# MICROBIAL BIOFILMS

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**Keywords**: Microbial adherence to cellular/inert substrata, Biofilms, Intercellular communication, Quorum Sensing (QS) mechanism, Dental plaque, Tolerance to antimicrobials, Anti-biofilm strategies, Ecological and biotechnological significance of biofilms

## Contents





## Summary

A biofilm is a sessile microbial community composed of cells embedded in a matrix of exopolysaccharide matrix attached to a substratum or interface. Biofilms are ubiquitous in natural, industrial and hospital settings and can contain different types of microorganisms (bacteria, archaea, protozoa, fungi and algae), each with specialized metabolic functions.

Biofilms are considered a primitive form of cellular differentiation and the most successful and competitive expression of the prokaryotic genome, the biofilm`s cells being metabolically more efficient, well protected and resistant to any kind of stress. Inside biofilms, a cell to cell -to-cell communication system, *quorum sensing (QS) and*

*response,* mediated by small molecules called autoinducers, is established. The intercellular communication can be intraspecific, interspecific and even interkingdom cross-talk between bacteria and the eukaryotic / host cells. The QS systems might enable pathogens to overcome the host defence mechanisms and have also immunomodulatory effects.

Microbial biofilms influence almost all aspects of our lives, being significant from medical, ecological, biotechnological and economic points of view. Whilst much of this impact is positive, there are many areas in which the presence and activities of biofilms are detrimental. Biofilms reveal their recalcitrance towards a lot of antibiotics and other antimicrobials used in medical and industrial fields. In natural environment the biofilm formation can be beneficial or detrimental, from human perspective, but always is a process with evolutionary potential and survival value for bacteria. In the medical field the biofilm formation by pathogens is always detrimental for human body, either when developed on cellular substrata, or on different medical devices generating chronic infections, difficult to treat.

The purpose of this review is to present the biofilms' structure and properties, their medical, ecological and biotechnological significance, as well as the present and future strategies for the assessment and control of biofilm's development in different environments.

## 1. Introduction

The first reports about multicellular prokaryotic communities on submerged surfaces are due to Zo Bell, a pioneer of biofilm microbiology (ZoBell et al., 1933, 1935), who stated the presence of adherent microbial associations in all natural environments. Studying the attachment of marine bacteria to glass slides he observed that this process is very rapid, and when the seawater was collected in sterile glass bottles there were more bacteria present on the surface of the glass as sessile bacteria than those in the free floating planktonic phase. ZoBell concluded that the nutrients in the seawater were probably concentrated on the solid surfaces and were thus attracting the bacteria, enhancing their growth and survival; he found too that many marine bacteria were sessile and that they grew preferentially attached to a surface. ZoBell postulated that biofilms holds the nutrients, bacteria and their enzymes are close to the surface and therefore could damage it (Lappin-Scott, 1999). A detailed description of these microbial communities or biofilms was realized approximately 40 years later by Costerton and his team, who emphasized the very significant role of these adherent microorganisms in human infectious diseases and many other processes (Costerton et al., 1978). Biofilms may form on living or non-living surfaces, and represent a prevalent mode of microbial life in natural, industrial and hospital settings.

Biofilms are ubiquitous and usually found on solid substrata submerged in, or exposed to an aqueous solution although they can form as floating mats on liquid surfaces and also on the surface of leaves or other surfaces, particularly in high humidity climates. Given sufficient resources for growth, a biofilm will quickly grow to become macroscopic. Biofilms can contain many different types of microorganisms, e.g. bacteria, archaea, protozoa, fungi and algae, each group performing specialized

metabolic functions. However, some organisms can form monospecies films, only under extreme conditions; for instance, biofilms can develop in the most extreme environments, such as the extremely hot, briny waters of hot springs ranging from very acidic to very alkaline, to frozen glaciers. The cells of a biofilm are embedded in a matrix composed by E.P.S. (extracellular polymeric substances), fibrilar or amorfous; the cellular density of a biofilm is between $10^4$ cells/cm$^2$ – $10^8$ cells/cm$^2$, these values being the limits that mark the difference between invisible and visible biofilms (Carpentier, 1999).

## 2. Definition

A biofilm is a sessile microbial community composed of cells embedded in a matrix of E.P.S. attached to a substratum or interface. The matrix is primarily of microbial origin and the cells encased in this matrix present a modified phenotype, especially with regard to growth rate and gene transcription (Donlan & Costerton, 2002). The biofilm's matrix, which is also referred to as *slime* is a reticular structure generally composed of water (95-99%), polysaccharides, extracellular DNA, proteins and minerals.

The term of *slime* was used by Christensen et al. (1982) to define the glycocalix produced by the strongly adherent strains of *Staphylococcus epidermidis* isolated from the infected surface of medical implants (Dunne, 2002); today this termbeing also used for other species.

## 3. Microbial Adherence

The last decades studies of microbial adherence to different substrata were leading to some clear ideas: 1) the survival of microorganisms in some natural habitats, including the medical ecosystems, is dependent on their capacity to adhere at surfaces/substrata and form biofilms; 2) the adherence process consists in an interaction of complementary molecules from the microbial surface: *adhesins*,such as capsules and glicocalix, pilli, fimbria, teichoic acids, LPS, S layer, and *specific receptors* on substratum, the *adhesins - receptors* interaction being similar with the *antigen – antibody one*, concerning the steric complementarity of reagents; 3) the adhesins expression is regulated and the clearing up of molecular mechanisms of regulation could be the premise of manipulation of adherence process: attachment/detachment (Costerton et al., 1978; Poxton, 1993; Saunders et al., 2000).

Adhesion represents an important and determining factor of microbial colonization of specific sites to plants and animals, and especially, an early step of infectious diseases pathogenesis, being a precondition of colonization and biofilm's formation (Cravioto et al., 1979; Cundell and Toumanen, 1995; Livrelli et al., 1996; Singleton et al, 1997; Cucarella et al., 2001; Yatsuyanagi et al., 2002).

For instance, some strains or pathotypes of *Escherichia coli*, generally an unpathogenic member of colonic microbiota, are responsible of a large spectrum of intestinal and extra-intestinal diseases. These strains are carrying specific adhesins (fimbriae, pilli) which increase capacity of these strains to colonize the intestinal tract, the attachment to

the intestinal cells representing the first step in the infectious diseases pathogenesis (Nataro et al., 1998).

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**Biographical Sketches**

**Veronica Lazar, w**ith 25 years experience in the field of medical microbiology and immunology, microbial ecology, Professor Veronica Lazar has specific expertise in:

1. Study of the bacterial adherence / invasion capacity and biofilm formation on cellular substrata and inert materials used in medicine;
2. Study of bacterial virulence and pathogenicity at cultural and molecular level;
3. Designing experimental protocols to investigate the microbial adherence and biofilm formation and its tolerance to antimicrobials (antibiotics, antiseptics, disinfectants);
4. Study of the Quorum sensing mechanism and inhibitors (vegetal or microbial products), with antibiofilm and antipathogenic activity.
5. Study of the interaction between the adherent bacteria and encased in biofilms and the cellular and serum immune effectors of the host;
6. The evaluation of the impact of human activity on the aquatic river ecosystems (study of physiological groups of microorganisms involved in carbon, nitrogen, sulfur cycles);
7. Study of antibioresistant enterobacteria strains isolated from the fresh waters, food, intestinal tract and clinical specimens; the phenotypical and genotypical study of aquatic reservoir of resistance and virulence genes;
8. Identification and demonstration of the efficiency of some products as ecological complementary or alternative methods to antibiotherapy (probiotics, prebiotics, vegetal extracts, new antimicrobials).
In addition, she has been awarded with a Romanian Academy Prize/ 2005 for a monograph – *Microbial Adherence* (2003) published by Rom. Acad. Press. She has two patents (published in 2010) concerning experimental models for determination of the susceptibility of adherent bacteria on biomaterials to antimicrobials.

**Eugenia Bezirtzoglou,** with 25 years experience in the field of microbial ecology of intestinal and food ecosystems, Professor Eugenia Bezirtzoglou has specific expertise in:
1. Gastrointestinal microflora
2. Bacterial biofilms
3. Anaerobic bacteria
4. Food microbiology and hygiene
5. Microbial ecology methods and techniques at cultural and molecular level
6. Developing methods for sampling and culturing bacteria
7. Designing experimental protocols to investigate the gastrointestinal ecosystem and factors influencing food microflora in health and disease.
In addition, she has been involved in many European (ECDC, EFSA) and National bodies (Ministries, Chemical State Laboratory) to offer her laboratory and teaching expertise on the above scientific fields.