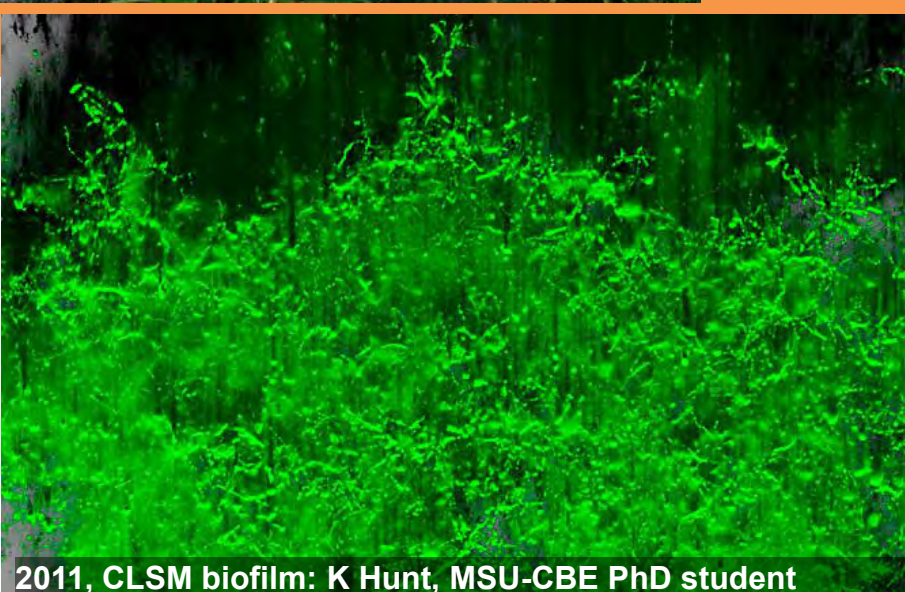
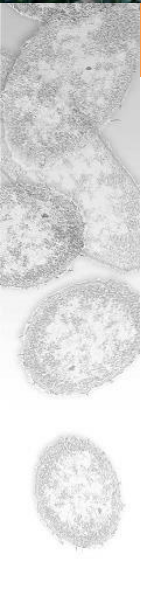


Fundamentals of Microbial Biofilms

*Center for Biofilm Engineering at
Montana State University*



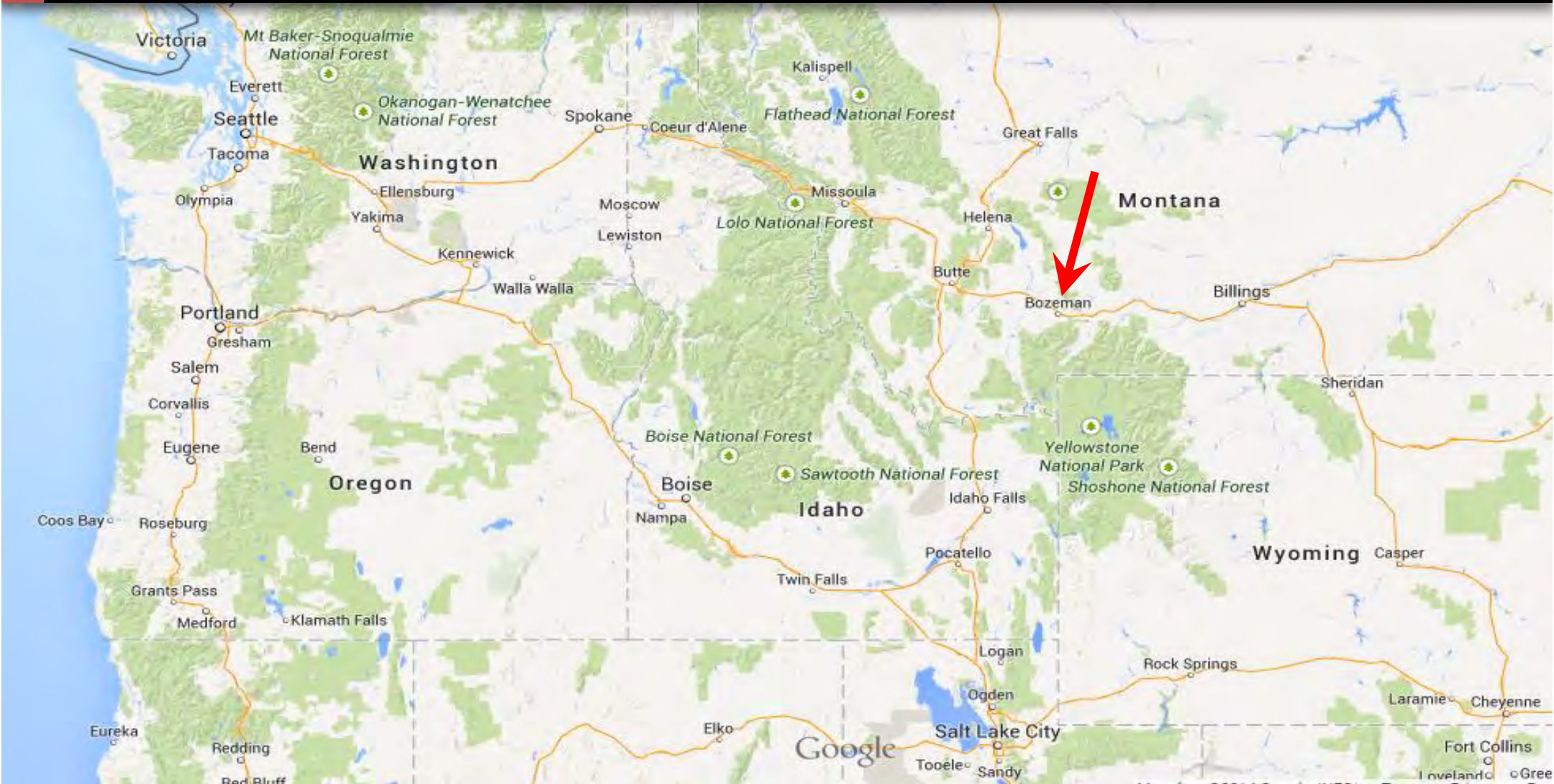
James N. Wilking
Assistant Professor, ChBE
Center for Biofilm Engineering
Montana State University

wilkinglab.com

CFP Biennial Meeting | 2016

Center for Biofilm Engineering

Bozeman, Montana



Free-swimming microbes vs. biofilms



Biofilms are all around us



COURTESY OF ASM, RUBY AND GERENCKSER

Photos by CBE staff and students
unless otherwise noted.



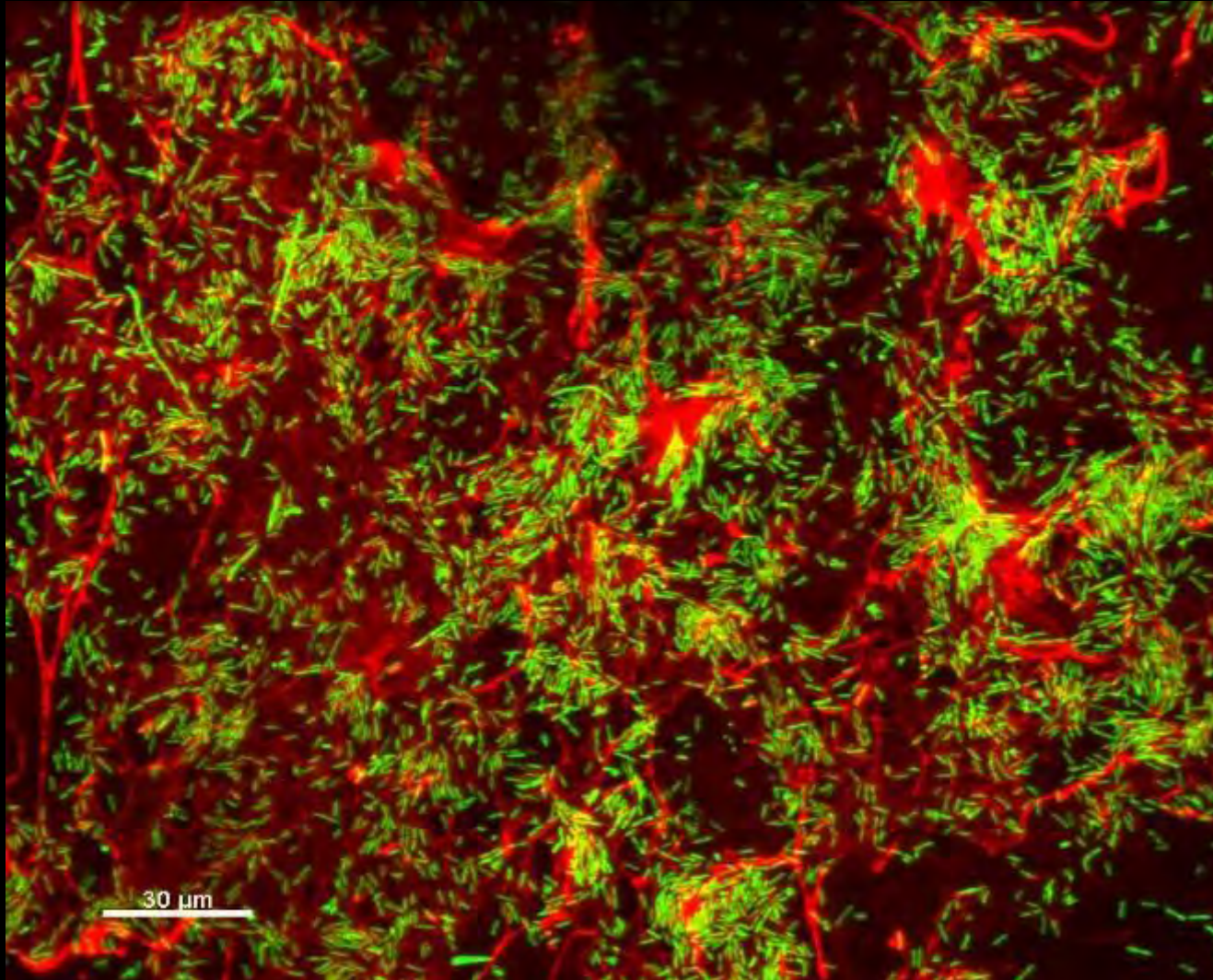
Extracellular matrix: a hallmark of microbial biofilms



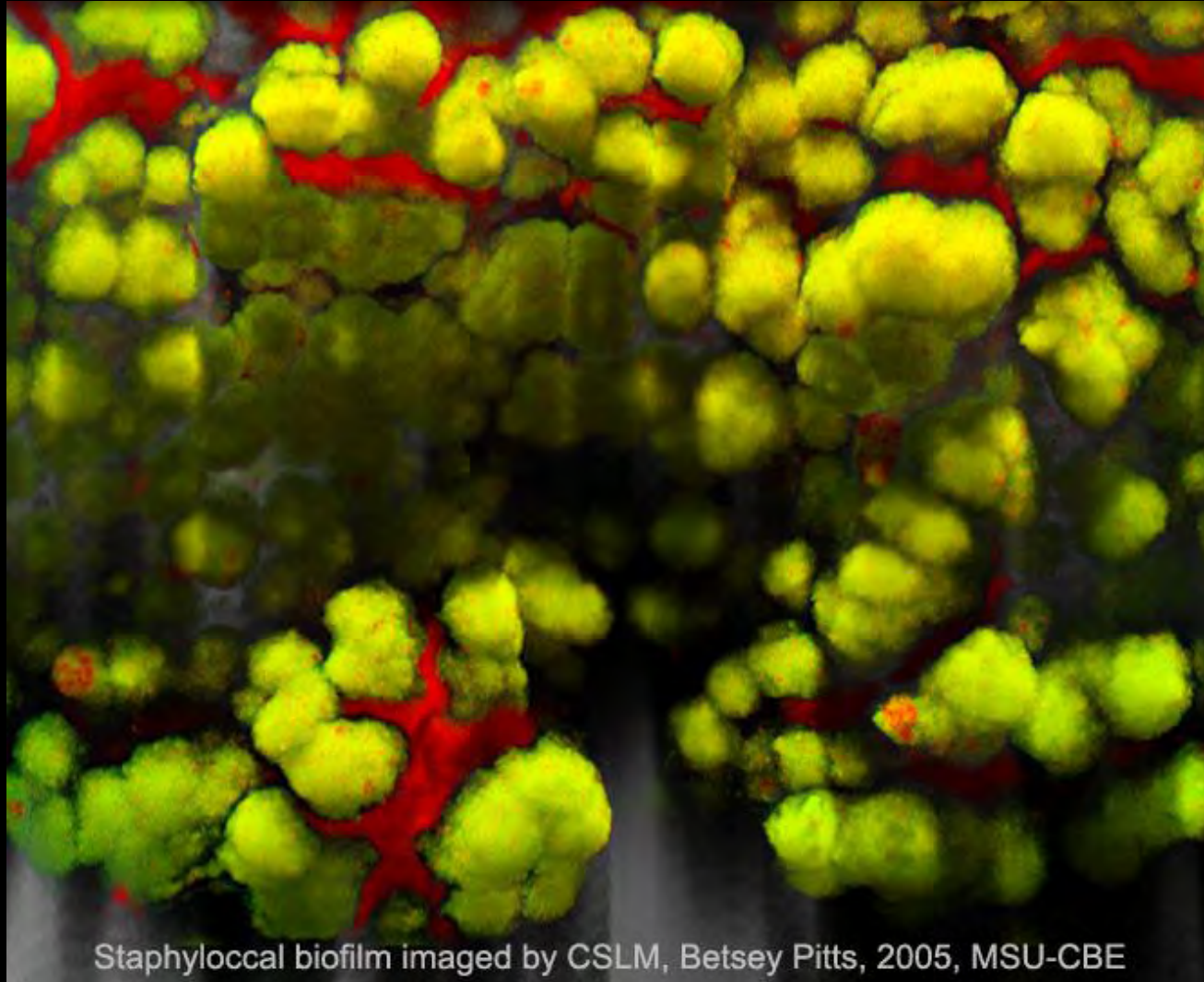
JW Costerton



Extracellular matrix: a hallmark of microbial biofilms



Extracellular matrix: a hallmark of microbial biofilms



Staphylococcal biofilm imaged by CSLM, Betsey Pitts, 2005, MSU-CBE

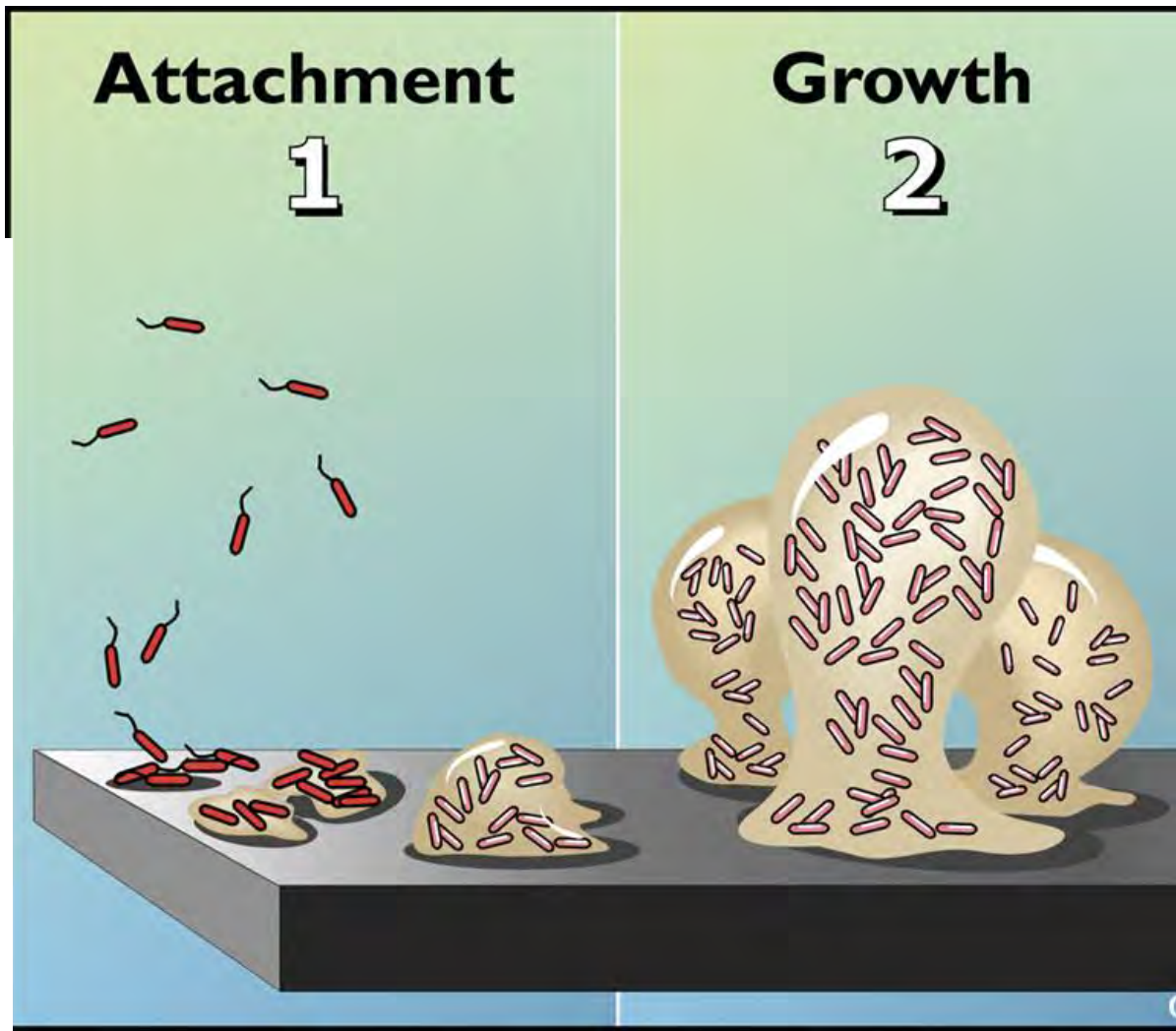
The extracellular matrix provides the biofilm with mechanical integrity



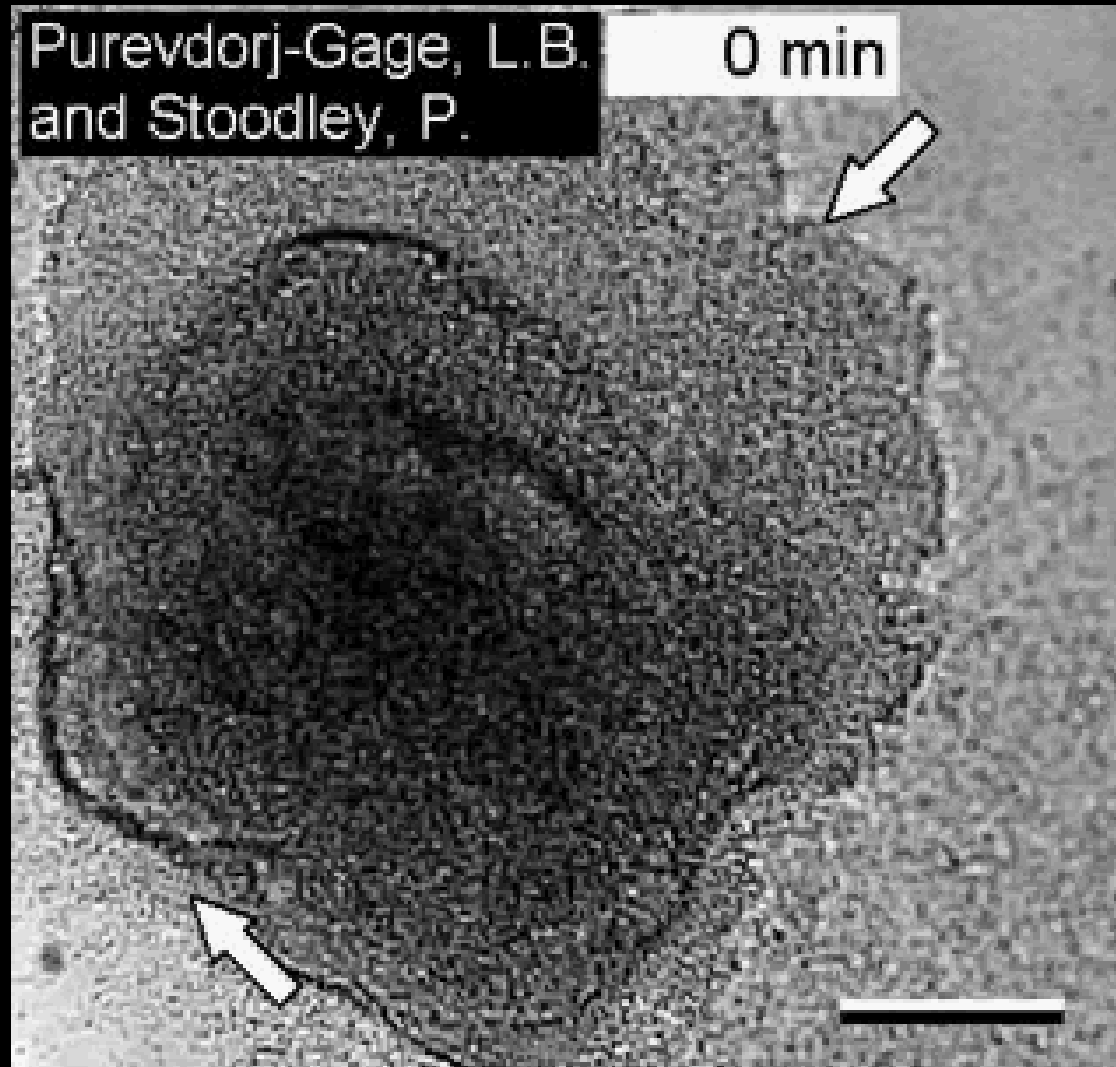
Biofilms undergo a “life-cycle”



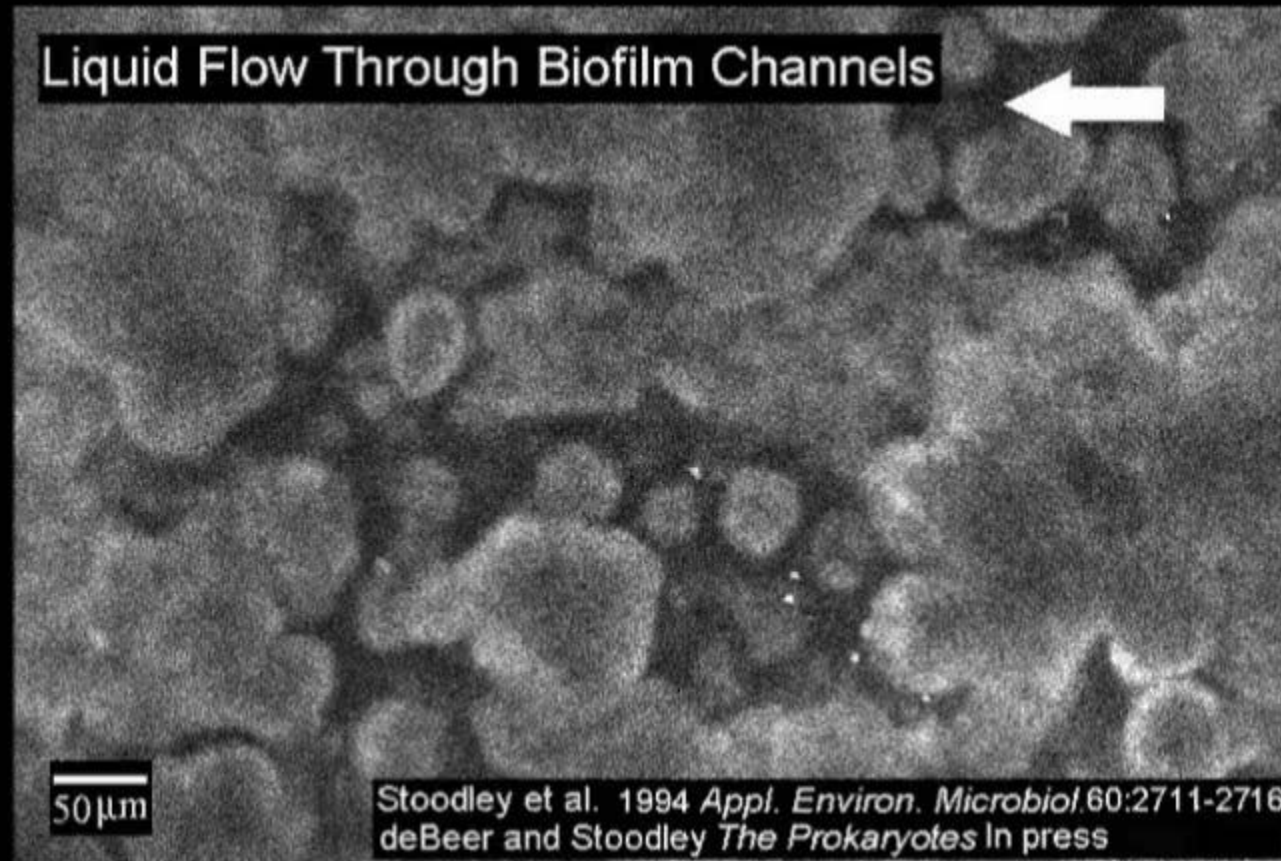
Biofilms undergo a “life-cycle”



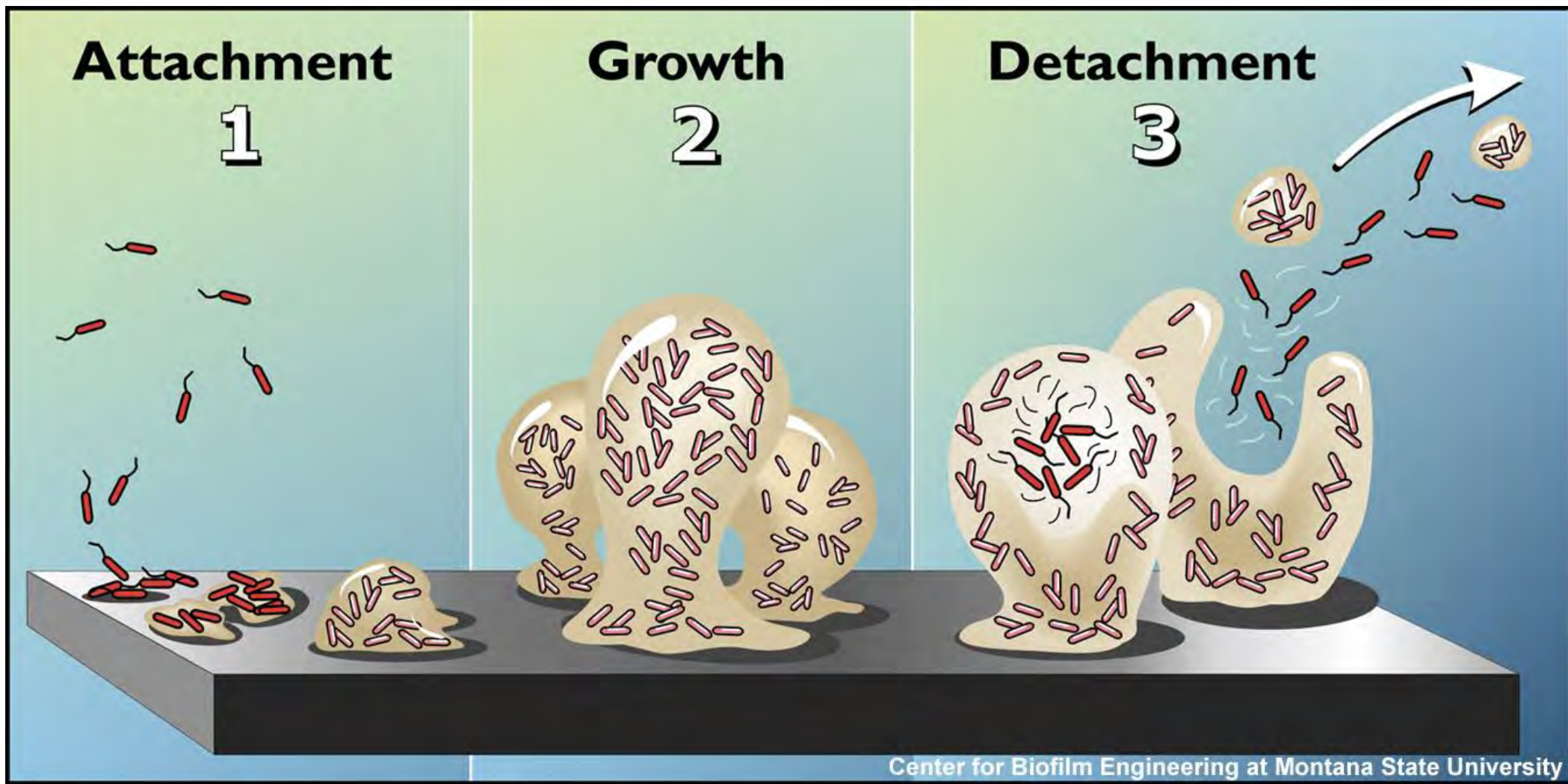
Biofilm growth and spreading



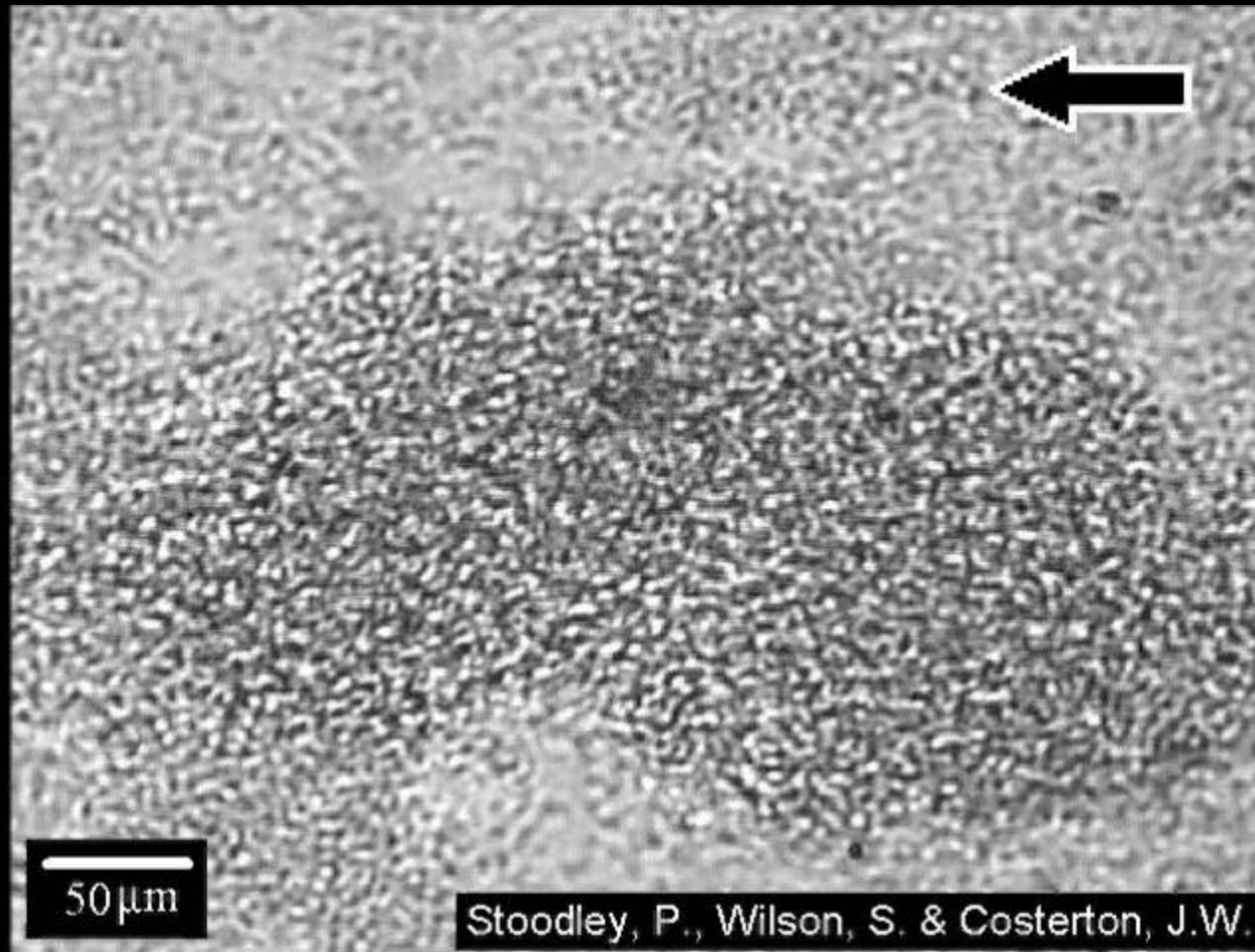
Biofilms form complex structures



Biofilms undergo a “life-cycle”



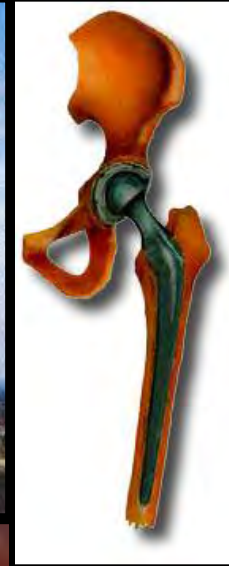
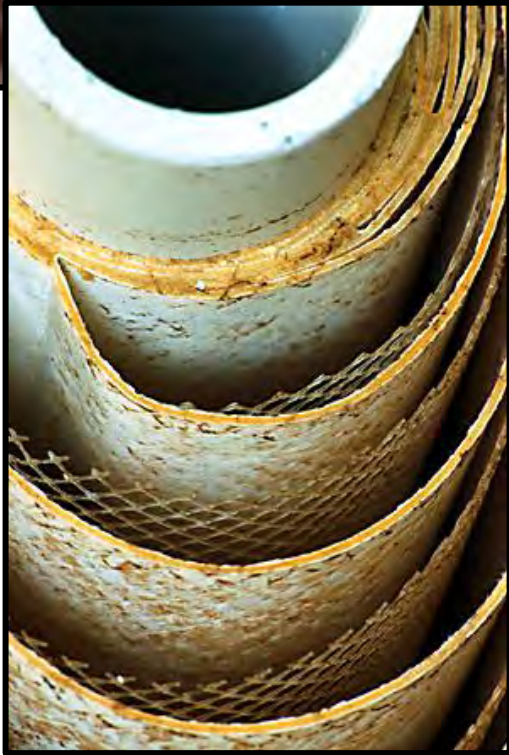
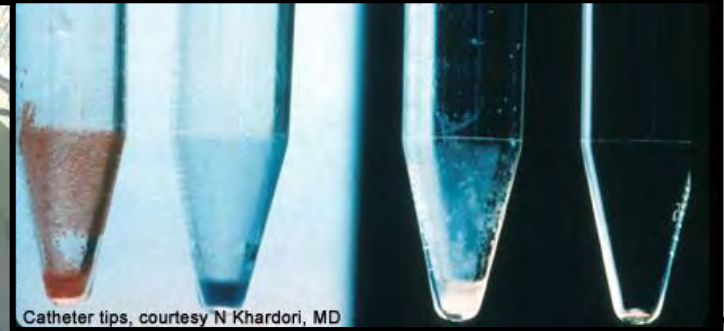
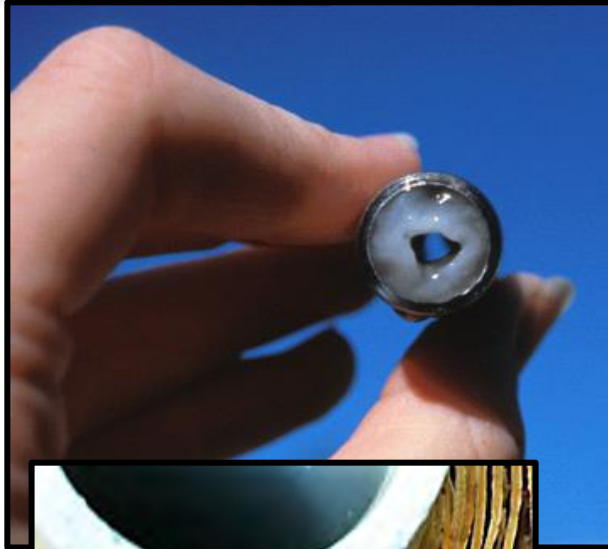
Biofilm detachment



Planktonic bacteria ready to be released!



Biofilms impact industry, environment & health



Center for Biofilm Engineering Industrial Associates

Consumer Products

Church & Dwight
Colgate-Palmolive
Johnson & Johnson
Kimberly-Clark
Masco
Procter & Gamble
Reckitt Benckiser
Sherwin Williams

Testing Laboratories

WuXi AppTec*

Energy

ExxonMobil
BP

Specialty Chemicals

BASF
BCG Solutions *
Clorox
Dow Corning
Dow Microbial Control
Ecolab/Nalco
NCH Corp.
Novozymes A/S
Sani-Marc
Sample6 Technologies*
Sealed-Air

US Gov't Programs/Labs

NASA

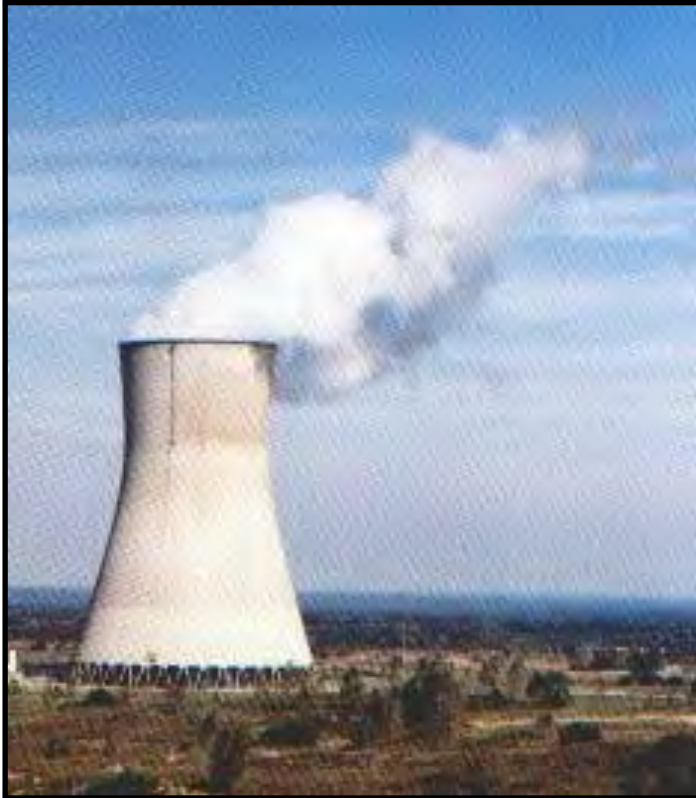
Health Care/Biomedical

3M
Bard Access Systems
Bausch & Lomb
Baxter Healthcare
Bend Research*
Covidien
ICU Medical
Kane Biotech*
KCI
Next Science*
Semprus Biosciences*
Steris
W.L. Gore

Biofilm in oilfield pipeline system



Cooling tower biofilms



Health-related biofilms

Sites of **Primary** and **Secondary** Biofilm Infection

**SITES OF
PRIMARY
INFECTION:**

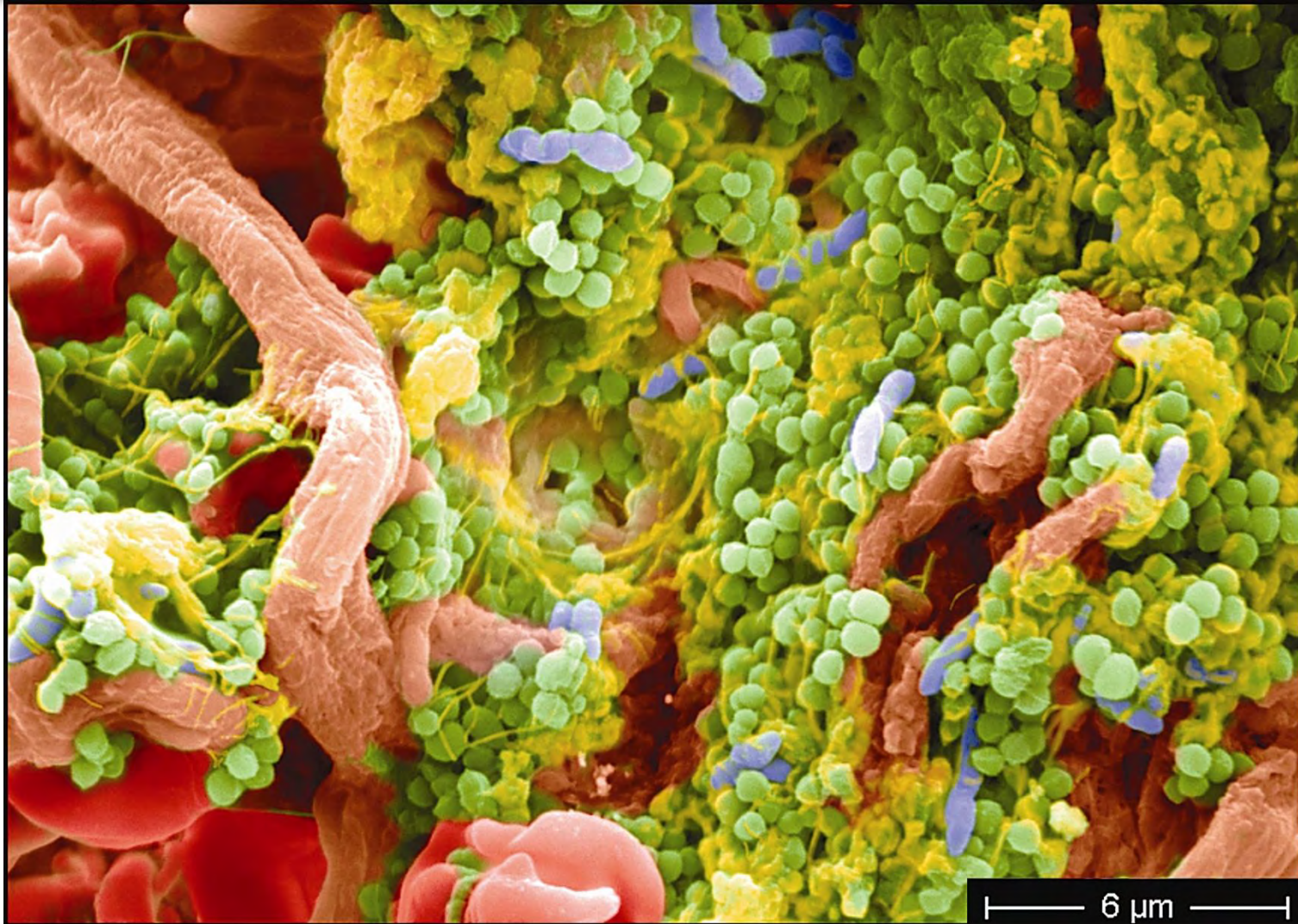
**Subvenous
catheter**

Mouth

Artificial hip implant

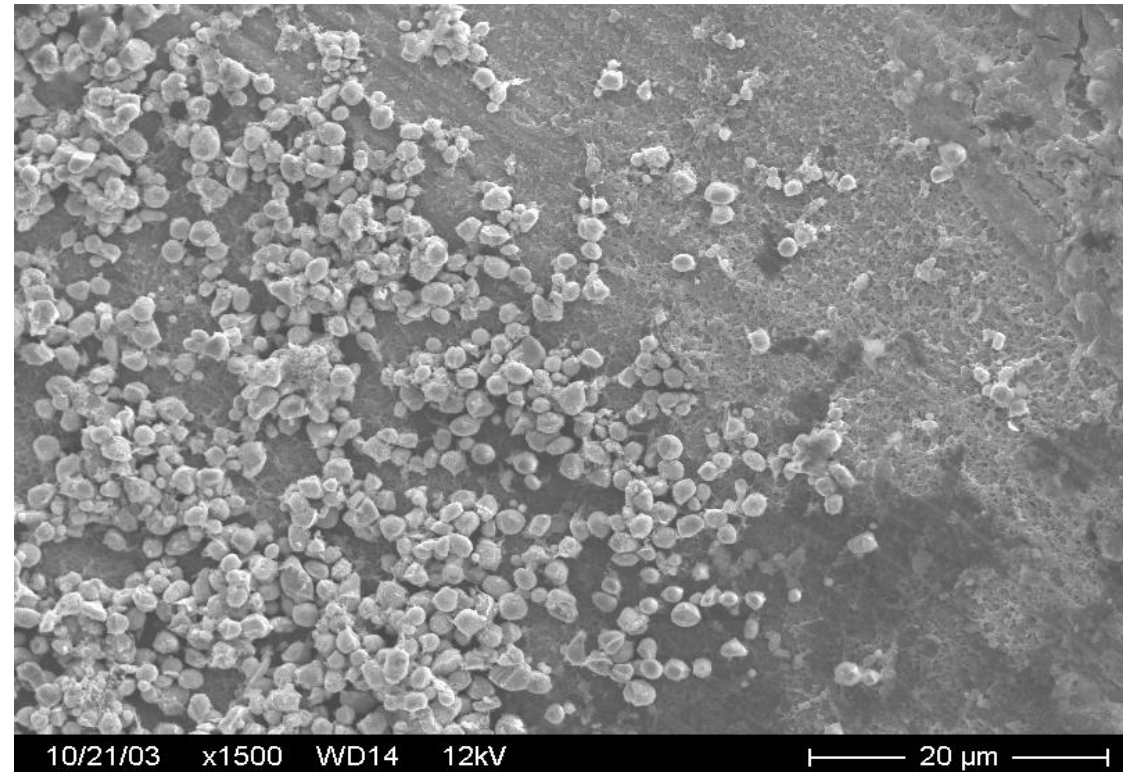
© 2003, Center for Biofilm Engineering at MSU-Bozeman

Chronic wounds

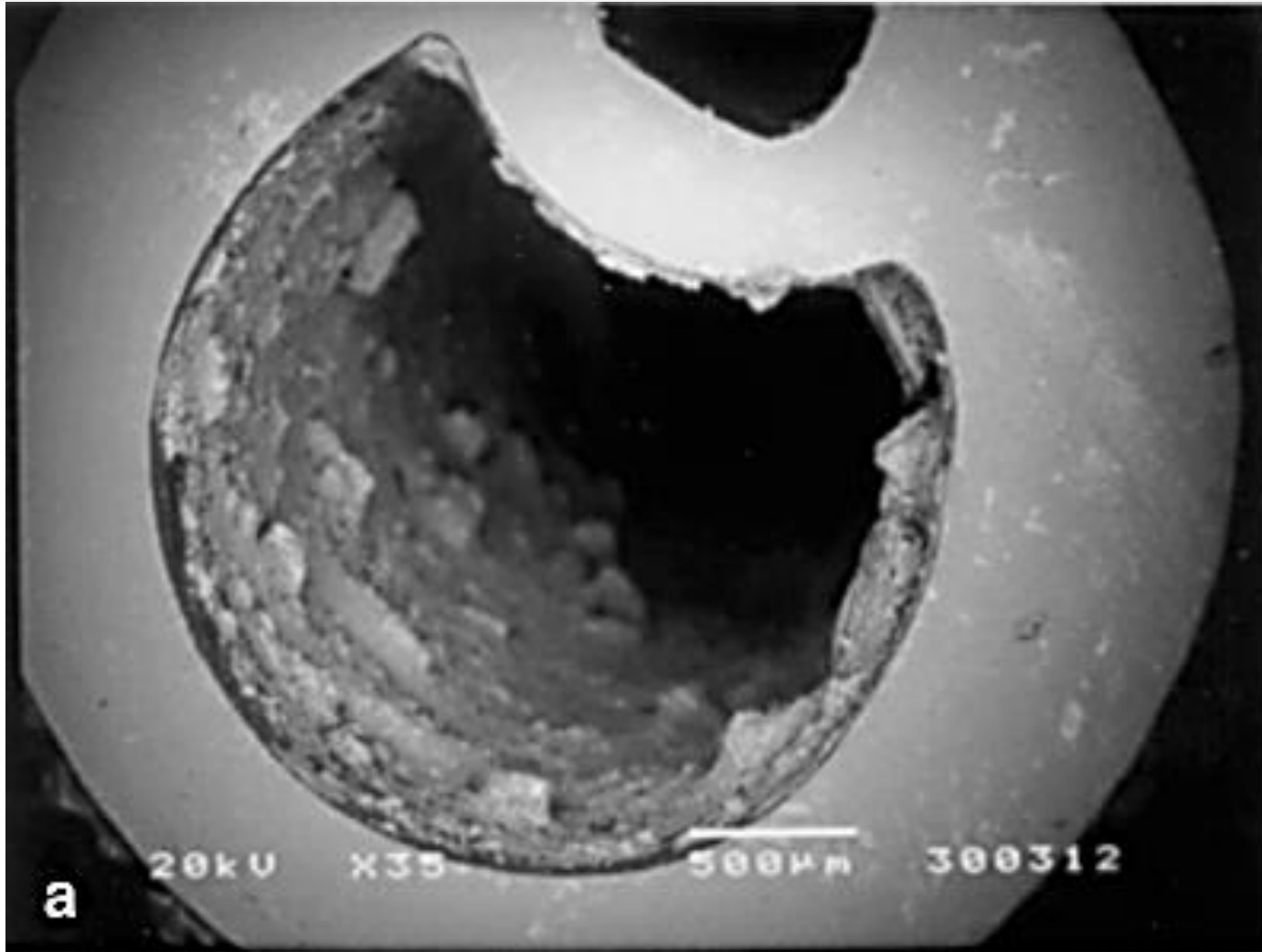


Ellen Swogger, Garth James et al., MSU-CBE, 2005. Cover image on *Wound Repair and Regeneration* 16(1), January-February 2008, ISSN 1067-1927, Blackwell Publishing

Elbow prosthesis biofilm



Urinary catheter encrustation



Morris, N.S. and Stickler, D.J. (2001) *BJU Int* 88:192

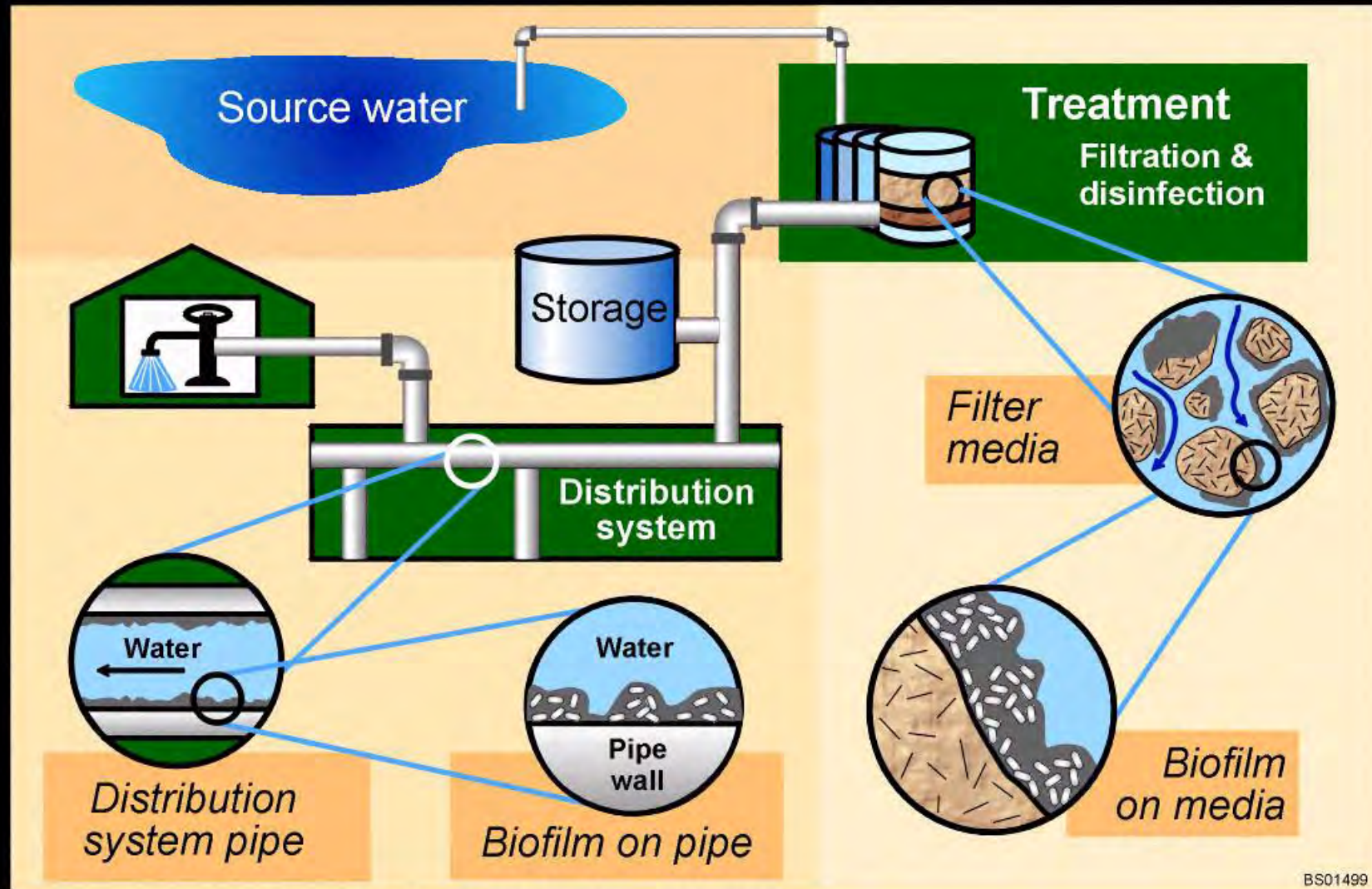
Dental caries



Fig 7-8 (B.) Detailed appearance of eroded focal hole (SEM; original magnification x3,690).
(Courtesy of A.Thylstrup)

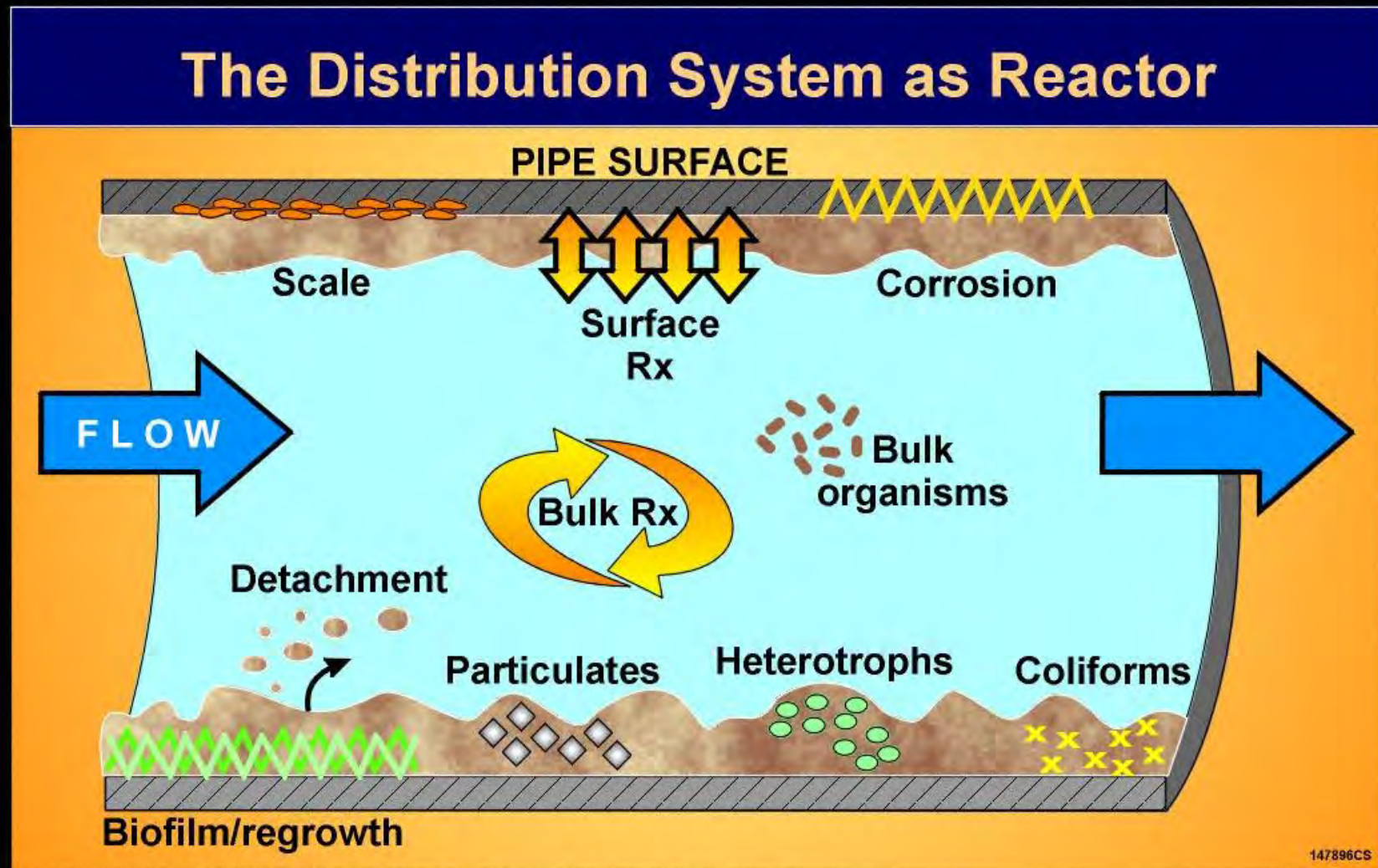
Where ever moisture and nutrients are present, there will be biofilms!

Biofilm in a water distribution system



BS01499

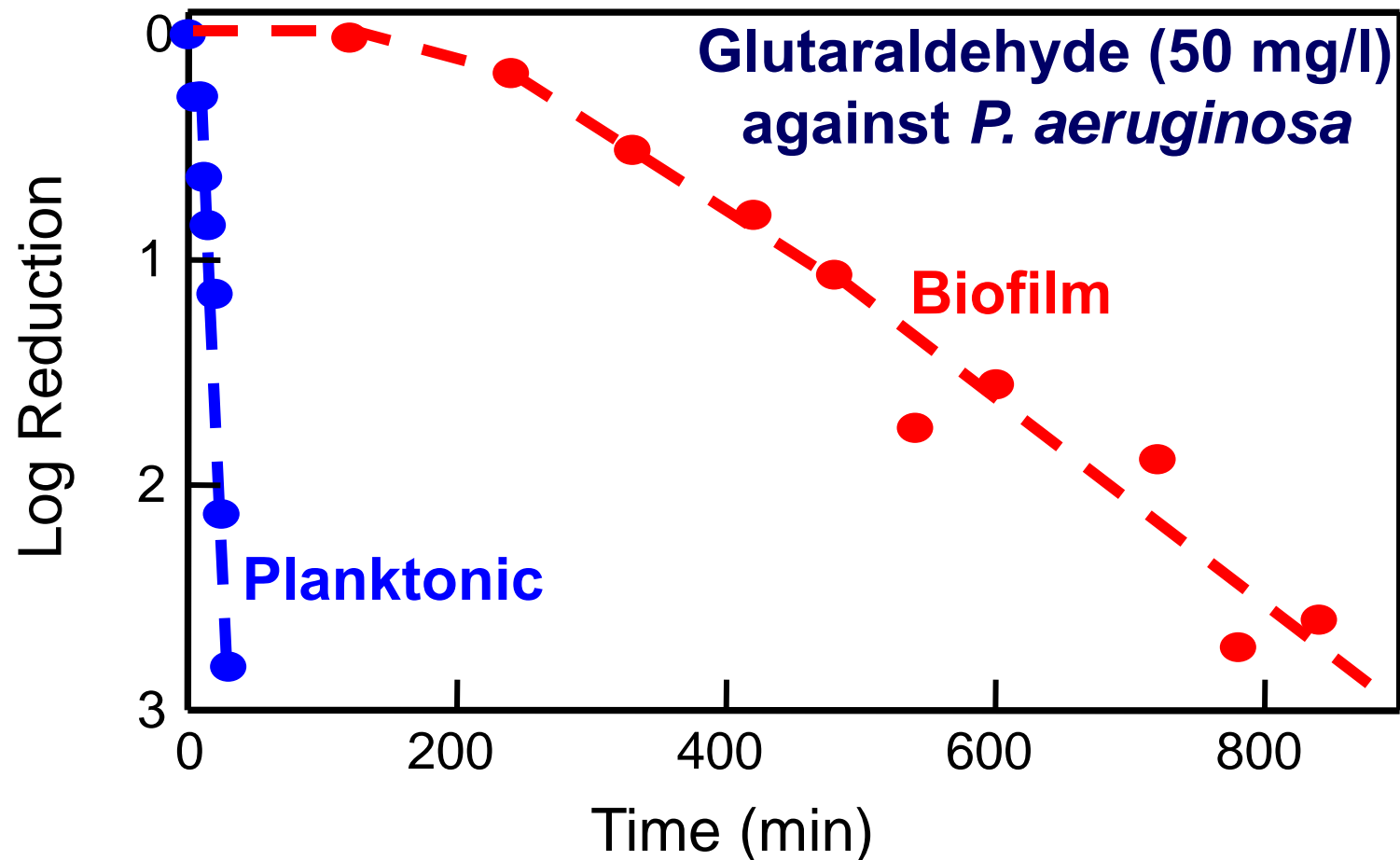
Biofilm in a water distribution system



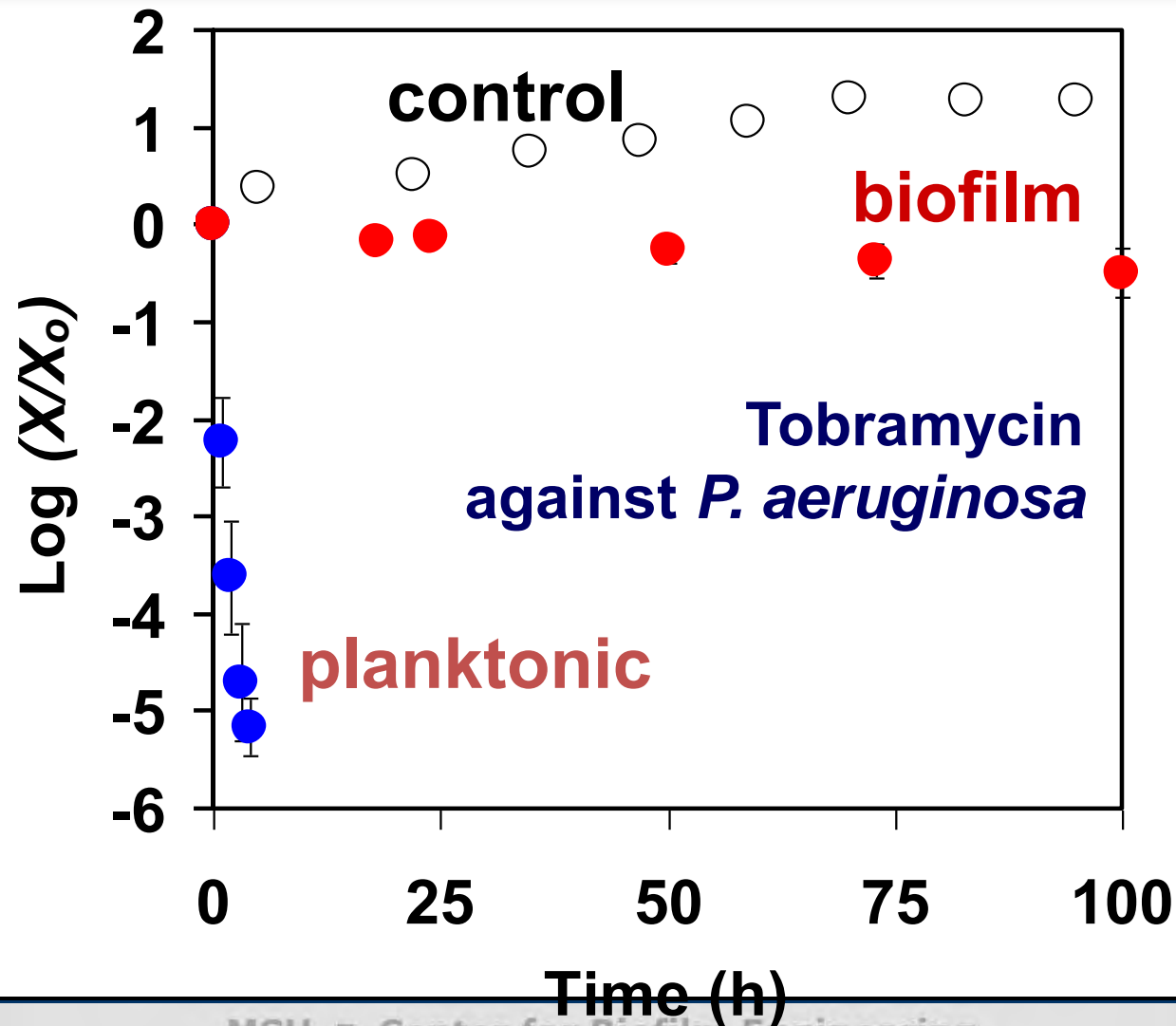
© 1996 CENTER FOR BIOFILM ENGINEERING, MSU-BOZEMAN

Why not just eradicate them with antimicrobial agents?

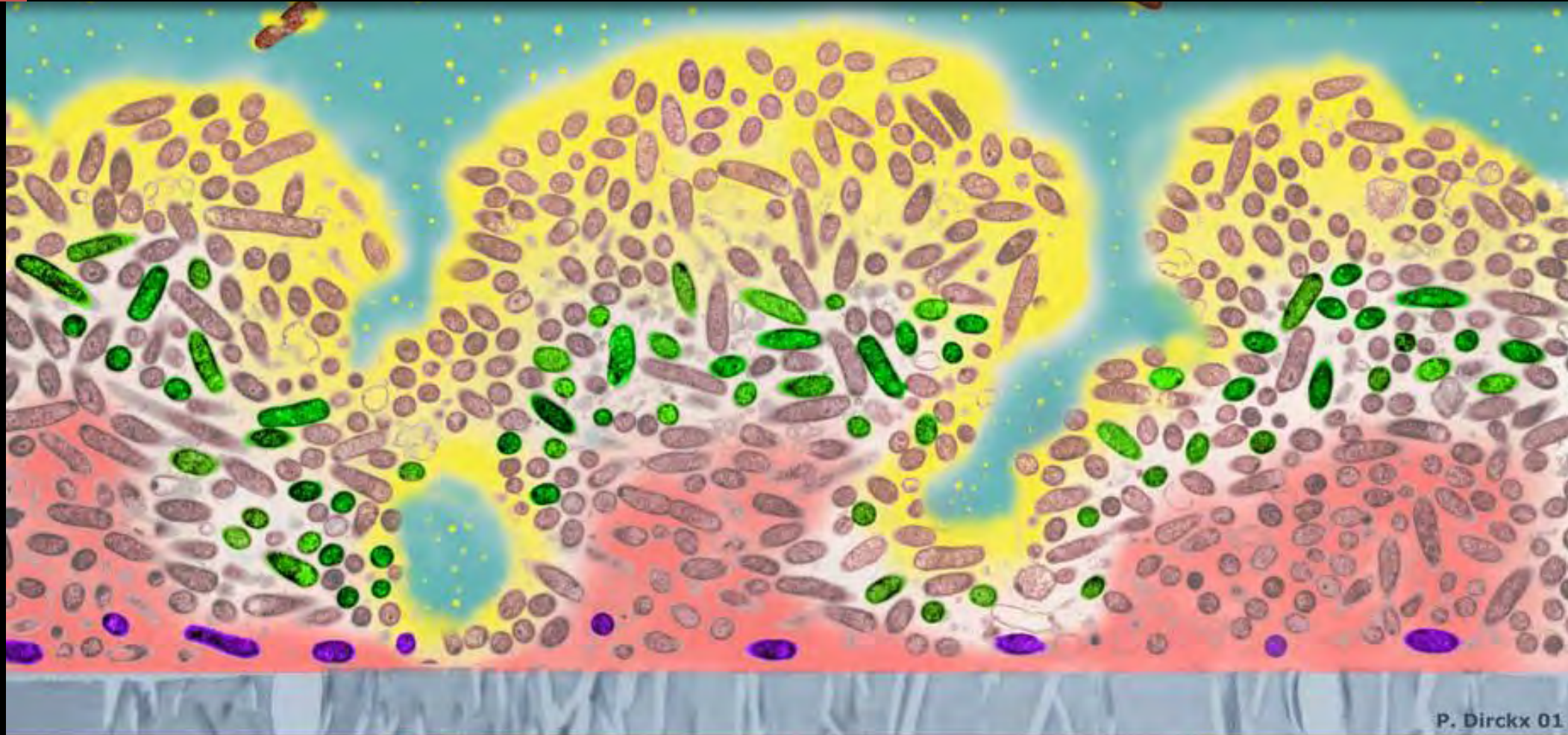
Biofilms are more tolerant of antimicrobial agents than are free bugs



Biofilms are more tolerant of antimicrobial agents than are free bugs



Antimicrobial tolerance can be understood in light of three concepts



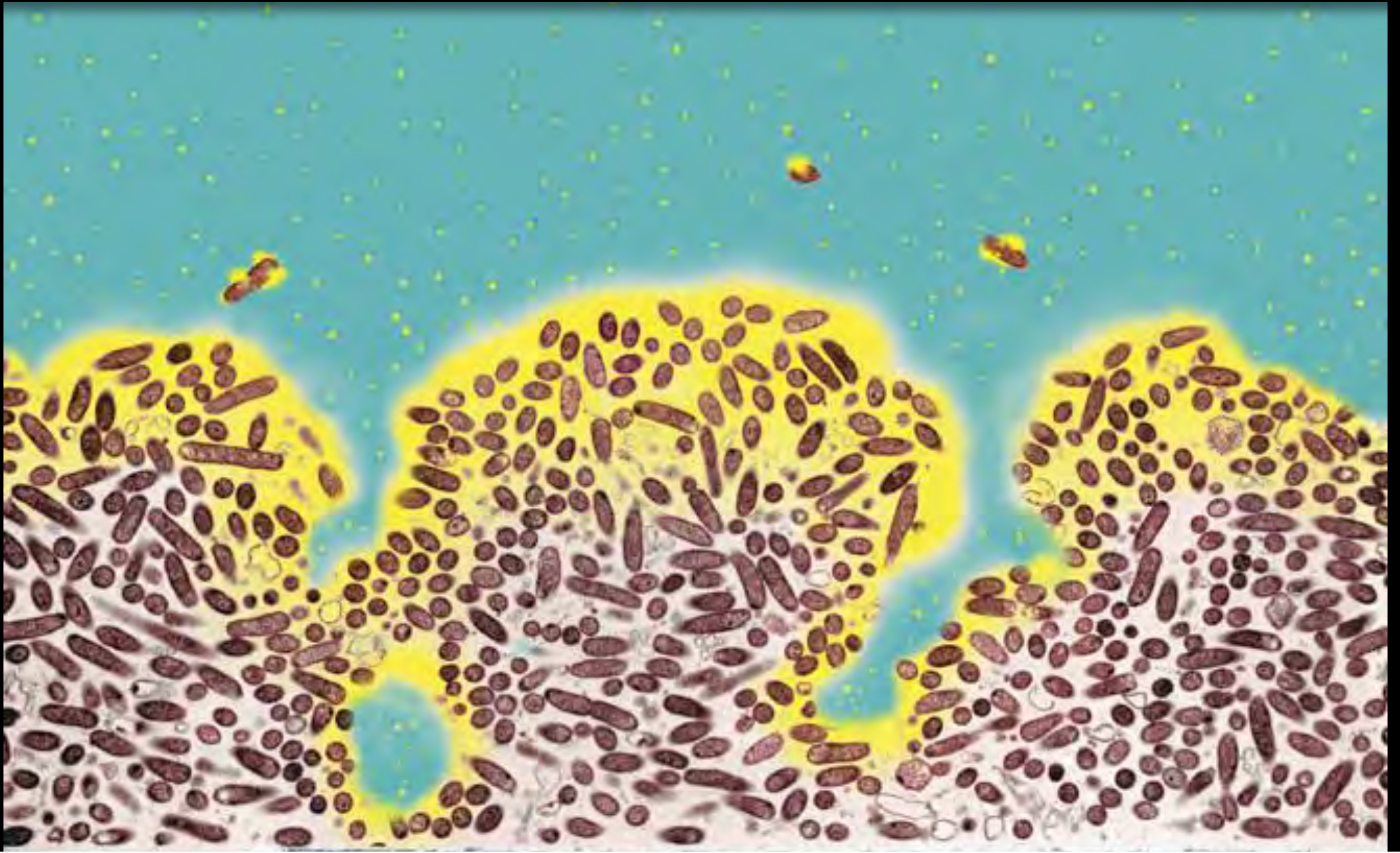
P. Dirckx 01

**Slow
Penetration**

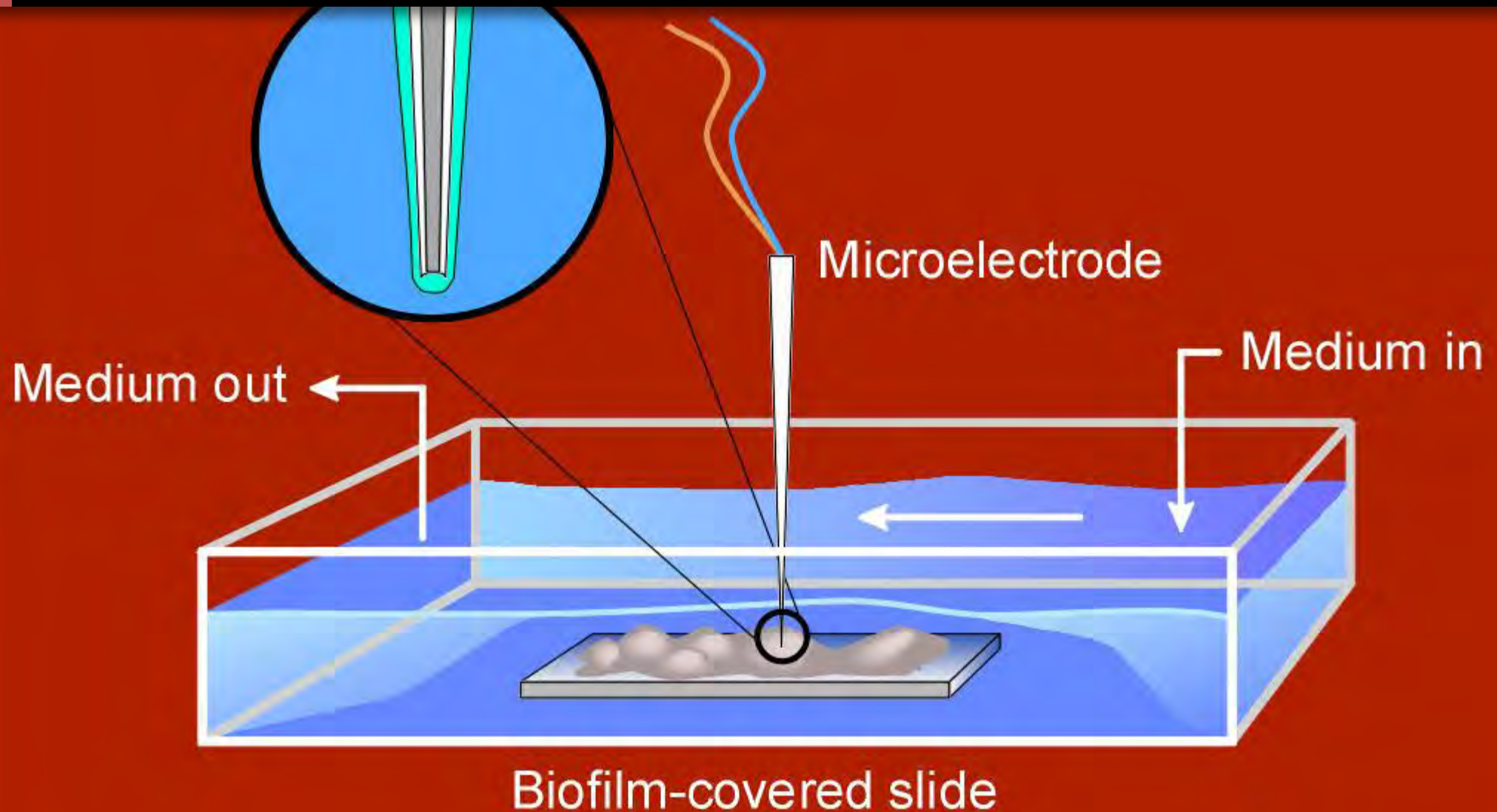
**Stress
Response**

**Altered
Microenvironment**

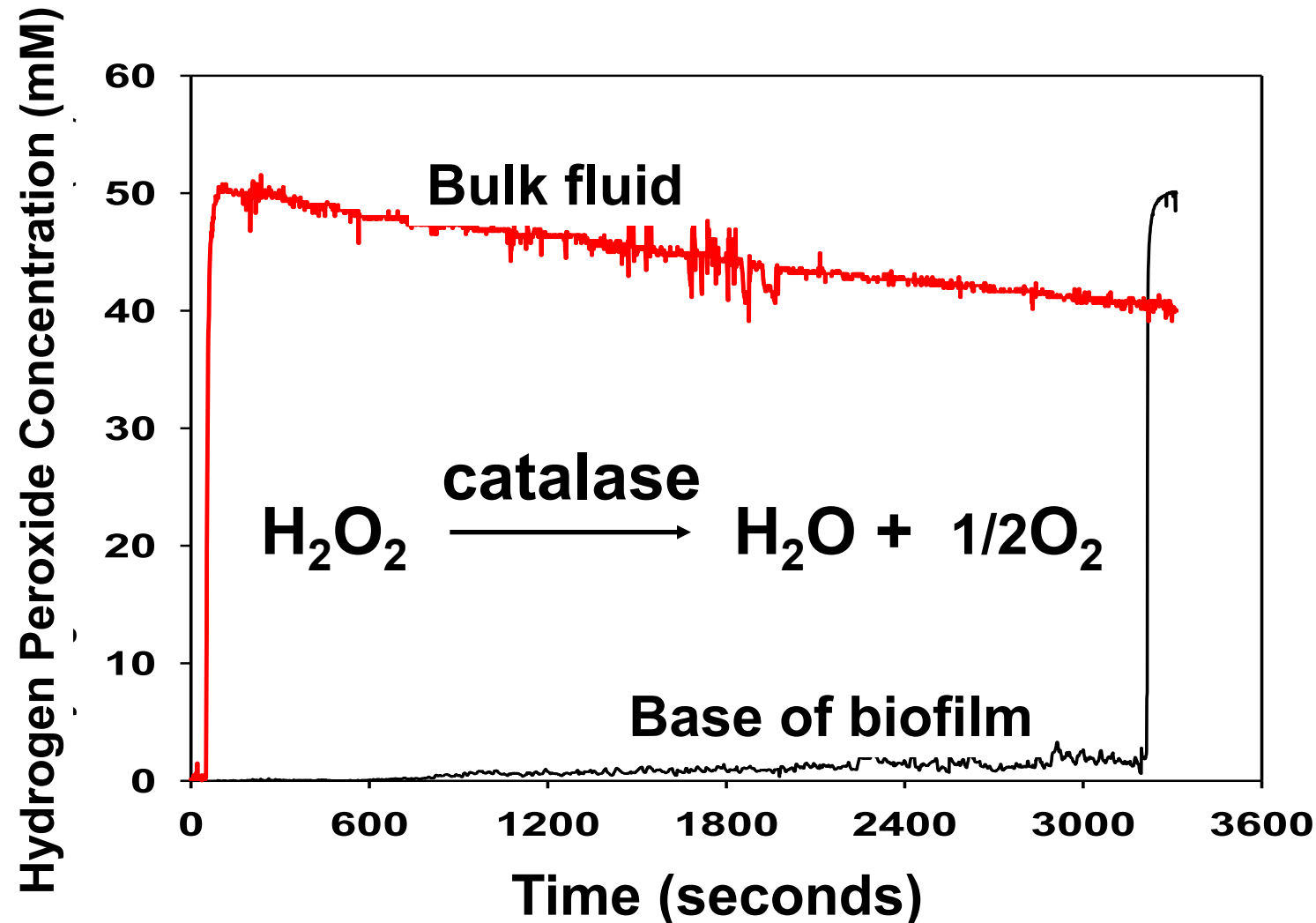
1. Slow penetration



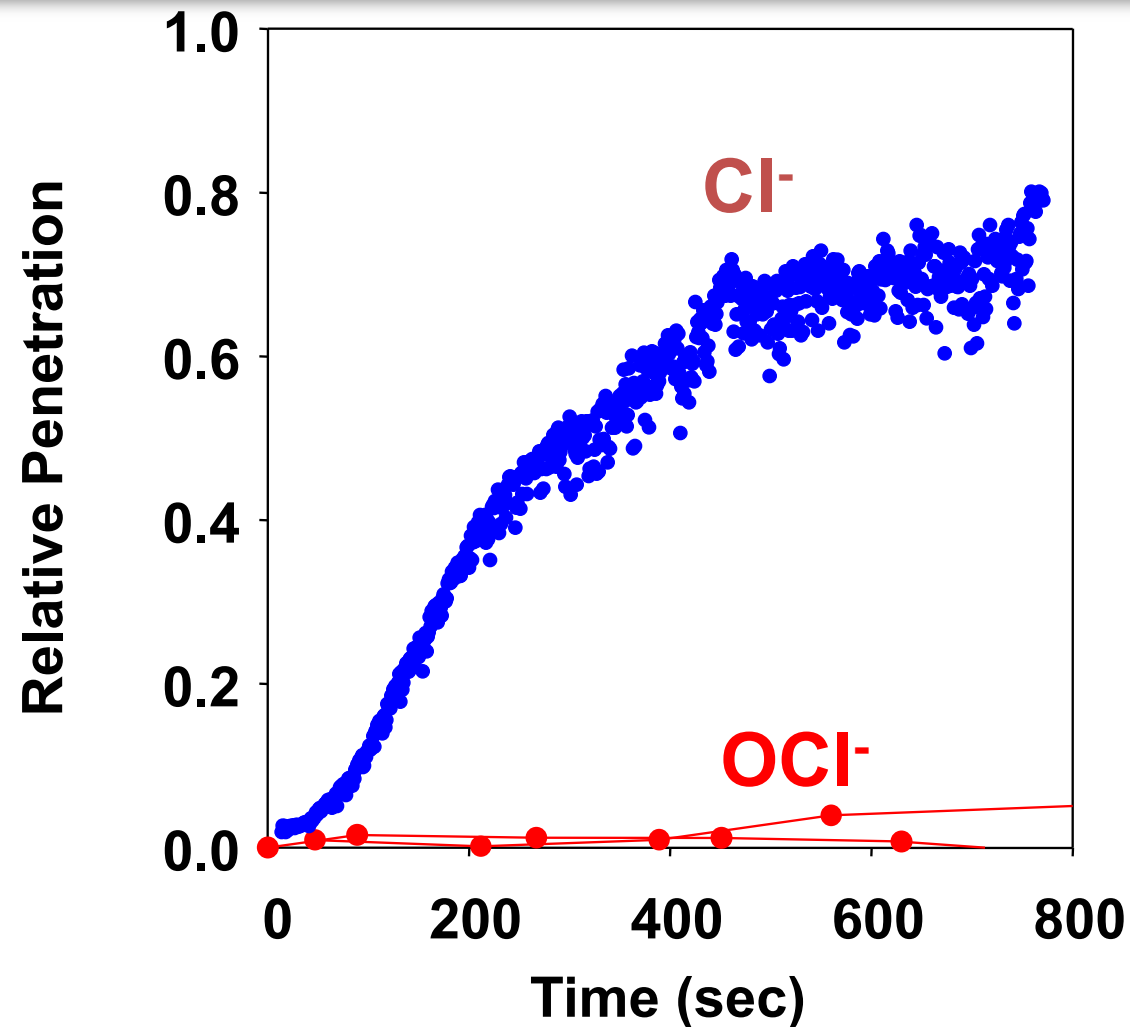
Measure penetration with microelectrodes



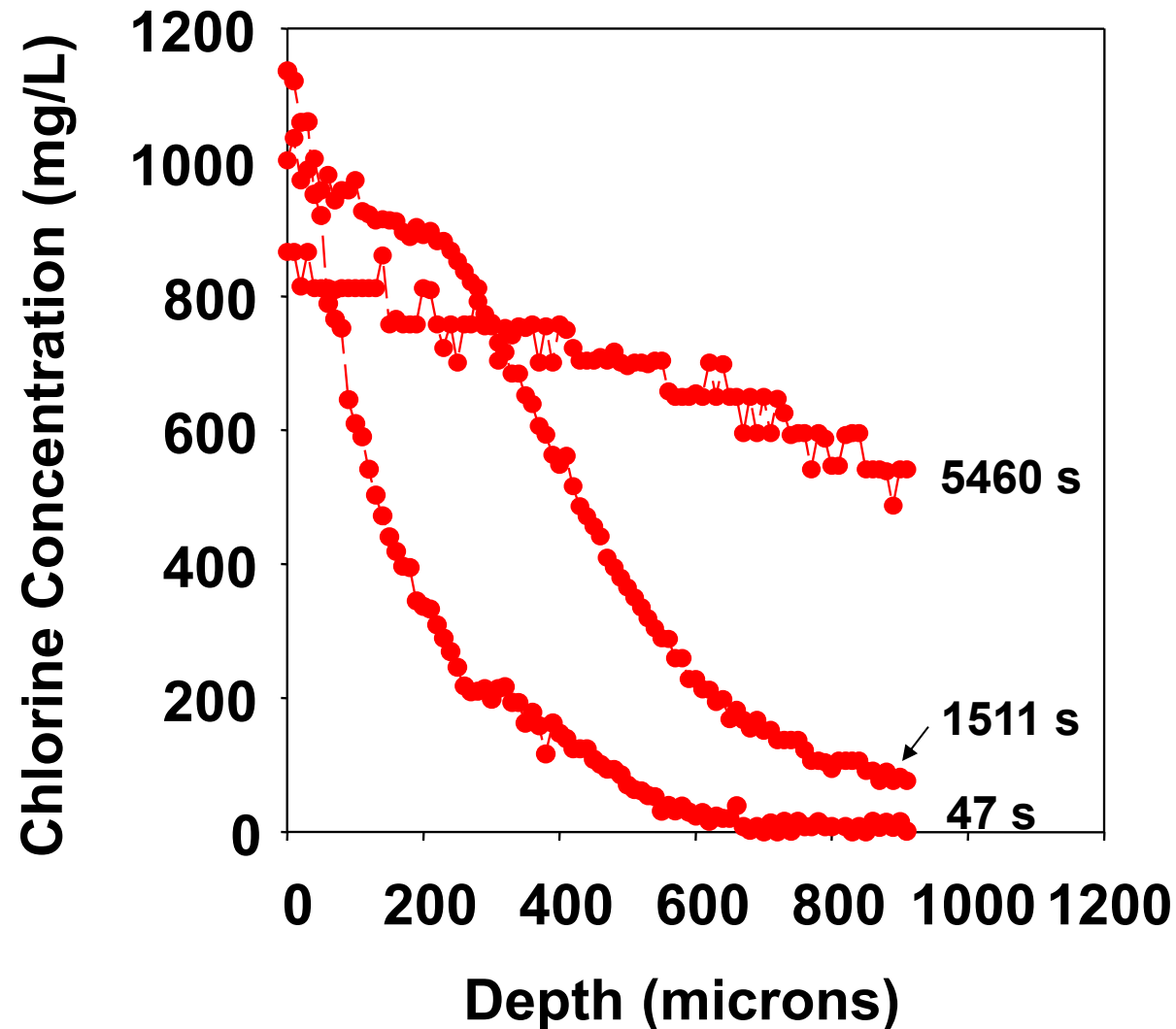
H₂O₂ fails to penetrate the biofilm



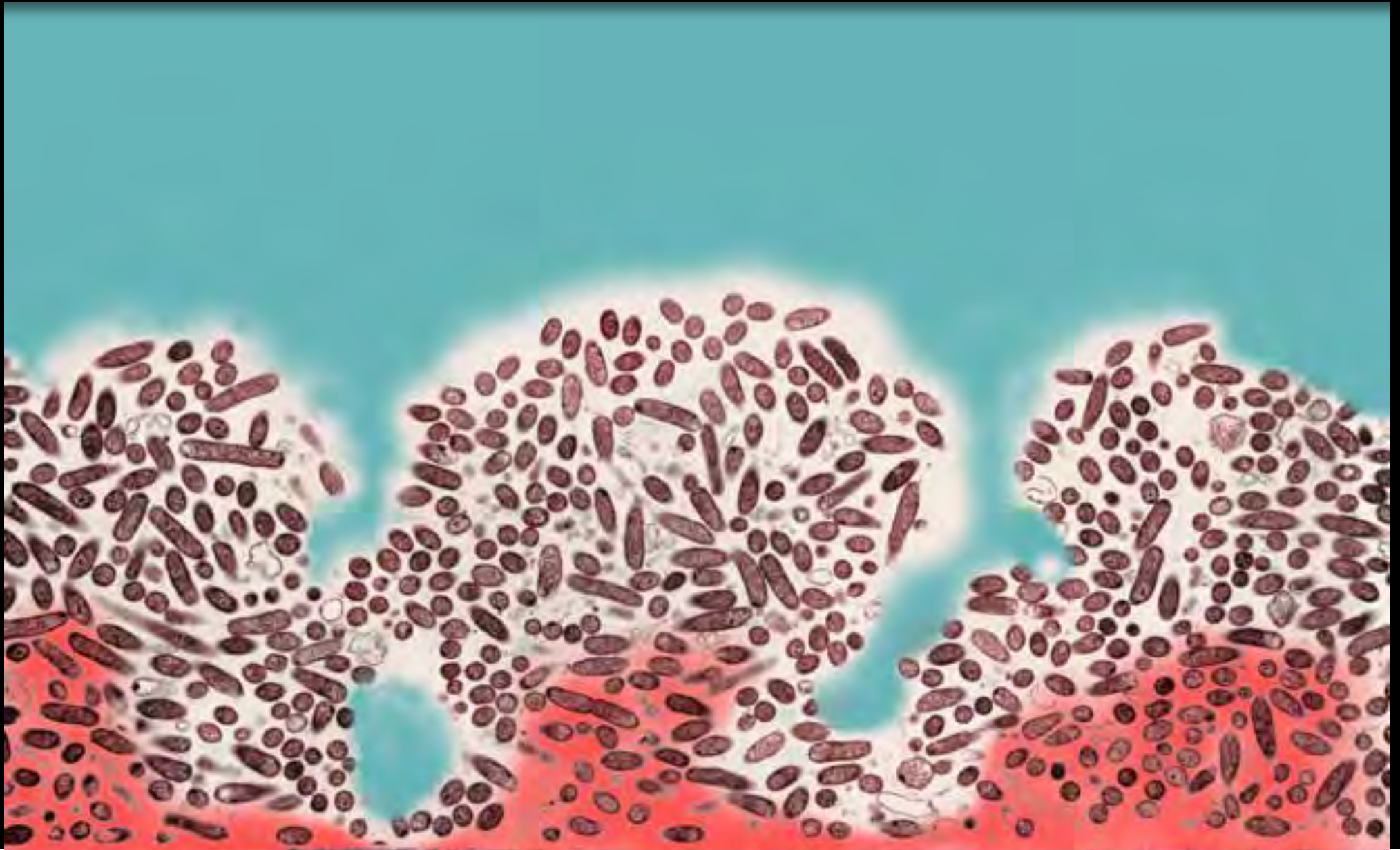
Chloride ions penetrate readily but hypochlorite ions do not



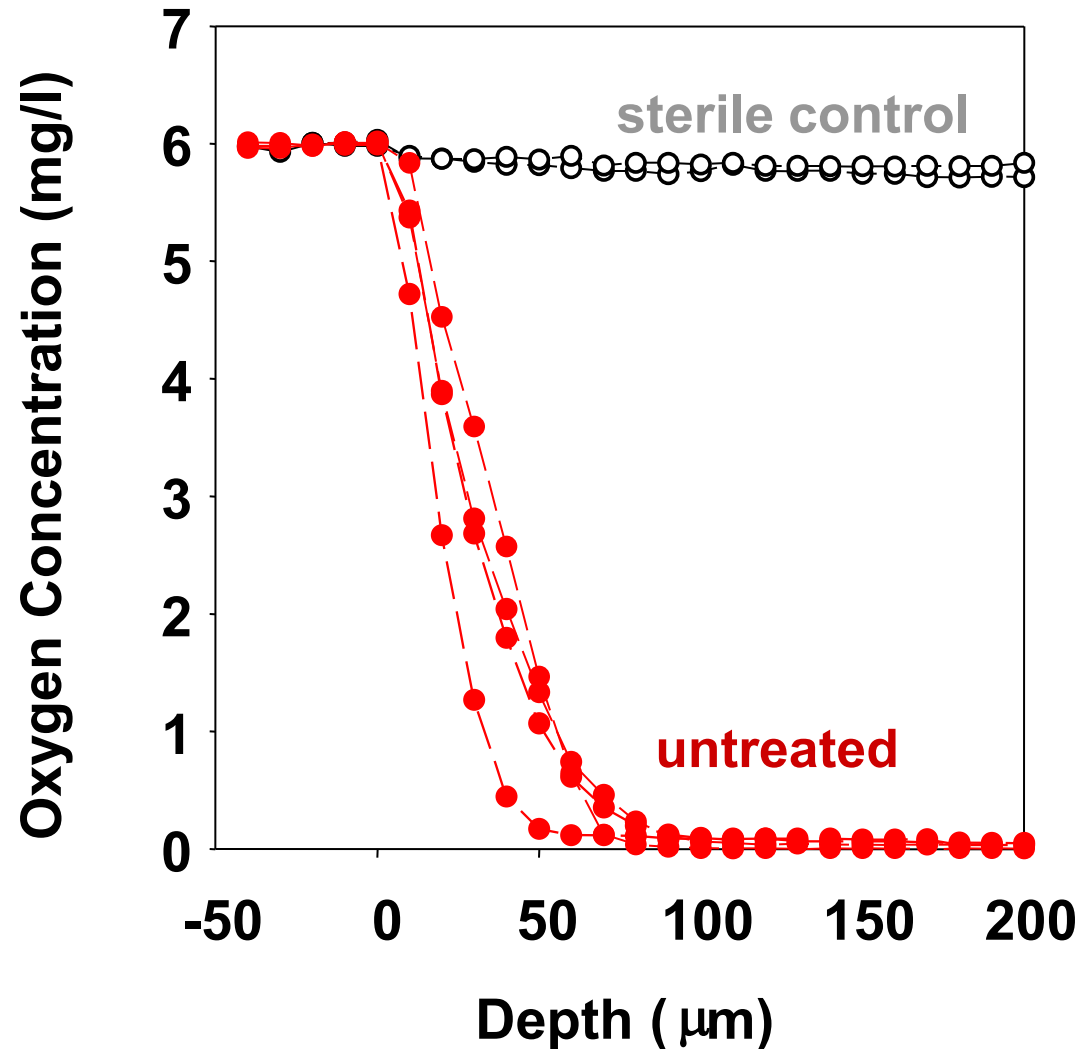
Hypochlorite penetrates biofilm slowly



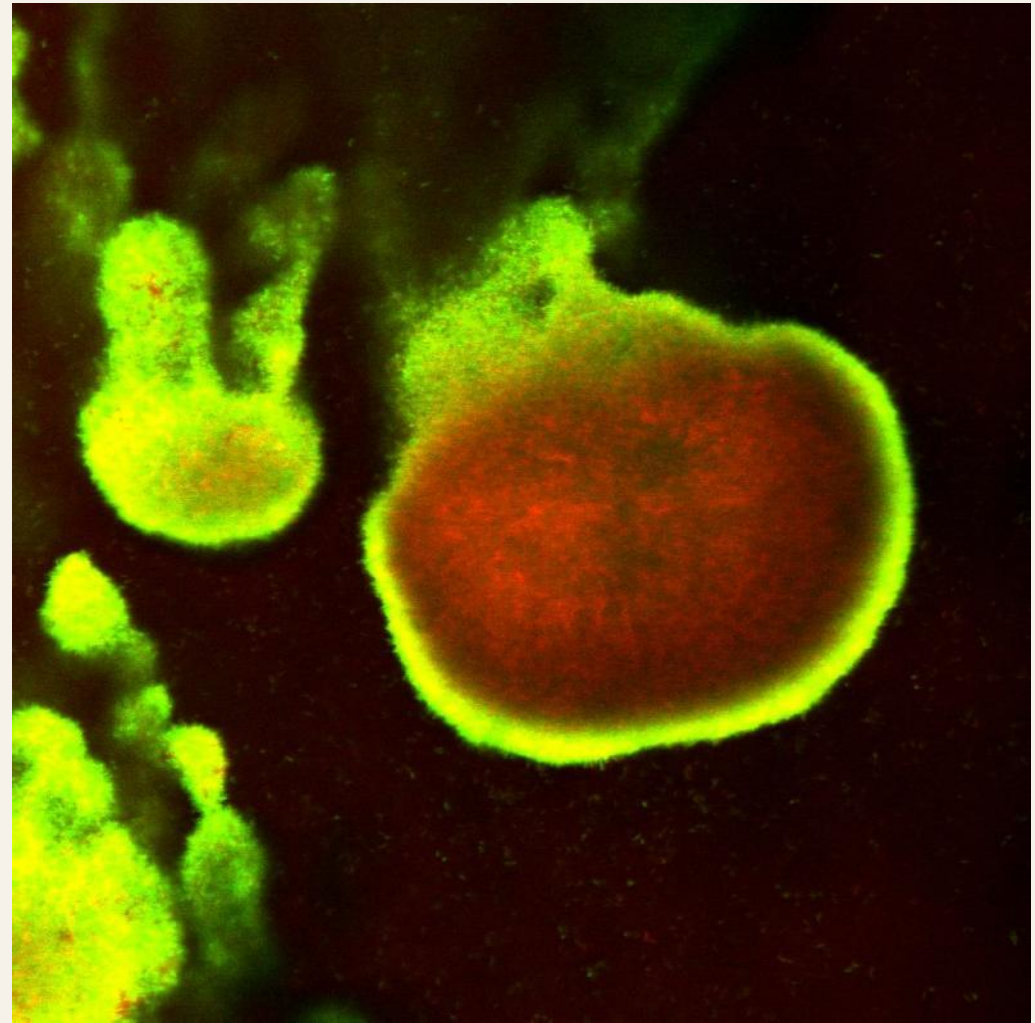
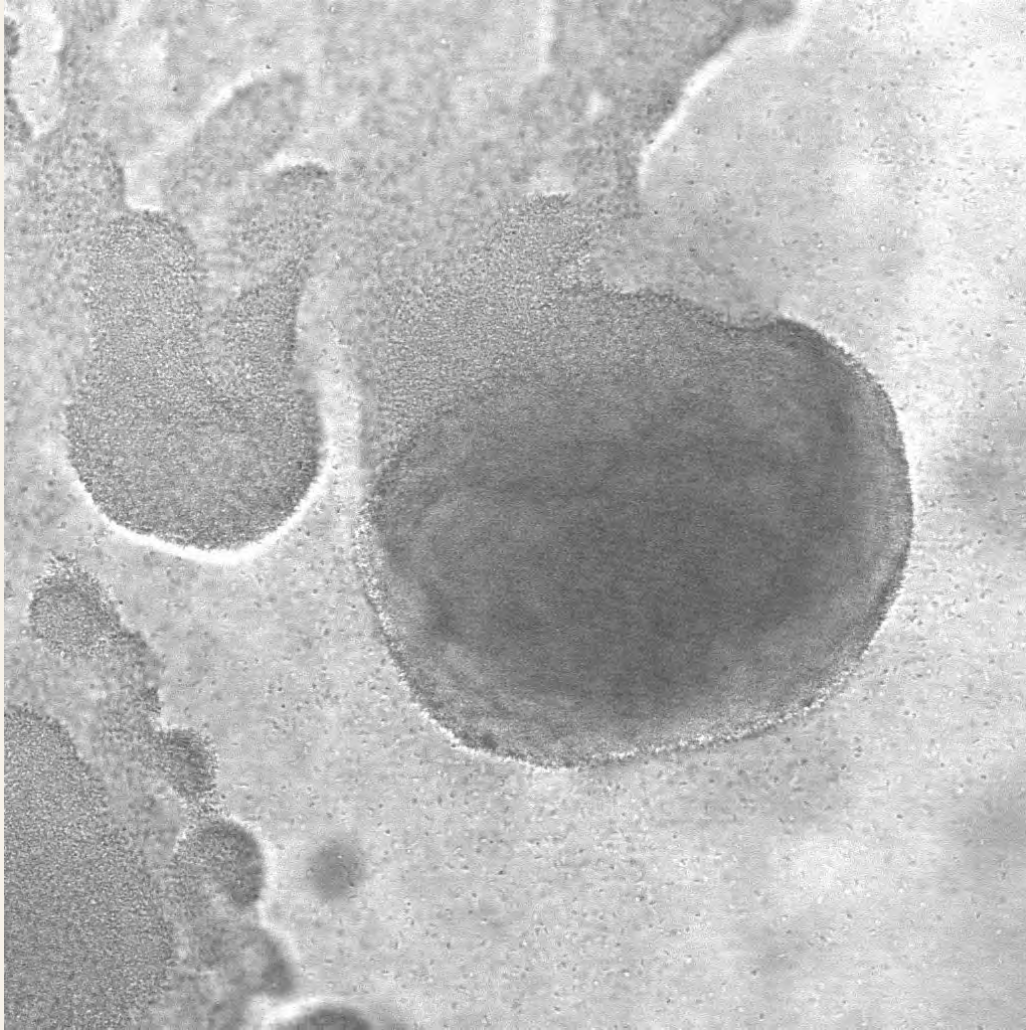
2. Altered Microenvironment



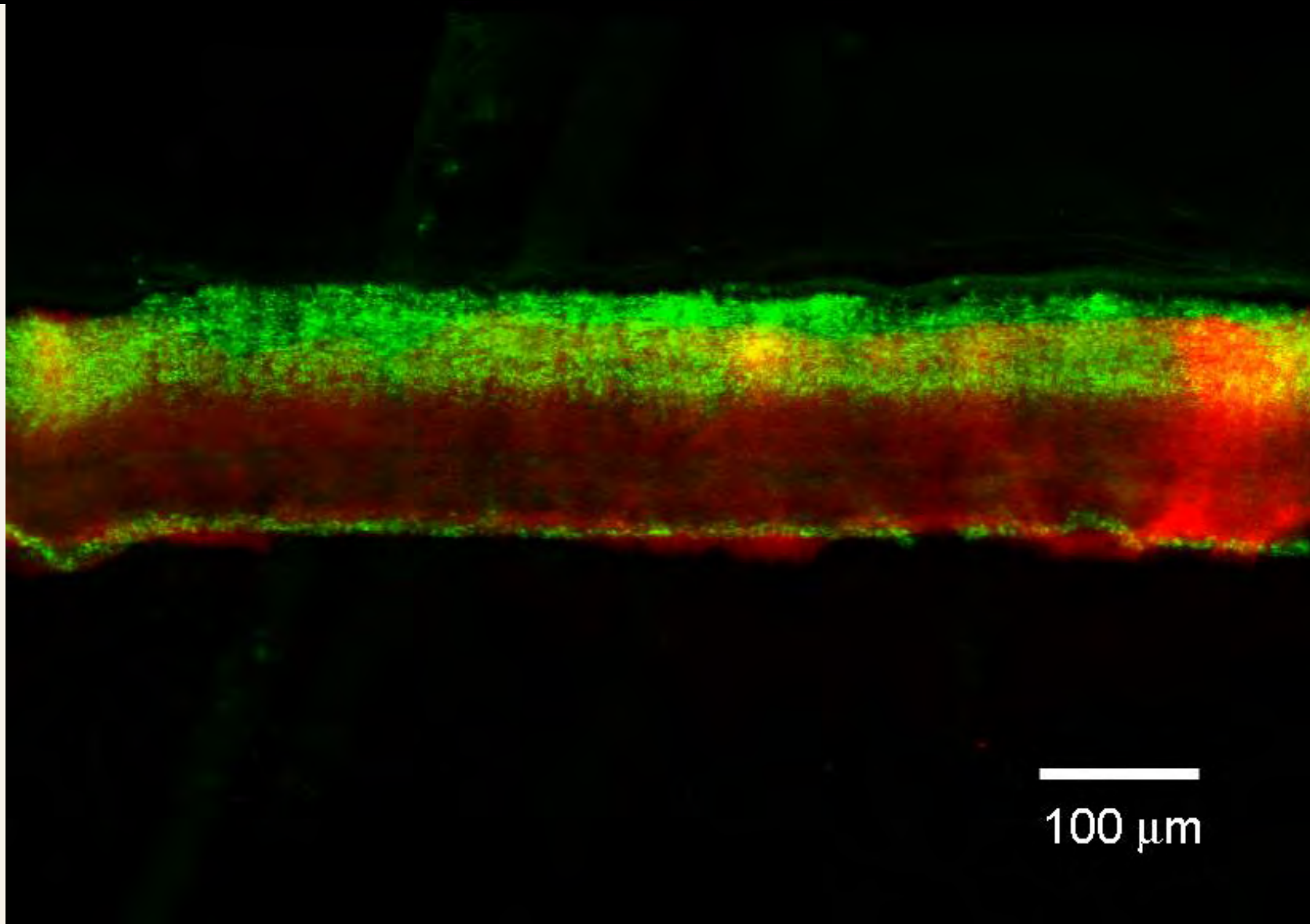
Oxygen in *P. aeruginosa* Biofilm



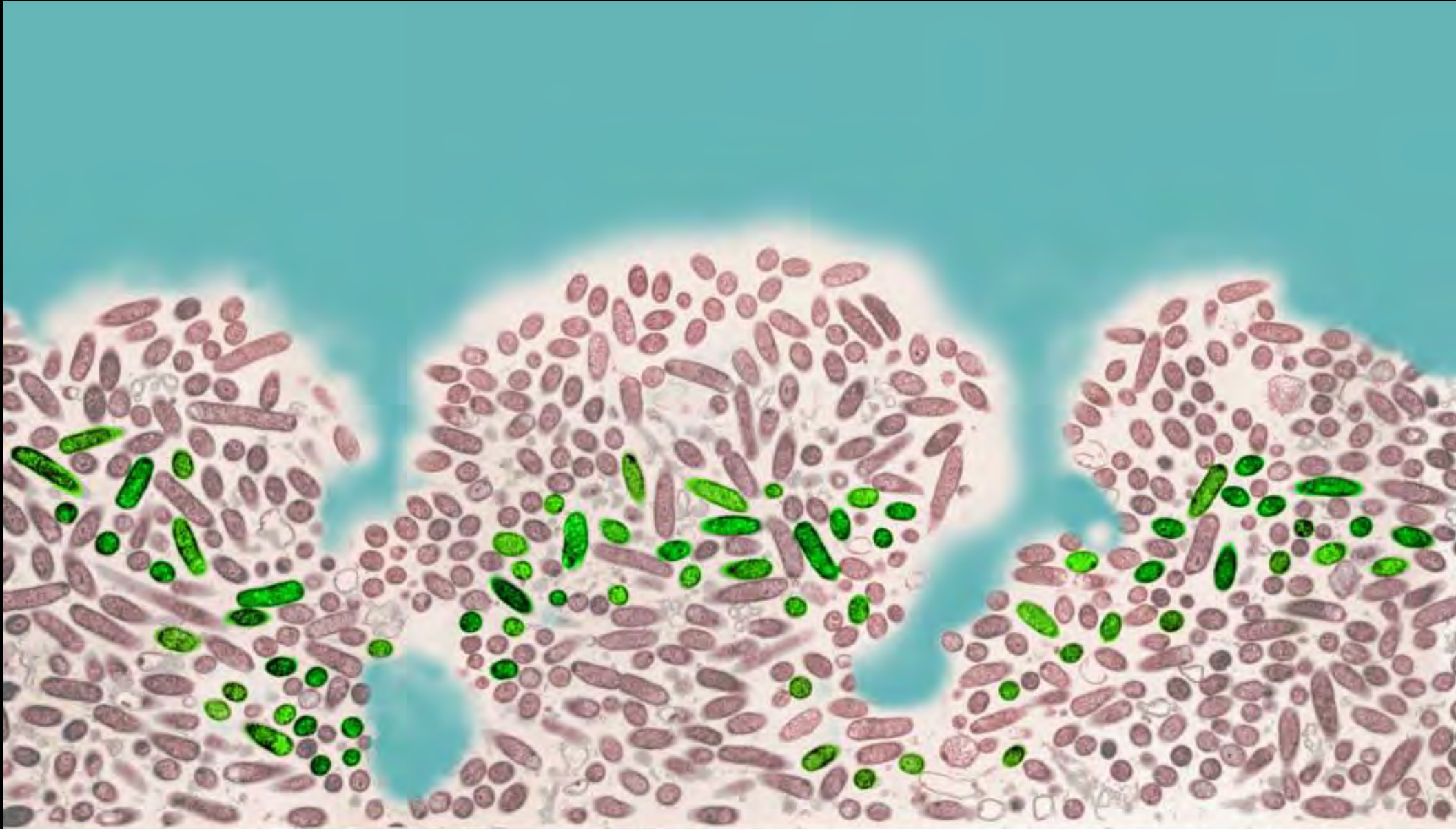
GFP Expression in *P. aeruginosa* Biofilm



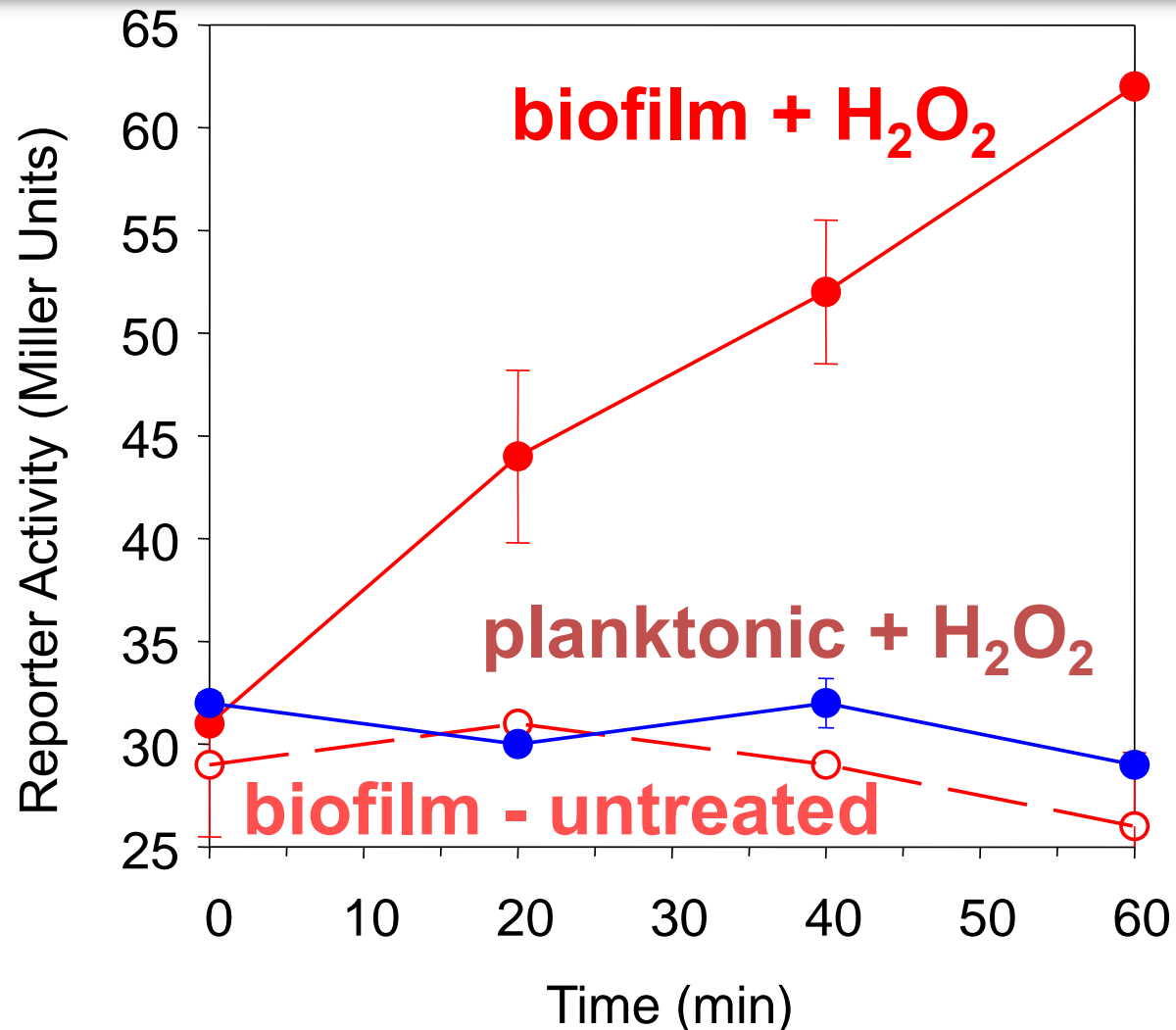
DNA Replication Pattern Biofilm



3. Stress Response



Catalase Induction in *P. aeruginosa* Biofilm



katB-lacZ

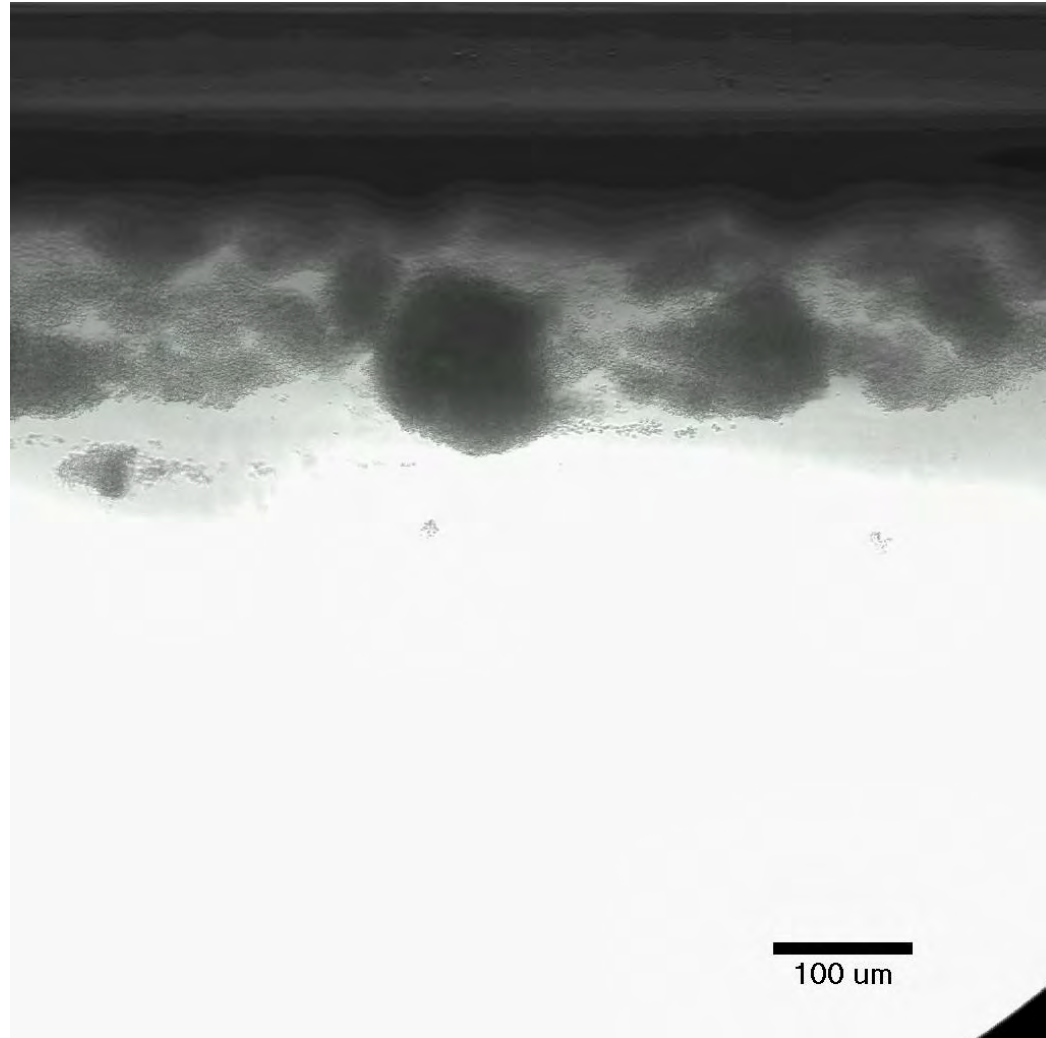
Elkins et al
(2000) *Appl. Environ. Microbiol.*
65:4594

Imaging antimicrobial action

S. epidermidis
biofilm staining
with Calcein AM
green (CAM)

Time: 1 hr

Vel = 6 cm/sec

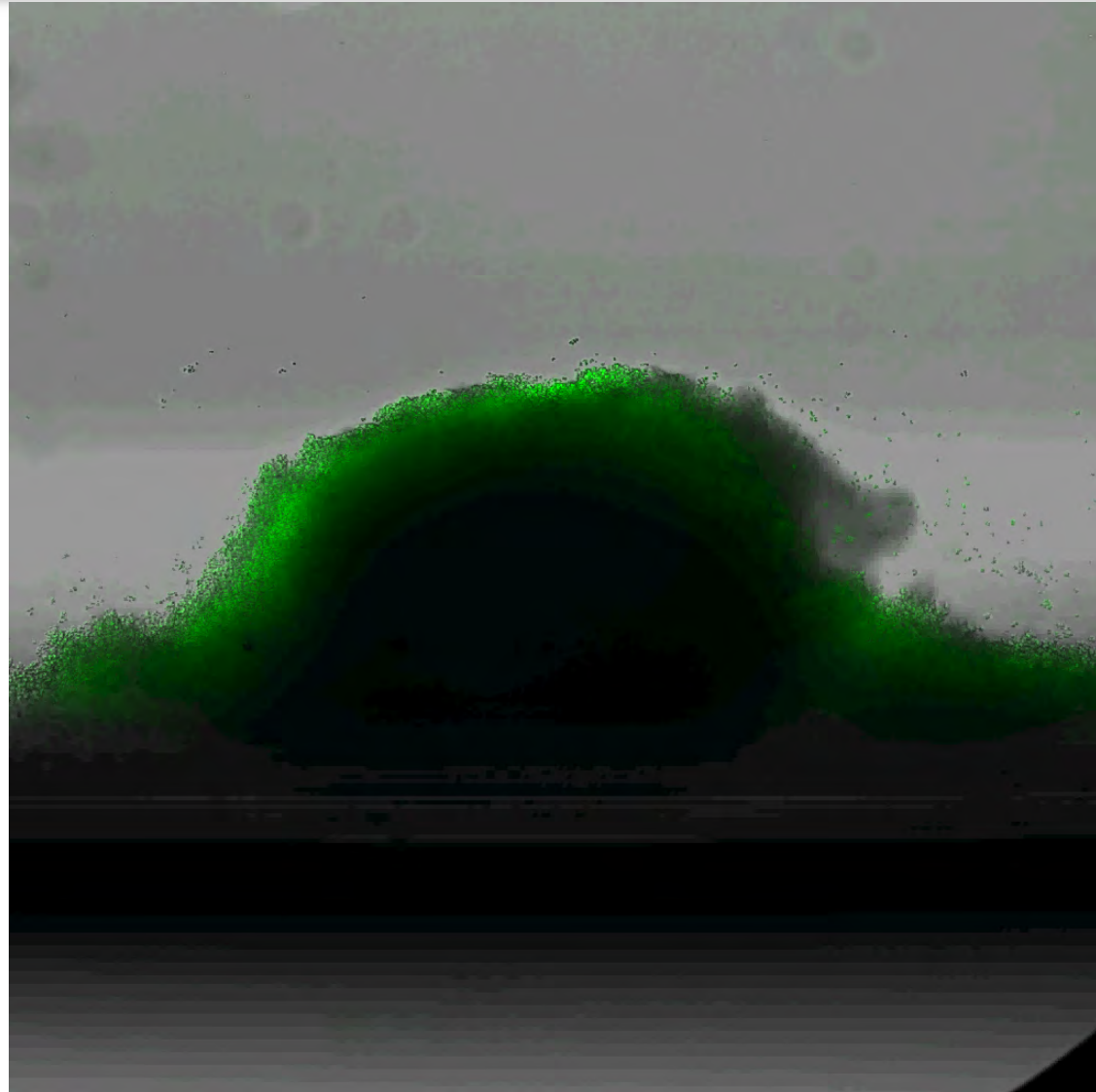


Imaging antimicrobial action

CAM-stained
S. epidermidis
biofilm treated
with 10 mg/L
sodium
hypochlorite

Time: 1 hr

Vel = 6 cm/sec

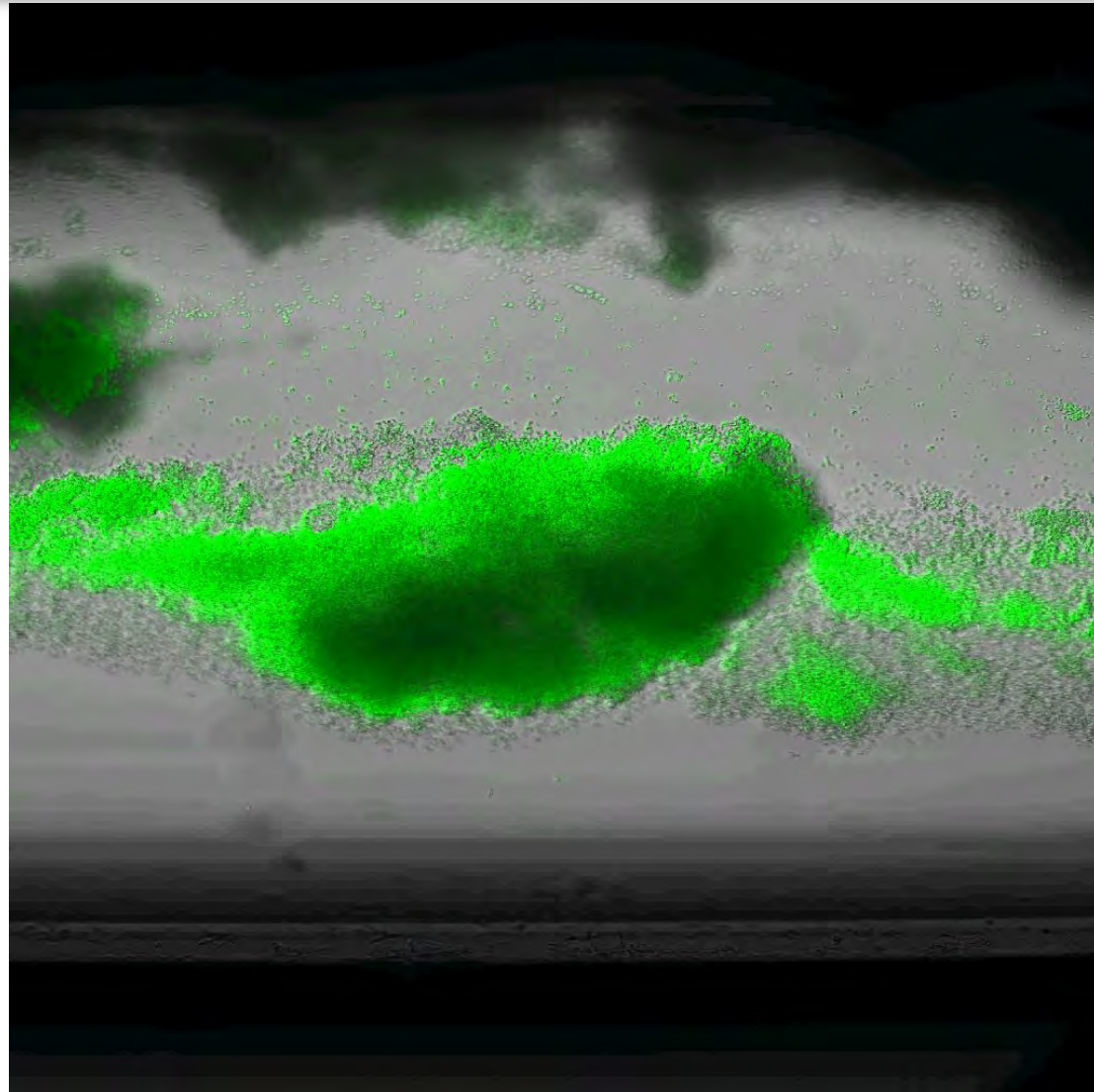


Imaging antimicrobial action

CAM-stained
S. epidermidis
biofilm treated
with 50 mg/L
sodium
hypochlorite

Time: 1 hr

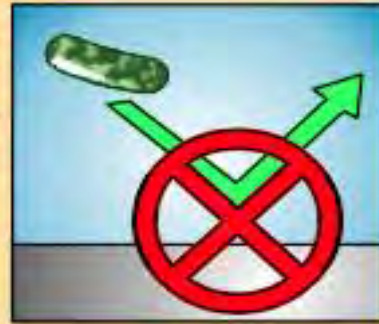
Vel = 6 cm/sec



W. Davison

Options for Microbial Control

Options for Microbial Control



Stop
Attachment



Stop
Growth



Block Matrix
Synthesis



Kill



Disrupt
Communication



Promote
Detachment



Mechanical
Removal

062001 StewP 6ways2ctr

Biofilm control in industrial systems

- Regular cleaning and antimicrobial dosing
- Antimicrobial access to the biofilm
- Contact time
- Materials Compatibility
- Measuring successful treatment



**Contents of these slides
were provided by faculty,
staff, and students in the
Center for Biofilm
Engineering at Montana
State University**

www.biofilm.montana.edu

**Thank you for your
attention!**