

Landfarming of Petroleum Contaminated Soils - What Goes Wrong

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What is landfarming?

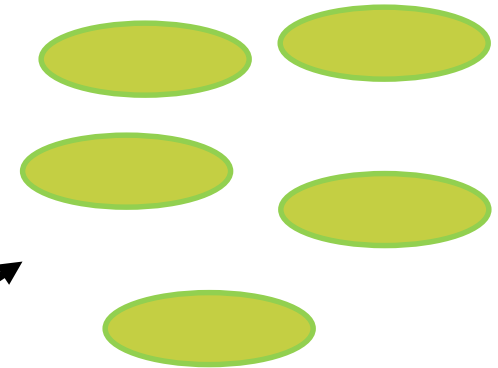
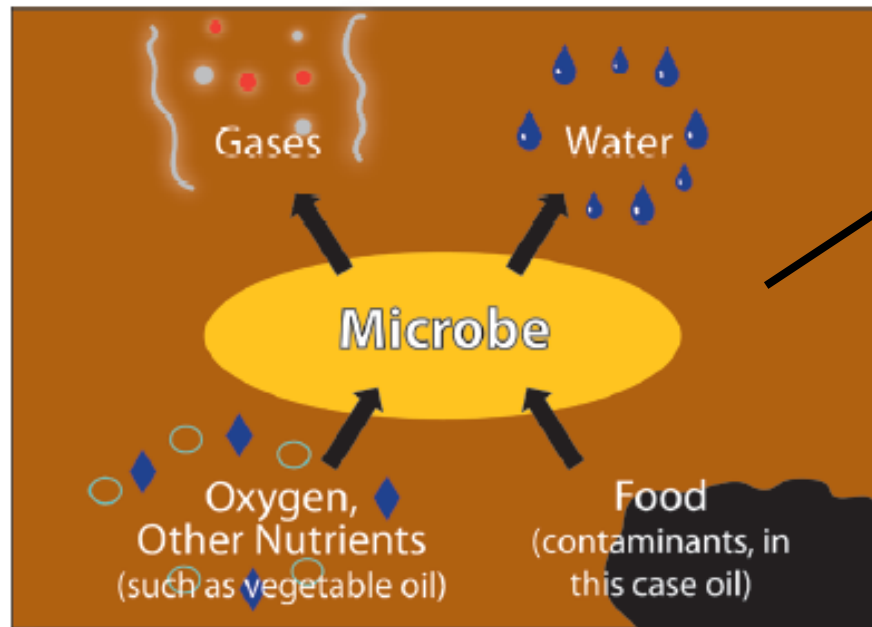
Facilitating the biodegradation of hydrocarbons in a **thin layer of soil** on the surface through

- the addition of soil amendments (N, P, organic matter)
- improving O_2 transfer into the soil
- maintaining proper moisture conditions

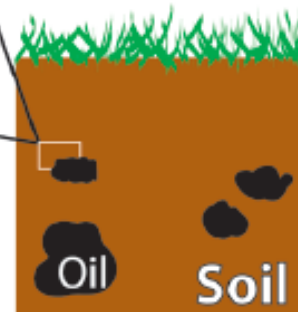
There are two types of landfarms:

- *in situ* - treatment occurs in place at the site of the spill
- *ex situ* - contaminated soil excavated and taken to a location remote from the site of the spill

Biodegradation, it's all about microbes eating hydrocarbons, it's all about growth



Optimizing biodegradation means optimizing growth



http://www.clu-in.org/download/citizens/a_citizens_guide_to_bioremediation.pdf

How do we optimize growth of hydrocarbon-degrading microbes?

- Getting the microbes together with the hydrocarbon
- Making sure the microbes have enough of the right nutrients
- Getting oxygen to the microbes
- Optimizing environmental conditions (to the extent we can)
- Moisture! Moisture! Moisture!

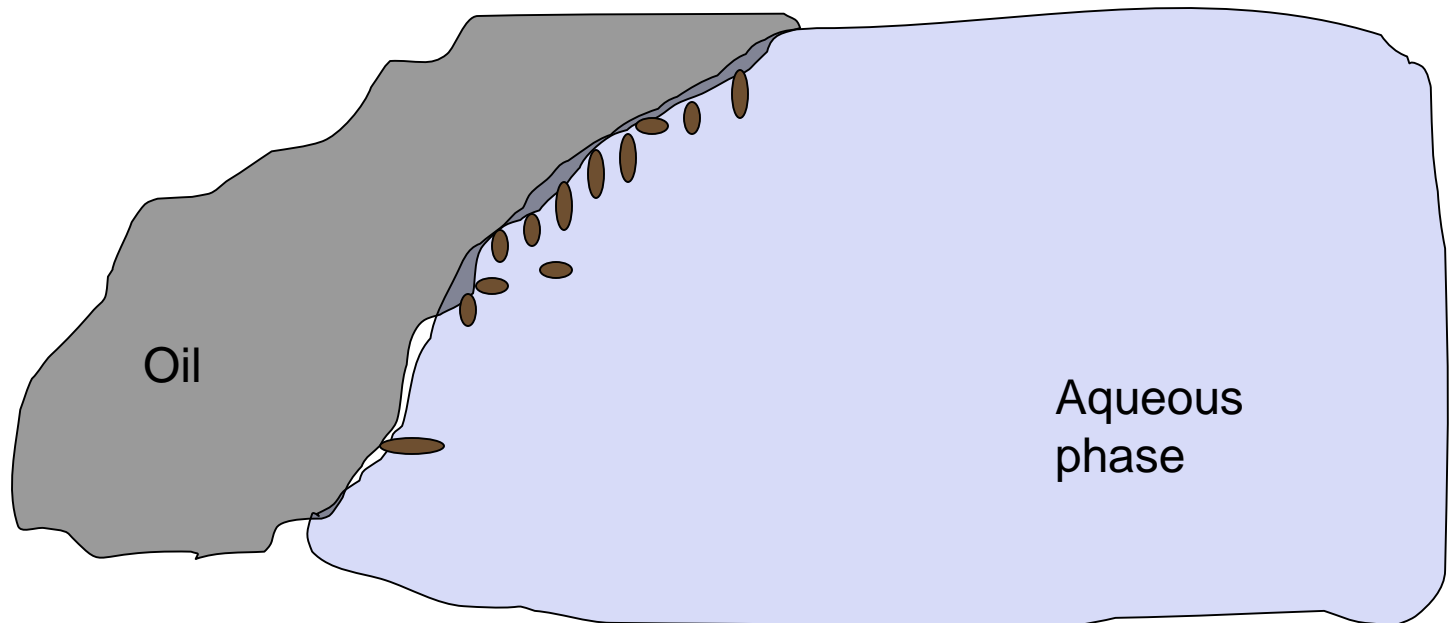
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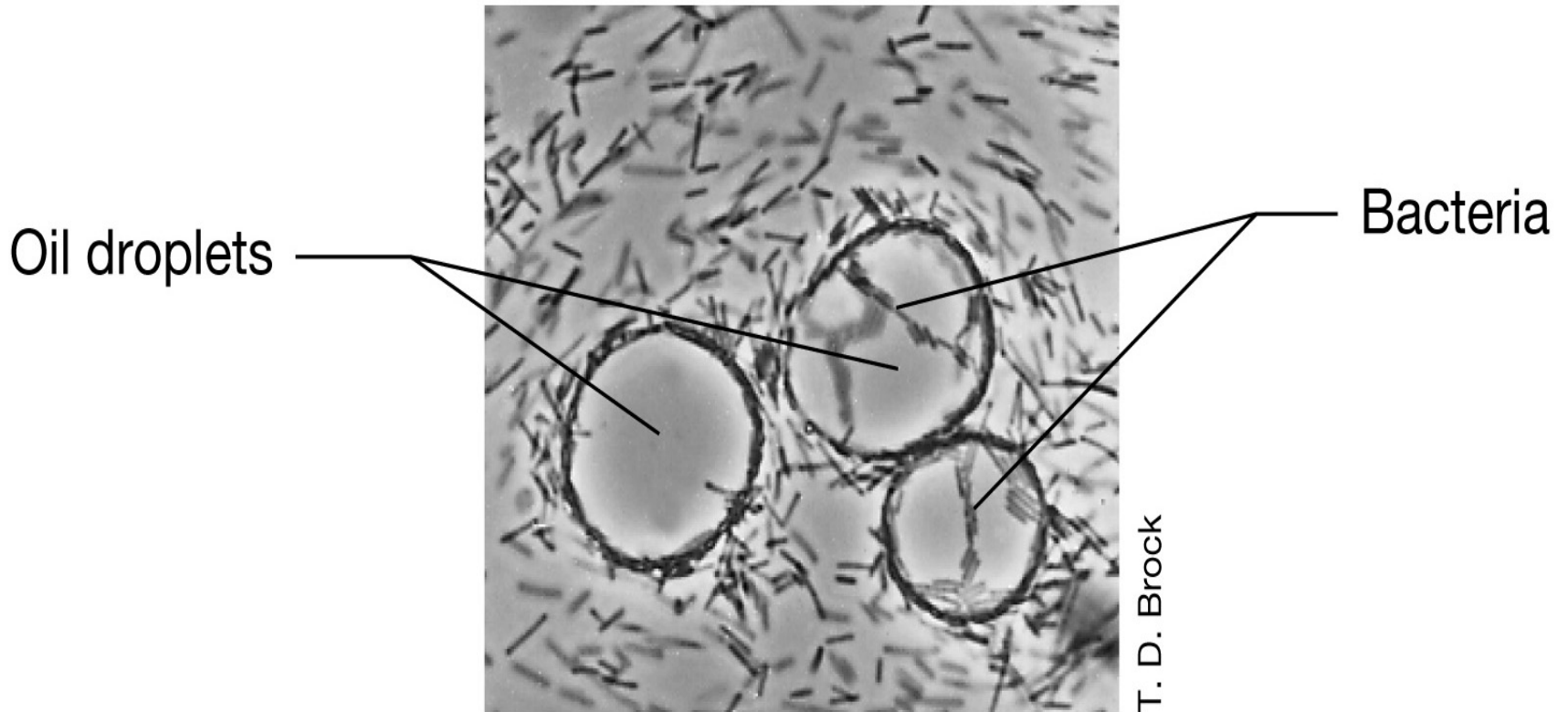
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Bioavailability of petroleum hydrocarbons

Most important mechanism

- Direct contact of microorganisms with a bulk liquid hydrocarbon phase (interfacial contact)
 - Disperse hydrocarbon in soil to create interface between hydrocarbon and soil moisture

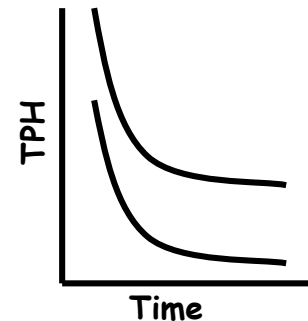




Droplets of mineral oil in a culture of hydrocarbon degrading bacteria

Higher initial hydrocarbon concentrations are associated with lower rates biodegradation rates and higher TPH concentrations at the bioremediation endpoint

- Hydrophobicity at high TPH
 - Soil aggregates do not water wet robbing microbes of moisture and transport of nutrients into the aggregates
- Clogging of macropores limiting oxygen penetration
- No more than 4-6% TPH loading



Dilution not possible?

May require ISCO after reaching bioremediation endpoint to meet treatment goals

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Elemental composition of a microorganism

Element	% of dry weight
Carbon	50
Oxygen	20
Nitrogen (N)	14
Hydrogen	8
Phosphorus (P)	3
Sulfur	1
Potassium	1
Magnesium	0.5
Calcium	0.5
Iron	0.5
Misc Inorganic	1.5

Notice that there is a big requirement for N and P!

You are what you eat, so bugs that eat hydrocarbons must also eat lots of N and P in order to grow

SPEEDBUMP



You can have too much of a good thing!

Safe fertilizer additions - based on data from literature*

Water content (%)	lbs N/1000 ft ²
5	1.8
10	3.4
15	5.0
20	6.3

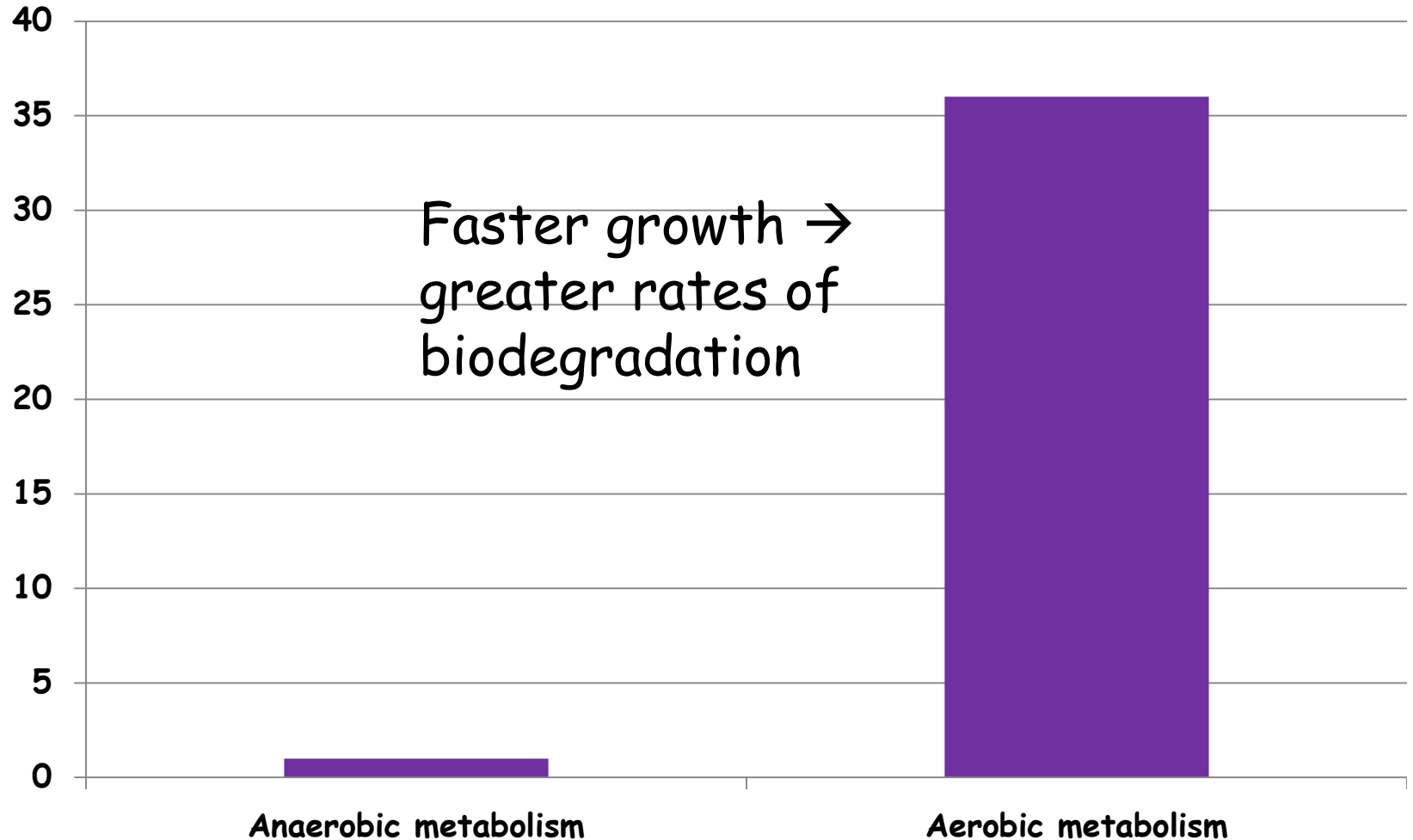
Add fertilizer in increments; monitor N,P concentrations

*Walworth, J.L., C.R. Woolard, J.F. Braddock, and C.M. Reynolds, J. Soil Contamination, 6: 465-480 (1997)

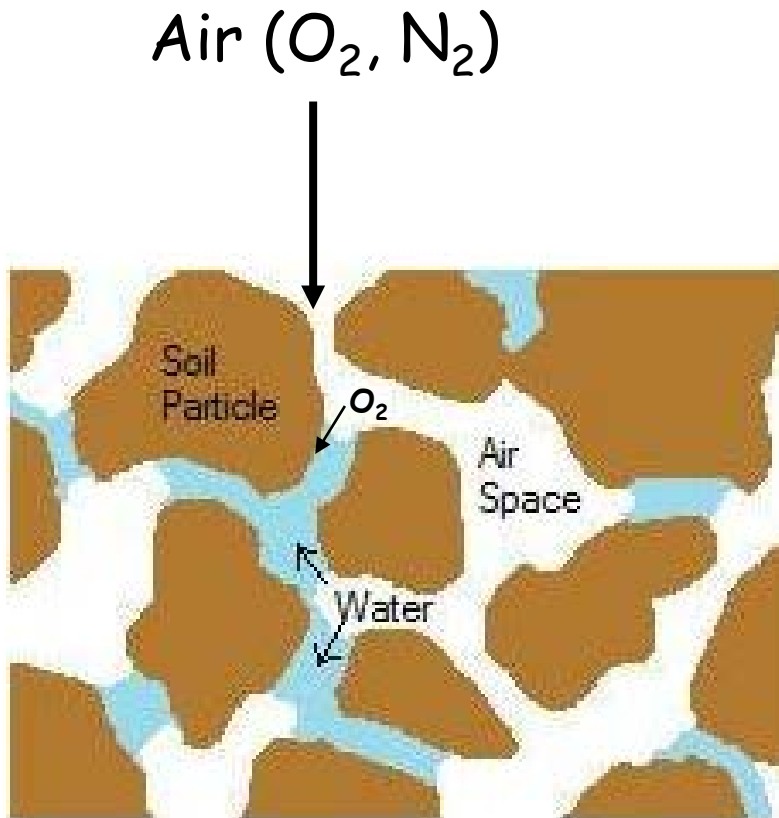
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Relative energy production in anaerobic and aerobic metabolism of hydrocarbons



Getting oxygen to the microbes



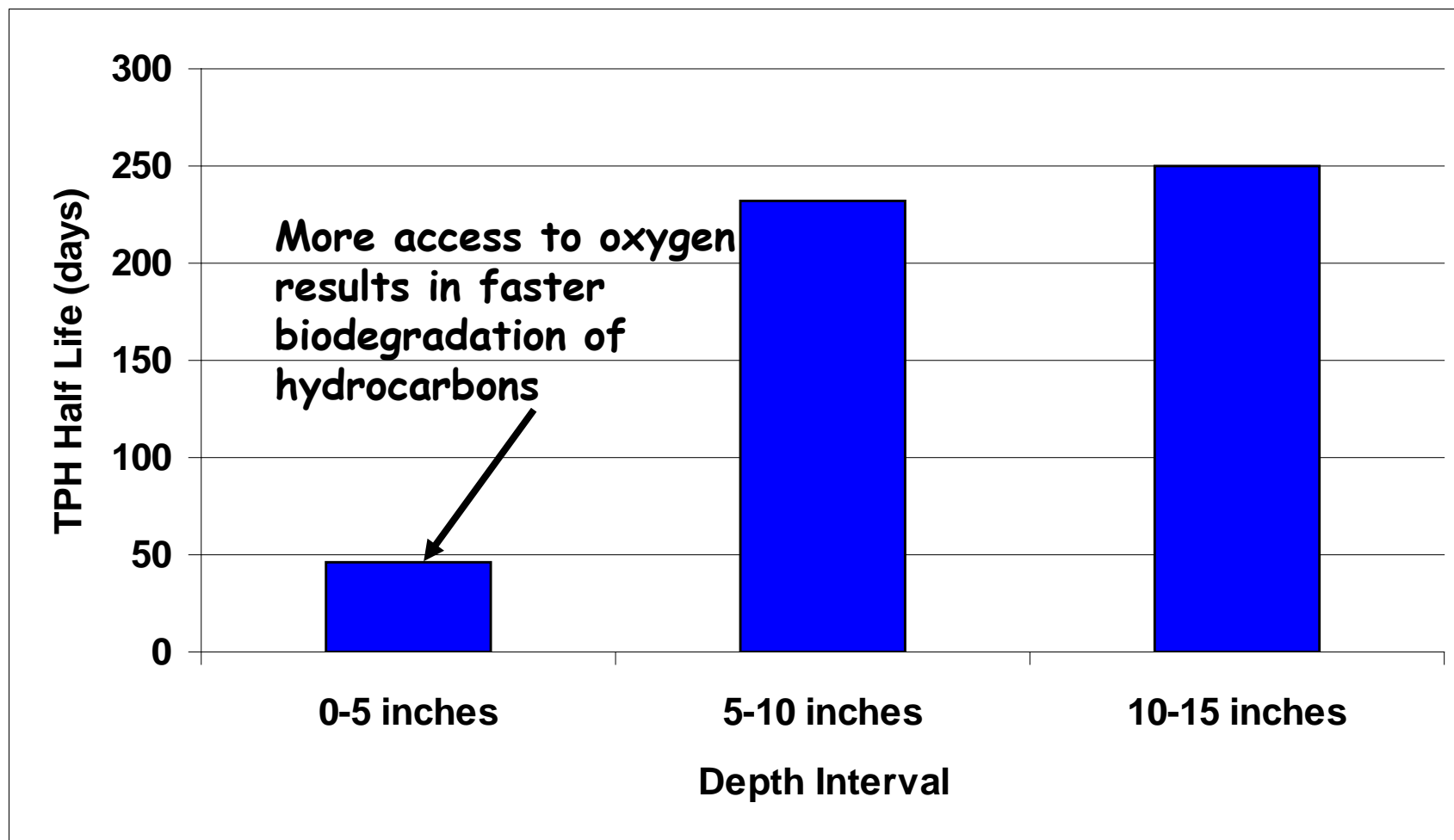
The solubility of O_2 in water at 80 °F is only about 8 mg/L (ppm).

The rate of transfer of a gas into water is proportional to the solubility of that gas in water

Rate of oxygen transfer into soil often limits rate of bioremediation

Biodegradation of diesel hydrocarbons in soil

Zytner, R.G., A Salb, T.R. Brook, M. Leunissen, and W.H. Stiver, Can. J. Civil. Eng., 28, 131-140 (2001)

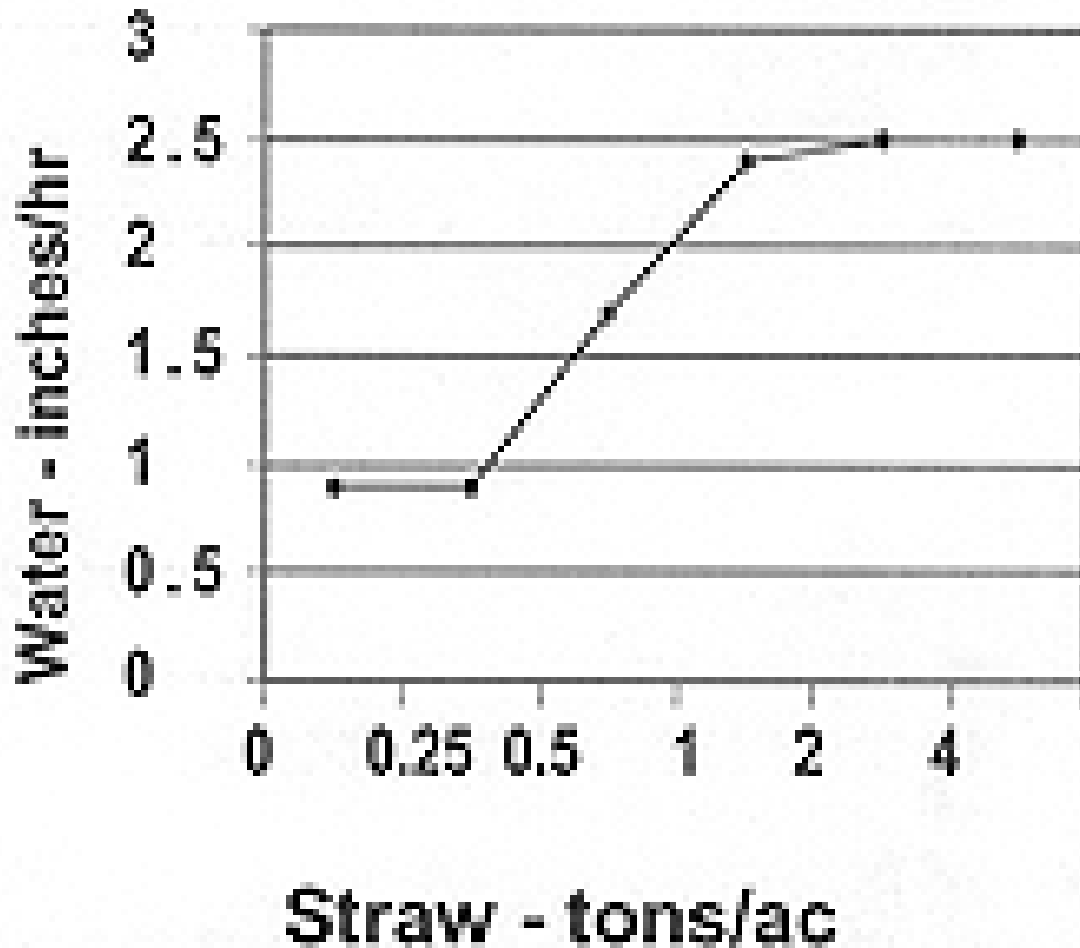


Recommended practice for landfarms

Increasing oxygen transfer into soil

- Organic matter
 - Blending organic matter into landfarm soil has several benefits including:
 - Aeration of the soil environment
 - Improved moisture retention
 - For every 1% of soil organic matter, the soil can hold 16,000 gallons of plant-available water per acre of soil down to one foot deep
 - Improved soil structure
 - Establishing a fertility base to improve re-vegetation upon closure

Effect of organic matter on infiltration rate



Water infiltration rates and oxygen penetration rates correlate

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Increasing oxygen transfer into soil

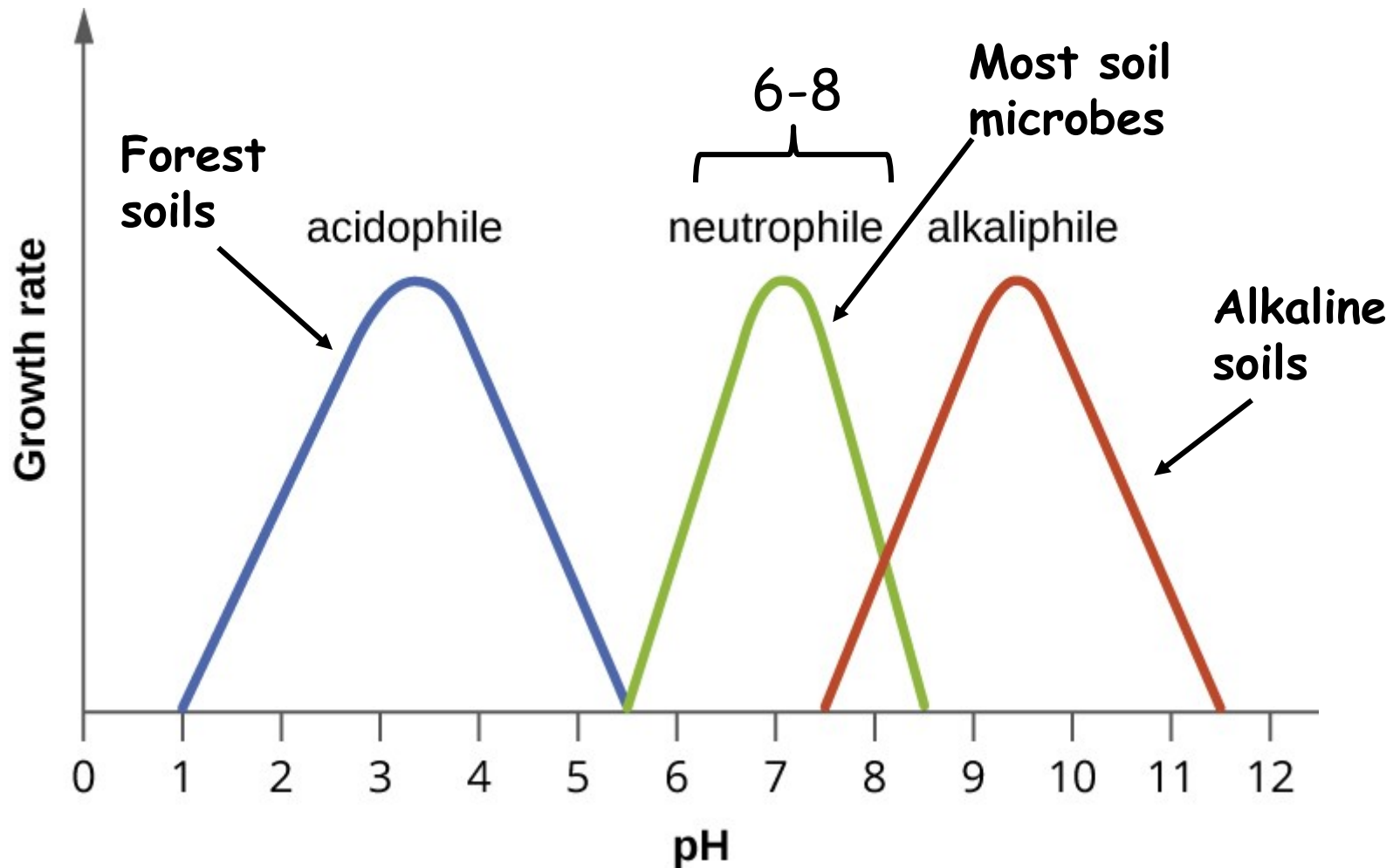
- Loosening the soil: cultivation
 - The benefits of cultivation of the landfarm include:
 - Maintaining a soil structure in the landfarm conducive to good oxygen transfer from the atmosphere
 - Vertical mixing of the soil ensures that the entire soil depth spends some time in the upper most active zone of biodegradation
 - More uniform distribution of nutrients in the soil profile
 - Overcome surface crusting



How do we optimize growth of hydrocarbon-degrading microbes?

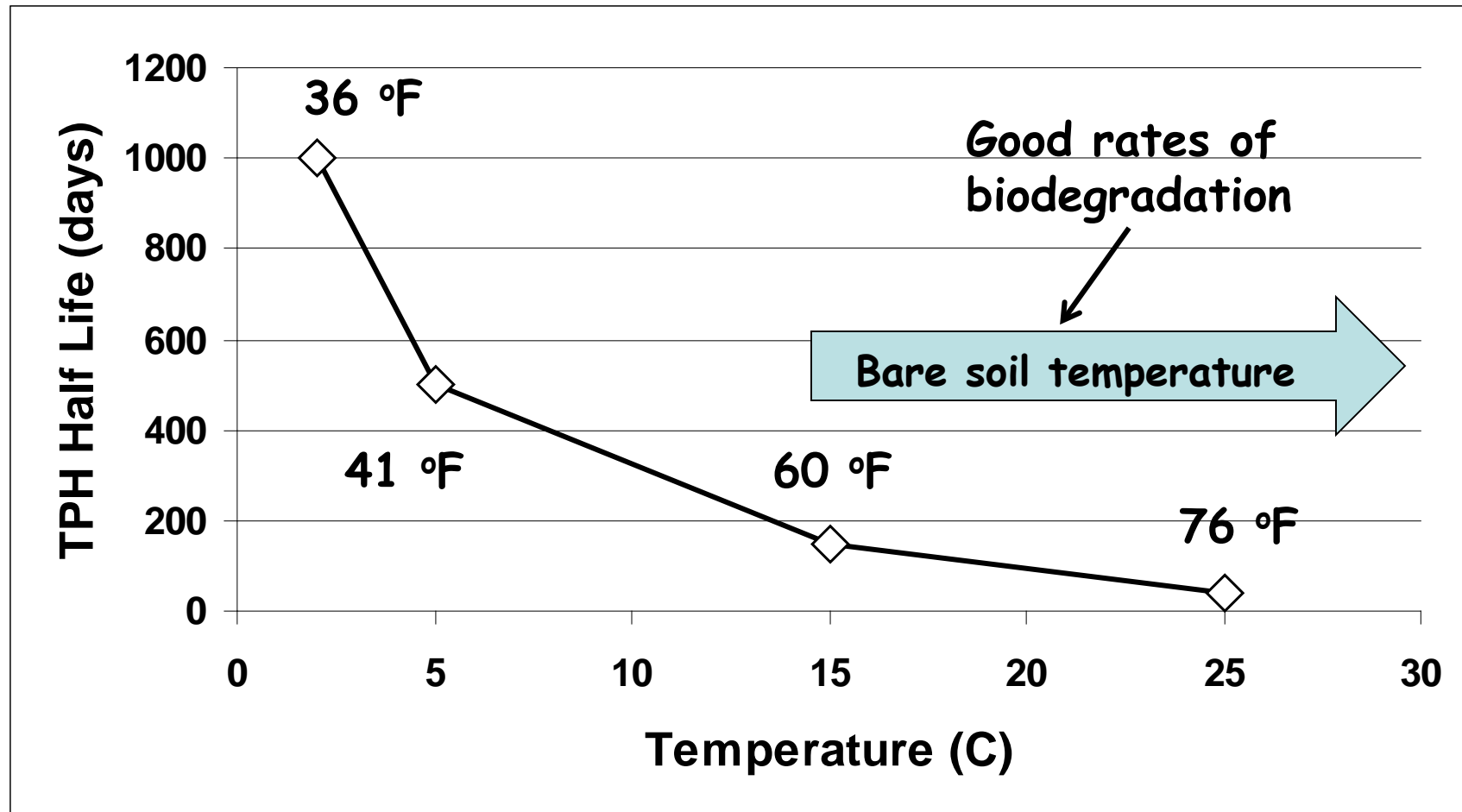
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Effect of environmental conditions on microbial growth - pH



Biodegradation rates of diesel hydrocarbons increase with temperature

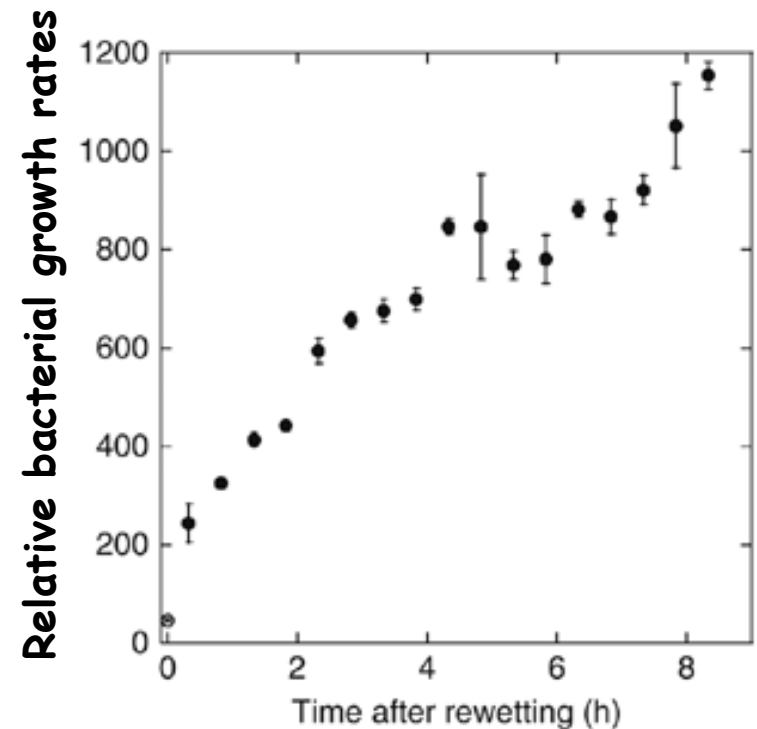
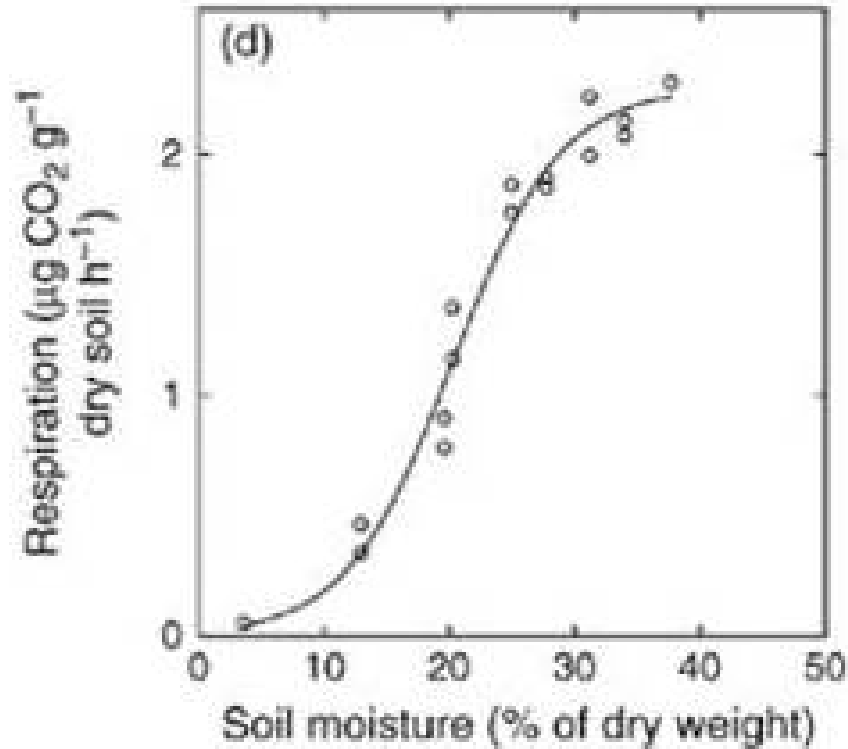
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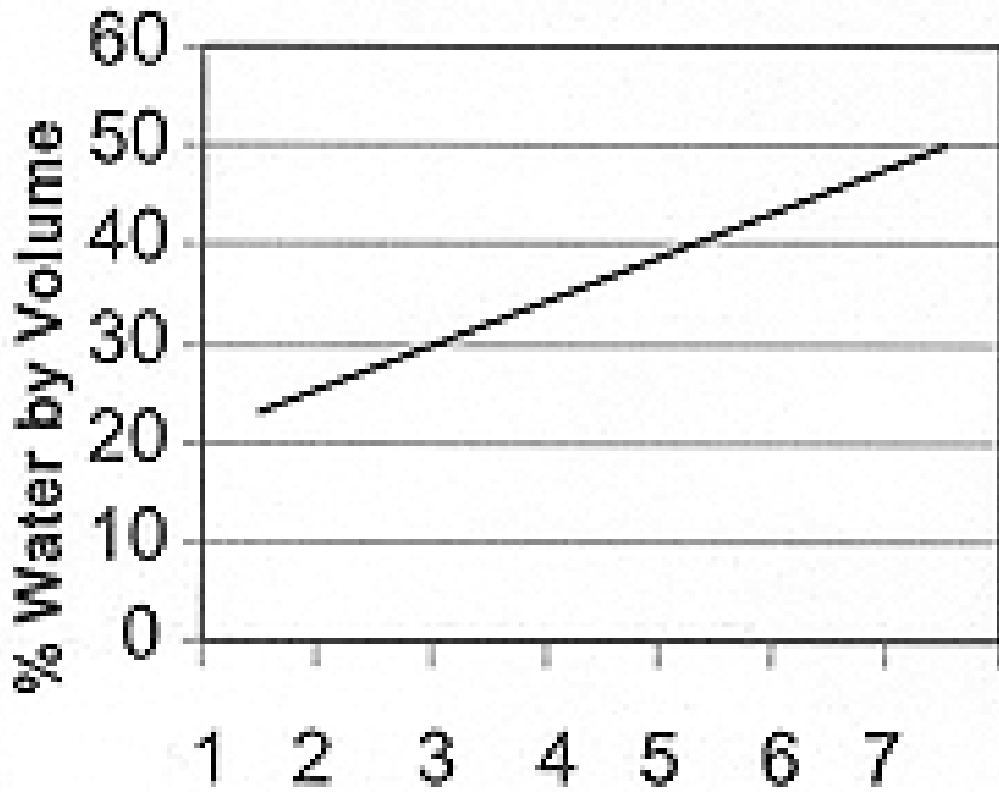


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Effect of soil moisture on growth of bacteria in soil



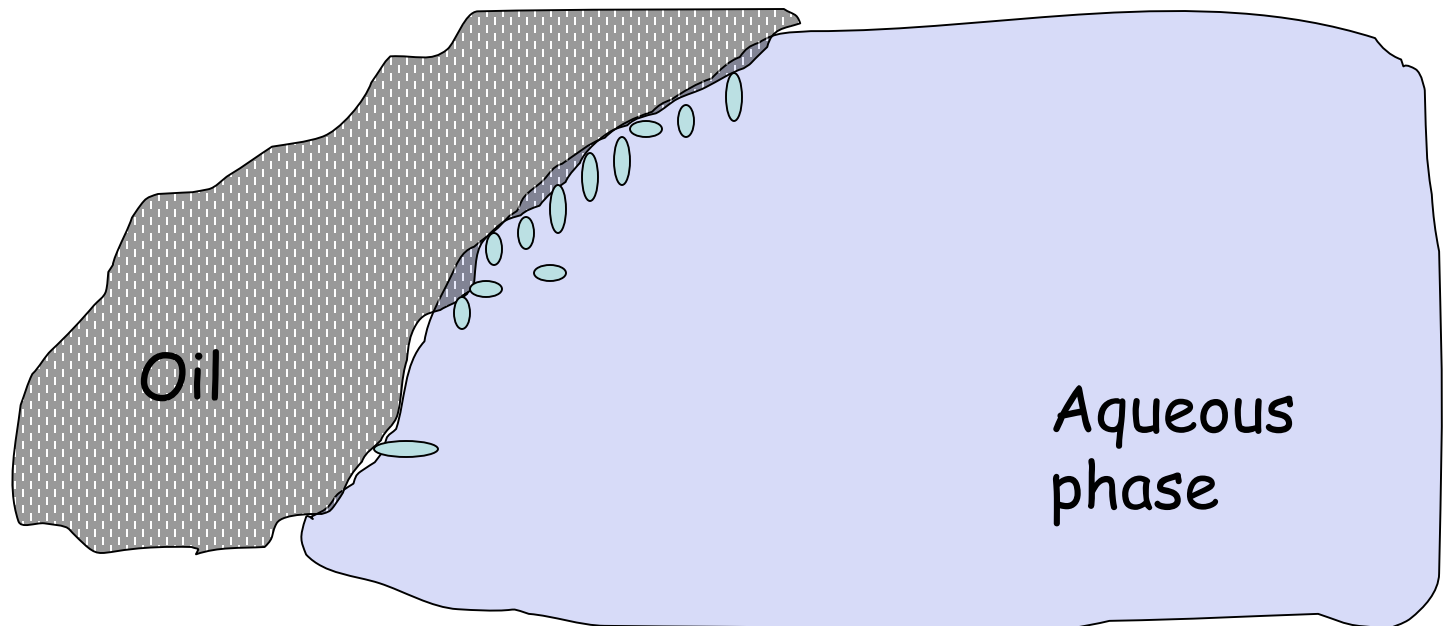


Percent Organic Matter by Weight

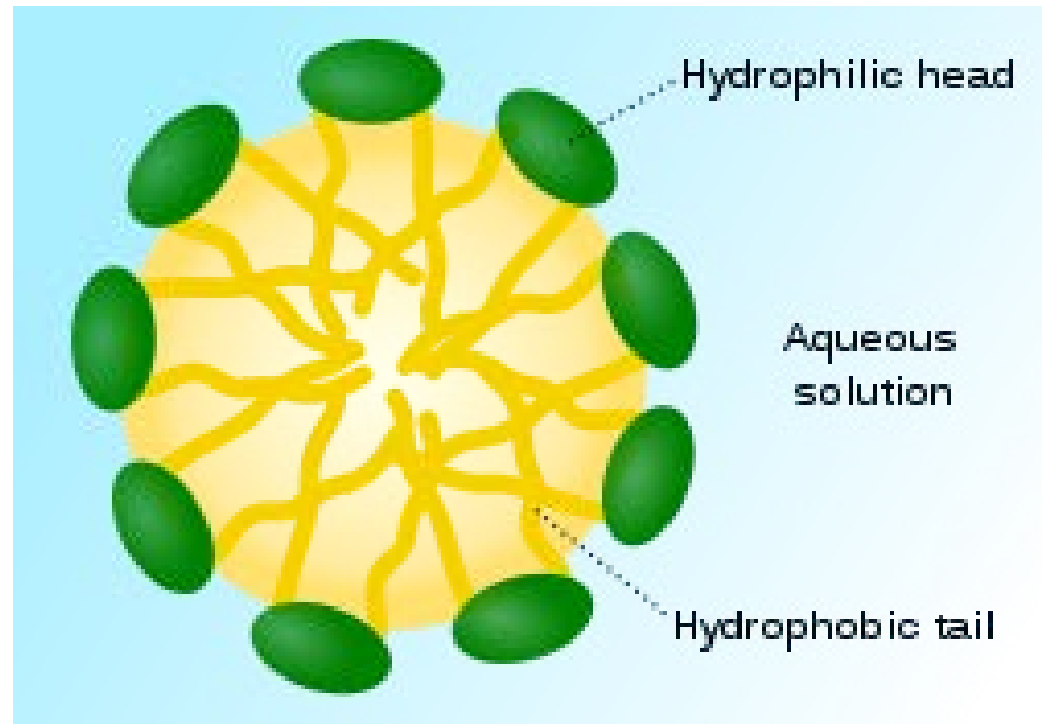
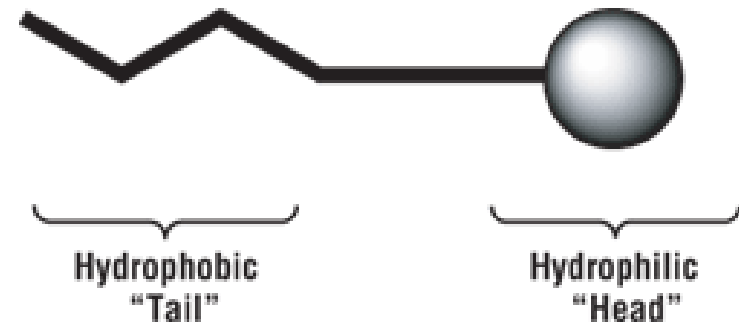
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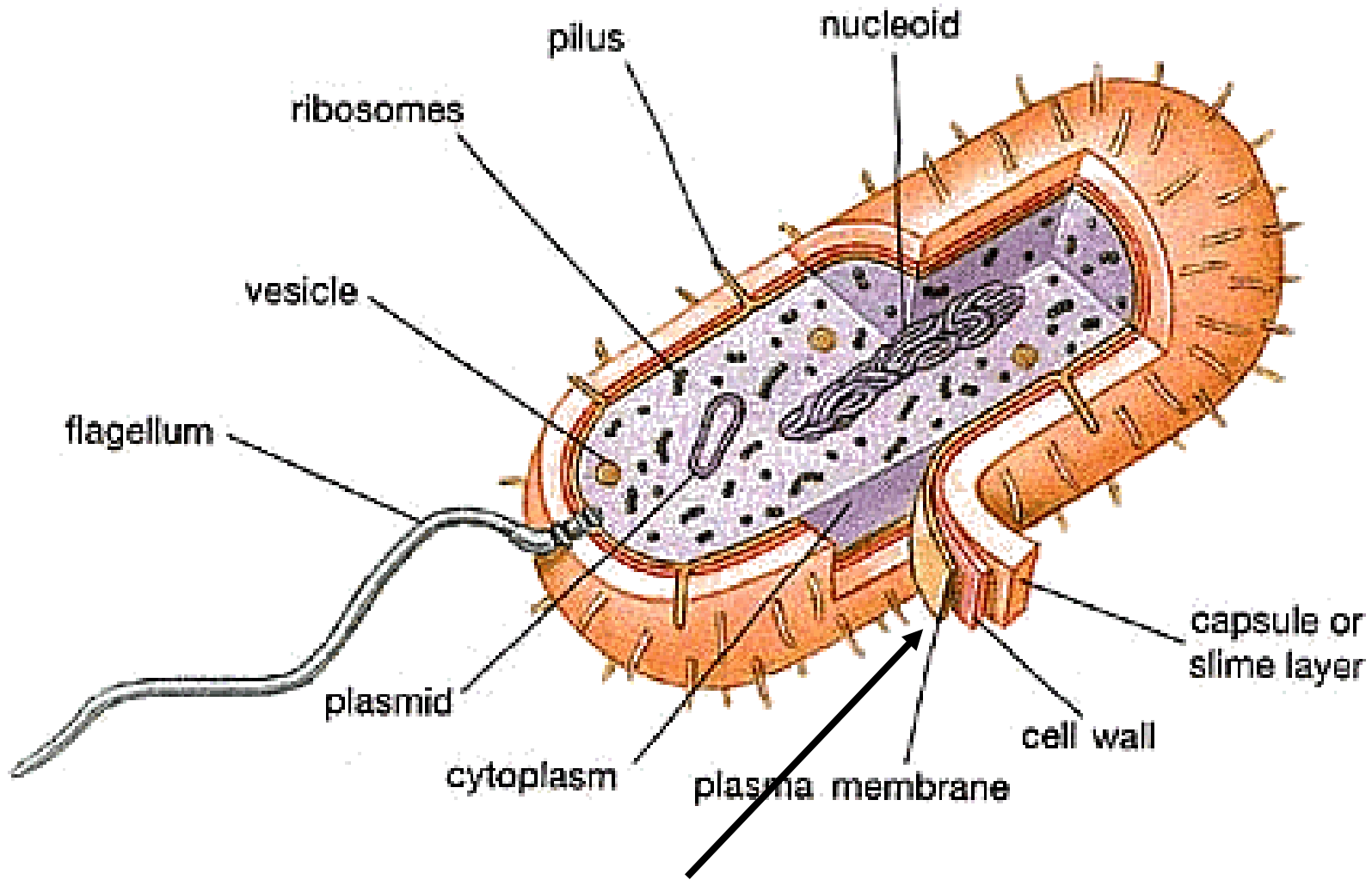
Evaporation is not your friend

- Solid phase hydrocarbons biodegrade at less than $1/10^{\text{th}}$ the rate of a liquid
- Loss of volatiles reduces the solubility of heavier hydrocarbons
- High rates of biodegradation and organic matter limit evaporation



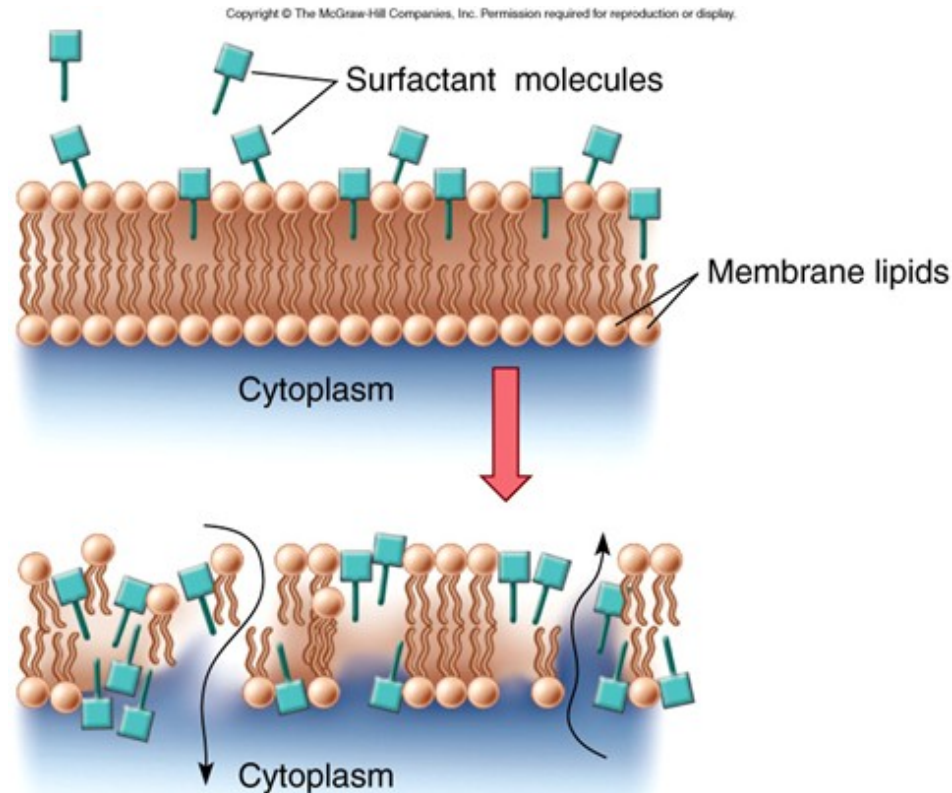
Be careful with soaps





The gateway to the cell

Cell membranes can be disrupted by detergents and surfactants



Surfactants and detergents can make membranes leaky

Any Questions?



**SCENIC
TURNOUT
AHEAD**

