?

• **Definition of oxidation:**
  “A reaction in which the atoms in an element lose electrons” or “the combination of a substance with oxygen”

• **Example**
  Formation of iron (III) oxide, \( \text{Fe}_2\text{O}_3 \), commonly called ”rust”

• **Definition of reduction:**
  “A reaction in which the atoms in an element gain electrons” or “a reaction in which oxygen is removed from a compound”

• **Example**
  Photosynthesis is the reduction of carbon dioxide to sugars and oxidation of water to oxygen
The chemistry behind decomposition...

- Aerobic degradation – general formula:
  \[ \text{CH}_2\text{O} \text{ (aq)} + \text{O}_2 \text{ (aq)} \rightarrow \text{CO}_2 \text{ (g)} + \text{H}_2\text{O} \text{ (aq)} \]  

What else than \( \text{CO}_2 \) and \( \text{H}_2\text{O} \) is formed?
- energy (heat)
- new cell material
- metabolites
- new organic compounds
- nitrate (\( \text{NO}_3^- \)), sulfate (\( \text{SO}_4^{2-} \))
- sodium (\( \text{Na}^+ \)), potassium (\( \text{K}^+ \)), calcium (\( \text{Ca}^{2+} \)), ... i.e. mineralization
Anaerobic decomposition

- Anaerobic bacteria can decompose dissolved organic matter (DOM), by partly oxidize DOM to carbon dioxide (CO$_2$) and the rest is reduced to methane (CH$_4$):
  \[
  2 \text{ CH}_2\text{O (aq) } \rightarrow \text{ CH}_4 \text{ (g) } + \text{ CO}_2 \text{ (g)}
  \]
  DOM       methane       carbon dioxide

- Nitrate- och sulfate ions as e- acceptors:
  \[
  \text{NO}_3^- \rightarrow \text{ NO}_2^- \rightarrow \text{ N}_2\text{O} \rightarrow \text{ N}_2 \rightarrow \text{ NH}_4^+
  \]
  \[
  \text{SO}_4^{2-} \rightarrow \text{ SO}_3^{2-} \rightarrow \text{ S} \rightarrow \text{ S}^{2-} \rightarrow \text{ HS}^- \rightarrow \text{ H}_2\text{S}
  \]
  H$_2$S (hydrogen sulfide) is a poisonous gas!

- In ”dead lakes”:
  \[
  \text{FePO}_4 \text{ (s) } \rightarrow \text{ Fe}^{2+} \text{ } + \text{ PO}_4^{3-}
  \]
  iron phosphate       iron (II)       phosphate
Degradation of organic material in a deposit/compost

Gas composition

- **N₂**
- **O₂**
- **CO₂**
- **CH₄**
- **H₂**
- Free fatty acids
- Easily degradable material

**Weeks**  **Months**  **10th of yrs**

![Graph showing gas composition over time](image)
Degradation speed for carbohydrates

- Glucose
- Starch
- Cellulose
- Lignin

Formed CO₂

Weeks
Kleinhempel’s model of humic acid