Biofilm Diversity

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Outline

- Biofilms as a biological community
- Insurance Hypothesis
- Biofilm Phenotype
- Phenotypic Diversity
  - Impacts of diversity
- Evolution of Genome
- Conclusions
- Summary of emerging themes in biofilm diversity research
Biofilm Living

- **Proximity of cells**
  - Metabolic interaction
  - Promote horizontal gene transfer of virulence traits
  - Enhance communication
  - Facilitate coordinated behavior

- **Group structure plays a key role in function**
  - Bacterial communities
Insurance Hypothesis

- Stability of many types of biological communities is enhanced by diversity.
- Physiological changes produced by biofilm growth can greatly enhance the survival of bacteria.
- “insurance hypothesis” – postulates that the presence of diverse subpopulations increases the range of conditions in which the community as a whole can thrive.
“Biofilm phenotype”

- Patterns of protein and gene expression associated with biofilm growth compared to planktonic culture.
- *S. aureus* – 20% differential regulation
- *E. Coli* – 10 %
- *S. enterica*
Phenotypic Diversity

- Diversification reflects adaptation to micro-environmental niches.
- Can produce variants with biofilm-specific phenotypes
Phenotypic Diversity

- Variants within biofilm-specific phenotypes
  - P. aeruginosa
  - Samonella enterica
  - V. cholerae
- “sticky” variant
  - Heightened resistance
- Heritable changes – but not dependent on QS
Rec A

- Produce genetic changes via recombination
- Inducing error-prone DNA polymerases as part of bacterial response (SOS response)
- Inactivation of RecA dramatically reduced biofilm induced phenotypic variation
- Chromosome location non-specific
Rec A

- Mobility diversity
  - Biofilm growth induces multiple genetic change in mobility
  - Variations in twitching and swimming ability
    - heritable
RecA

- Variation in nutritional requirements
RecA

- Pyomelanin – pigment that can protect against oxidants and radiation
Phenotypic Trade-offs

- Demonstration of fitness “trade-off” under different environmental conditions
- “winner” is not simply a superior competitor regardless of environment
Phenotypic Trade-offs

- Variation in attachment, detachment and susceptibility of RecA mutations
Impacts on resistance

- Variation of susceptibility in time and dose-dependent killing of biofilms by metals and antibiotics
Metal Toxicity

- Phenotypic variation is linked to biofilm multidrug and multimetal resistance.
- GacA-GacS – highly conserved 2-component system prone to inactivating mutations
Multifactorial model of multimetal resistance in biofilms
Impacts of species richness

- Biodiversity can also affect macrofouling processes
Evolution of Diversity

- Bacterial Genome Evolution

Diagram:
- Common bacterial ancestor
  - Genome reduction by deletion events
  - Gene acquisition by HGT
  - Mutations, rearrangements

- Intracellular bacterium, obligate intracellular pathogen, endosymbiont
- Extracellular bacterium, facultative pathogen, symbiont
- All lifestyles

Plasmid

GEI
Conclusions

- Some evidence to support the “insurance hypothesis” in biofilms has been demonstrated
- Biofilms have been shown to rapidly produce diversity in a wide range of phenotypic characteristics
  - Actual generation mechanisms are unknown
- Biofilms that have phenotypic diversity were better able to withstand applied physiological stress compared to biofilms unable to diversify
  - Functional diversity increases community survival
Summary

- Diversity is one of the emerging themes in current biofilm research.
- To understand the ecology and ecological concepts that regulate the stability of biofilm ecosystems it is necessary to be able to grow, observe and manipulate biofilms in the laboratory.
  - Transparent flow cells
- More research needs to be performed to determine the mechanisms by which diversity is generated.
  - Identification of phenotypes with specific niche specialties
  - Impact of diversification on pathogenic or ecological potential of community
- Capacity of members to switch phenotypes