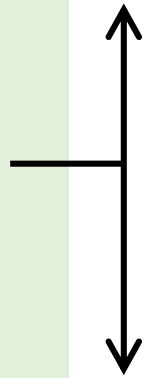
BB101 Quiz on May 31st 2023 (8 - 9:30 am)

1. Questions in Quiz will cover only Lecture 1 to Lecture 6 taught by R Mallik
2. Weightage = 10% of the part taught by R Mallik
3. There will be no “Re-Quiz”. No Crib-Sessions or Crib-Emails for Quiz
4. If you miss the Quiz for genuine reasons then Endsem Marks can be scaled up to compensate for the missed Quiz.
5. To do this, you must send an Email from your IITB-ID to Head-TA (cc R Mallik) with (1) Your Name and Roll number (2) Reason for missing the Quiz. This Email must be sent before 9PM of 1st June 2023.
6. Reason Genuine/Not Genuine will be decided according to IITB Academic rules



Lec1 - Proteins as Machines
Lec2 - Rotary Motors
Lec3 - Linear Motors
Lec4 - Artificial Nanomachines

Lec5 - The Cytoskeleton - Microtubules
Lec6 - The Cytoskeleton - Actin

Lec7 - Chemotaxis
Lec8 - Beating of Cilia

Lec9 - Muscle Contraction
Lec10 - Heartbeats
Lec11 - To Sing or to Fly

SECTION 3 : MOTION OF CELLS

LECTURE 1 : BACTERIAL CHEMOTAXIS

Roop Mallik

BB101 Spring 2023, IIT Bombay

Lec1 - Proteins as Machines
Lec2 - Rotary Motors
Lec3 - Linear Motors
Lec4 - Artificial Nanomachines

Lec5 - The Cytoskeleton - Microtubules
Lec6 - The Cytoskeleton - Actin

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Lec8 - Beating of Cilia

Lec9 - Muscle Contraction
Lec10 - Heartbeats
Lec11 - To Sing or to Fly

Resources

Chapters 4 and 19 of Physical Biology of the Cell, Phillips, Kondev, Theriot, Garcia

Molecular Biology of the Cell.
Alberts, Johnson,Lewis …. Walter

Howard Berg iBiology Talk

Primer on Bacterial Chemotaxis

Diversity of Motion in different Cell types

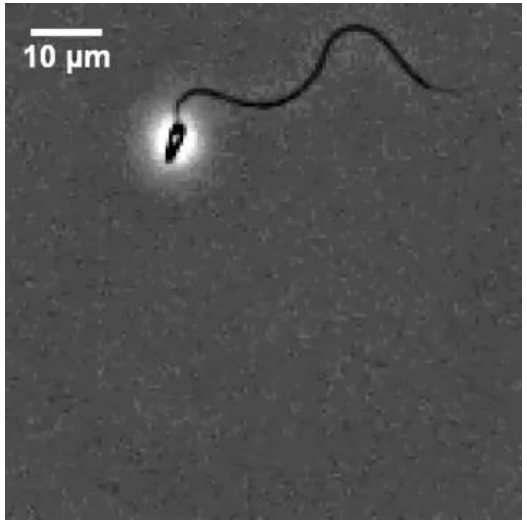
For today's Lecture

PROKARYOTE

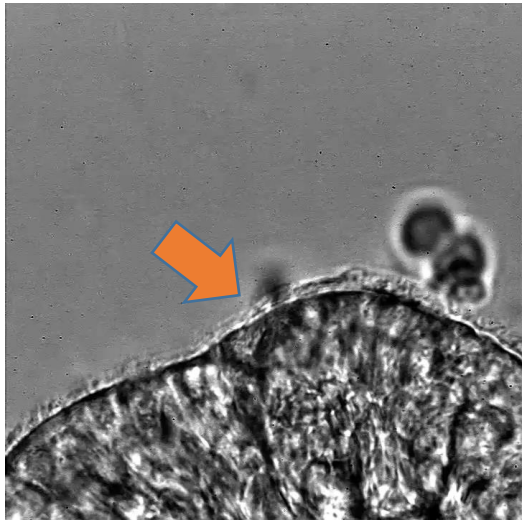
Bacteria

EUKARYOTES

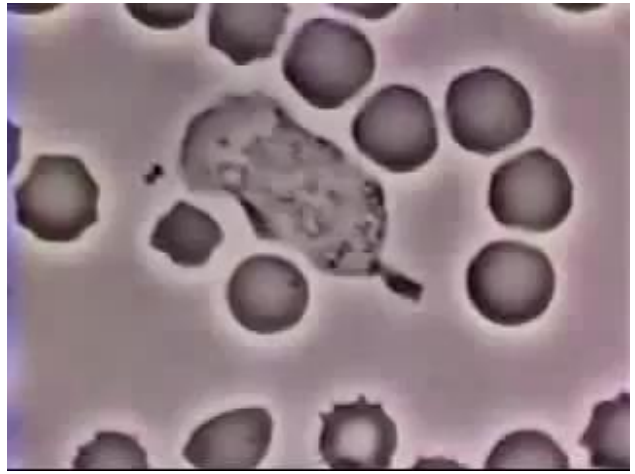
Sperm



Motion of Cilia on surface of Epithelial Cells (e.g. Lung airway)



White Blood Cell Catching bacteria



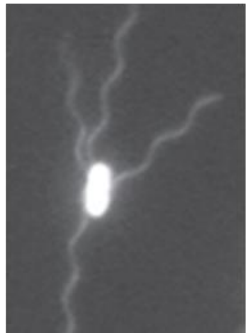
Both use "Flagella",
But mechanism is different
Bacteria :- Rotary Flagellar Motor
Sperm :- Whip-like flagella driven by Dynein

Whip-like motion of Flagella (Sperm) or Cilia (Epithelial Cell)
Driven by Dynein in the Flagella or Cilia

Different Mechanism
Actin Polymerization and Depolymerization
Discussed in Lec-6

PROKARYOTES - Bacterial Propulsion and Chemotaxis

Sometimes you see this..



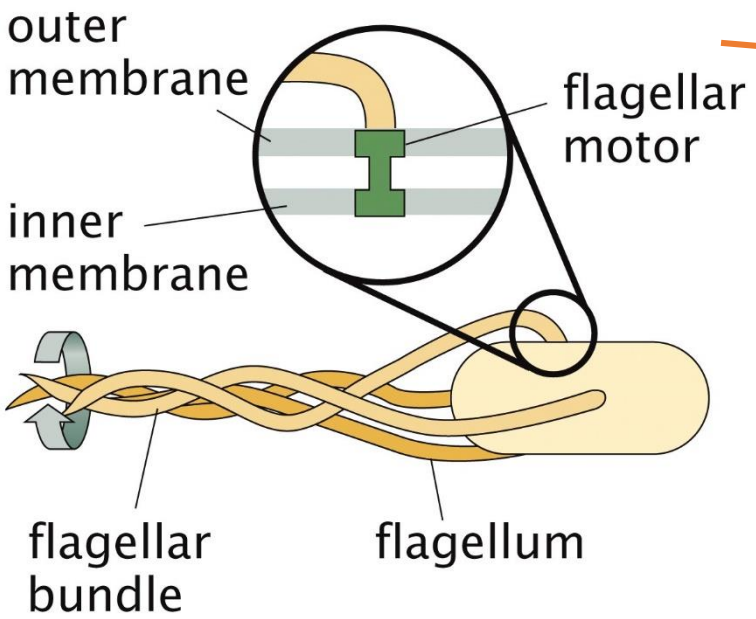
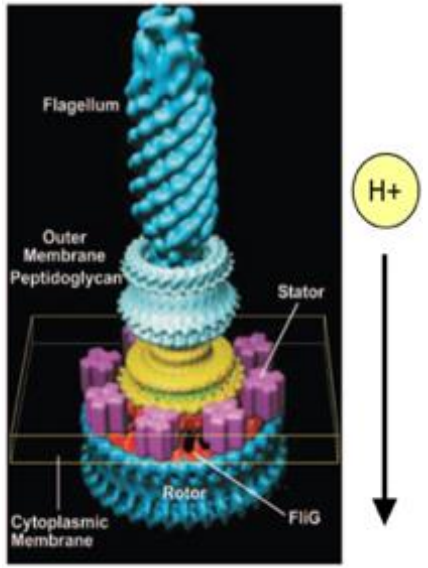


Figure 4.16a Physical Biology of the Cell, 2ed. (© Garland Science 2013)

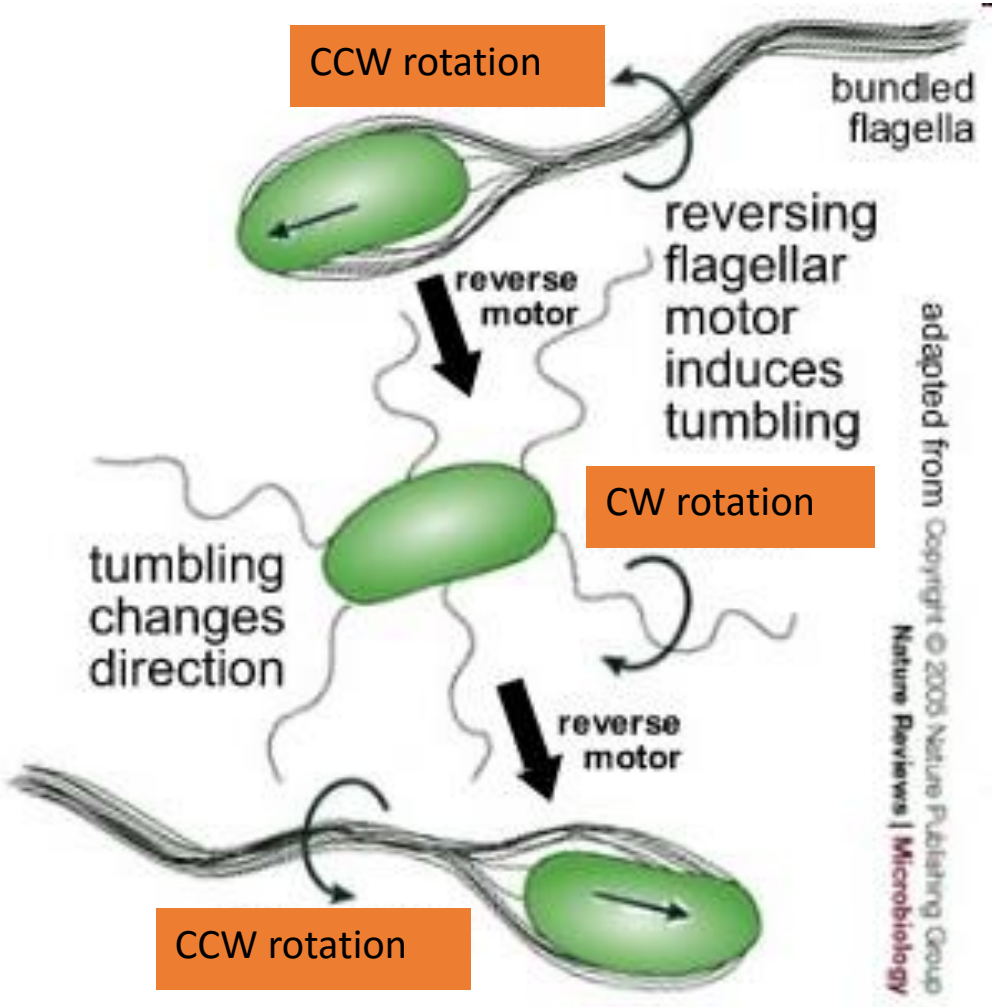
We have already discussed the Motor



But, how does the bacteria control this motor to find Food ?

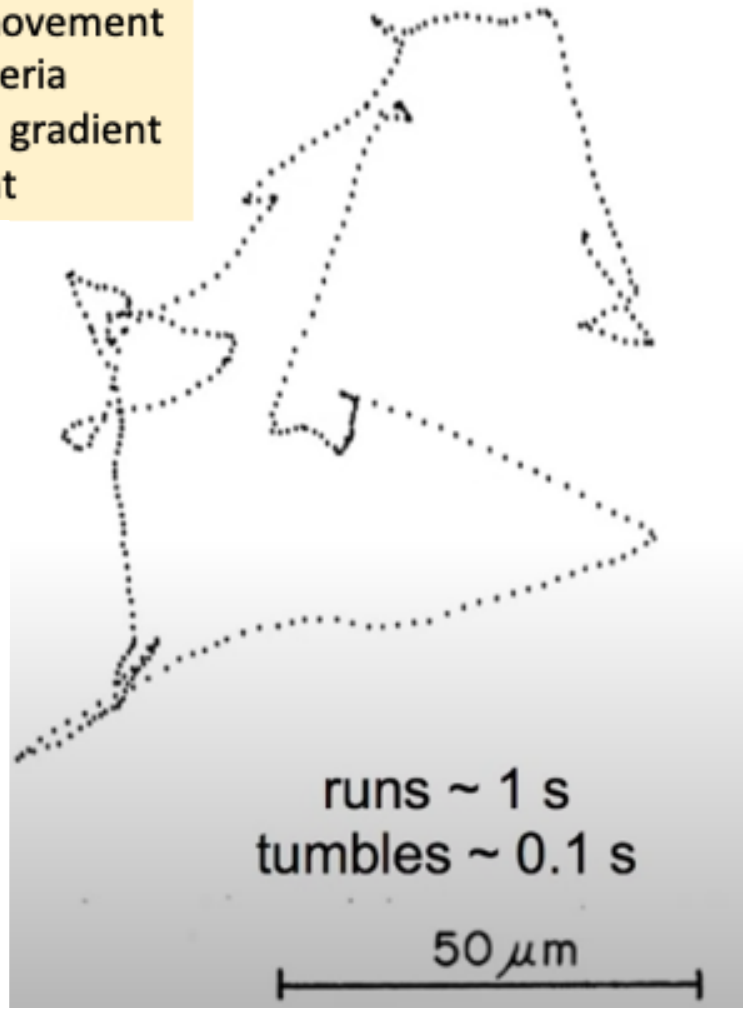
LIFE AS A BACTERIA

RUN → TUMBLE → RUN → TUMBLE → ….



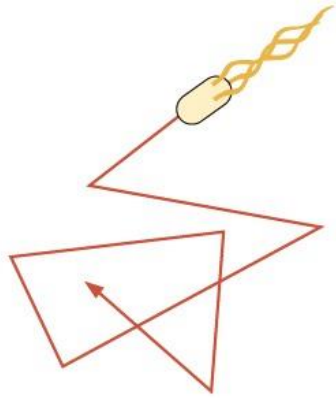
CW = Clockwise
CCW = Counter Clockwise

Actual movement of a bacteria when no gradient is present

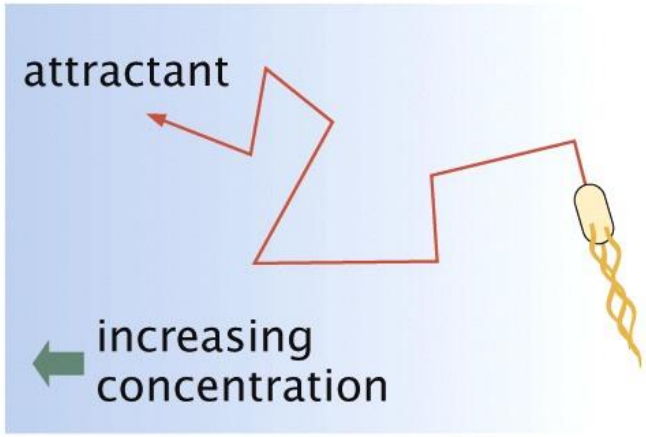


Ibiology talk by H. Berg
Chapters 4, 13 and 19 of
Rob Philips Physical Biology of the Cell

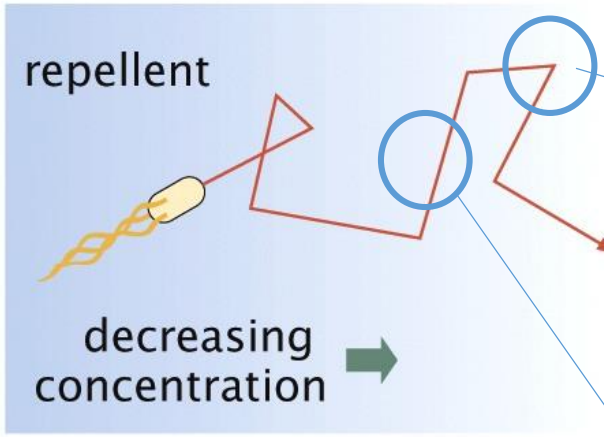
Bacteria Swim Towards Nutrients & Away from Repellents



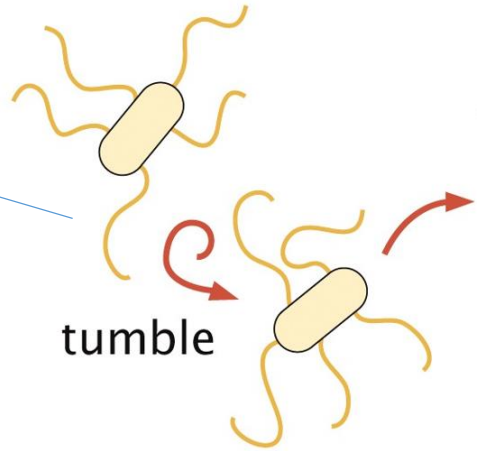
NO ATTRACTANT OR REPELLENT

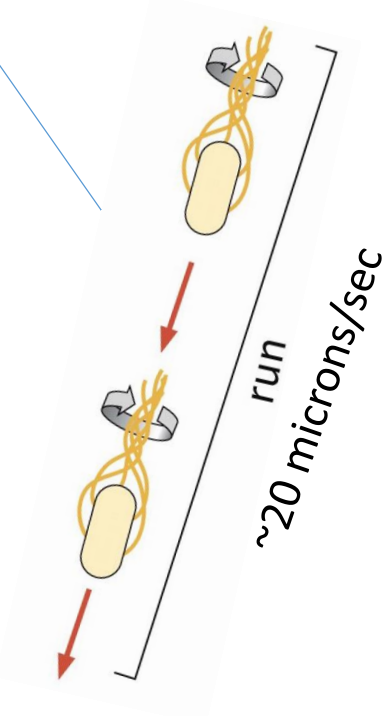


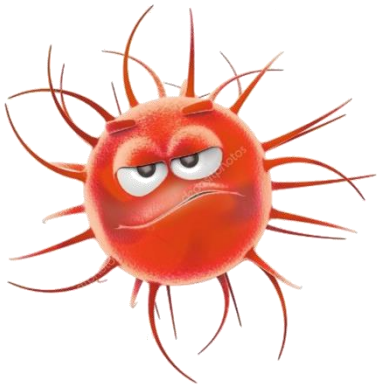
POSITIVE CHEMOTAXIS



NEGATIVE CHEMOTAXIS







<u>LIFE AS A BACTERIA</u>

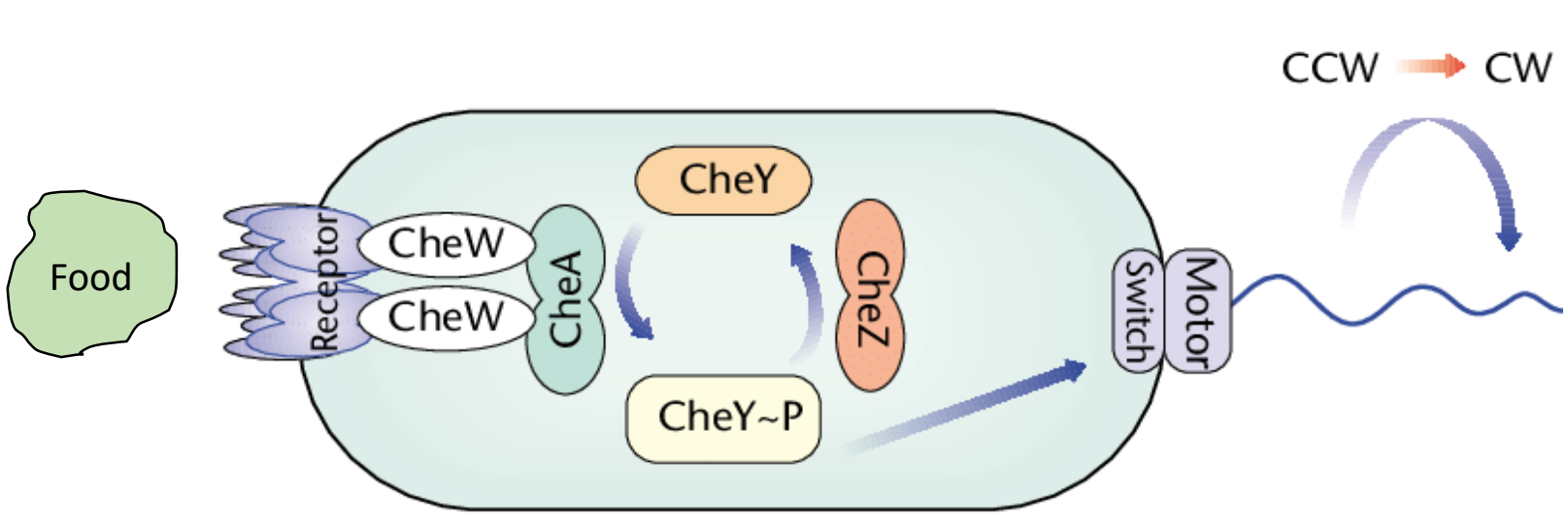
RUN → TUMBLE → RUN → TUMBLE → ….

… BINARY SWITCHING

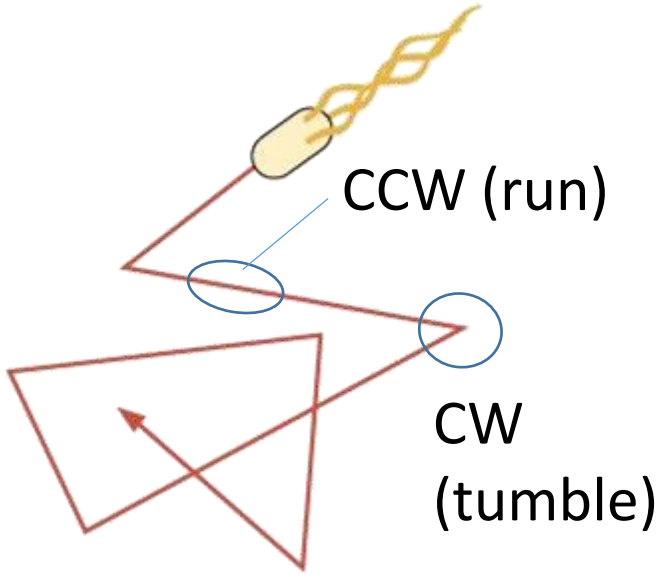
How is it implemented?

Physical Biology of the Cell, 2ed. (© Garland Science 2013)

What does molecule do ?	What is molecule called?	How does the molecule do it's job ?
1. **RECEPTOR** outside the Cell	***Receptor***	Receptor binds to Food outside the cell → Changes the shape of receptor inside the cell
2. **TRANSMITTER** of info to Cell interior	***CheW+CheA***	Bind food to receptor → CheW/CheA bind to Receptor → Now, activity of CheA increases (it is a Kinase)
3. **SWITCH** for motor (Run or Tumble)	***CheY***	CheA adds a Phosphate to CheY → CheY-P interacts with Flagellar Motor → CW → Tumble (Eat Food)
4. **RESET**	***CheZ***	CheZ is a Phosphatase → It Removes the Phosphate from CheY → Motor CCW → Run (find more food)

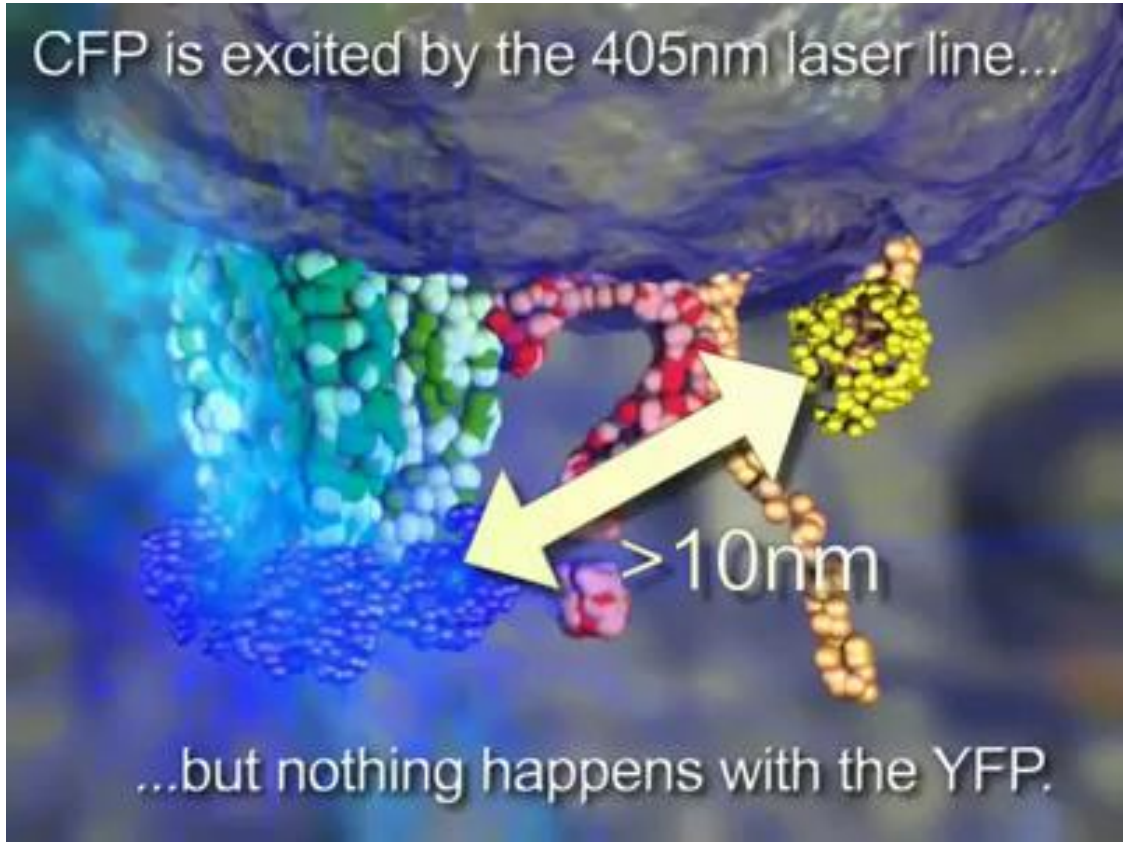


Michael Eisenbach, Weizmann Institute of Science



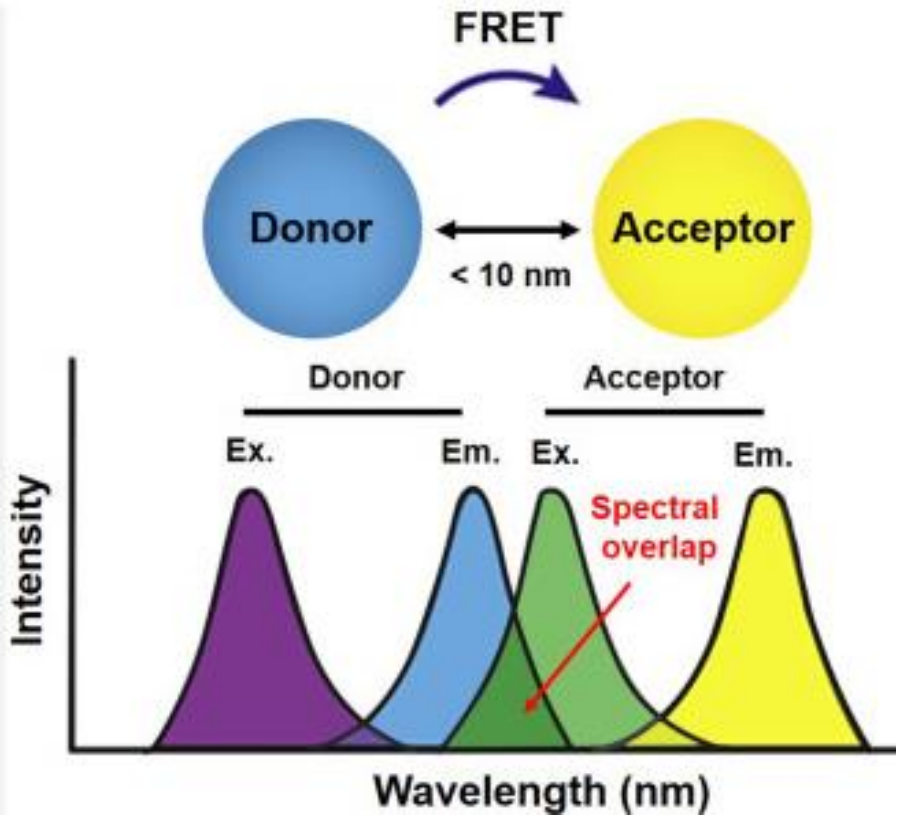
Bacteria are VERY small. How can we understand it’s internal machinery ?

FRET - Fluorescence Resonance Energy Transfer
Dr Othon Gervasio - 3D Scientific Animation



Link to Video

CFP – Cyan Fluorescent Protein - Donor
YFP – Yellow Fluorescent Protein - Acceptor



Source

Let's look at one experiment to test the Reset Mechanism

4. RESET *CheZ*

CheZ is a Phosphatase → It Removes the Phosphate from CheY → Motor CCW → Run (find more food)

Make a FRET pair between CheZ and CheY

Add food	→	Less interaction	→ YFP fluorescence decreases
Remove food	→	More interaction	→ YFP fluorescence increases

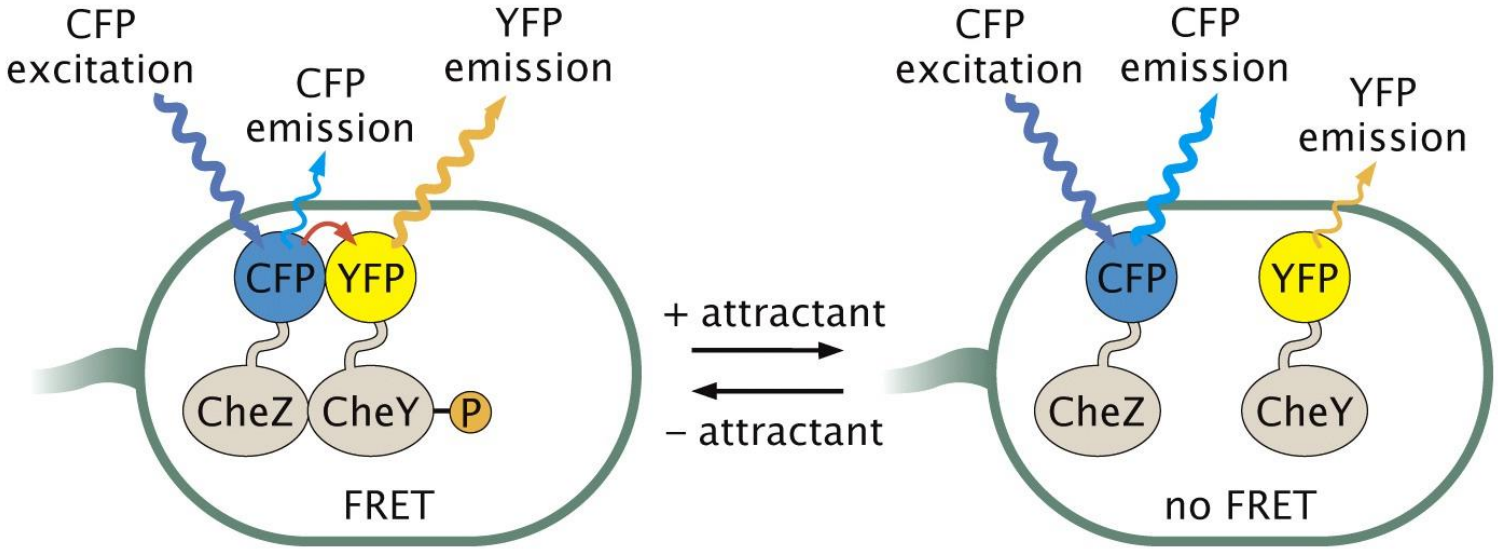


Figure 19.54a Physical Biology of the Cell, 2ed. (© Garland Science 2013)

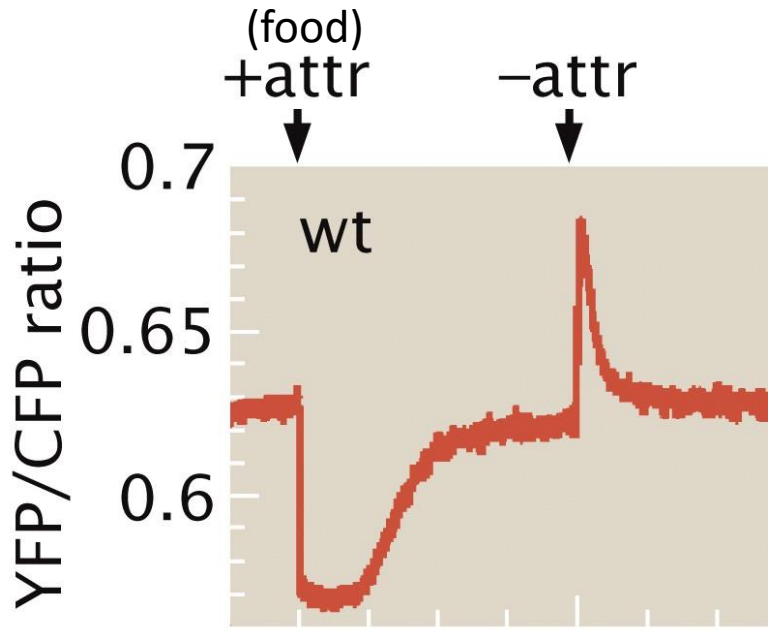
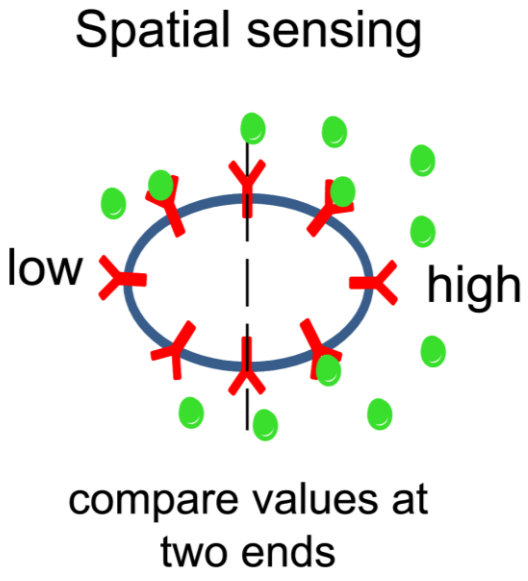


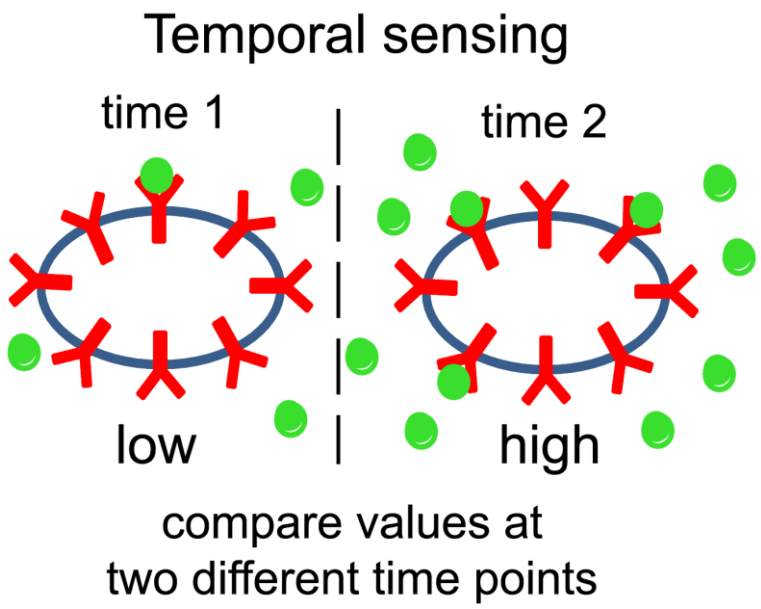
Figure 19.54b Physical Biology of the Cell, 2ed. (© Garland Science 2013)

How can Bacteria moves towards nutrients ?
Two possibilities :-

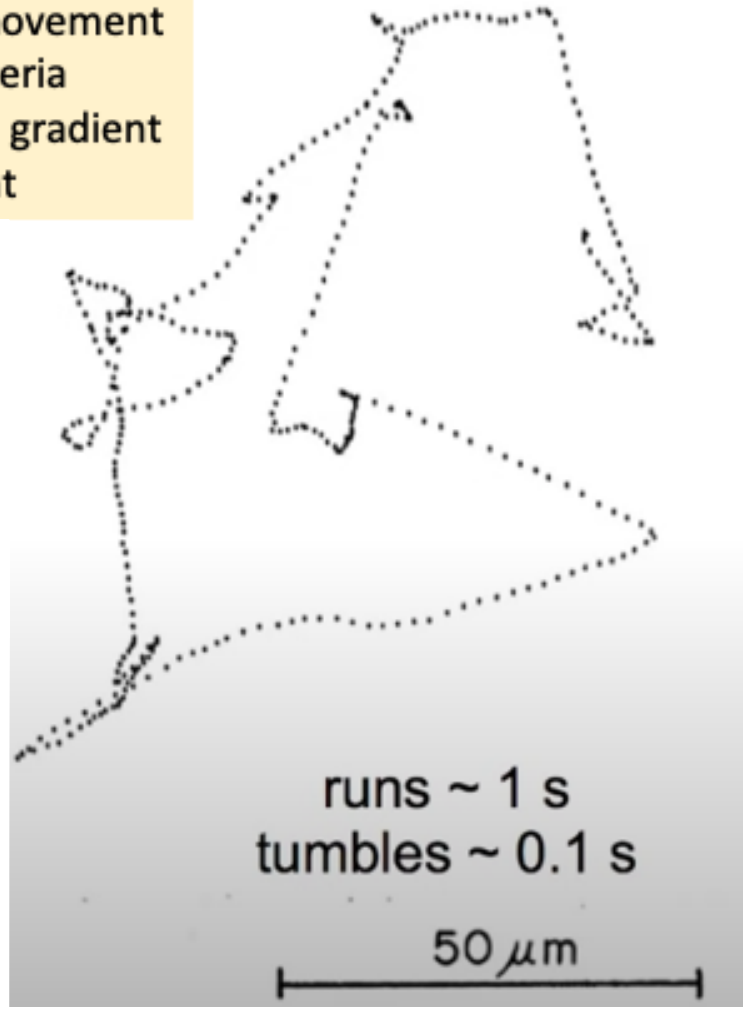
1. Compare Signals coming from Opposite ends of the bacteria (Spatial Sensing)

2. Compare Signals coming at different Time points (Temporal Sensing)





Actual movement of a bacteria when no gradient is present



Ibiology talk by H. Berg

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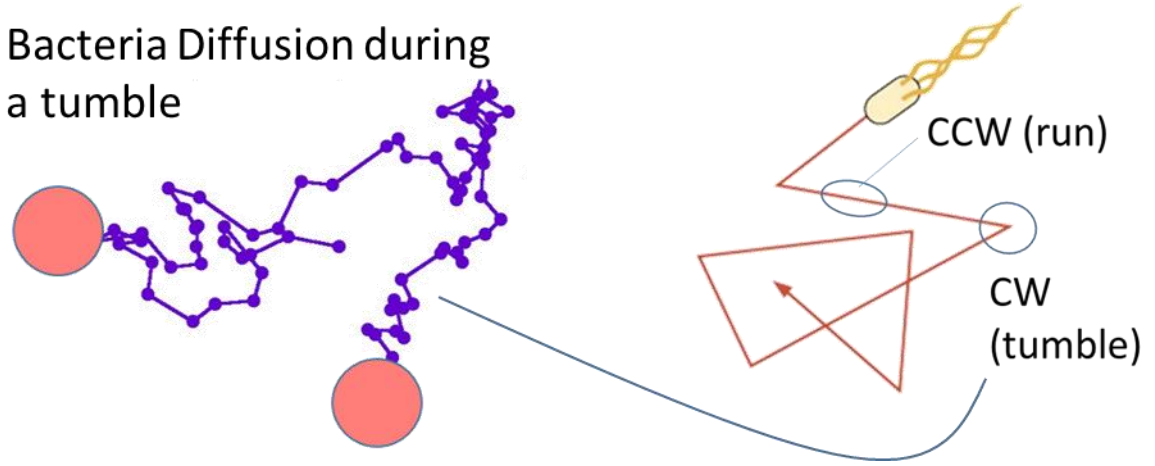
Would Spatial Sensing work ?



Bacteria of radius a = 1 micron

If bacteria diffuses distance "x" in time t (in 3D), then …

$\langle x^2 \rangle = 6Dt,\ D = kT/6\pi\eta a$

Diffusion constant
$D = \kappa T/6\pi\eta a$
η = viscosity
κ = Boltzmann constant

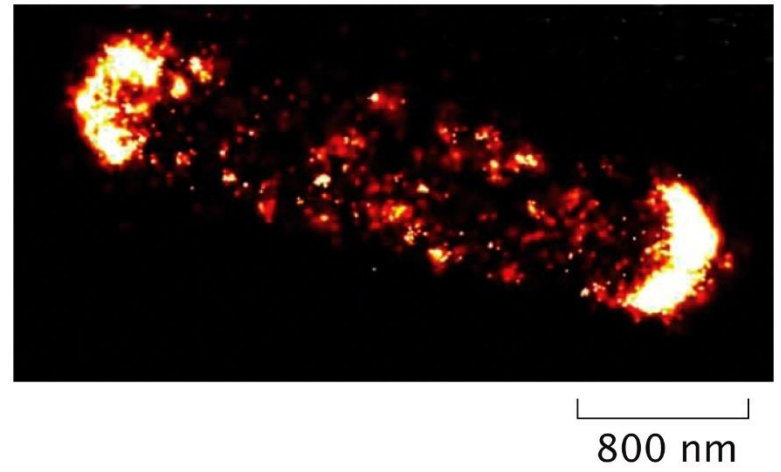


Figure 13.23b Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Put in the numbers

→ Bacteria diffuses a distance $x \approx 1$ micron in 1 second

But, food particle will diffuse ~3 microns in 1 second

(Assuming that the food particle is ~10 times smaller than bacteria)

Appears Controversial :-
Will diffusion wash out whatever the bacteria is sensing?
Can the bacteria "Count" reliably within its tumble?
Why are the sensors placed at two extreme ends of bacteria?

Howard Berg
iBiology Talk