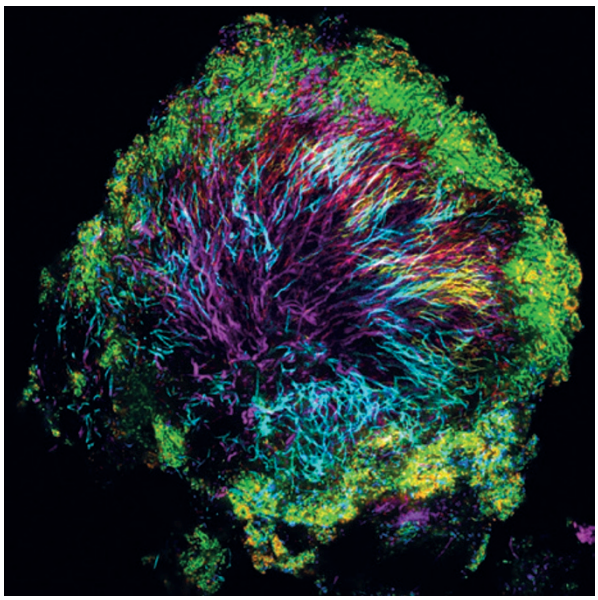
Nature Reviews Microbiology | Published online 8 Feb 2016; doi:10.1038/nrmicro.2016.21

MICROBIAL ECOLOGY

FISHing in the oral microbiota

Recent surveys of the oral microbiota have described the taxonomic composition of the various regions of the oral cavity in unprecedented detail. However, although these surveys have provided a glimpse of the biogeography of the oral microbiota at a gross scale, they have lacked the micrometre-scale resolution that is necessary to study the spatial organization of individual consortia of bacterial cells. Borisy and colleagues now use spectral fluorescence imaging to examine the consortium structures formed by nine key taxa of the oral microbiota, and report a radial arrangement in which intermingling taxa exhibit a complex set of physical and metabolic interactions.

As an alternative approach to the sequencing of homogenized samples, the microbiota of structurally preserved supragingival plaque samples were visualized using a combinatorial labelling and spectral imaging fluorescence *in situ* hybridization (CLASI-FISH) technique that was recently developed by the authors, which enables up to 15 fluorescent probes to be imaged simultaneously. Nine taxa were identified in data from the Human Microbiome Project as prevalent and abundant in the supragingival niche, and unique CLASI-FISH probes were designed for each of these taxa and applied to samples from 22 healthy volunteers. Several types of consortium structure were observed, including a spiny radial structure — reminiscent to the authors of hedgehogs — that was present in many of the samples. These 'hedgehog' structures were defined by signature radial protrusions of filamentous spines that were connected to cocci tips at the periphery and clumps of cells at the base; additional cells were present at the periphery or in an annulus ring beneath the periphery. Each of the nine taxa reproducibly occupied a characteristic position: *Corynebacterium* spp. (usually *Corynebacterium matruchotii*) filaments formed the framework; cells of the *Streptococcus*, *Porphyromonas*, Neisseriaceae and *Haemophilus–Aggregatibacter* taxa formed the periphery; *Fusobacterium* spp., *Leptotrichia* spp. and *Capnocytophaga* spp. cells formed the annulus; and *Actinomyces* spp. and *Corynebacterium* spp. cells formed the base.



Microbial consortium in human dental plaque. Image courtesy of G. G. Borisy and J. L. Mark Welch, The Forsyth Institute, Cambridge, Massachusetts, USA.

The authors propose that these 'hedgehog' consortia are seeded by the attachment of *Corynebacterium* spp. cells to a pre-existing biofilm coating the surface of a tooth. Once seeded, the *Corynebacterium* spp. filaments seem to have a central role in organizing the consortium, as they provide an attachment surface for *Streptococcus* spp. and *Porphyromonas* spp. cells at the periphery, where the crevicular fluid supplies nutrients. In turn, *Streptococcus* spp. cells provide an attachment surface for *Haemophilus* spp. and/or *Aggregatibacter* spp. cells and, through the aerobic metabolism of sugars, create an anoxic microenvironment in the annulus that favours the metabolisms of *Fusobacterium* spp., *Leptotrichia* spp. and *Capnocytophaga* spp. cells.

Therefore, a complex set of physical and metabolic interactions provides the framework for the spatial organization of the consortium. The authors conclude that the ability of *Corynebacterium* spp. cells to grow filaments from a tooth-coating biofilm base, which provides a framework for a multigenus metabolic consortium, explains the success of this genus in the supragingival niche, as measured by its prevalence and abundance in plaque. However, the relative importance of physical and metabolic influences on spatial positioning is not trivial to dissect. Furthermore, whether the social interactions between taxa in this consortium are founded on a mutualistic, commensal or parasitic basis will be a question for future research.

Naomi Attar

ORIGINAL ARTICLE Mark Welch, J. L. *et al.* Biogeography of a human oral microbiome at the micron scale. *Proc. Natl Acad. Sci. USA* http://dx.doi.org/10.1073/pnas.1522149113 (2016)