

MICROBIAL METABOLISM - Heterotrophy

<u>Reaction</u>	<u>Electron Donor</u>	<u>Electron Acceptor</u>	<u>Carbon Source</u>	ΔG° kcal/[mol]	Eh Range	<u>Organisms</u>
Aerobic Respiration						
$[\text{CH}_2\text{O}] + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$	CH ₂ O	O ₂	CH ₂ O	-114	+800 to +500	animals, algae, protozoa, fungi, & bacteria
Aerobic Chemoorganotrophy (Methane Oxidation)						
$[\text{CH}_4] + \text{O}_2 \rightarrow \text{HCO}_3^- + \text{H}_2\text{O}$	CH ₄	O ₂	CH ₄	-57	+800 to +500	<i>Methylococcus</i> <i>Methylomonas</i> <i>Methylobacterium</i> <i>Methylocystis</i>
Anaerobic Respiration						
<u>Denitrification</u>						
$5[\text{CH}_2\text{O}] + 4\text{NO}_3^- \rightarrow 2\text{N}_2 + 4\text{HCO}_3^- + \text{CO}_2 + 3\text{H}_2\text{O}$	CH ₂ O	NO ₃ ⁻	CH ₂ O	-107	+300 to -500	<i>Pseudomonas</i> <i>Thiobacillus</i> <i>Bacillus</i> <i>Spirillum</i> <i>Moraxella</i>
<u>Manganese Reduction</u>						
$[\text{CH}_2\text{O}] + 3\text{CO}_2 + \text{H}_2\text{O} + 3\text{MnO}_3 \rightarrow 2\text{Mn}^{++} + 4\text{HCO}_3^-$	CH ₂ O	MnO ₃	CH ₂ O	-83	+400 to +100	
<u>Iron Reduction</u>						
$[\text{CH}_2\text{O}] + 7\text{CO}_2 + 4\text{Fe(OH)}_3 \rightarrow 4\text{Fe}^{++} + 8\text{HCO}_3^- + 3\text{H}_2\text{O}$	CH ₂ O	FeOH	CH ₂ O	-27	+400 to +100	<i>Bacillus</i> <i>Pseudomonas</i> <i>Proteus</i> <i>Clostridium</i> <i>Desulfovibrio</i>
<u>Sulfate Reduction</u>						
$2[\text{CH}_2\text{O}] + \text{SO}_4^{--} \rightarrow \text{H}_2\text{S} + 2\text{HCO}_3^-$	CH ₂ O	SO ₄ ⁻⁻	CH ₂ O	-18	-100 to -400	<i>Desulfovibrio</i>
<u>Methanogenesis</u>						
$[\text{HCO}_3^-] + 4\text{H}_2 + \text{H}^+ \rightarrow \text{CH}_4 + 3\text{H}_2\text{O}$	CH ₂ O	CO ₂	CH ₂ O	-32	-350 to -450	<i>Methanosarcina</i> <i>Methanobacterium</i>

<u>Reaction</u>	<u>Electron Donor</u>	<u>Electron Acceptor</u>	<u>Carbon Source</u>	ΔG° kcal/[mol]	Eh Range	<u>Organisms</u>	
<u>Acetogenesis</u>							
$[2\text{HCO}_3^-] + 4\text{H}_2 + \text{H}^+ \rightarrow \text{CH}_3\text{COOH} + 2\text{H}_2\text{O}$			CH_2O	CO_2	CH_2O	-27	<i>Clostridium</i> <i>Acetobacterium</i>
<u>Fermentation (anaerobic)</u>							
<u>Homolactic</u>							
$6[\text{CH}_2\text{O}] \rightarrow 2[\text{CH}_3(\text{CHOH})\text{COOH}] + 2\text{H}_2\text{O}$			CH_2O	CH_2O	CH_2O	-32	<i>Streptococcus</i> <i>Lactobacillus</i>
<u>Heterolactic</u>							
$6[\text{CH}_2\text{O}] \rightarrow \text{CH}_3(\text{CHOH})\text{COOH} + \text{CH}_3(\text{CH}_2)\text{OH} + \text{CO}_2$			CH_2O	CH_2O	CH_2O	-16	<i>Leuconostoc</i> <i>Lactobacillus</i>
<u>Ethanolic</u>							
$6[\text{CH}_2\text{O}] \rightarrow 2\text{CH}_3(\text{CH}_2)\text{OH} + 2\text{CO}_2 + 2\text{H}_2\text{O}$			CH_2O	CH_2O	CH_2O	-32	<i>Saccharomyces</i> <i>cerevisiae</i>
<u>Mixed Acid</u>							
$6[\text{CH}_2\text{O}] \rightarrow \text{CH}_3(\text{CHOH})\text{COOH} + \text{CH}_3\text{COOH} + \text{CH}_3(\text{CH}_2)\text{OH} + \text{CO}_2 + \text{H}_2$			CH_2O	CH_2O	CH_2O	-54	<i>Escherichia coli</i>
<u>Propionic Acid</u>							
$9[\text{CH}_2\text{O}] \rightarrow 2[\text{CH}_3(\text{CH}_2)\text{COOH}] + \text{CH}_3\text{COOH} + \text{CO}_2 + \text{H}_2\text{O} + 3\text{H}^+$			CH_2O	CH_2O	CH_2O	-74	<i>Propionibacterium</i>
<u>Butyric Acid</u>							
$12[\text{CH}_2\text{O}] + 2\text{H}_2\text{O} \rightarrow \text{CH}_3(\text{CH}_2)_2\text{COOH} + 2(\text{CH}_3\text{COOH}) + 4\text{CO}_2 + 6\text{H}_2 + 3\text{H}^+$			CH_2O	CH_2O	CH_2O	-57	<i>Clostridium</i> <i>Eubacterium</i> <i>Butyrivibrio</i>

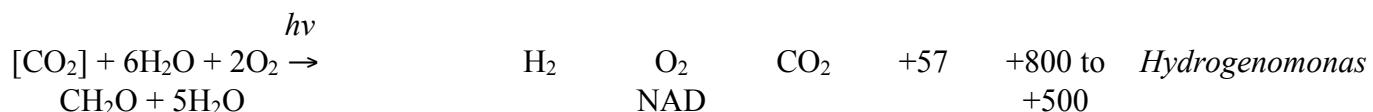
MICROBIAL METABOLISM - Autotrophy

<u>Reaction</u>	<u>Electron Donor</u>	<u>Electron Acceptor</u>	<u>Carbon Source</u>	ΔG° kcal/[mol]	Eh Range	<u>Organisms</u>
-----------------	-----------------------	--------------------------	----------------------	-----------------------------	----------	------------------

Aerobic Photoautotrophy



Hydrogen Oxidation

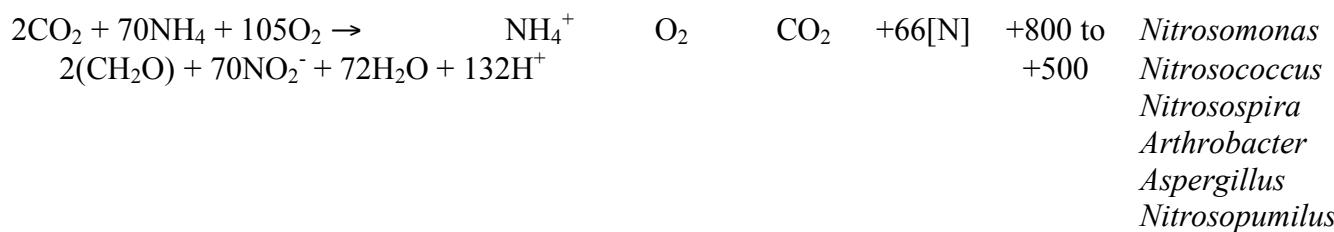


Anaerobic Photoautotrophy

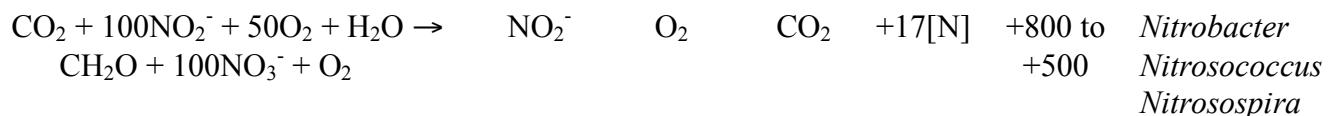


Chemoautotrophy (aerobic)

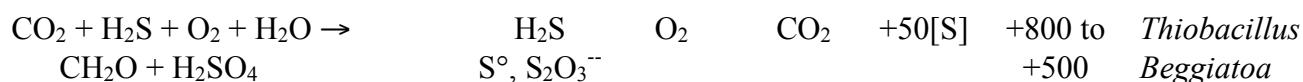
Ammonia Oxidation



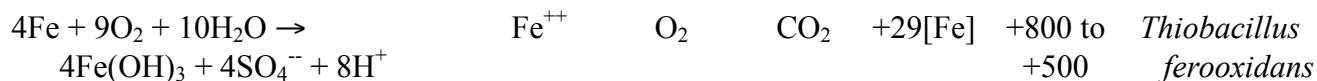
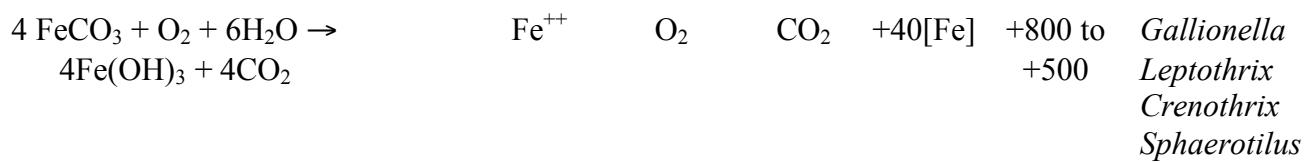
Nitrification



Sulfur Oxidation



<u>Reaction</u>	<u>Electron Donor</u>	<u>Electron Acceptor</u>	<u>Carbon Source</u>	ΔG° kcal/[mol]	Eh Range	<u>Organisms</u>
-----------------	-----------------------	--------------------------	----------------------	-----------------------------	----------	------------------

Chemoautotrophy (aerobic)Iron Oxidation*Acid pH**Neutral pH*Manganese Oxidation