

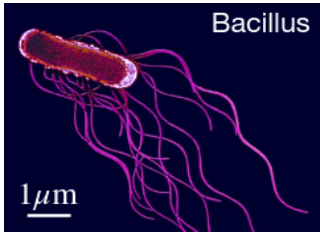


Theory of the transport of bacteria and statistical properties of adherent cells

Feyza Beziane

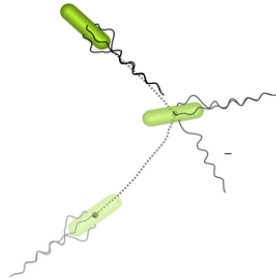
Supervised by François Detcheverry,
Cécile Cottin-Bizonne, Christophe Ybert

Swimming strategies of bacteria



Baumann "Microbiology"

Isotropic
Run-and-tumble

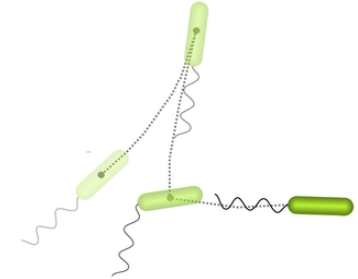


Run-reverse : reverse
run-and-tumble

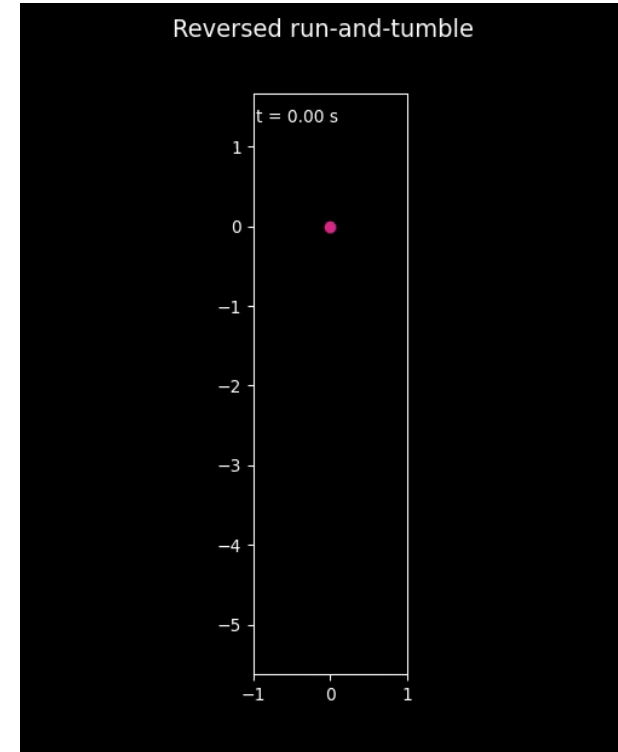
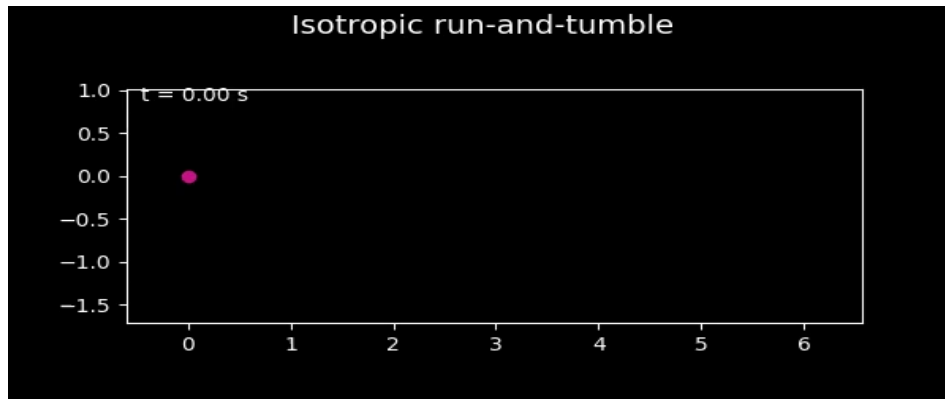


Taktikos *et al*, PO (2013)

Run-reverse-flick
(bimodal run-and-tumble)



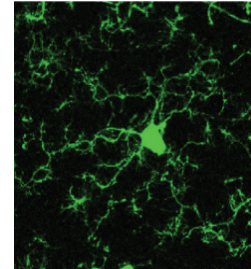
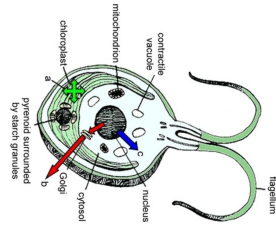
Swimming strategies of bacteria



Other microorganisms

Run-and-tumble

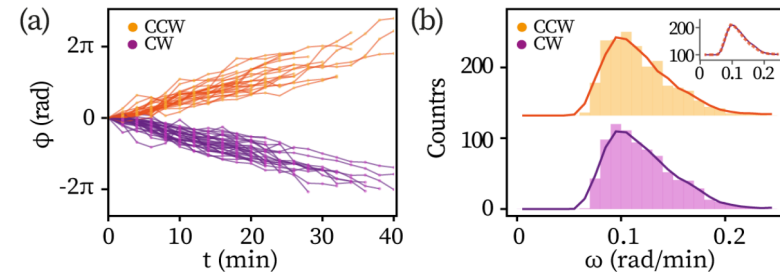
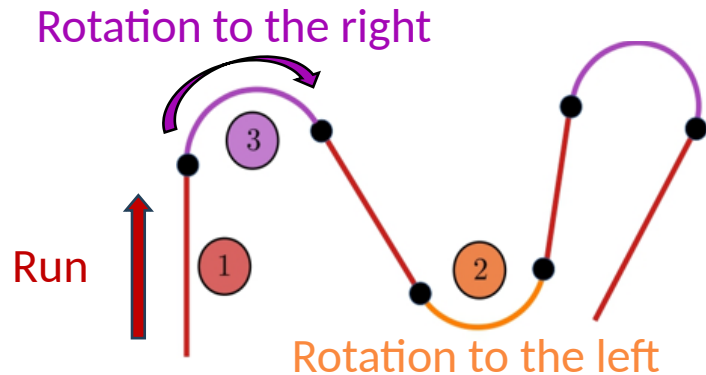
Micro-algae
(*C. reinhardtii*)



Migrating cells
(microglia)

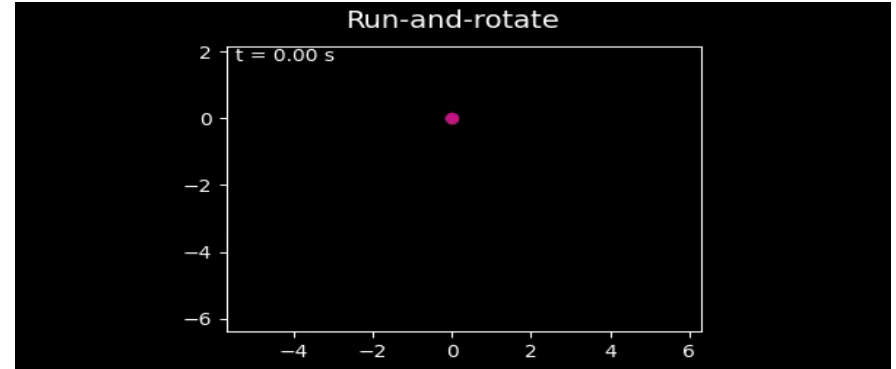
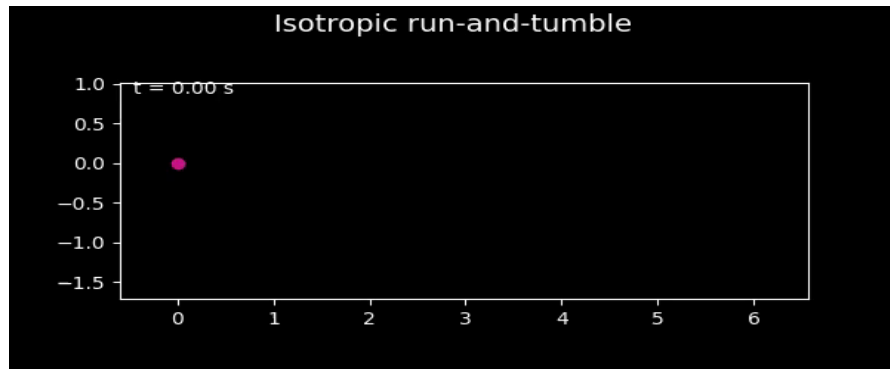
Audinat, Arnoux MS (2010)

A new pattern : Run-and-rotate



Zhang *et al*, PRR (2025)

Run-and-tumble vs. run-and-rotate



Question : transport properties ?

Motility



Transport

Fundamental
importance

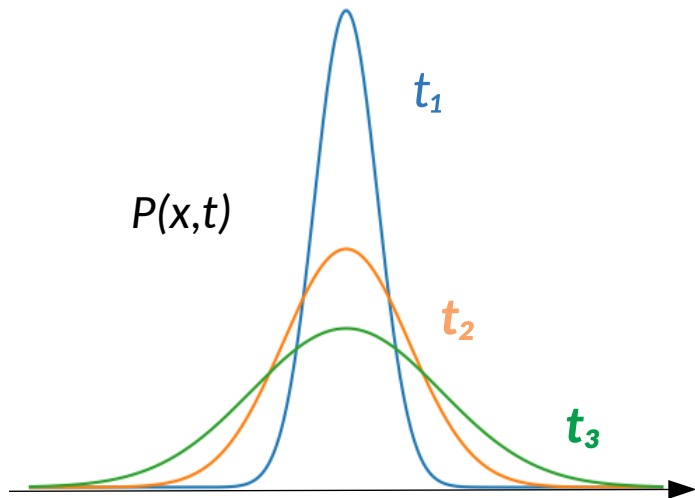
- Microbiology
- Access to resources, colonization media
 - Evolution advantages ?

Practical
importance

- Body infection
- Food contamination
- Aquifer contamination
- Rhizosphere

How to characterize the transport ?

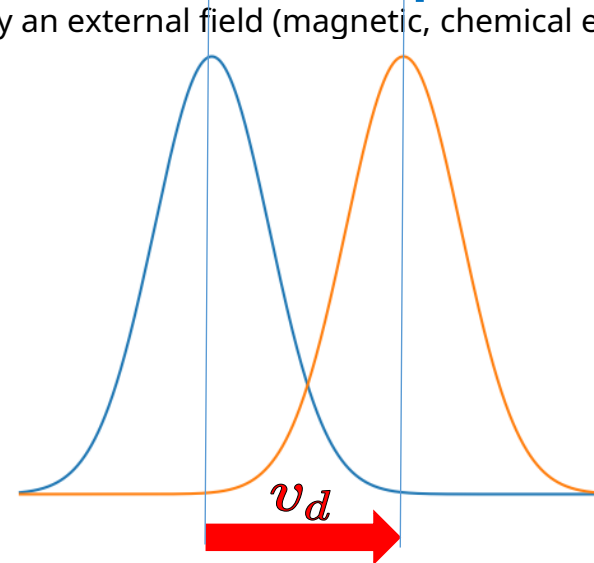
Non biased transport



Diffusion coefficient D

Biased transport

By an external field (magnetic, chemical etc.)

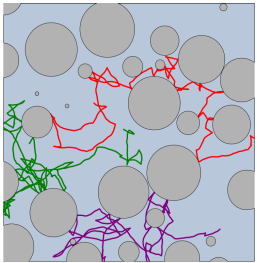


Drift velocity

**How transport depends on the strategy of motility ?
On the environment ?**

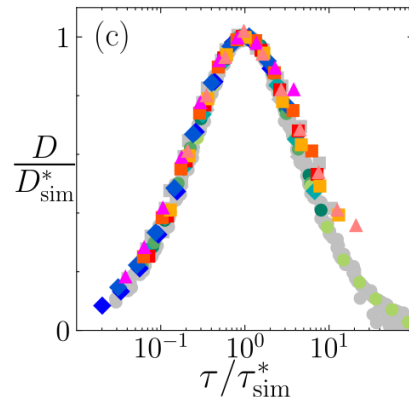
Anisotropic transport (numerical study)

Recent result in isotropic media



Pietrangeli et. al (2025)

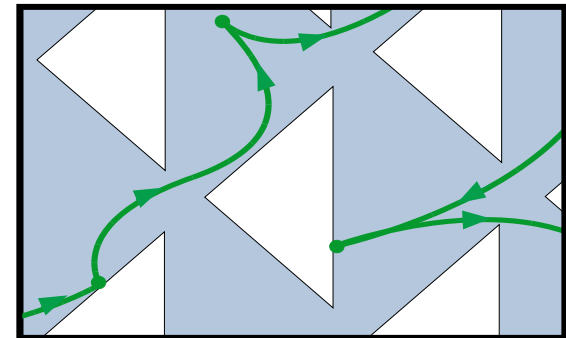
Universal law of dispersion in porous and isotropic media



Anisotropy of medium

Asymmetric obstacles

Rectification, bacterial sorting ?



v_d

Stream of bacteria

**What I've done so far :
Single particle in the bulk**

Rotational diffusion ?

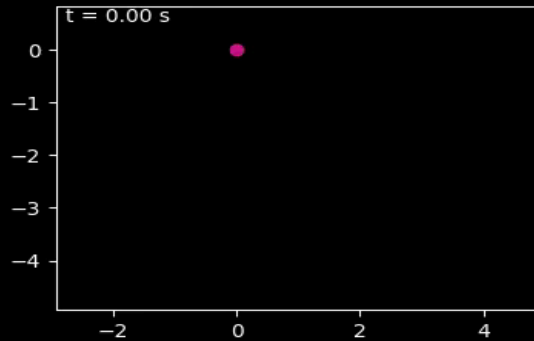
Collisions



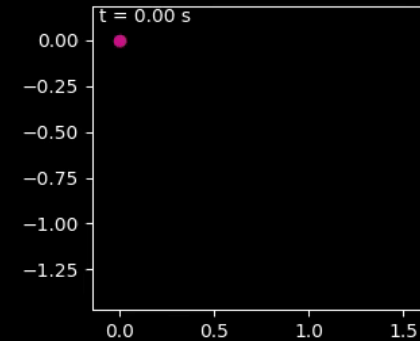
Rotational diffusion

= Random deviation of the orientation

Isotropic run-and-tumble without rotational diffusion

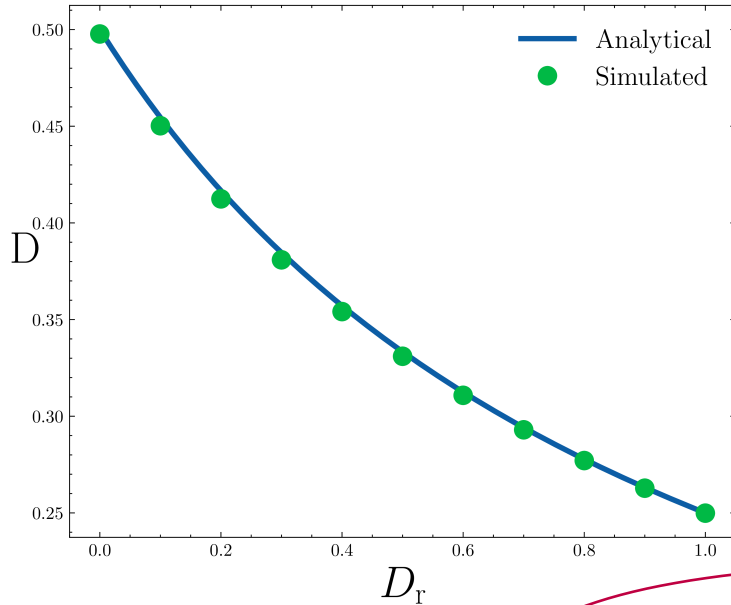


Isotropic run-and-tumble with rotational diffusion

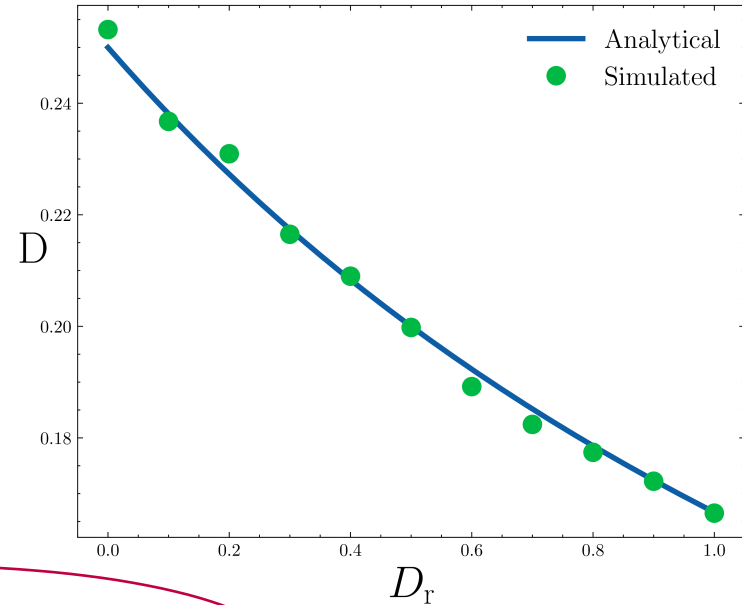


Run-and-tumble in the bulk - Results

Isotropic run-and-tumble






Reversed run-and-tumble



Valid code

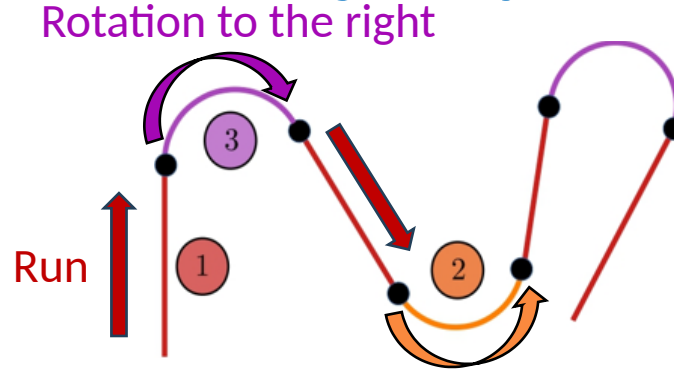
Run-and-rotate - Simplest case

Modes

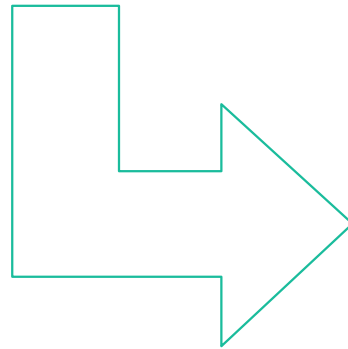
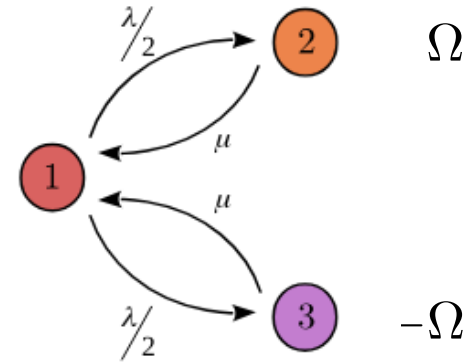
-  Straight displacement
-  Rotation to the left at constant angular velocity
-  Rotation to the right at constant angular velocity



Idealized trajectory



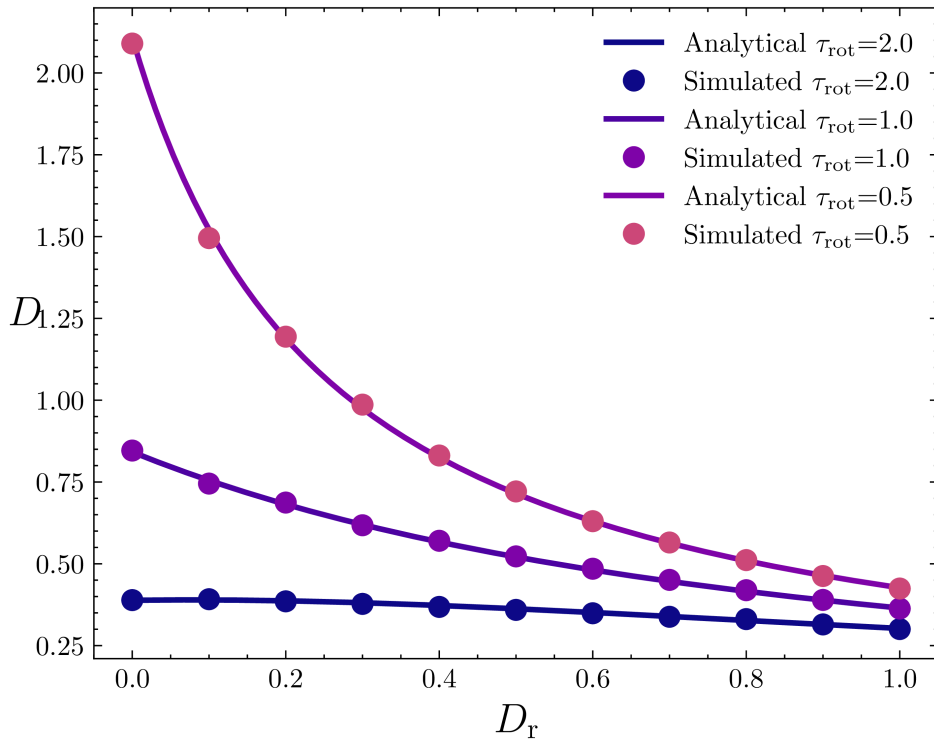
Transition rates



$$D = \frac{v_0^2 \mu ((\lambda + \mu)^2 + \Omega^2)}{2\lambda(\lambda + \mu)\Omega^2}$$

Run-and-rotate - Results

Diffusion coefficient



- Analytical formulas (M2 internship)
- Relative error < 3%

Valid code for run-and-rotate

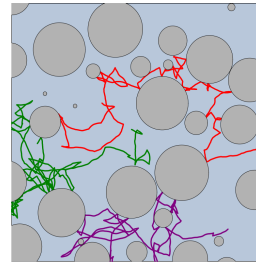


What's next ?

Run-and-tumble with obstacles

Circular obstacles

- Test the code with introduction of obstacles
- Recover result on porous and isotropic media

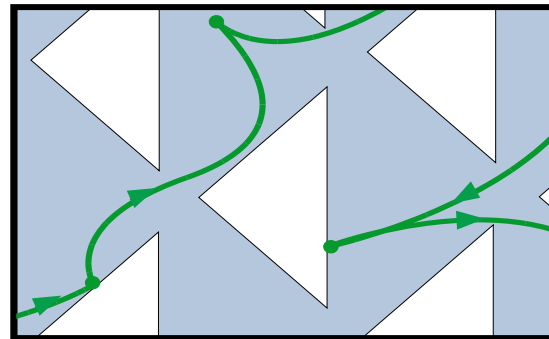


Pietrangeli et. al (2025)

Universal law of dispersion in porous and isotropic media

Triangular obstacles

- Extend code for asymmetric obstacles : triangles
- Analytical model for drift velocity as a function of volumic fraction



Stream of bacteria

Rectification, bacterial sorting ?



Thank you <3