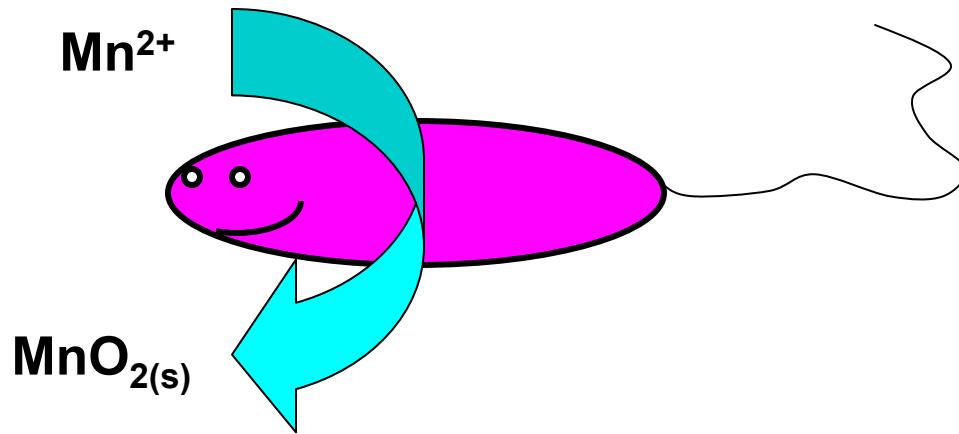


# Microbiology of Manganese Oxidation



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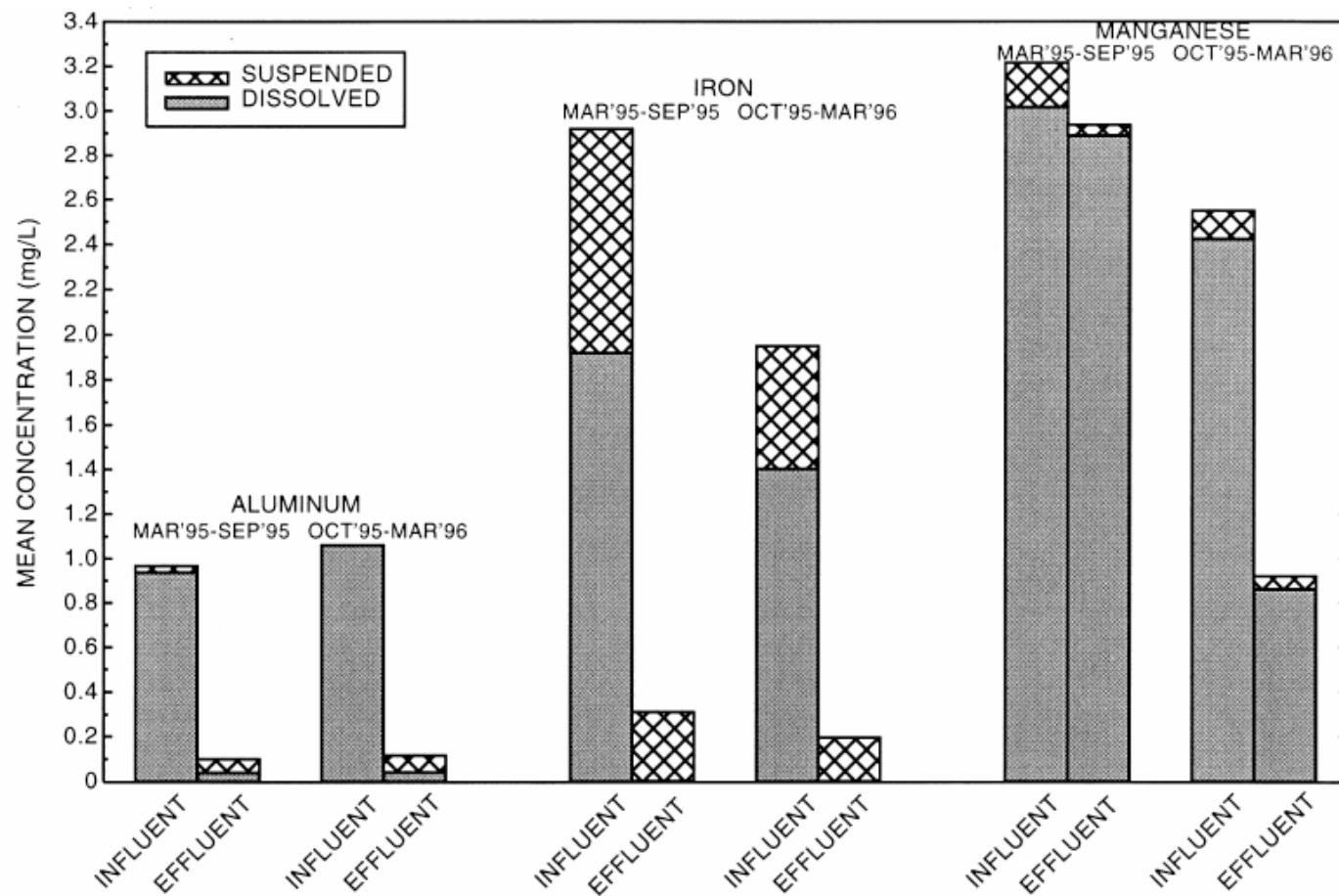
Appalachian Region Technology Transfer  
2005 Mine Water Treatment Conference  
August 17, 2005



# Manganese impacted water

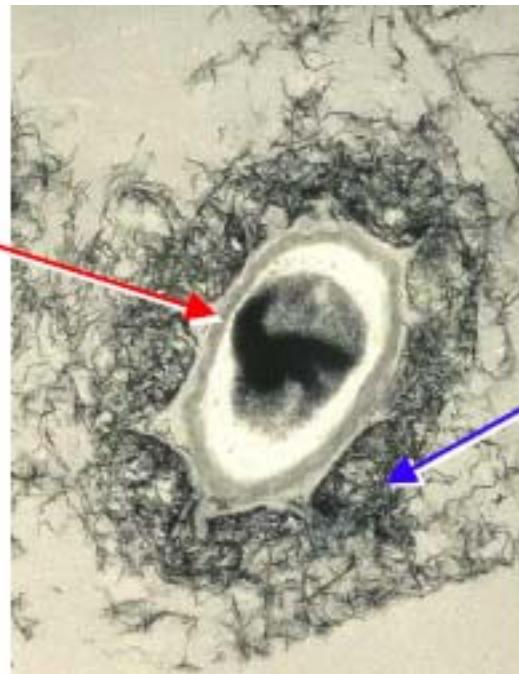


# Manganese removal in limestone beds



# Biogenic manganese oxidation

Mn(II) oxidizing bacteria



*Biogenic Mn-oxides*

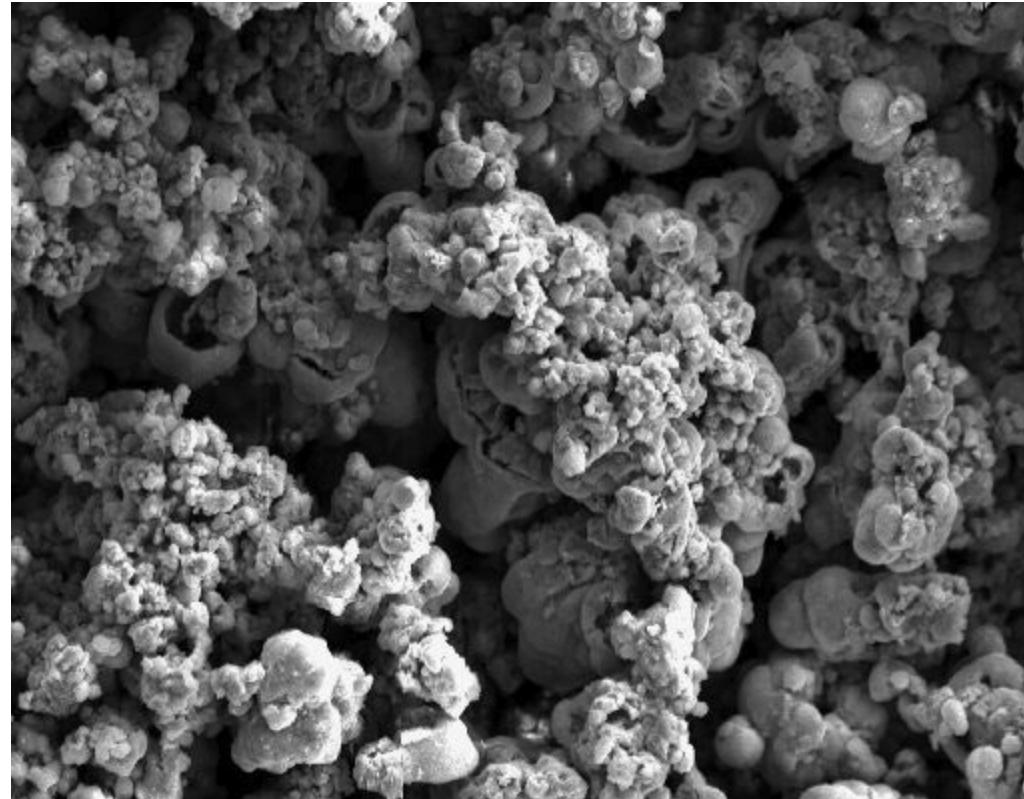
<http://www.nsf.gov/mps/che/nuggets/tebo.pdf>

# *Leptothrix discophora*



[http://soils1.cses.vt.edu/ch/biol\\_4684/Microbes/Leptothrix.html](http://soils1.cses.vt.edu/ch/biol_4684/Microbes/Leptothrix.html)

# Manganese nodules



*Provided by Charles Cravotta*

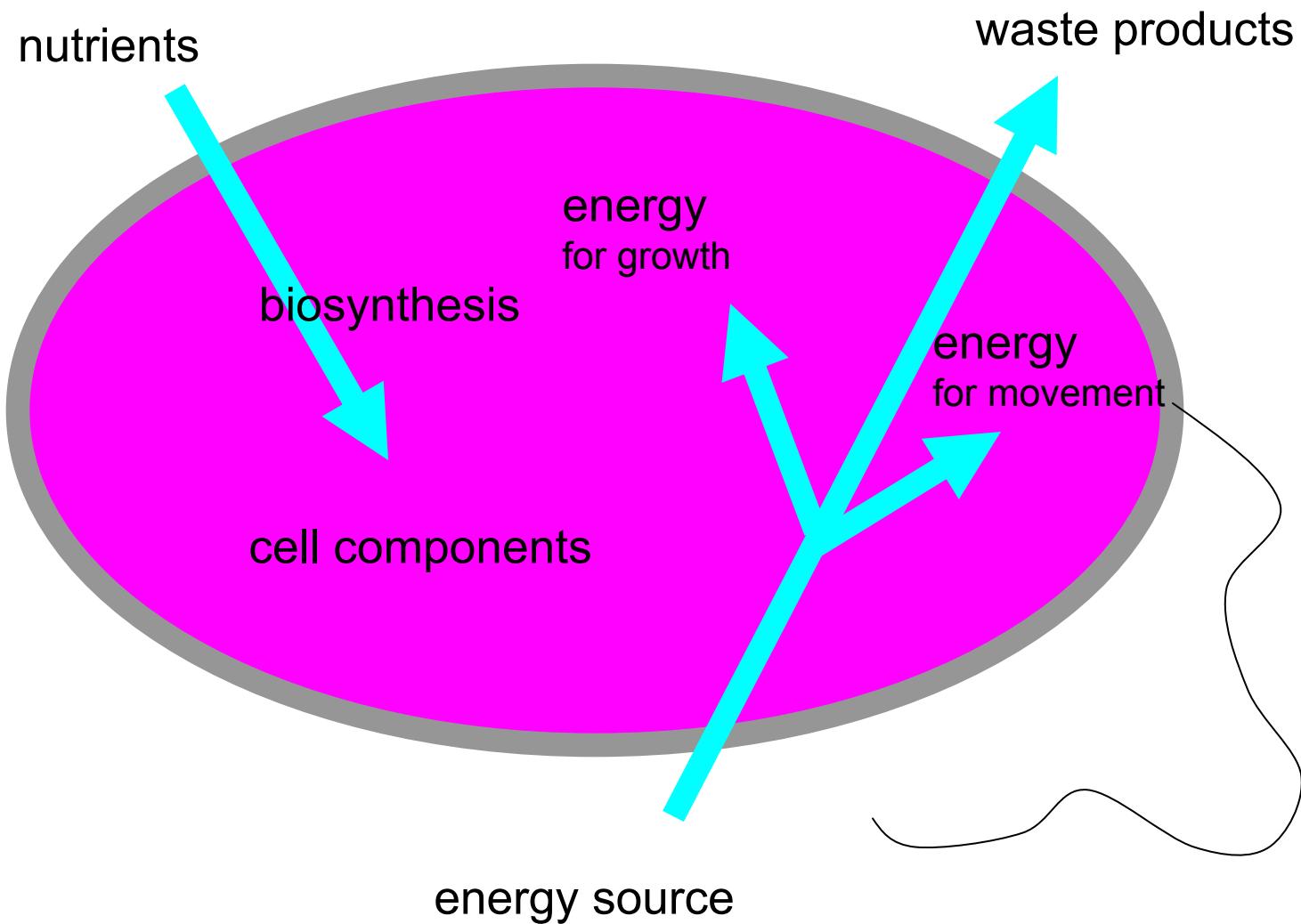
# Questions

*To what extent do bacteria contribute to manganese oxidation in limestone beds?*

*What are the environmental requirements to promote manganese oxidation in limestone beds?*

*What is an appropriate model for the bacterial component of manganese oxidation?*

# Microbial reactions



# Microbial requirements

growth materials

nutrients and carbon

electron donor

electron acceptor

appropriate conditions

# Microbially facilitated processes

## oxidation/reduction reactions

direct  
energy  
fortuitous

indirect

nutrient requirement

detoxification

# Synergism

Algae

Fungi

Organic producing ecosystem (e.g., wetland)

# Reasons for bacteria to oxidize manganese

Energy for growth

Mn(IV) reaction with from humic and fulvic acids to release organic nutrients

Response to low carbon stress

Response to toxic metals

Bind organic substrates to bacterial surface

# Modeling

## Stoichiometry

## Kinetics

# Carbon requirement

Autotrophic - CO<sub>2</sub>

Heterotrophic - organic carbon

Mixotrophic - can use both

# Stoichiometry

Manganese oxidation

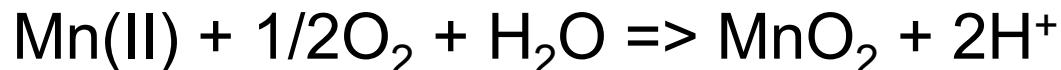


Possible microbial stoichiometries (unbalanced)

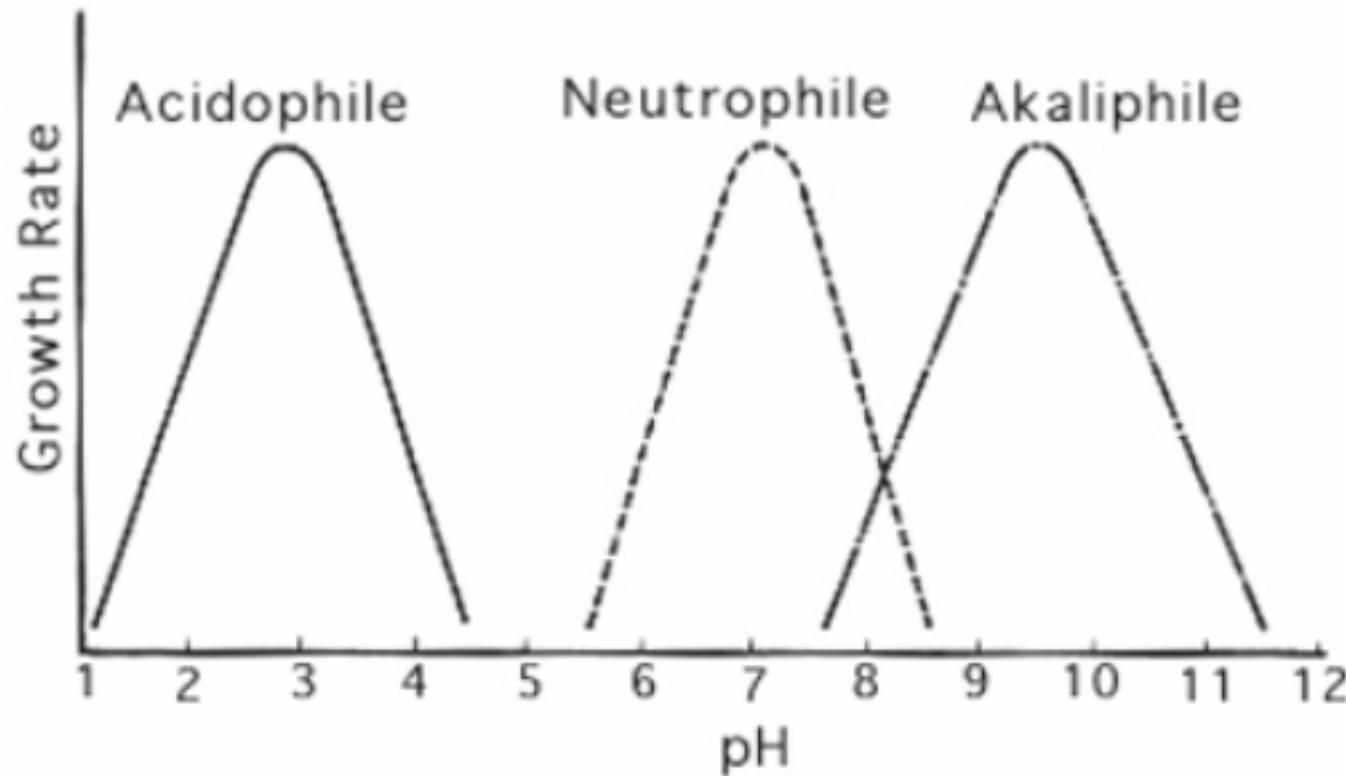
Autotrophic



Heterotrophic

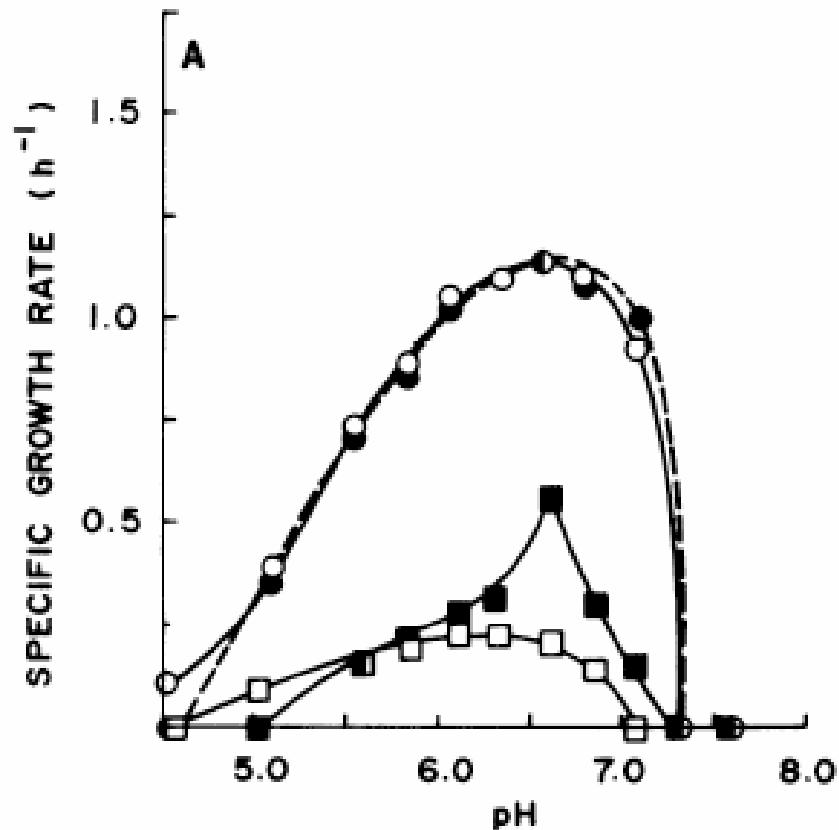
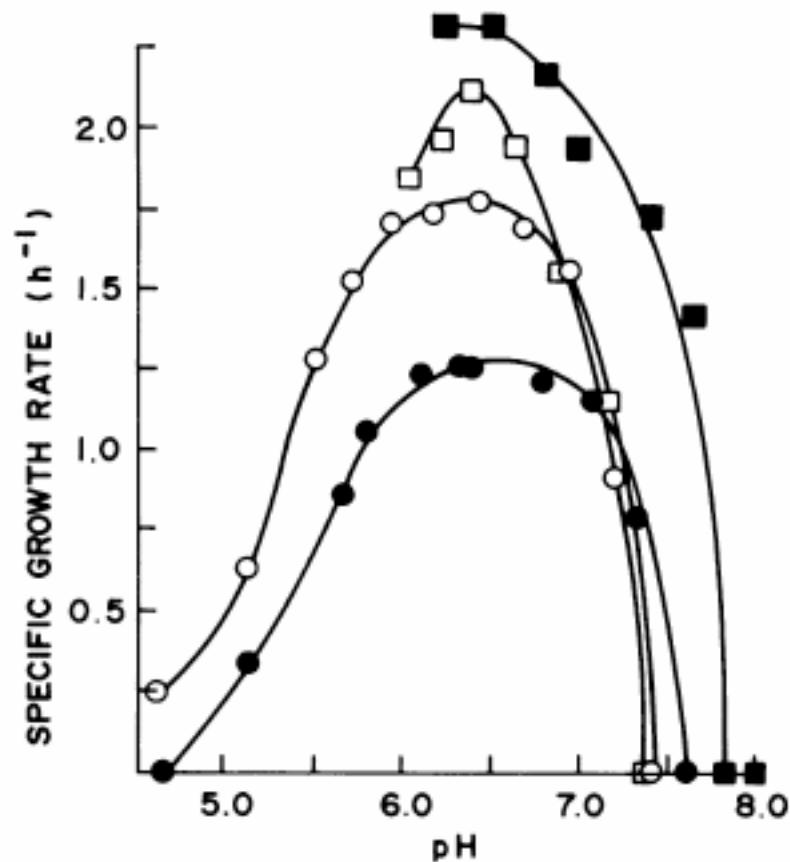


# Theoretical pH effects



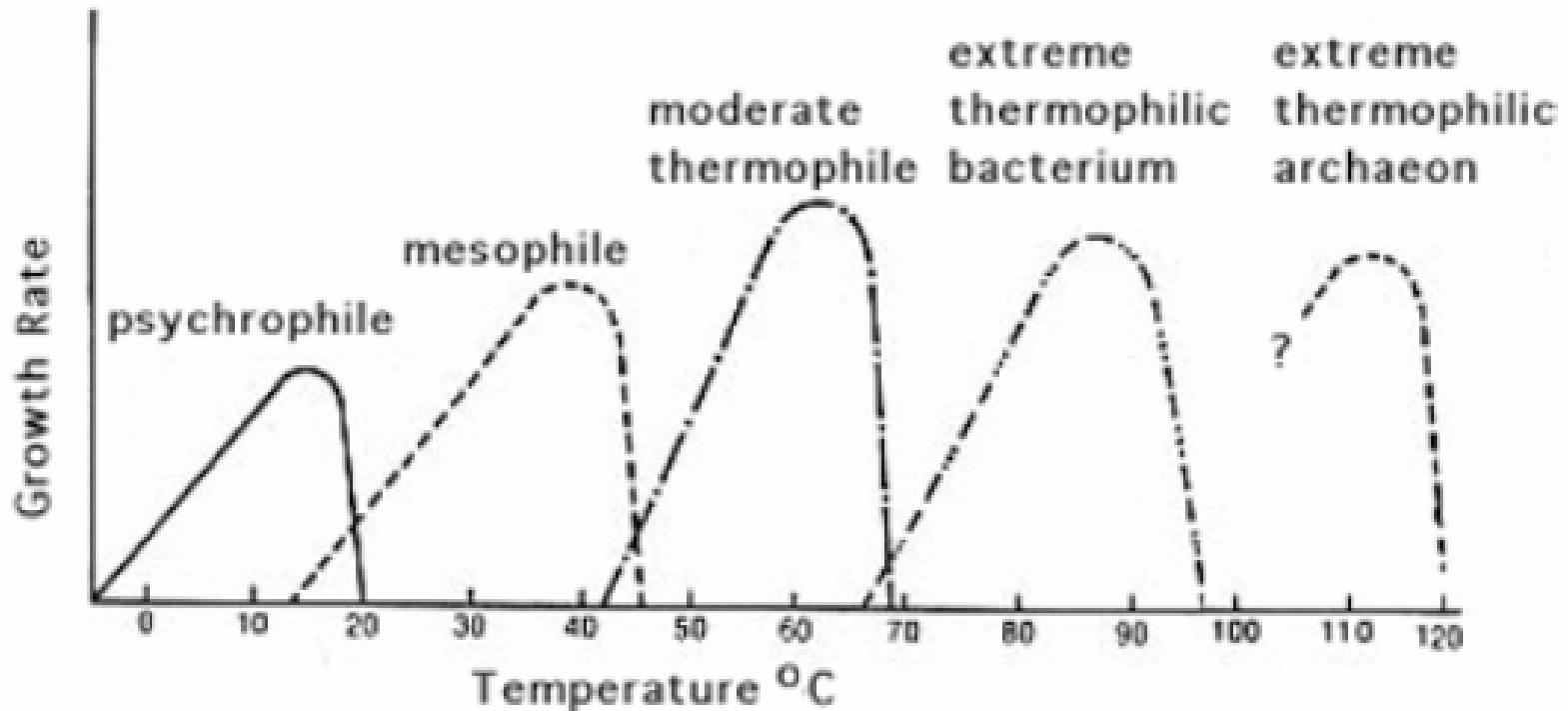
Todar 2004 Online Textbook of Bacteriology

# Typical pH effects data



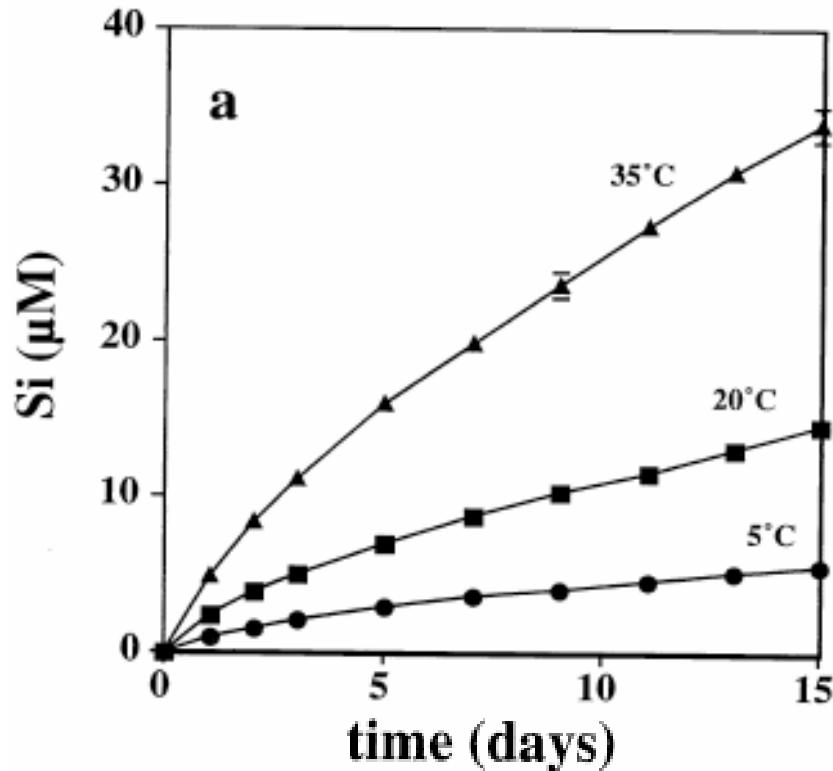
Therion et al. 1982

# Theoretical temperature effects

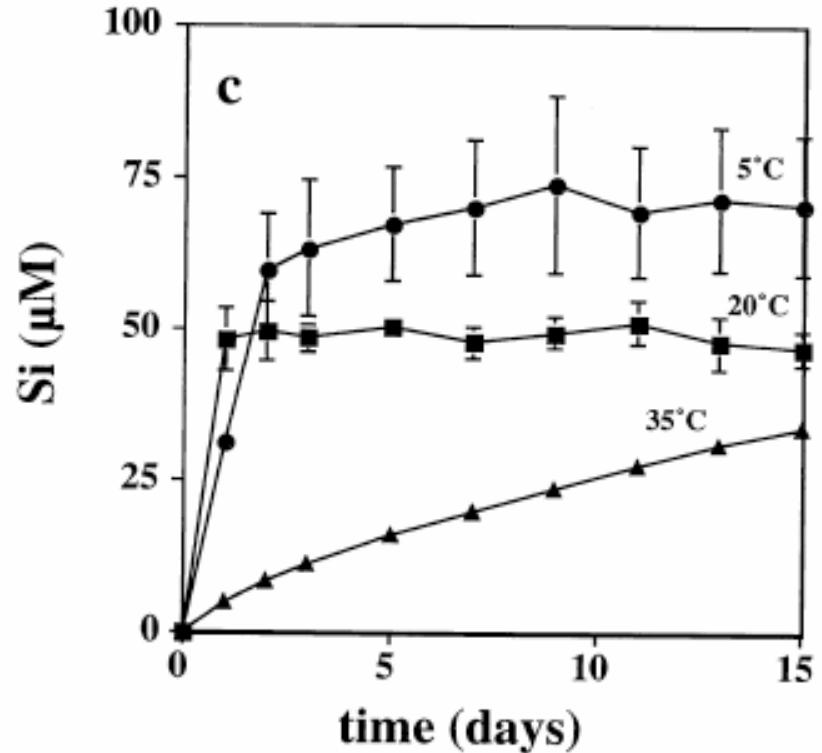


Todar 2004 Online Textbook of Bacteriology

# Typical temperature effects data



*abiotic feldspar dissolution*



*microbially facilitated  
feldspar dissolution*

# Possible kinetic model

$$\frac{d[Mn(II)]}{dt} = k_0[Mn(II)][O_2] + k_1[Mn(II)][MnO_2] + \text{microbial term}$$

Microbial term (heterotrophic, no energy from Mn(II) oxidation)

$$\frac{d[Mn(II)]}{dt} = k_3 \frac{[Mn(II)]}{K_{Mn} + [Mn(II)]} \frac{[O_2]}{K_{O_2} + [O_2]} [X_{Mn}]$$

$$\frac{d[X_{Mn}]}{dt} = k_4 \frac{[S]}{K_S + [S]} \frac{[O_2]}{K_{O_2} + [O_2]} [X_{Mn}]$$

# Summary

*To what extent do bacteria contribute to manganese oxidation in limestone beds?*

*Variable, difficult to establish*

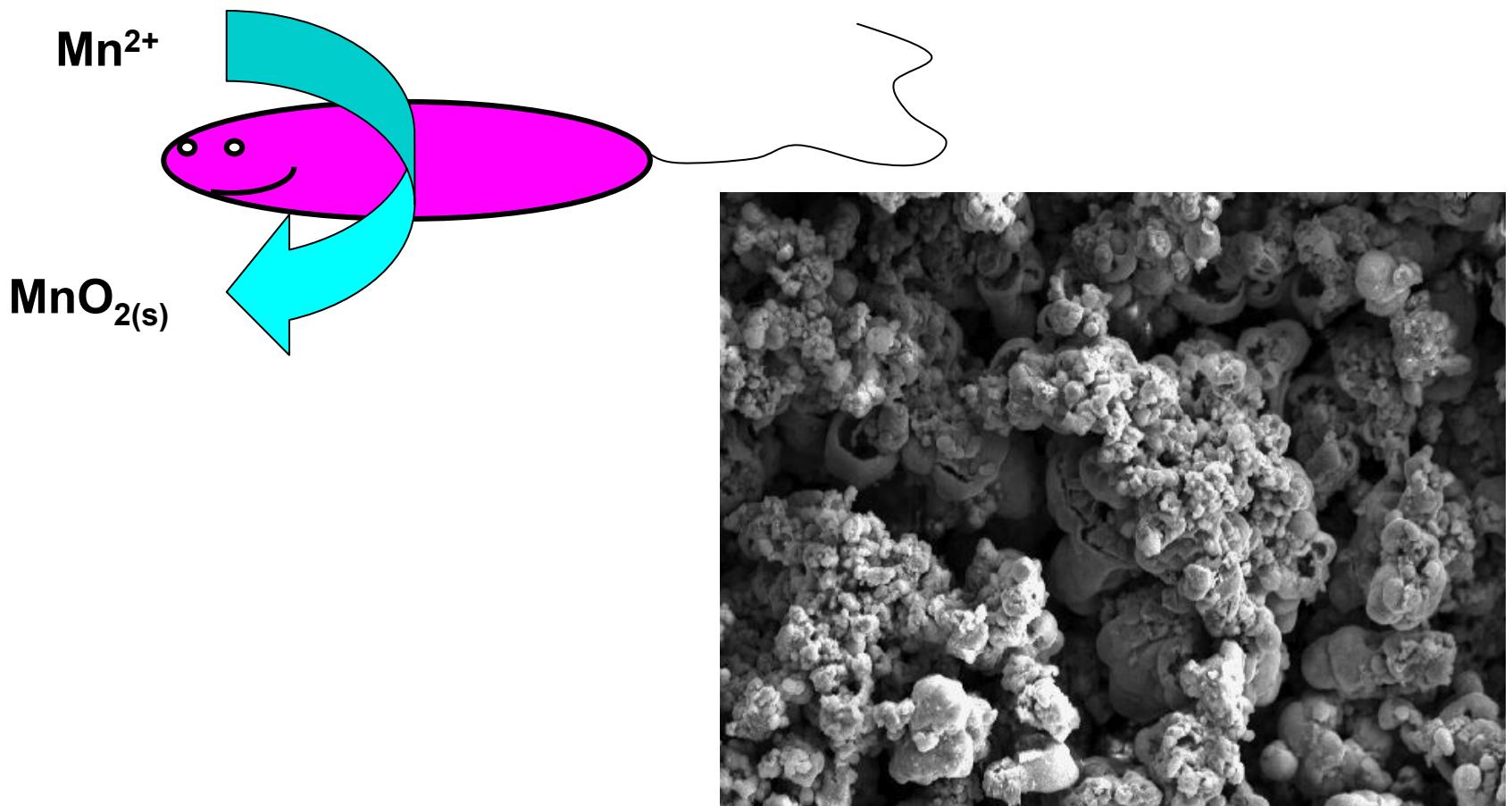
*What are the environmental requirements to promote manganese oxidation in limestone beds?*

*Importance of individual requirements not clear*

*What is an appropriate model for the bacterial component of manganese oxidation?*

*Model proposed for heterotrophic manganese oxidation*

More work is need in understanding  
microbial contribution



# Acknowledgements

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