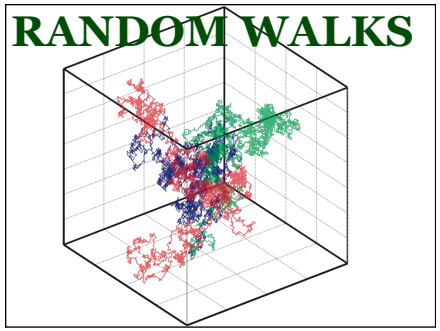
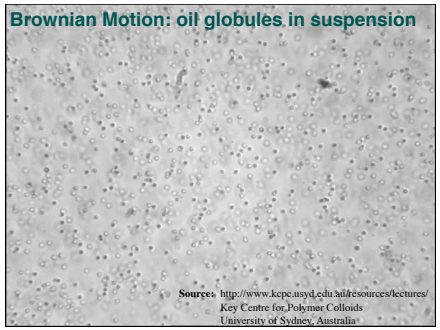
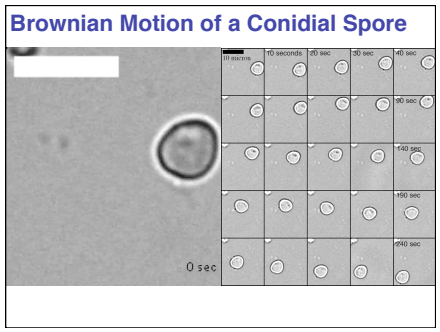


Biological Pumps

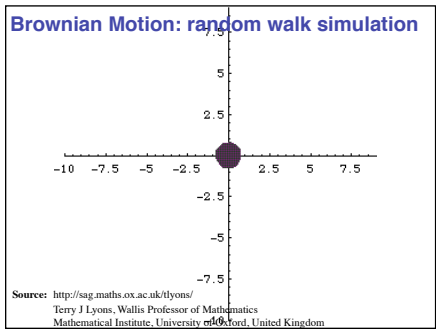
We first need to explore the nature of molecular motion through an aqueous milieu, to understand how molecules become available to the organism in support of life (as we know it!). Here is shown examples of the tracks of randomly moving particles (or cells).



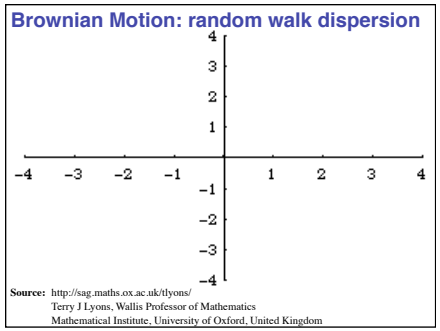
Here is an example of a more realistic portrayal of movement. Notes that the oil globules jostle but in addition, there is net movement in one direction: the interplay of random motion and mass movement.



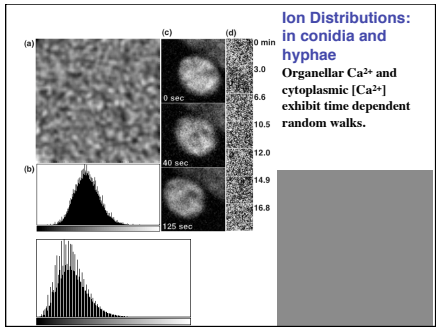
At the level of a single spore, the random walk nature of movement is clearly seen: no net movement occurs.



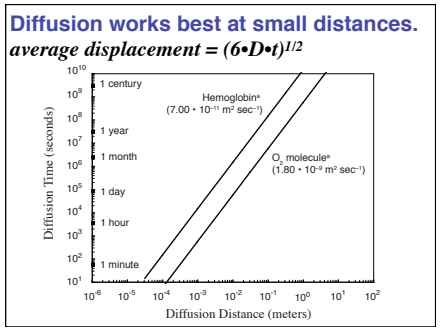
Mathematicians love to model random walks. They also enjoy stochastic processes and, of course, chaos



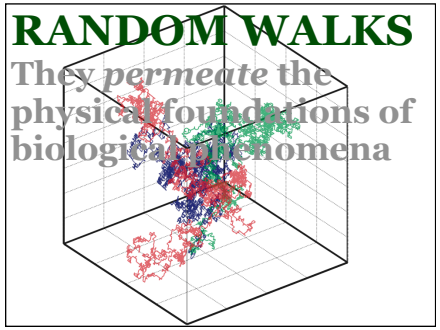
And of course, besides single particles, the diffusive spread of many particles can also be modeled.



In a biological context, it is not just the random walk (in this case of calcium ions) but the probability of a non-normal distribution, that may trigger a cellular response (in the case of a conidia, germination of a tube with inherent polar asymmetry).



Random walks take time! Lots of time if the distances are greater the the width of an average cell (about 10 microns).

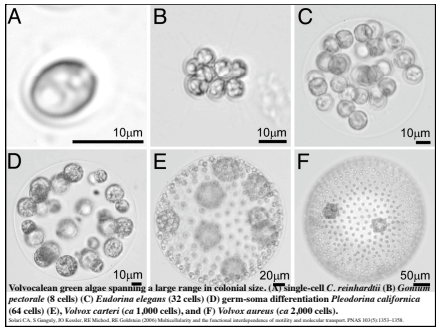


So, that's a random walk, but the cause of limitations if relative small distance have to be traversed. At farther distances, other mechanisms must be used for the survival of the organism.

Biological Pumps

Transporting Mechanisms in Biological Organisms.

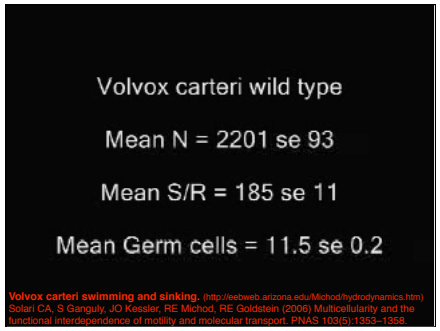
Biological Pumps.



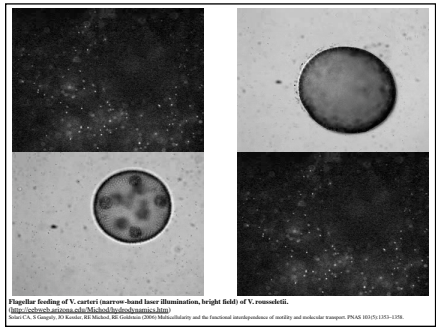
Volvocalean green algae spanning a large range in colonial size. (A) Single-cell *C. reinhardtii* (B) *Gonium pectorale* (8 cells) (C) *Eudorina elegans* (32 cells) (D) germ-soma differentiation *Pleodorina californica* (64 cells) (E), *Volvox carteri* (*ca* 1,000 cells), and (F) *Volvox aureus* (*ca* 2,000 cells).

Solari CA, S Ganguly, JO Kessler, RE Michod, RE Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport. PNAS 103(5):1353–1358.

Multicellularity is seen to various degrees in algal clades

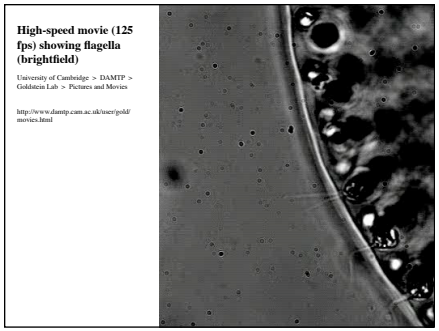


Volvox carteri swimming and sinking. (http://eebweb.arizona.edu/Michod/hydrodynamics.htm)
Solari CA, S Ganguly, JO Kessler, RE Michod, RE Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport. PNAS 103(5):1353–1358.

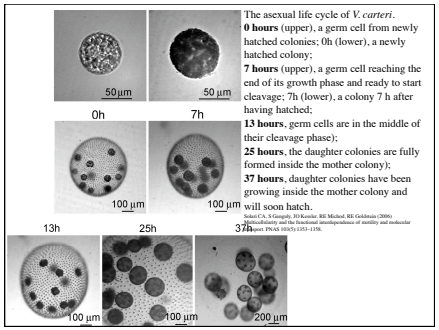


Flagellar feeding of V. carteri (narrow-band laser illumination, bright field) of V. rousseletii.
(http://eebweb.arizona.edu/Michod/hydrodynamics.htm)
Solari CA, S Ganguly, JO Kessler, RE Michod, RE Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport. PNAS 103(5):1353–1358.

As size increases, the organism must rely on transport above and beyond slow diffusion.



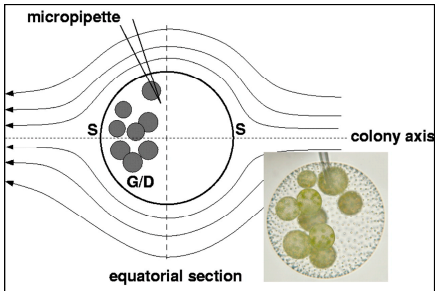
Coordinated flagellar motion is required for mass advective flow to occur at the organism's surface.



The asexual life cycle of *V. carteri*.
0 hours (upper), a germ cell from newly hatched colonies; 0h (lower), a newly hatched colony;
7 hours (upper), a germ cell reaching the end of its growth phase and ready to start cleavage; 7h (lower), a colony 7 h after having hatched;
13 hours, germ cells are in the middle of their cleavage phase);
25 hours, the daughter colonies are fully formed inside the mother colony);
37 hours, daughter colonies have been growing inside the mother colony and will soon hatch.

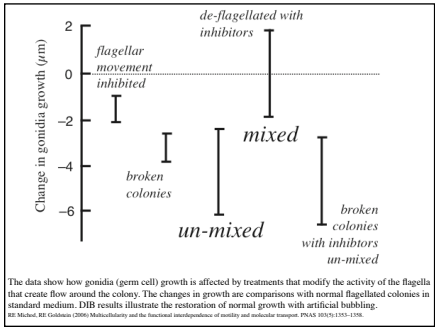
Solari CA, S Ganguly, JO Kessler, RE Michod, RE Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport. PNAS 103(5):1353–1358.

The biology of the Volvox colony can be used to explore *experimentally* the use of advective flow versus diffusion



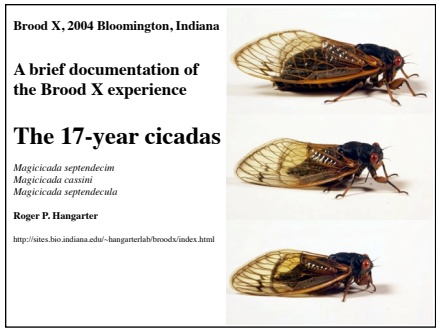
SMicropipette aspiration of V. carteri for PIV studies. Schematic shows streamlines symmetric about the colony axis, on which are located the two stagnation points (S). Germ cells/daughter colonies (G/D) are located in posterior half of colony. Dashed line indicates equatorial section of PIV flow field used to determine maximum fluid velocity.
Solari CA, S Ganguly, JO Kessler, RE Michod, RE Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport. PNAS 103(5):1353–1358.

The biology of the Volvox colony can be used to explore *experimentally* the use of advective flow versus diffusion: This was done by measuring the gorwth of daughter colonies within the mother colony.

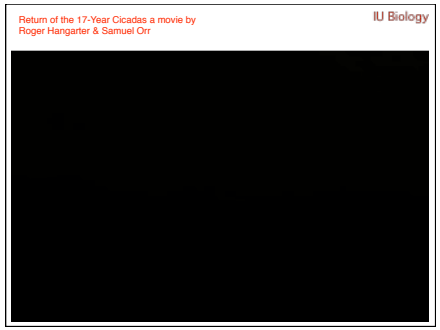


The data show how gonidia (germ cell) growth is affected by treatments that modify the activity of the flagella that create flow around the colony. The changes in growth are comparisons with normal flagellated colonies in standard medium. DIB results illustrate the restoration of normal growth with artificial bubbling.
RE Michod, RE Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport. PNAS 103(5):1353–1358.

In the absence of advective flow, daughter colonies grew poorly compared to colonies provided with nutrients by advective flow.

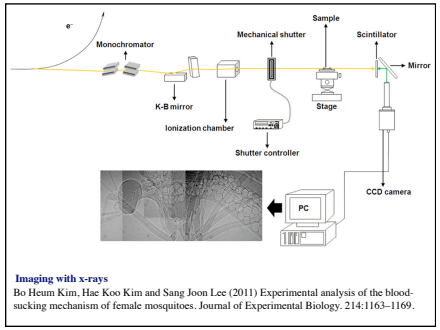


Volvox uses a ‘simple pump’. More complex organisms use many different types of pumps. The example we will explore here is the sucking pump of cicadas.

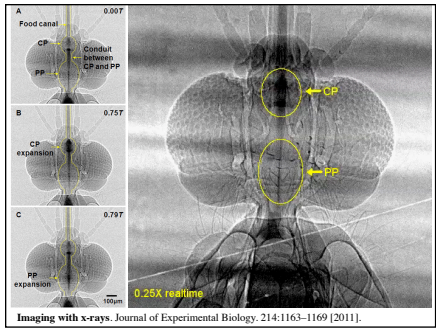


Cicada biology is cool.....

Not only cicadas, but other organisms use sucking pumps. Mosquitos are a fascinating example.



Mosquito pumps are one example where a tiny insect gets imaged with a **mega** biophysical toy: An x-ray synchrotron.



Imaging with x-rays. Journal of Experimental Biology. 214:1163–1169 [2011].

Mosquito pumps are one example where a tiny insect gets imaged with a **mega** biophysical toy: An x-ray synchrotron.