Life and Cycle. Exploring the diversity of Biological Organisms.

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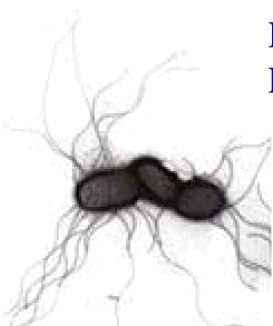
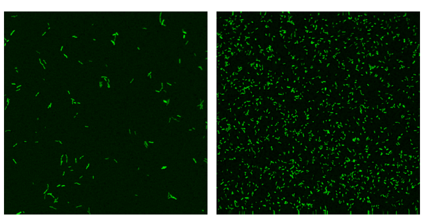
Bacterial Diversity



Bacteria are an ancient clade, known for their biochemical diversity, which can be molded to bioengineering needs in biotechnology.

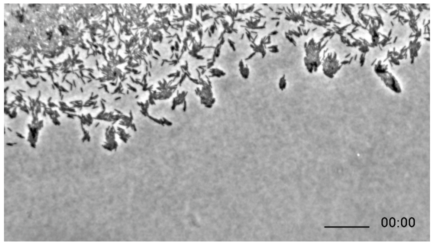


Time-lapse microscopy of *Pseudomonas aeruginosa* bacteria expressing green fluorescent protein. Bacteria were grown in continuous-culture-flow cells, and quickly form a biofilm.

Bacteria were grown in continuous-culture-flow cells, but the flow cell chambers were continuously perfused with lactoferrin, preventing biofilm formation.

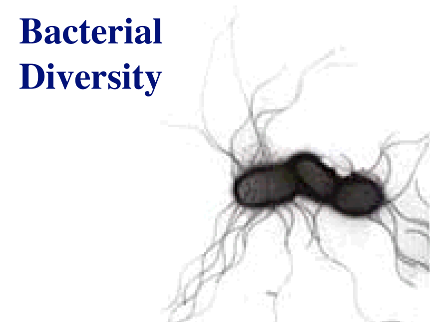
Source: A component of innate immunity prevents bacterial biofilm development. Pradeep K. Singh, Matthew R. Parsek, E. Peter Greenberg and Michael J. Welsh. Nature 417, 552-555 (30 May 2002) doi:10.1038/417552a

They are, of course, potential pathogens, and biofilm formation is one example of a growth process in pathogenicity.



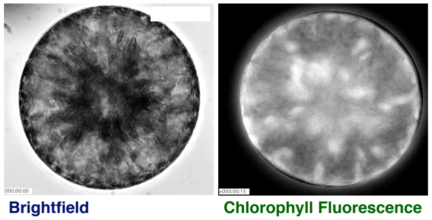
Xylella fastidiosa colony morphology. Twitching motility of wild-type *X. fastidiosa* within the peripheral fringe of a 24-hour-old colony on the surface of nutrient agar. Scale bars, 20 µm; time, h:min (similar to Movie1a, J. Bacteriol. 187: 5560-5567, 2005).

This is an example of growth patterns in a plant pathogen specialized for infection of xylem (water-conducting vessels) in plants.



Algae are an example of eukaryotes, characterized for their intracellular complexity, and multicellular forms.

Shape-shifting of a unicellular algal eukaryotes.

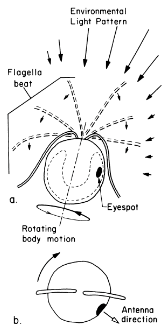


Eremosphaera viridis

High light intensity causes the chloroplasts to migrate to the center of the cell, to protect against photo-oxidation during photosynthesis. Photo-sensing and even molecular motors must operate together for this to work (a process studied by third year Biophysics students).

Chloroplast translocation and responses to high light intensity are one aspect of the biophysics of photosynthesis. Biophysics students at York contributed to research on this phenomenon as summer research assistants.

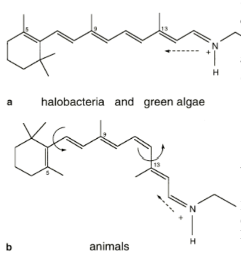
FIG. 2. *Design principles of phototaxis in Chlamydomonas. (a) Side view of cell; (b) end view. The incident light pattern is indicated by solid arrows. The eyespot, which lies inside the chloroplast (dashed line), forms part of the antenna. Rotation of the cell causes the antenna to scan the incident light. This produces a signal that controls the flagellar beat (see Fig. 3). The antenna direction (open arrow) is normal to the cell surface. The antenna is most sensitive to light coming from this direction. Successive positions of the flagella during the power stroke are shown. Flagellar motion causes the cell to translate with the flagellar end forward and to rotate in the left-hand sense.*



Foster KW, and RD Smyth (1980) Light antennas in phototactic algae. Microbiol. Rev. 44:572–630.

Unicellular eukaryotes have vision, constructed with similarities and differences from animal vision systems.

Rhodopsins are found in all kingdoms: prokaryote and eukaryote.



Structure of rhodopsin chromophores in

a halobacteria (archaea) and algae (plants)

b in metazoan (animals).

Peter Hegemann (1997) Vision in microalgae. Planta 203:265–274.

The pigment is similar to rhodopsin in animals.

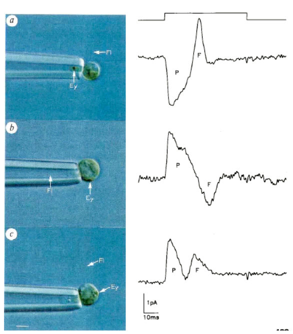
Light-induced photoreceptor (P) and flagellar (F) currents, whose sign depends on the orientation of the cell in the pipette.

a. The eyespot (Ey) is inside the pipette.

b. The flagella (Fl) is inside the pipette, and

c. Eyespot and flagella are outside the pipette. Scale bar 10 μm.

Harz H, and P Hegemann (1991) Rhodopsin-regulated calcium currents in *Chamydomonas*. Nature 351:489–491.



Light-sensing results in an action potential.

“Vision” in Single-Celled Algae

Suneel Kateriya,[1] Georg Nagel,[2] Ernst Bamberg,[2] and Peter Hegemann[1]

[1]Institut für Biochemie, Universität Regensburg, 93040 Regensburg; and [2]Max-Planck-Institut für Biophysik, 60439 Frankfurt am Main, Germany

Photosynthetic unicellular algae have a unique visual system. In Chlamydomonas reinhardtii, the pigmented eye comprises the optical system and at least five different rhodopsin photoreceptors. Two of them, the channelrhodopsins, are rhodopsin-ion channel hybrids switched between closed and open states by photoisomerization of the attached retinal chromophore. They promise to become a useful tool for noninvasive control of membrane potential and intracellular ion concentrations.

News Physiol. Sci. 19:133–137 [2004]

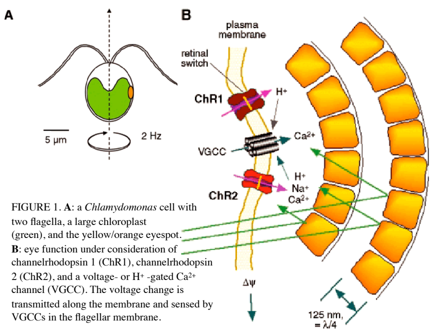
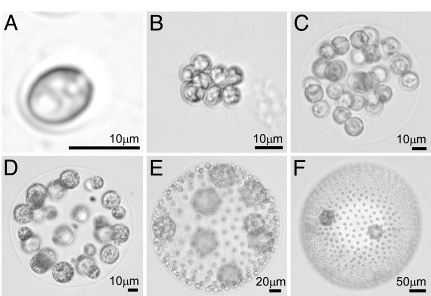


FIGURE 1. **A**: a *Chlamydomonas* cell with two flagella, a large chloroplast (green), and the yellow/orange eyespot. **B**: eye function under consideration of channelrhodopsin 1 (ChR1), channelrhodopsin 2 (ChR2), and a voltage- or H^+ -gated Ca^{2+} channel (VGCC). The voltage change is transmitted along the membrane and sensed by VGCCs in the flagellar membrane.

The eyespot is in fact a mirror.

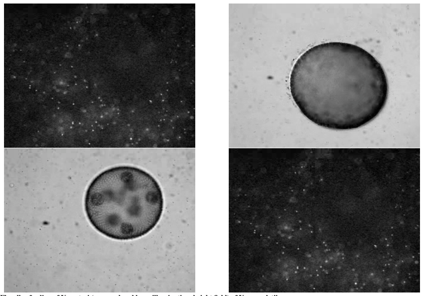
unicellular complexity is exemplified in Tracheolomonas.



Species of volvocalean green algae spanning a large range in size. Shown are the single-cell *C. reinhardtii* (A), undifferentiated colonies *Gonium pectorale* (8 cells) (B) and *Eudorina elegans* (32 cells) (C), and those with germ-soma differentiation *Pleodorina californica* (64 cells) (D), *Volvox carteri* ({approx}1,000 cells) (E), and *Volvox aureus* ({approx}2,000 cells) (F).

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



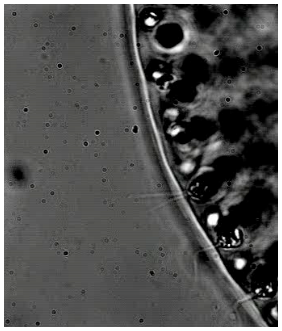
Flagellar feeding of V. carteri (narrow-band laser illumination, bright field) of V. rousseletii.
(http://eebweb.arizona.edu/Michod/hydrodynamics.htm)
Solari CA, S Ganguly, JO Kessler, RE Michod, RE Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport.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

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

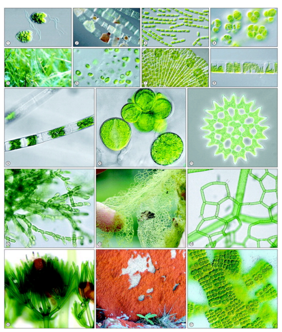
High-speed movie (125 fps) showing flagella (brightfield)

University of Cambridge > DAMTP > Goldstein Lab > Pictures and Movies

http://www.damtp.cam.ac.uk/user/gold/movies.html

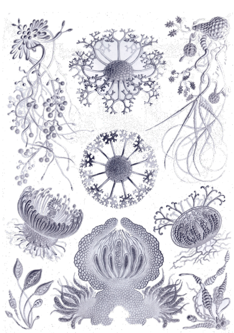


Coordinated flagellar motion is required for mass advective flow to occur at the organism's surface.



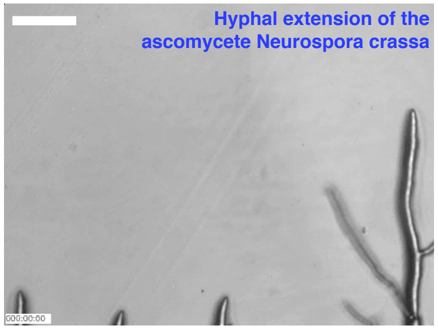
Algal Diversity

(photo by V. Flechtner)

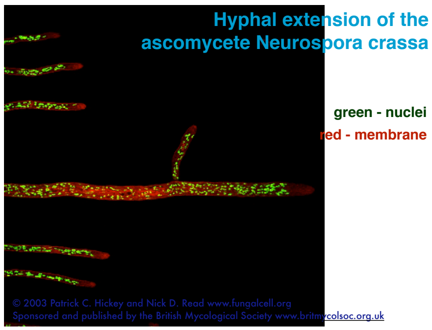


Fungal Diversity

(illustration: Ernst Haeckel)



The heterotrophic fungal groups grow fast. Growth is driven by internal hydrostatic pressure.



Coordinated motion of intracellular organelles is crucial to maintain cellular fidelity during growth.

Fungal micro-*hydraulics*:

Reynolds number

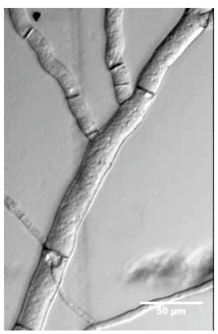
$$\mathrm{Re} = \frac{\rho \bullet J_v \bullet r}{\eta} = 4.5 \bullet 10^{-5}$$

density (1 g ml^{-1}); velocity (5•10^{-4} cm sec^{-1}); radius (9•10^{-4} cm); viscosity (0.01 g sec^{-1} cm^{-1})

Pressure gradient

$$\frac{dP}{dx} = \frac{8 \bullet J_v \bullet \eta}{r^2} = 4.9 \bullet 10^{-4} \text{ bars cm}^{-1}$$

velocity (5•10^{-4} cm sec^{-1}); viscosity (0.01 g sec^{-1} cm^{-1}); radius (9•10^{-4} cm)



Organellar movement can be driven by mass flow of the cytoplasm

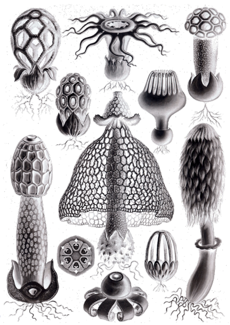
The Fastest Flights in Nature: High-Speed Spore Discharge Mechanisms among Fungi

Levi Yafetto, Loran Carroll, Yunluan Cui, Diana J. Davis, Mark W. F. Fischer, Andrew C. Henterly, Jordan D. Kessler, Hayley A. Kilroy, Jacob B. Shidler, Jessica L. Stolze-Rybczynski, Zachary Sugawara, Nicholas P. Money. PLoS ONE doi:10.1371/journal.pone.0003237

Data for Pilobolus:

Launch speed: **9 m / sec**
Measured maximum acceleration: **210,000 m sec^{-2}**
Estimated range: **2.9 m**

Fungal Diversity



(illustration: Ernst Haeckel)

Plant and Animal Development

Plants and animals exhibit a higher level of complexity during development of their multicellular bodies.

Plant and Animal Development

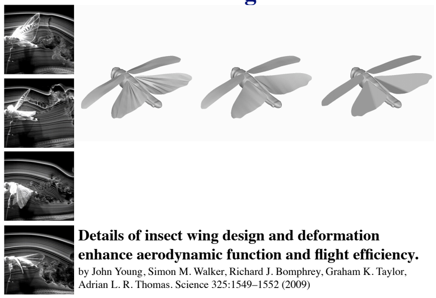
Credit: Robert P. Goldstein, UNC Chapel Hill
source: http://www.abac.edu/kmccrae/BIOL2050/ch1-13/Animations/Animations.html

The cellular lineage of each cel in the final form of the organism C. elegans was elucidated years ago, leading to a Nobel Prize for Sydney Brenner.

Plant and Animal Development

Credit: Robert P. Goldstein, UNC Chapel Hill
source: http://www.abac.edu/kmccrae/BIOL2050/ch1-13/Animations/Animations.html

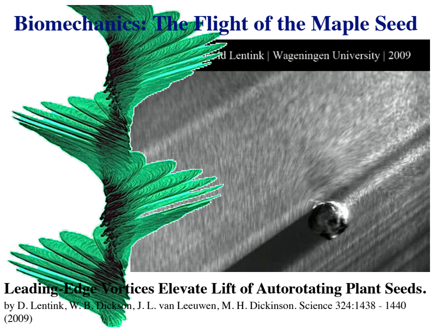
Biomechanics: The Flight of the Locust



Details of insect wing design and deformation enhance aerodynamic function and flight efficiency.
by John Young, Simon M. Walker, Richard J. Bomphrey, Graham K. Taylor, Adrian L. R. Thomas. Science 325:1549–1552 (2009)

Biomechanics (and biomimetics) is a big deal. The flight of the locust is only one example. A lot of this work relies on wind tunnel experiments, and intense computational analysis.

Biomechanics: The Flight of the Maple Seed



Leading-Edge Vortices Elevate Lift of Autorotating Plant Seeds.
by D. Lentink, W. B. Dickson, J. L. van Leeuwen, M. H. Dickinson. Science 324:1438 - 1440 (2009)

Biomechanics (and biomimetics) is a big deal. The flight of the maple seed is another example. A lot of this work relies on wind tunnel experiments, and intense computational analysis.

Life and Cycle

For a biophysicist, being conversant with the remarkable diversity of Biological Organisms is important.

Choose the right organism for the right experiment

Choose the right organism for the right experiment