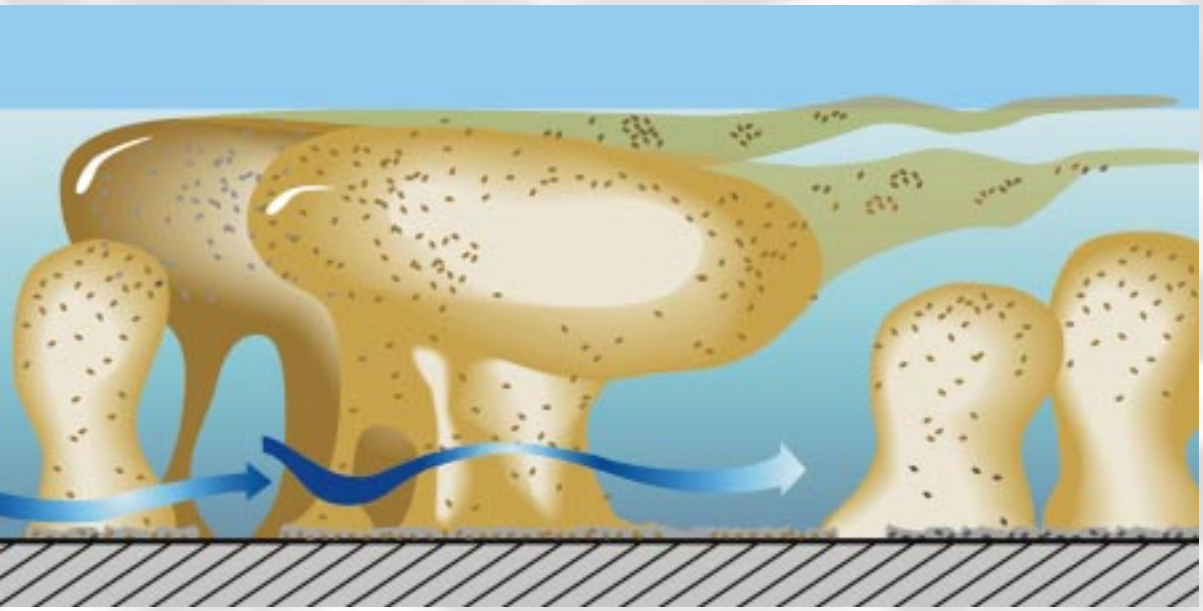
Biofilms: united they stand, divided they fall

Peter Gilbert & Hilary Lappin-Scott



A preview of the topics to be discussed in the SGM Main Symposium *Community Structure and Co-operation in Biofilms* at the University of Exeter, 12–13 September 2000.

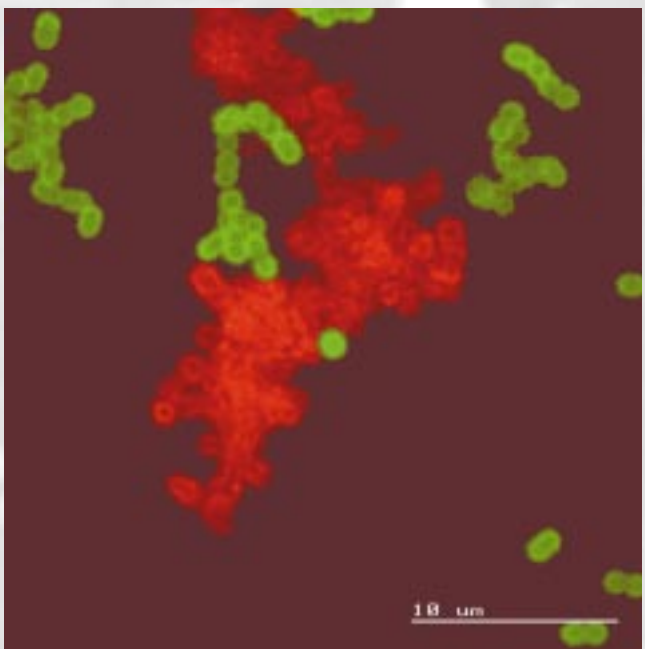
ABOVE:
Diagrammatic representation of morphological data from dozens of natural and *in vitro* biofilms, in the *x*–*z*-axis, showing the microcolonies and water channels that comprise these complex and highly structured communities. The sessile biofilm cells actually grow in matrix-enclosed microcolonies, of various shapes, and these microcolonies are often deformed by high shear forces to produce the streamers seen to project into the bulk fluid.

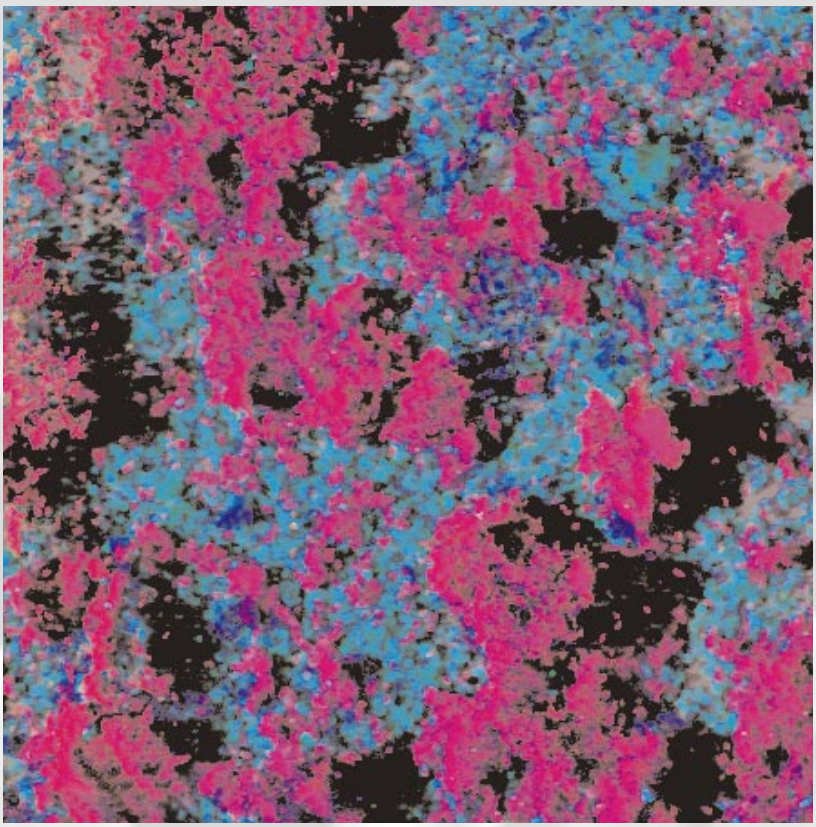
COURTESY DR J.W. COSTERTON, MONTANA STATE UNIVERSITY, USA/ARTWORK PEG DIRCKX

The introduction of the term 'biofilm' into general microbiology is relatively recent but the concepts that it embraces are not new. This umbrella term encapsulates the notion that bacteria, yeasts, moulds, and indeed some micro-fauna, co-exist in nature as spatially organized communities and that such communities can survive and exploit circumstances beyond their capabilities as individual microbes. Biofilms therefore epitomize the collective strength of the individual within a community structure and it is only when such interactions are studied that we can fully understand the way that microbes impinge upon all aspects of life.

The keystone of biofilm study has been the general recognition that even single species of bacteria, when attached to surfaces and interfaces, express phenotypes that are not seen in liquid culture. For various genera whole cassettes of genes are repressed or de-repressed under the apparent control of touch receptors. Particularly, the 'sessile phenotype' more often displays a reduced susceptibility towards various antibacterial treatments and a more aggressive pathogenesis or corrosion potential than does the free-living planktonic cell. Part of the explanation for the unique properties of biofilm communities comes from the localized high cell densities that they facilitate through the synthesis of an extensive extracellular polymeric matrix. Such polymers not only cement the bacterial cells to the surface but also maintain a spatial arrangement of the different community members and are capable of entrapping many extracellular products and enzymes. Under such circumstances populations of cells become quorate and through the mediation and accumulation of cell–cell signals, such as the *N*-acyl-homoserine lactones in the case of Gram-negative bacteria, alter phenotypes at the level of transcription. Cross-signalling between different species and genera allows complex, multi-functional consortia to become established. It is often only one of these properties, resistance, corrosion, degradation or biofouling potential, that renders them worthy of study by the industrial or medical microbiologist, and for consideration as therapeutic targets by medicinal chemists. In the Exeter symposium we seek to expose the commonality of process which links these disparate practical problems.

The formation and maintenance of a biofilm is a dynamic process involving a complex interaction of physical and biological processes. Irreversible attachment of planktonic cells to a surface is indicated by a loss of Brownian motion and within a few minutes a number of transcription events are initiated. These particularly concern not only the up-regulation of exopolymer biosynthesis and the deposition of the glycocalyx, but also the orchestration of many other physiological and biosynthetic events. In nature micro-organisms rarely encounter an uncolonized surface, yet much can be learnt about the transition from a planktonic to sessile mode of growth through studies where cleaned, sterile surfaces are exposed to growing suspensions of bacteria. This is of immediate practical importance to the colonization of an implanted medical device or prosthesis, setting the framework through which new materials may be designed to delay or prevent biofilm formation. The





BACKGROUND:
A mixed community biofilm composed of bacteria and fungi.
COURTESY HILARY LAPPIN-SCOTT AND SARA ROBERTS

LEFT:
Confocal micrograph of a biofilm community with seven different species. The biofilm was fixed and embedded, and differentially labelled probes targeting *Pseudomonas putida* R1 (red), *Acinetobacter* sp. C6 (green) and all other eubacteria (blue) were added.
COURTESY PROFESSOR S. MOLIN, TECHNICAL UNIVERSITY OF DENMARK

BELOW:
SGM Symposium Volume 59.

precise nature of the colonizing species and its relationship with other bacteria determines the nature of the biofilm formed. In dental plaque such inter-relationships have been well characterized but similar processes are involved wherever surfaces are exposed to environmental micro-organisms.

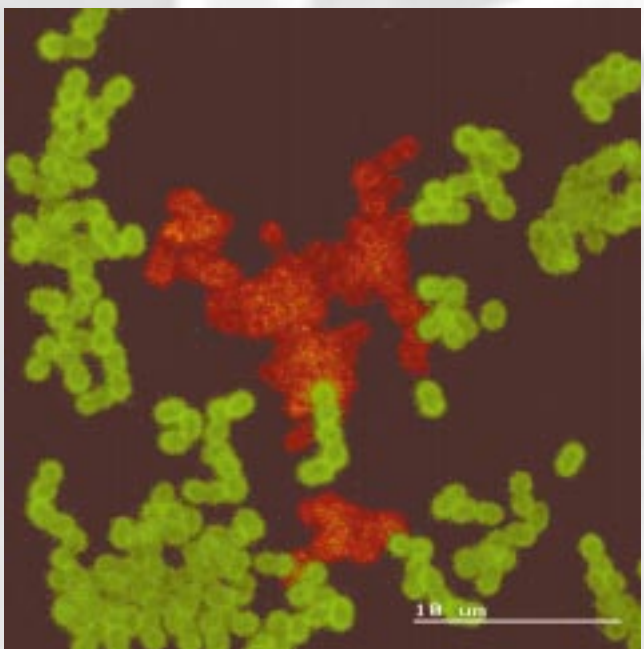
The main symposium will be complemented by a second session entitled *Medical Implications of Biofilms*, organized by the Cells & Cell Surfaces and Microbial Infection Groups, examining aspects of biofilm physiology in the context of health and disease. There are also two evening workshops, one focusing on young researchers working in the areas of *Biofilm Formation and Control* and a second on *Teaching the Topic of Biofilms*. The latter will focus on three fundamental questions:

- What elements of the biofilm story should be included in the undergraduate curriculum?
- What properties of biofilm microbiology can be introduced into undergraduate practicals given the equipment constraints of the undergraduate laboratory?
- What strategies of dissemination are most likely to be successful in getting information about biofilms to curriculum developers, textbook authors, planners of educational symposia and teachers?

We believe that the combined programme offers a superb opportunity for the novice and experienced 'biofilmologist' alike to gain a rounded insight into the impact that biofilms have on our lives and on the study of microbiology. We hope that those of you attending who have not already been bitten by the biofilm bug will be drawn to re-examine research in your area in the context of bacterial attachment and organization into communities.

Further details and a booking form appear in the enclosed programme booklet for the meeting. The symposium will be published as a book in the redesigned *SGM Symposium* series (vol. 59). A review of the book and an order form will appear in a future issue of *Microbiology Today*.

● *Peter Gilbert, University of Manchester*
● *Hilary Lappin-Scott, University of Exeter*



LEFT:
Representative CSLM images of a *Streptococcus gordonii* (green) and *Actinomyces naeslundii* (red) biofilm. Left panel: coadhesion of a single streptococcal cell (centre) bound to a clump of actinomyces and coadhesion of chains of streptococci to two different lobes of the clump of actinomyces (upper centre). Right panel: coadhesion of streptococci and actinomyces (upper centre) and bridging of adherent streptococci by a small clump of actinomyces (lower centre).
COURTESY DR P. KOLENBRANDER, NIH, BETHESDA, MD, USA