Isfahan University of Technology
Department of Chemical Engineering

Course: Biological Processes for Wastewater Treatment
Semester 92-2

Lec3: # Microbial Ecology

Microbial diversity
Microbial ecology
Selection
Adaptation
Enrichment
Cometabolism

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Microbial Diversity

- Microbes live in a variety of habitats because of their abilities to
  - Use a variety of carbon and energy sources
  - Grow under different physical conditions

- estimated to be ~ 5 x 10^6 prokaryotic species (bacteria and archaea) on Earth

- soil can contain ***thousands of species*** of prokaryotes per gram

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Microbial Diversity

- Every organism has a unique range of capabilities, some of which might be useful in an engineered process
- Every organism has a unique range of conditions under which it will **grow** or at least **survive**
- Environmental systems are likely to be characterized by relatively **few dominant species** and a **large number of low-abundance species**
- **Open environments** permit the growth of heterogeneous communities
- wastes typically are heterogeneous mixtures of organic and inorganic compounds

therefore a diverse community of microorganisms can be expected in a given environmental system

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- **Environmental conditions** on organisms abundance (which organisms are selected)
  - major energy and carbon sources
  - dissolved oxygen concentration
  - concentration of other electron acceptors (*e.g.*, NO_3^-, SO_4^{2-}, Fe^{3+})
  - pH
  - temperature (psychrophiles, mesophiles, thermophiles)
  - salinity
  - availability of nutrients

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- **biological process engineering** involves control of the microbial community's immediate environment

Therefore we have control, to a large extent, over microbial selection.

This is the key to success in the application of biological processes to waste treatment

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Microbial Ecology

- The study of how microorganisms interact with each other and with their environment.

- What microorganisms are present?
- What metabolic reactions **could** the microorganisms **carry out**?
- What reactions are they **carrying out**?
- How are the different microorganisms interacting with each other and the environment?

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Microbial Ecology

- What microorganisms are present?

Community structure

  - Enumeration of the number of distinct microbial types present
  - Abundance of each type
  - Spatial relationships among the different populations

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Microbial Ecology

- What metabolic reactions **could** the microorganisms **carry out**?
- What reactions are they **carrying out**?

community function,
or what the organisms individually or collectively do?

potential activity and the range of behaviors possible.
what behaviors actually occur under the circumstances

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Microbial Ecology

- How are the different microorganisms interacting with each other and the environment?

The physical relationships among different microorganisms and materials that they produce, consume, and (especially) exchange define their *interactions, the* essence of microbial ecology

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- Design and operation of process in Env biotech are **practical way**s

  in which **microbial ecology is manipulated** so that

  a microbial community achieves a **desired goal**.

- To control a system's microbial ecology
  - Selection
  - Exchange of materials
  - Adaptation

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Selection

Within a microbial community,
all the individual microorganisms are not the same in terms of the biochemical reactions they carry out and other phenotyps.

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Selection

Selection is a process in which those individuals who are most fit to survive in their environment generate the greatest number of duplication.

Over time, the selected microorganisms establish a stable and **dominant** population in the community, continuing to carry out their biochemical reactions.

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Exchange of substrate

One of the most important strategies

for **survival and selection** in microbial communities is

exchange of materials among different types of

microorganisms.

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Exchange of substrate

one cell releases a molecule into the environment, and another cell takes it up in such a way that one or both cells benefit.

Thus, the main connections in a microbial ecosystem involve the exchange of molecules, not the consumption of one cell by another.

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Exchange of substrate

reduction of CO2 to organic carbon by autotrophs,

Release of partially oxidized organic intermediates,

cycling of inorganic elements

Exchange of substrate

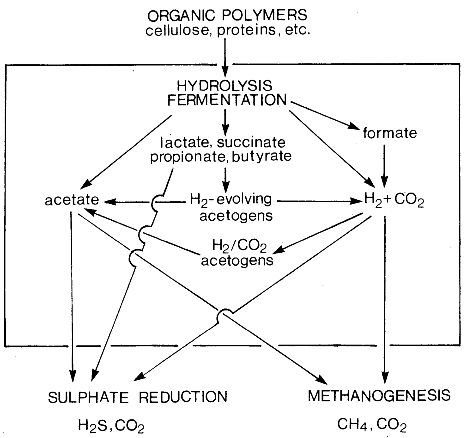

Fig. 2.13 The principal pathways for the complete anaerobic degradation of organic matter. The overall process involves the concerted action of many different types of organisms. All the fermentations lie within the box and the central roles of H_2 and acetate are clear. Sulphate reduction and methanogenesis are considered in the next section.

Obligate syntrophy between an acetogen and a methanogen is common

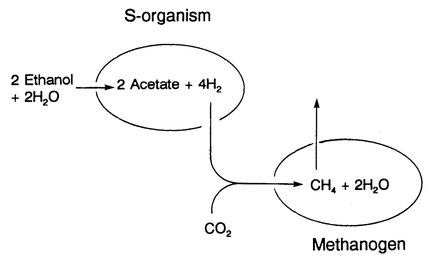

Fig. 2.23 '*Methanobacillus omelianskii*' — a syntrophic consortium of two organisms which are completely dependent on one another. $\Delta G^{0\prime}$ for the S-organism and the methanogen are, respectively, 19 kJ/2 ethanol and −131 kJ/methane, so the overall syntrophic reaction is exergonic (−112 kJ/methane).

Each species (e.g., a methanogen and an acetogen) requires the other: the acetogen provides the hydrogen; the methanogen prevents a build-up of hydrogen (which inhibits the acetogens)

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Exchange of substrate

Synergistic interactions

Syntrophy (cross – feeding)

Obligate syntrophic

Syntrophy: A process whereby

two or more microbes **cooperate** to degrade

a substance neither can degrade alone

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adaptation

microbial ecosystems are able to **respond to changes** in their environment, particularly changes that stress the community.

Examples of stresses include

changes in temperature, pH, or salinity;

exposure to a toxic material;

exposure to xenobiotic organic molecules;

changes in the availability of substrates.

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adaptation

Adaptation is any response that ultimately leads the community to eliminate the stress or find a way to maintain its function despite the stress.

The **adaptation period** is the time interval between the **initial exposure to the stress** and when the community **has adapted**.

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adaptation

Native organisms are almost always better adapted to the local environmental conditions than added organisms would be

mechanisms of adaptation:

- selective enrichment,
- enzyme regulation,
- exchange of genetic information,
- inheritable genetic change,
- alteration of their environment.

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- To isolate and study a particular organism, researchers must isolate microorganisms from nature and establish them in pure cultures.
- Enrichment culture is a selective medium and incubation procedure that selects for desired organisms and against undesired ones.

  Success requires a proper inoculum, culture medium and incubation conditions.

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Co-metabolism

- **Co-metabolism** is defined as the **simultaneous degradation** of two compounds, in which the degradation of the second compound (the secondary substrate) depends on the presence of the first compound (the primary substrate).

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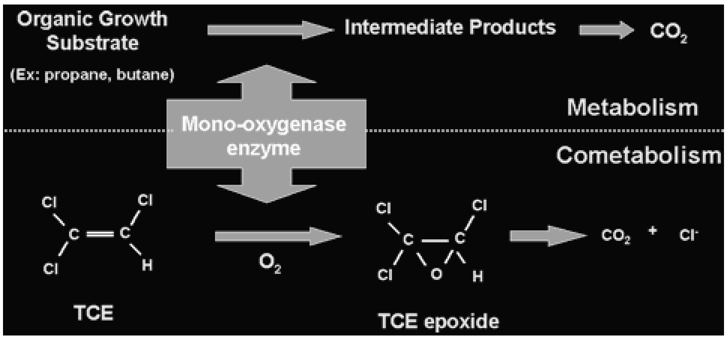
Co-metabolism

- in the process of metabolizing methane, propane or simple sugars, some bacteria, such as *Pseudomonas stutzeri OX1*, can degrade hazardous chlorinated solvents, such as tetrachloroethylene and trichloroethylene, that they would otherwise be unable to attack.



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