Transport and deposition of bacterial plant pathogens: Some considerations from a biological and microbial ecology perspective.

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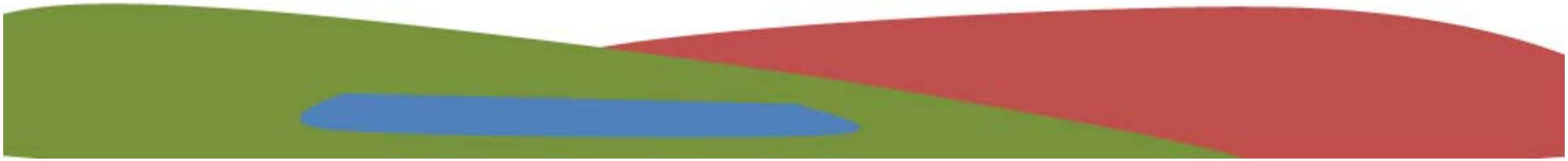


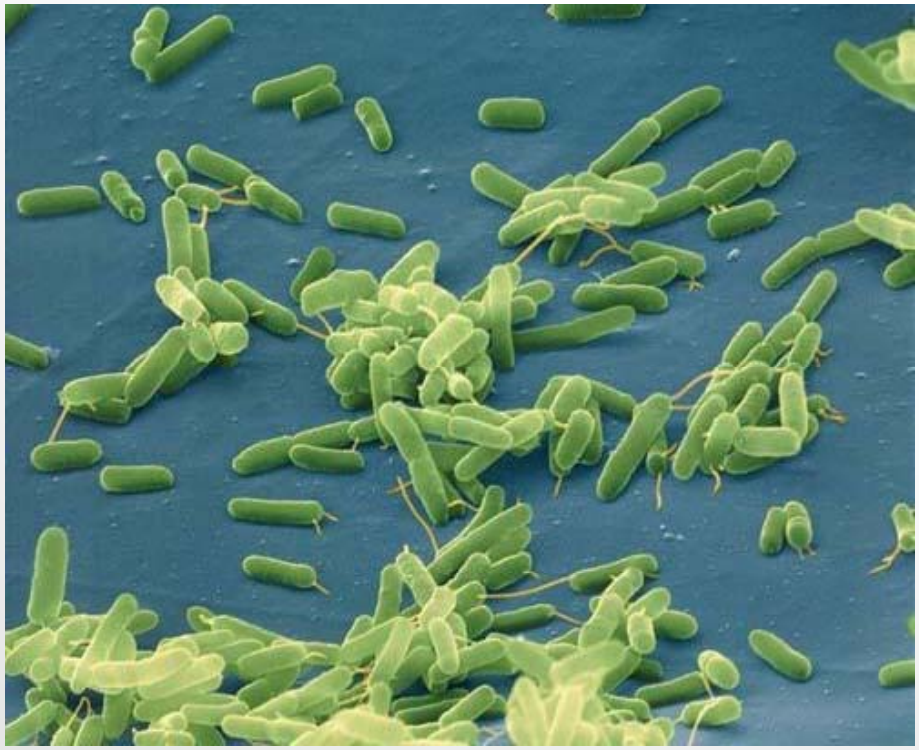
Laying the groundwork

- The perspective of a plant disease epidemiologist
- Focus on bacteria
- Explore how the biology and ecology of microbes interact with the BBL and PBL
- Bring is back to several plant pathogens and the implications of new insights

Epidemiology of bacterial plant disease spread

- With a few notable exceptions, the long-distance spread of bacteria diseases has been overlooked
- Transport process assumed to be largely passive
- Pathogens assumed to be metabolically inactive during transport
- IN, CCN by bacteria – well known; not understood
- Hints of bigger things – early descriptions of a bigger role for bacteria in the atmosphere

Does being at the bottom of the evolutionary chain automatically mean you are dumb?



Pseudomonas aeruginosa

http://www.sciencemusings.com/blog/2005/10/talking-bacteria.html

Two microbial traits worth considering…

- Biofilms
  - A structured community of microorganisms encapsulated within a self-developed polymeric matrix
  - Characterized by surface attachment, structural heterogeneity, genetic diversity, complex community interactions
- Quorum sensing
  - A type of decision-making process used by decentralized groups to coordinate behavior
  - In bacteria, coordinated gene expression according to the local density of their population

Biofilms are everywhere…

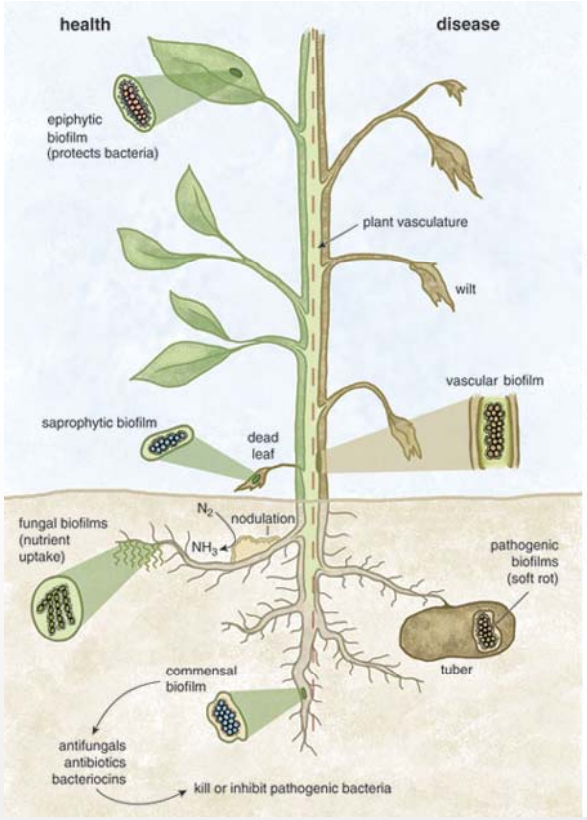
On our teeth

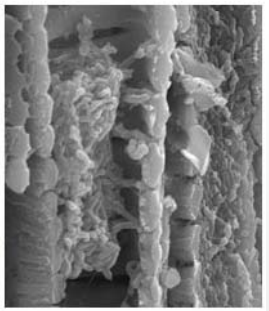
http://www.delftoutlook.tudelft.nl/info/indexe0ee.html?hoofdstuk=Article&ArtID=511

In our pipes

www.pall.com/corporate_42572.asp

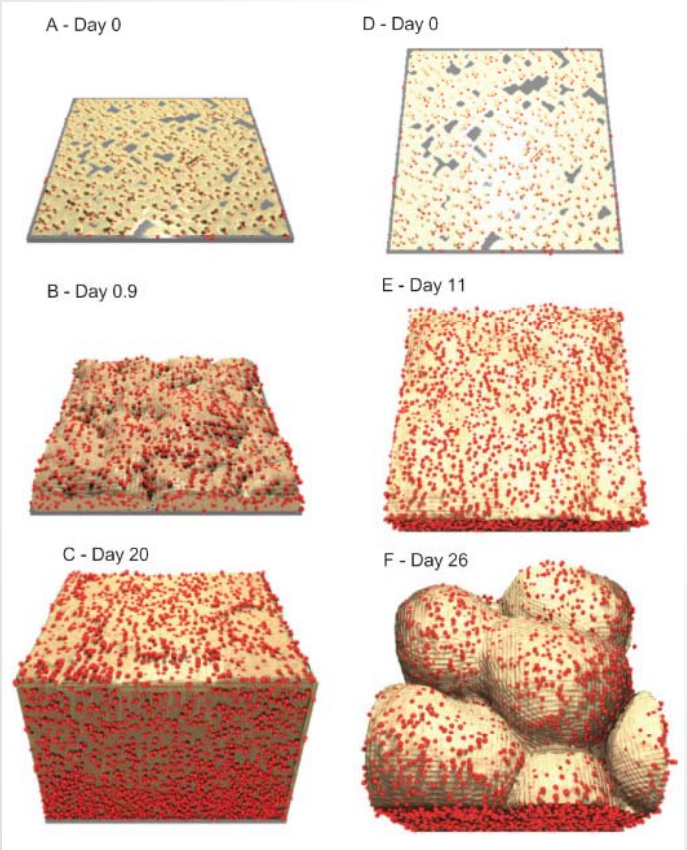
In and on our plants





http://www.americanscientist.org/issues/num2/biofilms/2

Biofilms respond to their environment

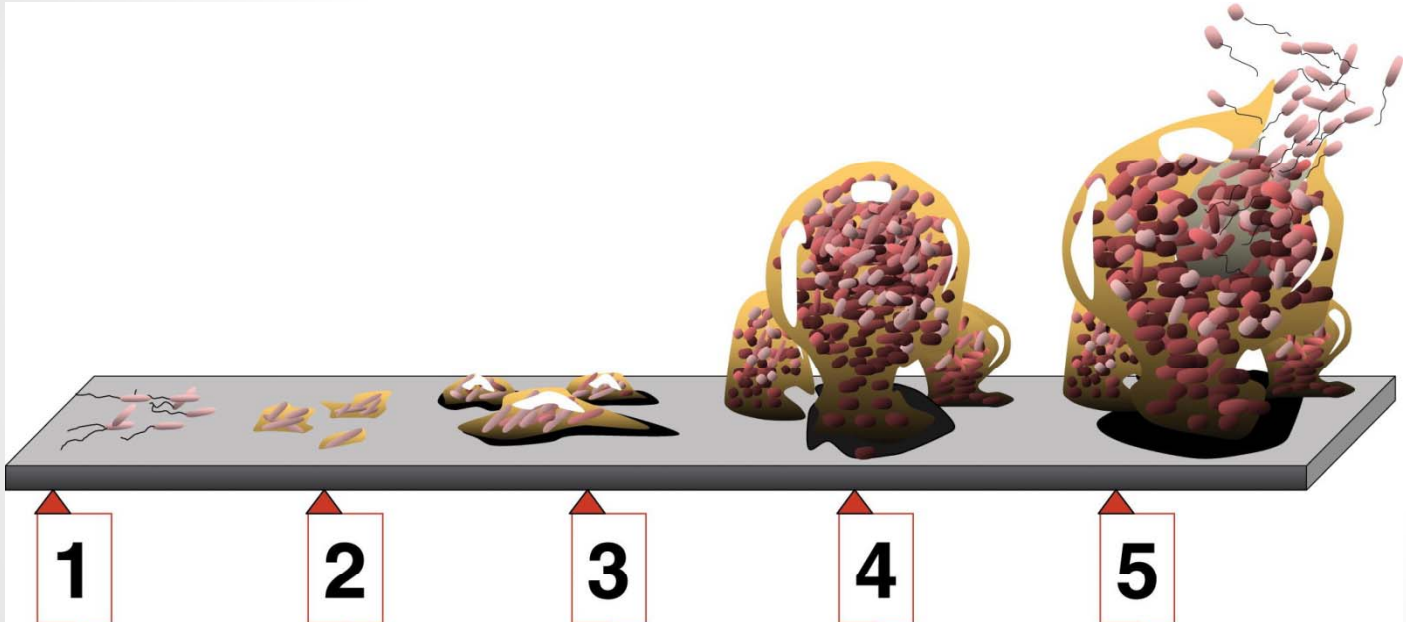


Oxygen-rich Oxygen-poor

- Nutrients
- Water
- Temperature
- Toxins
- Competition
- Internal stresses

Alpkvist, , Biotech Bioengr. 94:961

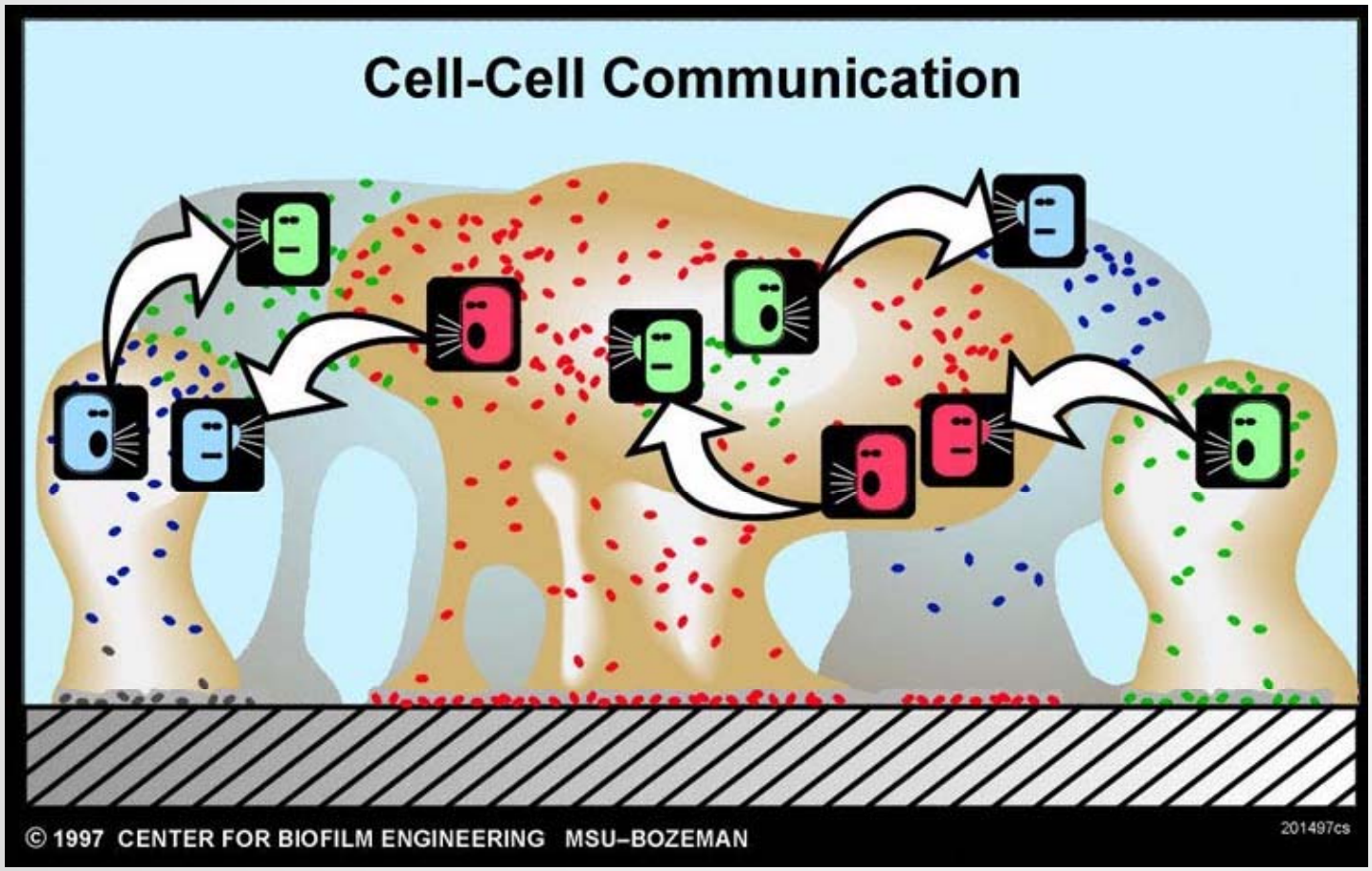
Five stages of biofilm development



Stage 1, initial attachment; Stage 2, irreversible attachment; Stage 3, maturation I; Stage 4, maturation II; Stage 5, dispersion.

Monroe, PLoS Biology 5:e307

Biofilms can be heterogeneous communities, and they communicate



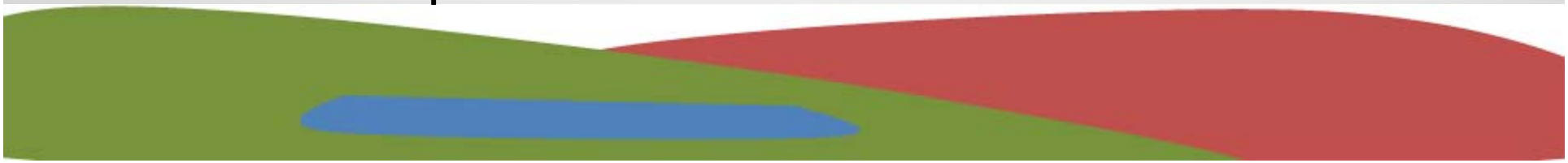
Quorum Sensing

More on quorum sensing

- Small molecular compounds (e.g., N-acyl-homoserine lactones [AHLs])
- Can activate up to 50% of the bacterial proteome
- Results can be physiological, phenotypical, protective, initiative (infection, dispersal, etc.)
- Communication an be intra-species, inter-species, prokaryotes and eukaryotes.
- Defense mechanisms disrupt or otherwise disable the communication signal.

Having shown bacteria are not so dumb, how does this affect dispersal?

- Known facts
  - Bacteria are known bioaerosols
  - Bacteria can move long distances
  - Bacteria respond to their environment – biofilms, QS
- Unknown or little-known
  - Do bacteria influence the aerosol environment?
  - Are biofilms present in aerosols?
  - Is quorum sensing active in aerosols?
  - If the above has some truth, how do these facts affect dispersal?

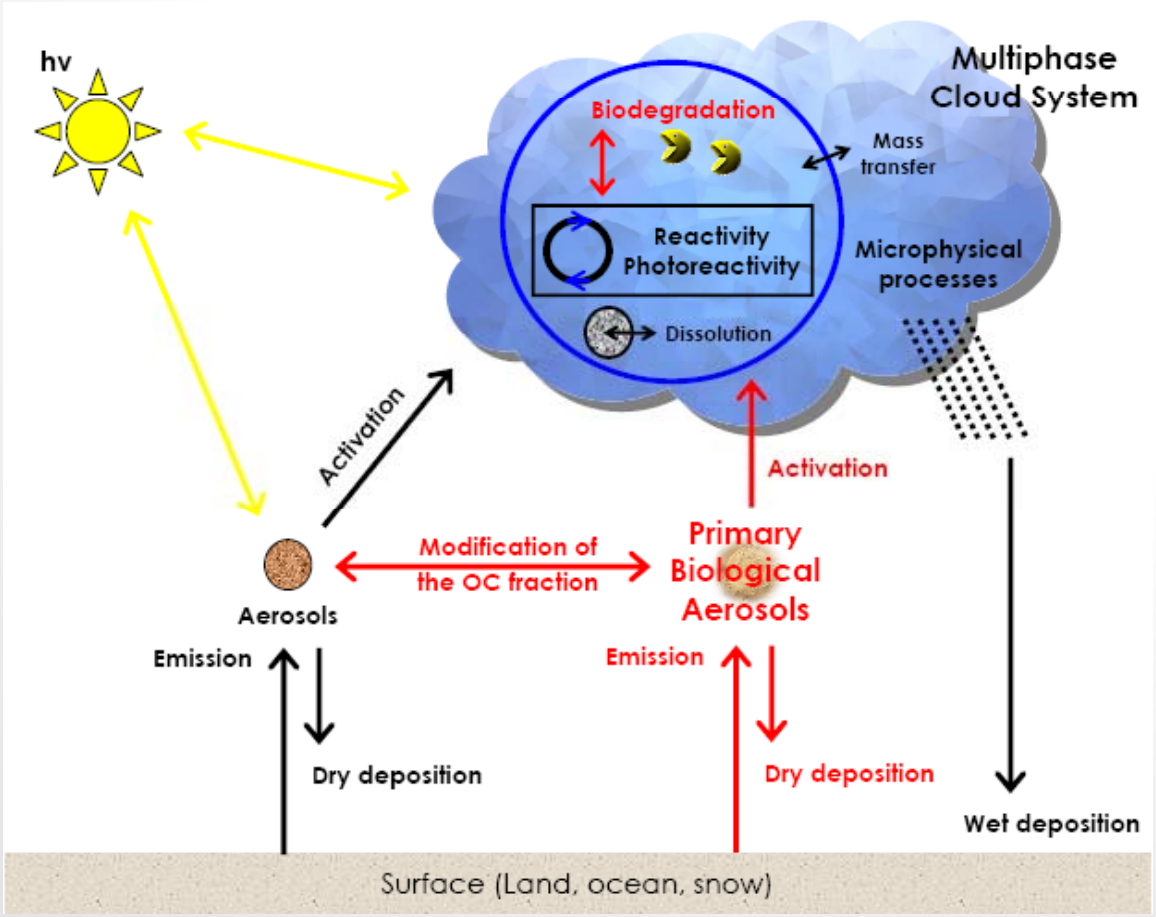


Do bacteria influence the aerosol environment?

Yes, but there is much to learn

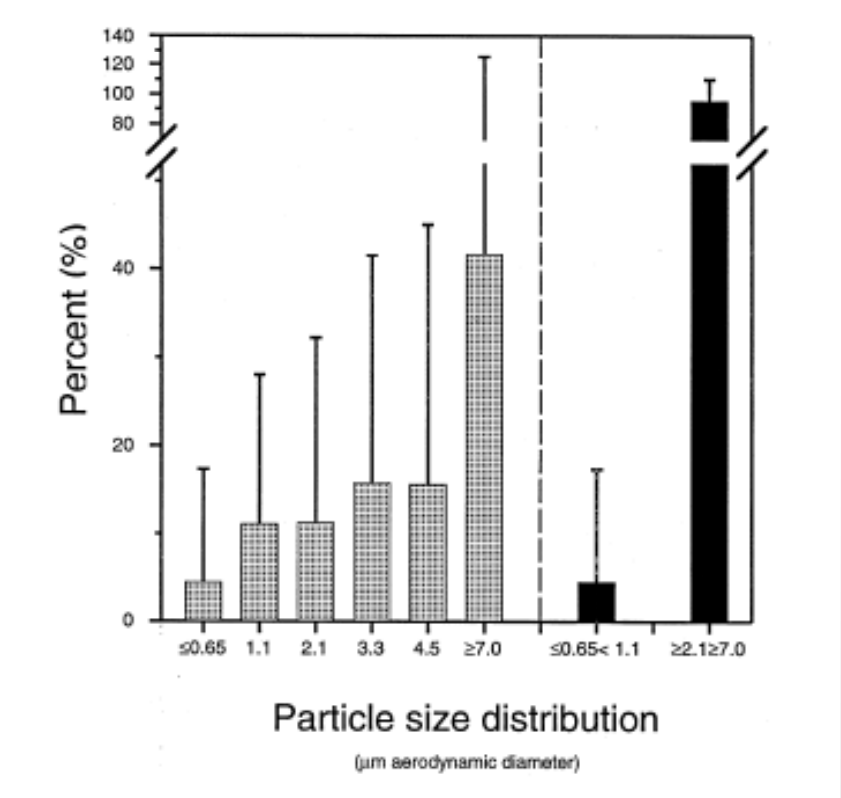
- Absorb water vapor below saturation (CCN)
- Then becomes giant CCN
- Serves as IN as high as -2°C
- Utilizes organic volatiles (e.g., dicarboxylic acids)
- Compete with photochemistry in liquid aerosols (e.g. Fe complexing by bacteria)
- Interacts with nitrogen and sulfur in the atmosphere

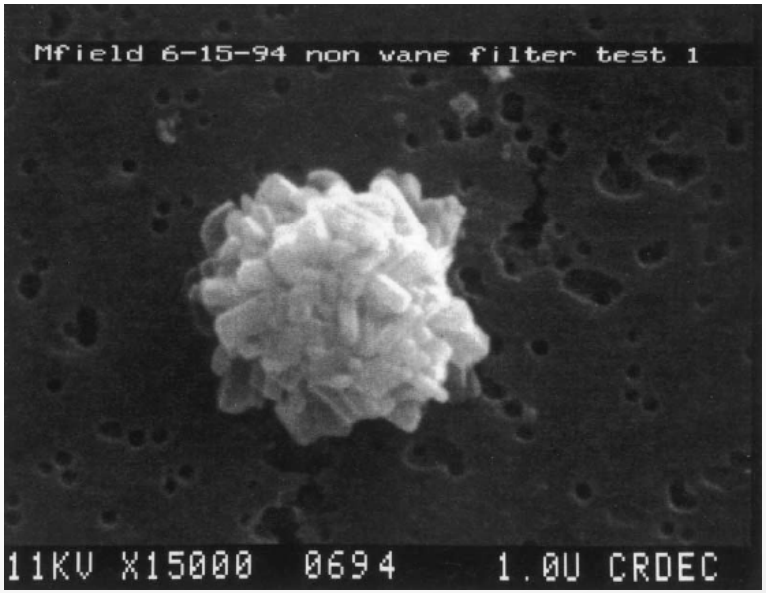
Effect of biological aerosols on atmospheric chemistry



Deguillaume et al. Biogeosciences 5: 1073

Are biofilms present in aerosols? Yes





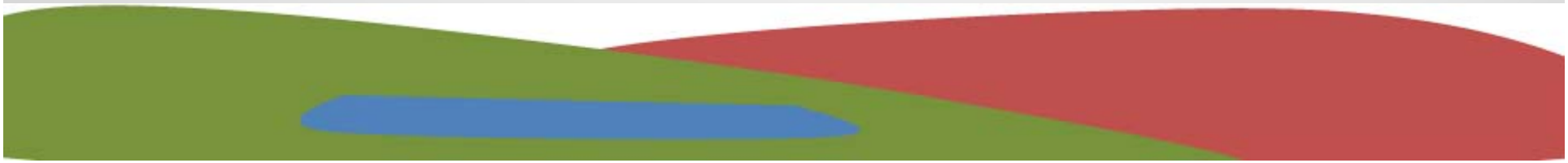
Lighthart , FEMS Microbiol. Ecol. 23:263-74

Biofilms in aerosols

- Aids significantly in aerosolization
- Serve as a survival mechanism
- Allows metabolic functions
- Permits reproduction
- Support multiple species

Is quorum sensing active in aerosols?

?...We do not know



If the above has some truth, how do these facts affect dispersal?

- Biofilms offer mechanisms for release of bacteria at opportune times
- Unlike passive transport of fungal pathogens, bacteria have mechanisms to function in communities, deal with stresses, and grow within its airborne environment
- Dispersal can be enhanced
- Long-range spread of bacterial pathogens also enhanced

Back to the early hints

- *Ralstonia* paper – Maybe bacterial pathogens can be dispersed in rain and snow
- Back in 1982 Dave Sands and colleagues proposed "bioprecipitation"
- Recent news and research papers propose the importance of bacteria in rain and snow
- Movement to "consolidate microbiology and atmospheric sciences in the upcoming era of bio-meteorology" – Cindy Morris
  Morris et al. 2008 Biogeosciences Discuss 5:191-212

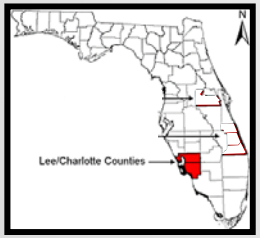
Fire Blight on Apple

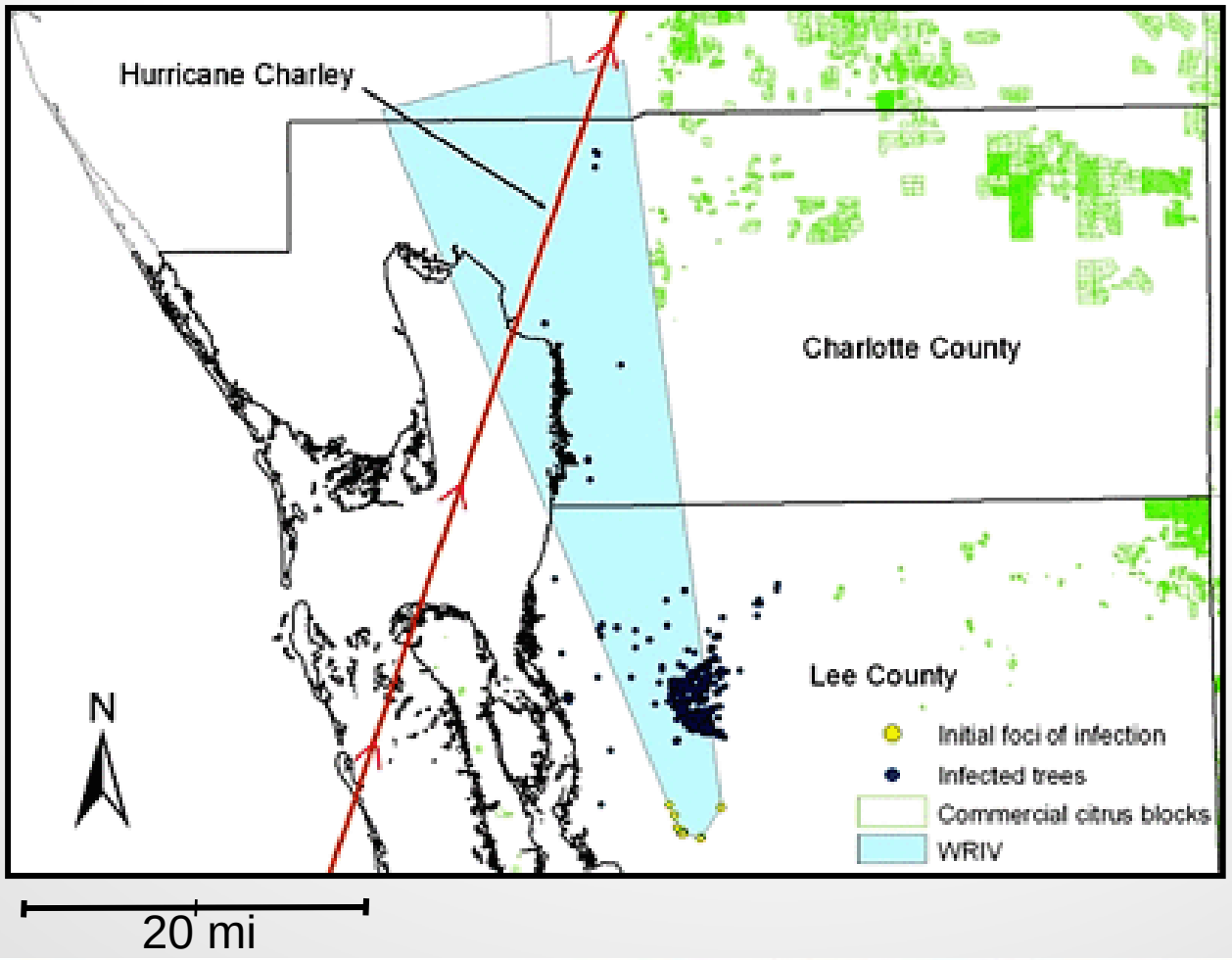
- Caused by *Erwinia amylovora*
- Infection types: Blossom blight; Shoot blight; Canker blight; Trauma blight; Rootstock blight
- Dispersal by rain, insects and wind
- Long-range dispersal occurs but mechanism is uncertain
- Potential for aerosolization: bacterial strands; insect transport and trauma events; & birds

Asian Citrus Canker

- Caused by *Xanthomonas axonopodis* pv. *citri*
- Infection is through stomates or wounds
- Local spread limited to 570m
- Hurricanes changed the assumptions
- High winds can drive bacteria into plant
- Bacteria release from lesions 1-5 min after wetting
- Disease appeared up to 75 km from source

Asian Citrus Canker





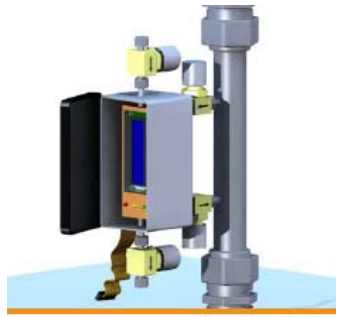
Irey, et. al., Plant Health Progress doi:10.1094/PHP-2006-0822-01-RS

New Directions for Studying Bacteria in the Atmosphere

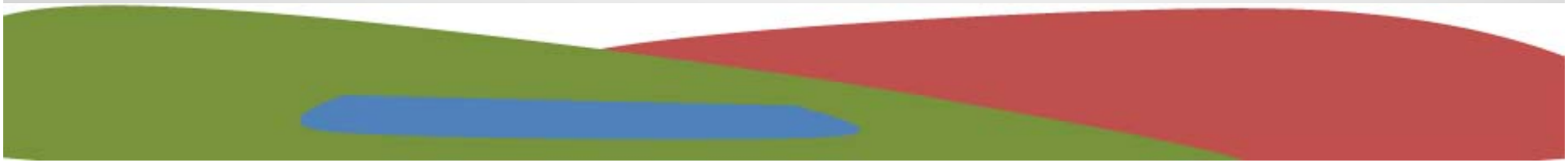
- Better understanding of the bacteria
  - Non-culturable bacteria
  - Research the aerial ecology of bacteria
  - Better understanding of genes and gene function
- New tools for monitoring bacteria
  - Bacterial genomics
  - Rapid DNA analysis
  - Real-time monitoring technologies
  - Advance sampling technologies to study bacteria *in situ*

New Detection Technologies

- Present molecular detection
  - Lyse the bacterium
  - Cut out the DNA region of interest
  - Amplify the selected DNA using PCR
- Future systems (2-5 years out)
  - Attach a fluorophor to the region of interest and detect the electron emission though amplification
  - Attach an iron probe to the region of interest and detect using magnetics
  - Detection sensors could have 1M sensor sites
  - Detection systems sensors can be reconstituted
  - Additional sensors could detect viability



Thank you



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