

Small Things Considered

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A blog for sharing appreciation of the width and depth of microbes and microbial activities on this planet.

A Game of Dice

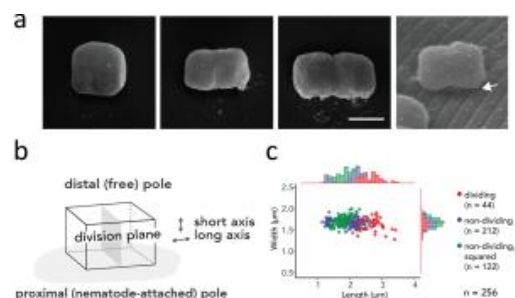
by Christoph

When on the 3rd day of creation – or the 5th, the Old Testament isn't quite clear here – the Bacteria and Archaea were summoned to choose their shapes, there was at once a run on rods and cocci; spirillae were also immediately sold out. The Alphaproteobacteria frolicked and adorned themselves with all available prosthecae (https://en.wikipedia.org/wiki/Prosthecae_bacteria), cell appendages, that they cherish to this day. A few Archaea had snatched the quadrangular chips – one is still around today, *Haloquadratum walsbyi* (https://en.wikipedia.org/wiki/Haloquadratum_walsbyi) – after the ever faster phages had quickly distributed the fancy icosahedra among themselves. Thus, for one loitering sulfur-oxidizing Gammaproteobacterium from the Chromatiales (https://en.wikipedia.org/wiki/Purple_sulfur_bacteria), only the cube remained. Well, mumbled "*Candidatus Thiosymbion cuboideus*", then I'll just challenge the millimeters-long Stilbonematinae (<https://en.wikipedia.org/wiki/Stilbonematinae>) worm *Catanema* sp. "Guadeloupe" from the day 5 lot of creatures to a game of dice... Spoiler: the two have become close friends and still roll the dice today (Figure 1a).

Silvia Bulgheresi's lab (<https://archaea.univie.ac.at/research/silvia-bulgheresi-lab/>) at the Archaea Biology and Ecogenomics Unit (<https://archaea.univie.ac.at/>) of Vienna University, Austria, is interested in the remarkable efforts – one could easily talk about "contortions" – that certain bacteria make to successfully colonize the cuticle (https://en.wikipedia.org/wiki/Cuticle#Cuticle_of_invertebrates) of nematodes as ectosymbionts (also called epibionts) (<https://en.wikipedia.org/wiki/Epibiont>) a special yet not rare form of symbiosis. Two years ago, Philipp Weber described in detail "*Candidatus Thiosymbion oneisti*" and its lengthwise cell division (<https://schaechter.asmblog.org/schaechter/2019/09/a-vertical-symbiont-keeps-its-chromosome-oriented-towards-the-host.html>) in this blog (Nanne Nanninga had first introduced it in these pages) (<https://schaechter.asmblog.org/schaechter/2012/11/a-bacterium-learns-long-division.html>). Now, Philipp Weber and colleagues have published (<https://www.sciencedirect.com/science/article/pii/S2589004221015224>) their recent studies of "*Candidatus Thiosymbion cuboideus*", a relative of "Oneisti" (and the authors won't mind when I call the bacterium not by its full name hereafter but simply refer to it as "Cuby").

Viewed from above by scanning electron microscopy (SEM), Cuby cells lie somewhat disorganized and jumbled but tightly packed on the cuticle of their nematode host; a few appear to be in the process of dividing (see [frontpage](#)).

(<https://schaechter.asmblog.org/a/6a00d8341c5e1453ef02942f91c4a3200c-300wi>). Carefully prepared single cells revealed their real shape: tiny cubes with average edge lengths for non-dividing cells of $1.5 \times 1.7 \times 1.3 \mu\text{m}$ (Figure 1c). In relative terms, the calculated cell volume of $\sim 3.3 \mu\text{m}^3$ is roughly 3-times that of a "standard" *E. coli* cell (<http://book.bionumbers.org/how-big-is-an-e-coli-cell-and-what-is-its-mass/>) ($1.3 \mu\text{m}^3$). Like Oneisti cells, Cuby cells arrange as a monolayer in which every cell is attached to the host cuticle. The rod-shaped Oneisti cells stand upright and cramped like in a palisade, with one cell pole attached to the host (see [here](#)) (<https://schaechter.asmblog.org/a/6a00d8341c5e1453ef017c335123f897ob>.) With the Cubies, it looks more like a cobblestone pavement (think of the infamous Paris-Roubaix (https://cdn-ctstaging.pressidium.com/wp-content/uploads/2020/12/CORVOS_00021181-029.jpg) bike



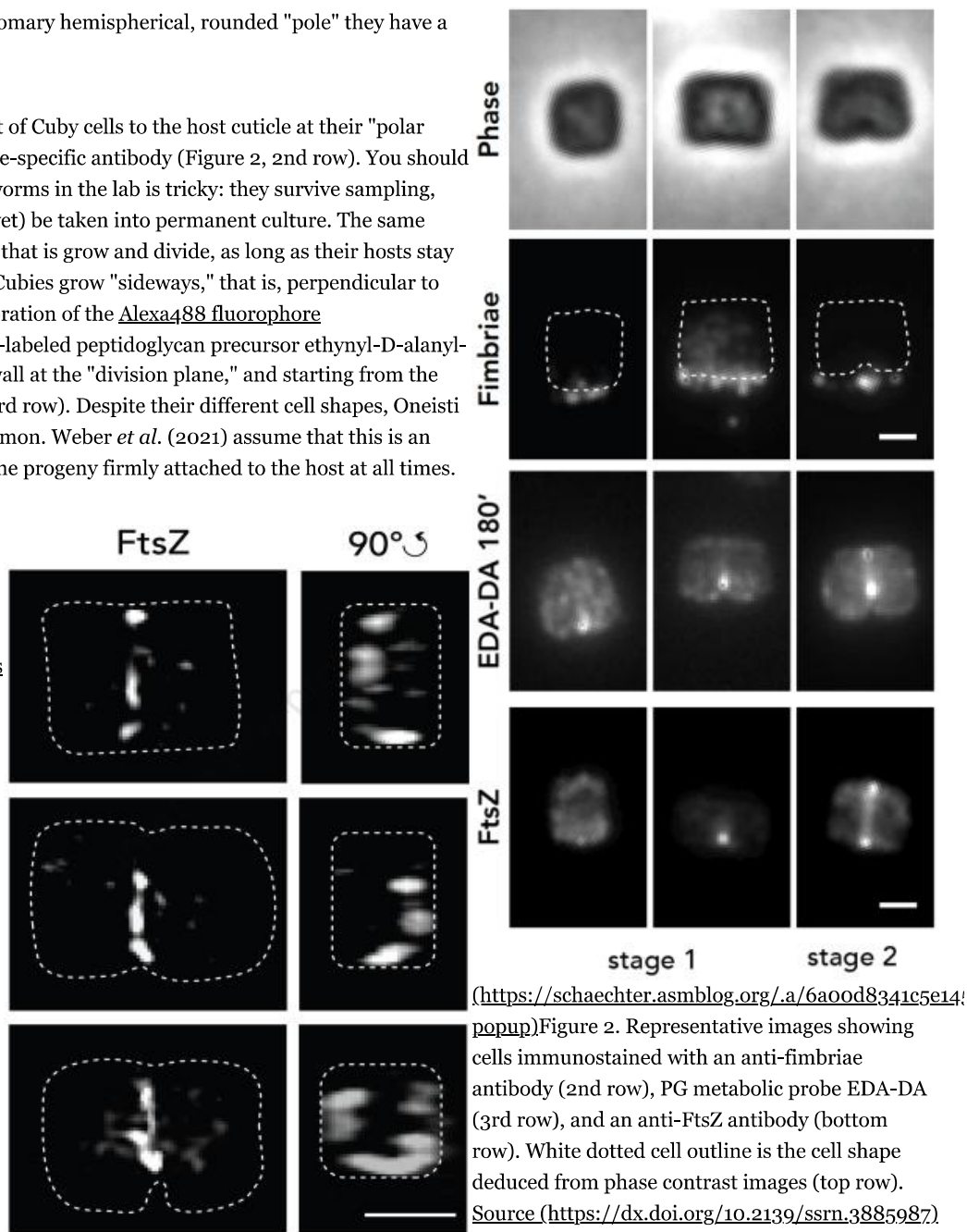
(<https://schaechter.asmblog.org/a/6a00d8341c5e1453ef02942f91c4a3200c-300wi>) (Click to enlarge)

Figure 1. **a** Scanning electron micrograph (SEM) images display three representative *Ca. 'T. cuboideus'* cells arranged from the youngest to the oldest (three leftmost panels) and a cell that is attached to the worm's cuticle (rightmost panel; arrow = fimbriae). **b** Model of *Ca. 'T. cuboideus'* growth and division. **c** Scatter plot shows the length and width of 259 *Ca. 'T. cuboideus'* cells, grouped into the categories dividing (red, n=44), non-dividing (blue n=212) and non-dividing squared (green=122). Frontispiece: (SEM) showing the bacterial coat of *Ca. 'T. cuboideus'* cells on *Catanema* sp. "Guadeloupe" cuticle, top view. Scale bar: 1 μm . [Source](https://dx.doi.org/10.2139/ssrn.3885987) (<https://dx.doi.org/10.2139/ssrn.3885987>)

race course). And rather than having the customary hemispherical, rounded "pole" they have a flat "polar plane" (Figure 1b).

Weber *et al.* (2021) confirmed the attachment of Cuby cells to the host cuticle at their "polar plane" by staining live samples with a fimbriae-specific antibody (Figure 2, 2nd row). You should know that working with the bacteria-coated worms in the lab is tricky: they survive sampling, and also transport when frozen, but cannot (yet) be taken into permanent culture. The same applies to the worms' epibionts: they're alive, that is grow and divide, as long as their hosts stay alive. Nevertheless, the authors showed that Cubies grow "sideways," that is, perpendicular to the "polar plane," because they found incorporation of the [Alexa488 fluorophore](https://en.wikipedia.org/wiki/Alexa_Fluor) (https://en.wikipedia.org/wiki/Alexa_Fluor)-labeled peptidoglycan precursor ethynyl-D-alanyl-D-alanine (EDA-DA) into the extending cell wall at the "division plane," and starting from the (nematode-attached) polar plane (Figure 2, 3rd row). Despite their different cell shapes, Oneisti and Cuby have this "sideways" growth in common. Weber *et al.* (2021) assume that this is an adaptation to the strict requirement to keep the progeny firmly attached to the host at all times.

Cuby didn't stop to surprise the researchers when it came to cell division. It has, like Oneisti, the full set of genes encoding the regular division proteins including the tubulin homolog FtsZ (see our recent [Pictures Considered #52](#)



(https://schaechter.asmblog.org/a/6a00d8341c5e1453efo282e13c9f3a200b-

popup)Figure 3. 3D Structured illumination microscopy (SIM) images of cells immunostained with an anti FtsZ antibody. No membrane indentations appear in the two top cells, whereas the two bottom cells are invaginated. The left column shows the front view and the right column a 90° shifted side view. Scale bar 1 μm. Source (https://dx.doi.org/10.2139/ssrn.3885987).

(https://schaechter.asmblog.org/schaechter/2021/05/pictures-considered-52.html).) In the test tube, FtsZ polymerizes into long, straight rods but inside cylindrical cells like growing *E. coli* cells one can observe them briefly as shorter side-by-side filaments spiraling along the inner membrane. Since they are occluded from the cells poles and also from the nucleoid – or better: from the two nucleoids in growing cells – they accumulate at midcell where cell division will take place. While the divisome proteins direct the synthesis of the septal peptidoglycan they simultaneously tether FtsZ arcs to the membrane, and the overlapping arcs give the appearance of a successively constricting "FtsZ" ring (this is a rather sketchy outline of a highly complex process, mind you). In Cuby, Weber *et al.* (2021) found FtsZ located as short filaments at the sideways-oriented division plane, and there preferentially at the proximal (nematode-attached) side aligning with commencing invaginations (Figure 2). A closer inspection by 3D structured illumination microscopy (https://pubmed.ncbi.nlm.nih.gov/28406495/) (3D-SIM) revealed that the short FtsZ filaments arrange

without much overlap along the square-shaped division plane, including filaments with apparent kinks, unheard of so far for FtsZ (Figure 3). They did not observe septal closure. Thus, it remains an open question how the very last stage of cell division is orchestrated, which proteins are involved, and how they are spatially organized. It would be intriguing to learn if the "FtsZ square" ever changes shape into a "constricting ring" at any point or whether a bidirectional zipper-like mechanism starting from the proximal (nematode-attached) side does the job, which would nicely maintain the cubic cell shape.

But maybe the difference between a annular 'division zone' as in cells with a cylindrical or spherical shape, rods and cocci, and a more-or-less quadrangular 'division plane' as in Cuby isn't such a big deal after all? The researchers should look over the shoulders of colleagues who are struggling with such problems in Archaea (they certainly do, as they're affiliated with the [Archaea Biology and Ecogenomics Unit](https://archaea.univie.ac.at/) (<https://archaea.univie.ac.at/>) of their university.) Also other "archaeologists" investigate cell division: Kanika Khanna had recently reported here in STC about it and the particular role of the archaeal FtsZ homolog, FtsZ1, in: [The Cake-Cutting Problem in the Archaeal World](https://schaechter.asmblog.org/schaechter/2020/09/the-cake-cutting-problem-in-the-archaeal-world.html) (<https://schaechter.asmblog.org/schaechter/2020/09/the-cake-cutting-problem-in-the-archaeal-world.html>).

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OR SIGN UP WITH DISQUS [?](#)**Philipp Weber** • a month ago

What a pleasant surprise to read about Cuby here at STC. Cuby's role in the old testament made my day!

Hope to meet you soon again, Christoph!

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**°christoph** Mod ➔ **Philipp Weber** • a month ago

glad you enjoyed it, Philipp! Actually, It cannot have been much of a surprise to read about Cuby here in STC ;-)

I hope you have a chance to dive a little deeper into the stunning preferential start of invagination at the host-oriented plane! Sure, the square-ish arrangement of the FtsZ filaments is cute and adds a new aspect to the known "flexibility" that FtsZ filaments show. I wonder if FtsZ alone can trigger this invagination at the host-oriented plane, but then: what else could?

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