Biological Degradation of Pollutants — Growth versus Cometabolism

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I. Types of Biological Degradation —

A. Contributing to growth

1 As growth substrate — Use of components as nutrients with incorporation of carbon or nitrogen into cell structure

2 As electron acceptor — "Respiration"

3 As part of energy supply to a consortium — With benefit to each member

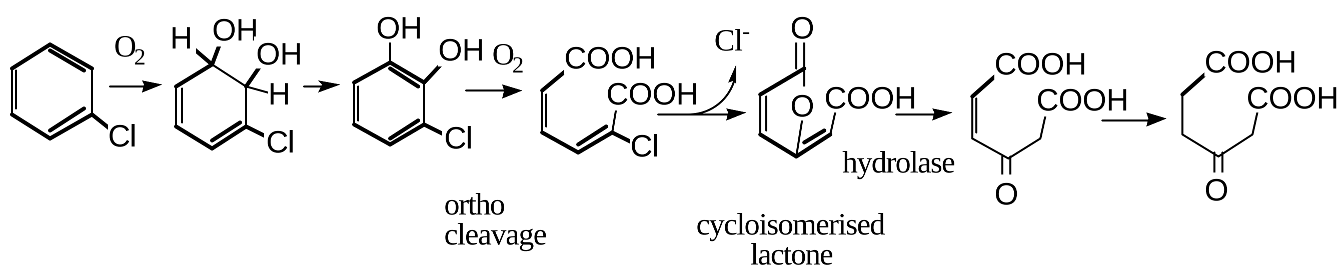
B. Cometabolic (not for growth)

Degrees of enzyme non-specificity

II. Examples of degradation that Contributes to Growth

A. As Growth substrate — Aerobic degradation of benzene ring

— of chlorobenzene:



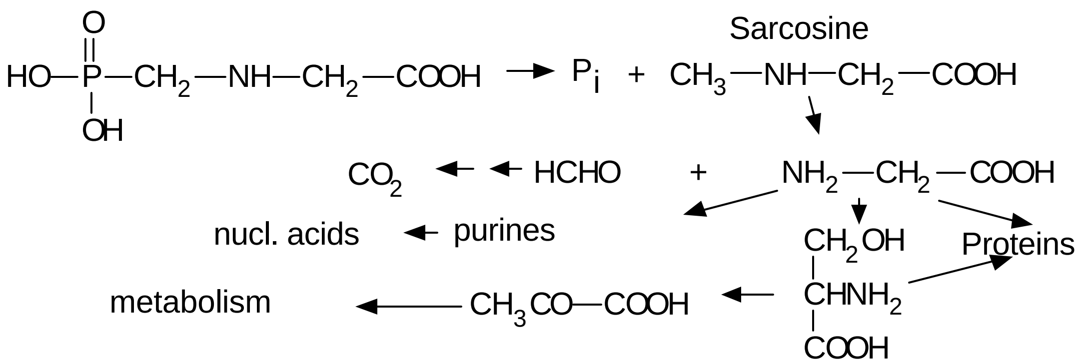
Complete pathway, products feed into intermediary metabolism, 14-C labeled carbon appears as CO2 and cell carbon, complete degradation and use indicated by incorporation of ring carbons

B. Growth on dichloromethane

Hyphomicrobium and Pseudomonads: A group which is also able to degrade methanol, some have adapted to CH_2Cl_2 rather than CH_3OH [1, 2].

C. Use as a source of nutrients

Degradation of glyphosate by various bacterial species, yielding phosphate through oxidation of phosphonate moiety, use of phosphate as sole source of P [3]:



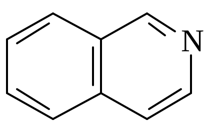
Some *Alcaligenes* spp stop with phosphate and sacrosine, using only P_i if other carbon sources available [4]

Carbofuran is degraded variously as sole nitrogen source or as sole carbon source or both [5]

Degradation of acetonitrile as sole nitrogen source by a *Pseudomonas putida.* Also use of carbon as sole source [6]. Also applies to benzonitriles

$H_3C—CN$

Use of isoquinoline as sole N and C source by enrichment cultures from creosote site [7]



Cyanate (OCN-) used as sole N source by *Pseudomonas* [8].

Other examples of use as sole source of nitrogen: some attacks on 2,4-dinitrotoluene, EDTA (ethylenediaminetetraacetic acid, $(CH_3COO)_2NCH_2CH_2N(OOCCH_3)_2$)

D. Chlorinated compounds can serve as electron acceptor under anaerobic conditions

3-Chlorobenzoate dechlorination increased yield of sulfate reducer, DCB-1 (now *Desulfomonile tiedjei*) [9]

E. Degradation as member of consortium

1 Dechlorination of Cl-benzoate by anaerobic consortium.

Grows on hydrogen and pyruvate; supplied by 2 other partners in consortium (benzoate fermenter and methanogen), which it supplies with benzoate from dechlorination [10].

2 Dechlorination of PCE by a consortium. Increased growth yields [11]

III. Cometabolism

Detected as no growth as sole source of carbon and no uptake of ^{14}C into cells, But also as no increase in yield

Can be roughly classified by degree of non-specificity. Start with more specific, end with least specific

A Aerobic degradation of PCB, cometabolism of closely related structures

Aerobic degradation of PCBs is by bacteria that have been enriched using biphenyl (eg, [12])

Many aerobes isolated that dechlorinate different combos of 2, and 3 Cl PCBs at different rates, mostly *Alcaligenes, Acinetobacter, Arthrobacter, and Corynebacteria*

May not be able to derive energy from declorinating higher Cl PCBs. Biphenyl used as growth substrate and to induce PCB degradation enzymes

B. Aerobic degradation of PAHs, closely related structures

Patterns of PAH oxidation are complex, eg. Isolate could grow on pyrene, phenanthene, anthracene, fluoranthene, and chrysene as sole C; but could only cometabolize naphthalene, dibenzofuran, fluorene, & dibenzothiophene [13].

C Cometabolic aerobic TCE degradation by *Ps. putida* strains grown on toluene or phenol. more nonspecificity

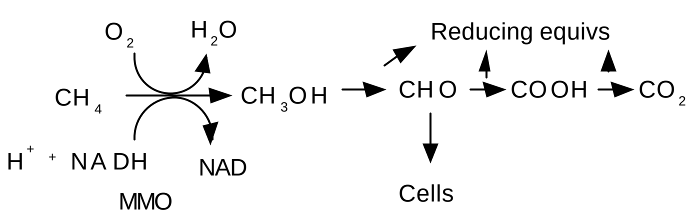
uses toluene dioxygenase enzyme. Also degrades 1,1-dichloroethene, but not 1,2-dichloroethene.

Does not degrade chlorinated ethanes or methanes

D Dechlorination of chlorinated aliphatic hydrocarbons by methane-oxidizers, methanotrophs, more nonspecificity

Important part of carbon cycle

Methane monooxygenase first step in methane oxidation to CO_2



Requires oxygen and energy (NADH)

Similar to action of Cyt P450 monooxygenase in liver

MMO attacks trichloroethylene; 1,1,1-trichloroethane; mono & dichloroethane, methane and ethene; chloroform; other alkanes and alkenes, also hydroxylates aromatics

E Aerobic dechlorination of dioxin and PCB by lignin peroxidase, very nonspecific

White-rot fungi, eg, *Phanerochaete chrysosporium* degrade lignocellulose complex using lignin peroxidase and cellulase, extracellular enzymes.

Lignin peroxidase works by producing •OH free radicals from excreted hydrogen peroxide, H_2O_2 and other active oxygen species, that randomly attack hindered structures in the lignin complex. Thus its attack is very non-specific—"shotgun" approach rather than binding to a specific substrate site.

Degrades dioxin; PCBs (up to hexa); Lindane; DDT; BaP; chlorinated benzoic acid, vanillin, guaiacol, aniline, and phenols. Requires low carbon and low nitrogen.

Following are subject to ongoing research. Hard to classify but probably can be considered to involve both growth and cometabolism

F Anaerobic degradation: Carbon tetrachloride and Chloroform to dichloromethane and CO_2, Note that at least some of this activity does not require living organisms [14].

G Reductive dechlorination of PCBs. Can enrich for the activity by refeeding with PCBs: Benefit? [15]

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