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BIOFILMS AND BIOCIDES

INTRODUCTION
Antimicrobials and biofilms

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We hear more and more about microbes developing resistance to antimicrobials, which are also referred to as antibiotics and antimicrobial agents. Antibiotics are biologically produced chemical agents that are used to control microbial infection in humans and animals. Most antibiotics are produced by microorganisms. The best known example is penicillin, a broad-spectrum antibiotic active against many Gram-positive bacteria, produced by the fungus *Penicillium chrysogenum.* Antibiotics normally have a single target site in cells. Antimicrobial agents, sometimes referred to as microbiocides or biocides, are inorganic or organic chemicals, which are toxic to microbes. Antimicrobial agents are used to control microbes found in everyday household and industrial environments, such as drains, cutting boards, contact lens cases, swimming pools, toilets, metal working fluids and cooling towers. Most antimicrobial agents can act against many microbial target sites.

The greatest cause for concern in the use of antibiotics is the trend of some human pathogens to become resistant to them. Strains of *Staphylococcus*, *Streptococcus* and *Pseudomonas* that are resistant to multiple antibiotics are now commonly found in hospital environments. The presence of these resistant organisms is caused, in part, by the inappropriate use of antibiotics, being either overprescribed or not taken correctly by the patient. We now hear about the possibility that some antimicrobial agents may confer antibiotic resistance on bacteria. We are also learning more about links between biofilm formation and persistent or recurring human infections, as well as the role of biofilms in difficult to control microbe-contaminated industrial systems. In part the difficulty comes from the means which are used to measure antimicrobial efficacy and to determine prescribed doses, which do not always include all the factors that are encountered in the field. Antibiotics or biocides are most often tested against planktonic cultures, usually in pure culture. In reality, they should be tested against multispecies cultures and biofilm communities.

Biofilms appear to generally confer resistance to microbes against a wide range of antibiotics and antimicrobials, as well as protection against environmental stresses. What is the link, if any, between biofilm formation and the emergence of resistant strains, and can the two combine to produce super-resistant strains? Initial concerns about microbial resistance centered on human pathogens, but now we are beginning to learn about resistance associated with antimicrobials used in household products. The development of ''superbugs'' whose resistance to antimicrobial agents also make them resistant to antibiotics is now commonly reported in the press. We are all aware of papers on bacterial resistance to ''Triclosan.''

Normally, research deals with laboratory microbes under very controlled conditions. Does microbial resistance to antimicrobials used in household products really occur in everyday life? Do environmental bacteria become resistant to antimicrobials in a similar way as pathogens become resistant to antibiotics? If so, are there many different resistance mechanisms or a few general strategies common to many types of bacteria? If bacteria do become resistant, when the antimicrobial agent is removed, what happens to the bacteria? Will they be outcompeted because the ''nonresistant'' strain of bacteria is better able to grow in the non-antimicrobial environment? Could it be that bacteria we think are resistant have never been affected by the antimicrobial, because they are within the protective niche of a biofilm? Does the extracellular material of the biofilm prevent penetration of the antimicrobial, or is there extracellular enzymatic activity within the biofilm that destroys the antimicrobial? What other factors may be involved in resistance? One could be the lack of microbial activity. Some work suggests that the attachment of cells to surfaces results in upregulation of multidrug efflux pumps, even in the absence of antibiotics. Why would biofilm formation alone be intrinsically linked to such resistance mechanisms? Other theories point to subpopulations of ''persisters,'' mutants resistant to apoptosis, in both biofilm and planktonic communities, which can survive antimicrobial onslaughts. Many papers have been written on this subject, and many more will be before this matter is settled.

At the 2001 SIM meeting, an excellent session was presented on this topic, ''Bacterial Resistance to Biocides in Industrial Systems.'' In addition, there were some excellent papers from the biofilm session, ''Monitoring and Control of Microbial Biofilms.'' Some of the papers dealt with bacterial resistance in biofilms, and others on the physiology and properties of biofilms. Both sessions presented a wide range of topics that led to interesting discussions lasting long after the formal sessions were completed. The papers in this special issue of JIM&B were inspired by these sessions.

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