Swimming and rafting of E.coli microcolonies at air-liquid interfaces

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The dynamics of active colloidal suspension and swimming microorganisms is strongly affected by solid-liquid and air-liquid interfaces. In this contribution, the motion of *E.coli* at air-liquid boundary is analyzed. We observed and characterized the motion of both isolated *E.coli* and microcolonies. Both of them follow circular trajectories.

Single bacteria preferentially show a counter-clockwise motion. In few cases, complete circles are apparent (Fig 1B) while, the more frequent condition is characterized by circular arcs connected by cusps (Fig 1A). Each cusp corresponds to a tumbling phase where the *E.coli* momentarily stops its motion and changes swimming direction. CW and CCW motion of flagellated microswimmers close to an interface can be explained in terms of fluid dynamic interaction between the swimmer and the surface. No-slip boundary condition at the fluid interface gives rise to CW motion, while swimming close to a free-slip interface results in CCW trajectories [1-4]. CW swimmers are slightly slower than CCW ones, while no statistically significant difference is found concerning the radius of curvature R of the trajectories (p-value > 0.05), Fig 1C. The occurrence of a small percentage of CW swimming bacteria can be ascribed to the presence of molecules in the media that can alter the usual free-slip behavior of an air-liquid interface resulting in region with higher viscosity where no-slip or partial slip condition hold. Indeed, the local presence of high concentration of molecules secerned by the bacteria in specific regions, would result in an increase of the local viscosity [3]. This occurrence can explain also the smaller velocity of the CW swimmer.

Differently from the single swimmers, microcolonies do not show a preferential direction of rotation. CW (Fig 2D-F) and CCW (Fig 2A-C) rotations occur with the same probability (Fig 2G). The average speed of microcolonies is lower than single swimmer one and no significant difference in the speed of CW and CCW rotating colonies is observed. These occurrences indicate that the mechanism underlying the microcolony motion is different from the single swimmer. We propose a simple mechanical model where the microcolonies move like rafts constrained to the air-liquid interface to explain the experimental data.

Finally, we observed that the microcolony growth is due to the aggregation of colliding single-swimmers, suggesting that the microcolony formation resembles a condensation process where the first nucleus originates by the collision between two single-swimmers.

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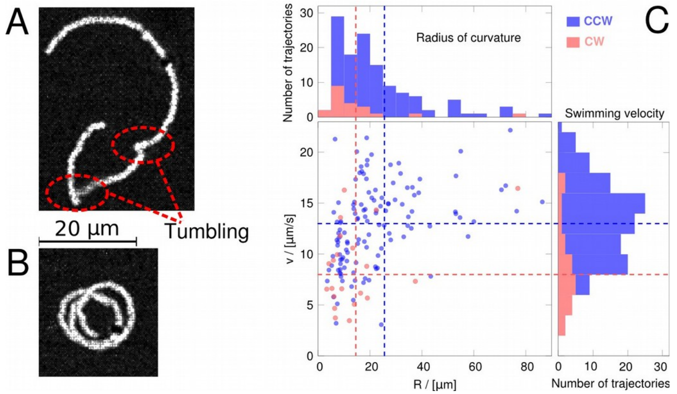

Figure 1. Single *E.coli*. The microswimmer trajectories are constituted by a sequence of circular arcs (A,B). The cusps between two consecutive arcs correspond to tumbling. C) Radius of curvature R *vs* swimming velocity *v*. Each point corresponds to a single circular arc. Red and blue points refer to CW and CCW trajectories, respectively. Horizontal and vertical dashed lines are the mean values. CCW swimmers move significantly faster than CW swimmers (p-value $< 10^{-6}$) while radius of curvature difference are not statistically significant (p-value > 0.05).

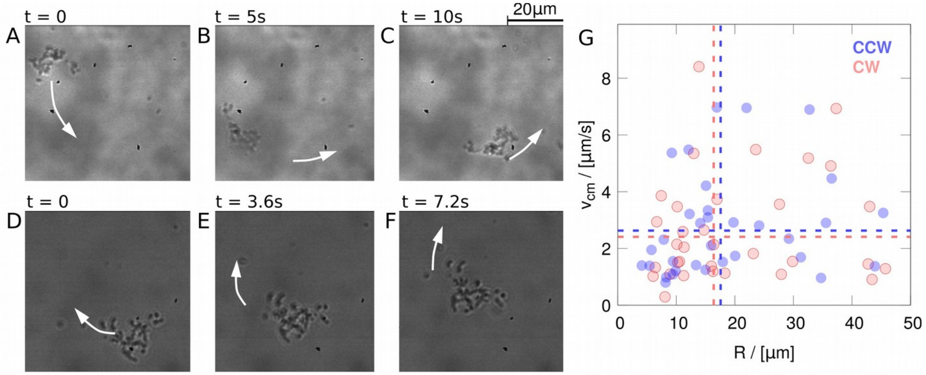

Figure 2. Microcolonies move like 2D rigid raft suspended at the air-liquid interface and exhibit both CCW (A-C) and CW motion (D-F). Panel G reports the scatter plot of the speed v_{cm} *vs* the radius of curvature *R* of the microcolony center. Red and blue symbols refer to CW and CCW motion of the raft center, respectively. CW motion occurs 52% of the cases while CCW 48%, the difference is not significant. Horizontal and vertical lines correspond to the average CW and CCW radius of curvature and speed. No significant difference is observed between CW and CCW for both average speed and radius of curvature.