IYNT 2022

Main Problems for Science Fight 1
4. Microscopic swimmers

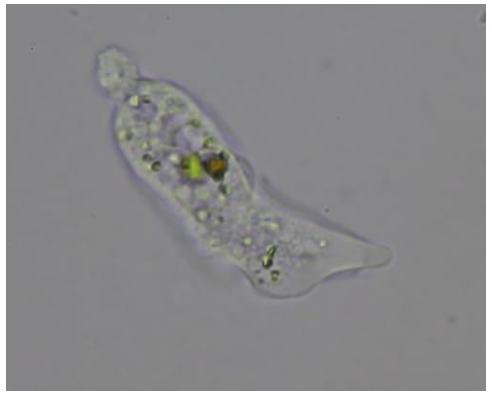
Team Starry Night
Andrei Saguna National College

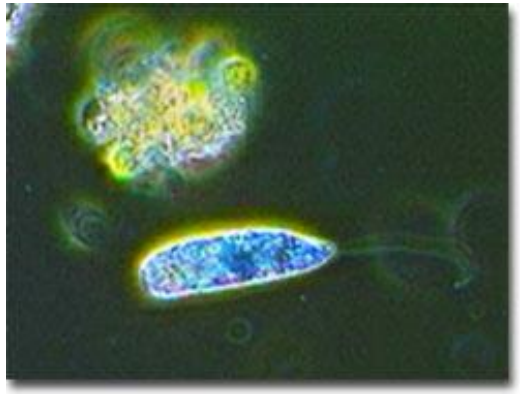
The Problem Statement

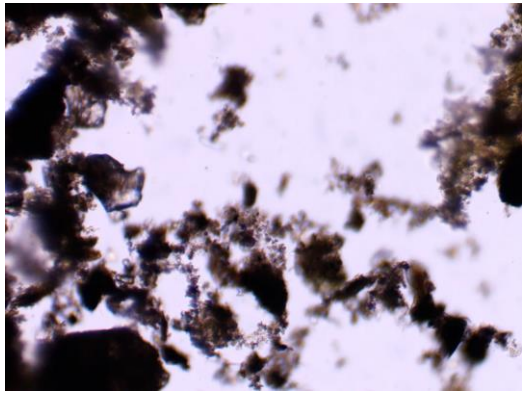
Investigate experimentally and theoretically the locomotion of bacterial or eukaryotic cells that use natural flagella to move in a liquid.

Aim of the study

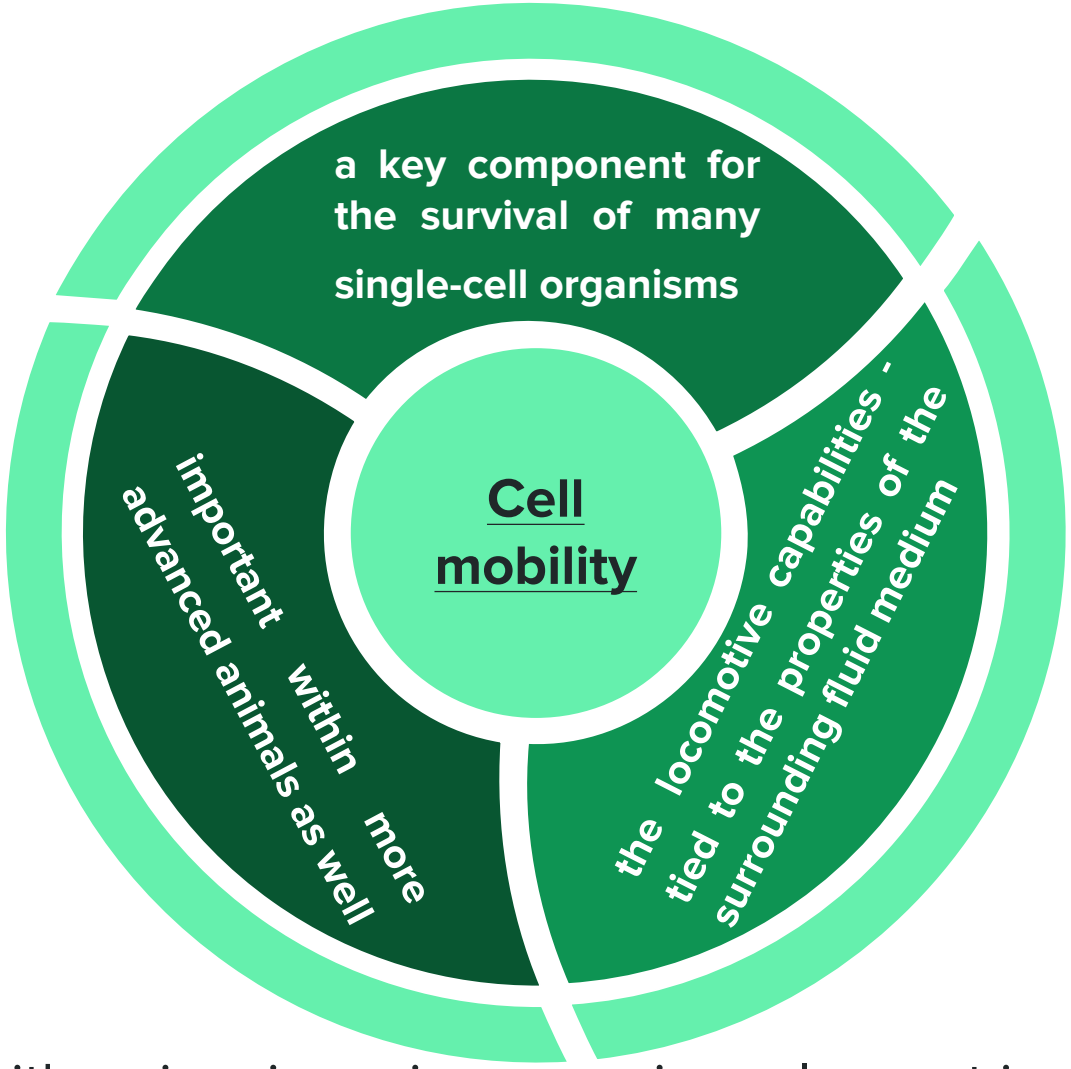
- understanding the motion of the cell
- determining the mechanism by which cells move through a liquid medium

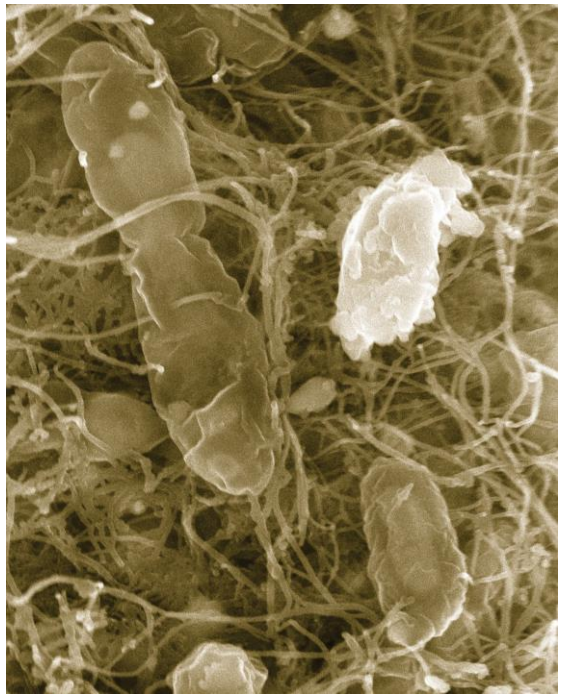






Theoretical part of the study

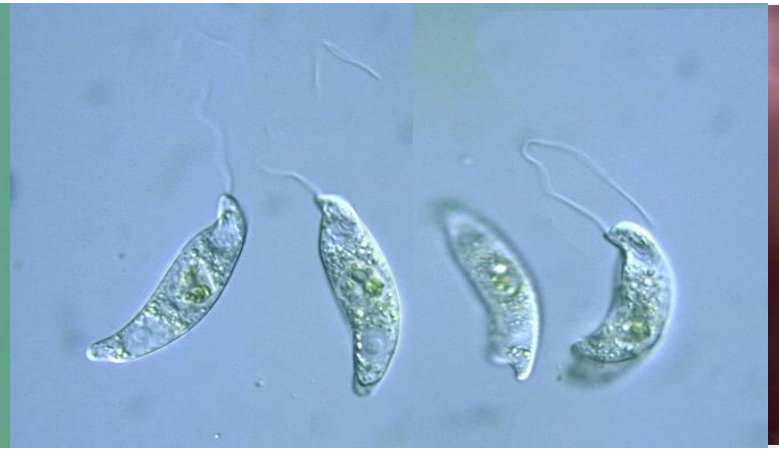


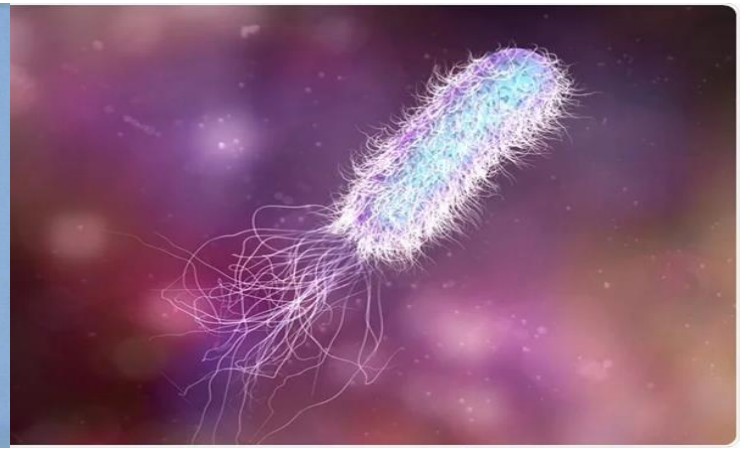


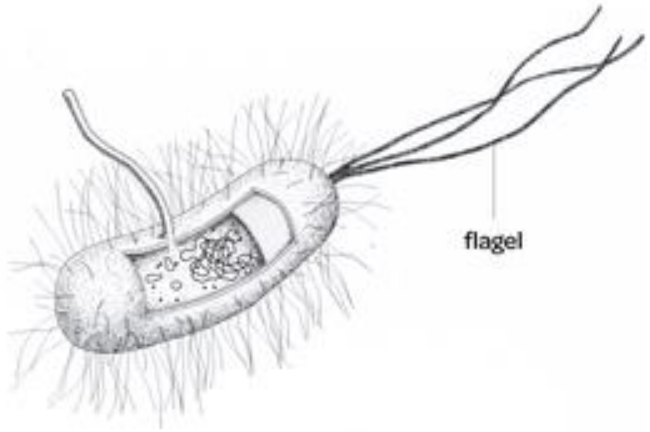
Our world is filled with swimming microorganisms. In most instances, swimming is driven by **the active motion of filamentary objects.**

What is a flagellum?

- a whip-like structure that allows a cell to move in aqueous environments
- used by different organisms
- an organelle of locomotion, besides helping with gathering food and with circulation

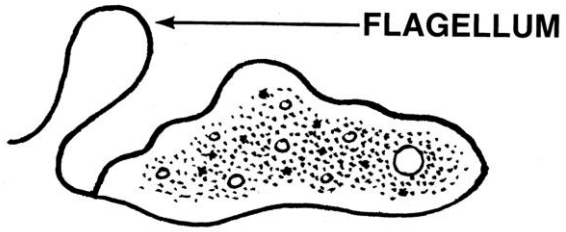






Flagellum

- found in:



- many prokaryotic cells
  - bacteria
- some eukaryotic cells
  - some protozoa
  - some animals

- **functions:**
- movement
- sometimes sensing the environment

- **looks like:**
- tail
- whip

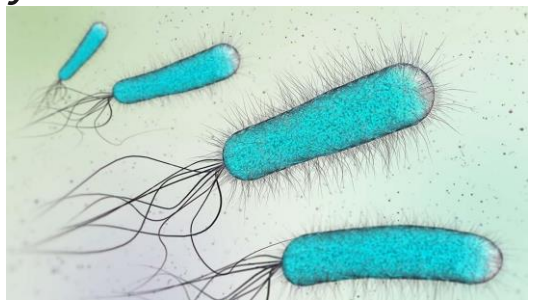
Prokaryote

– a unicellular organism that lacks membrane-enclosed nucleus:

Escherichia coli, *Bacillus subtilis*, *Helicobacter pylori*

The structure of a prokaryote:

- a basal body
- cytoplasmic membrane
- cell wall
- short hook and helical filament

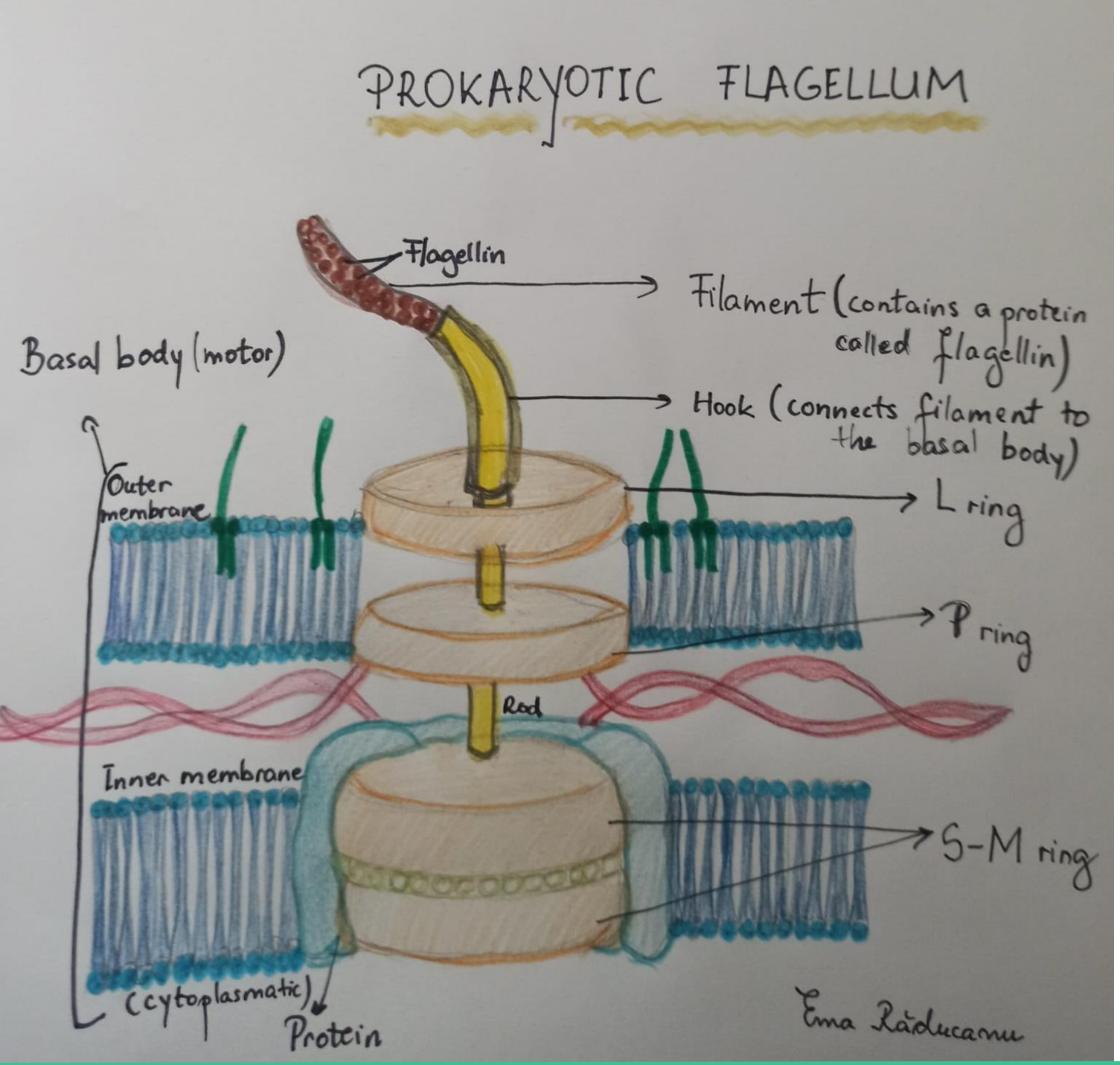


Getty Images

Photo: Kts design

Prokaryotic flagella → helical appendages which help in motility

Prokaryotes rotate their helical flagella and propels rings present in the basal body which are involved in the rotary motor that spins the flagellum.



- simple structure
- made up of protein flagellin
- rotatory movement
- proton driven

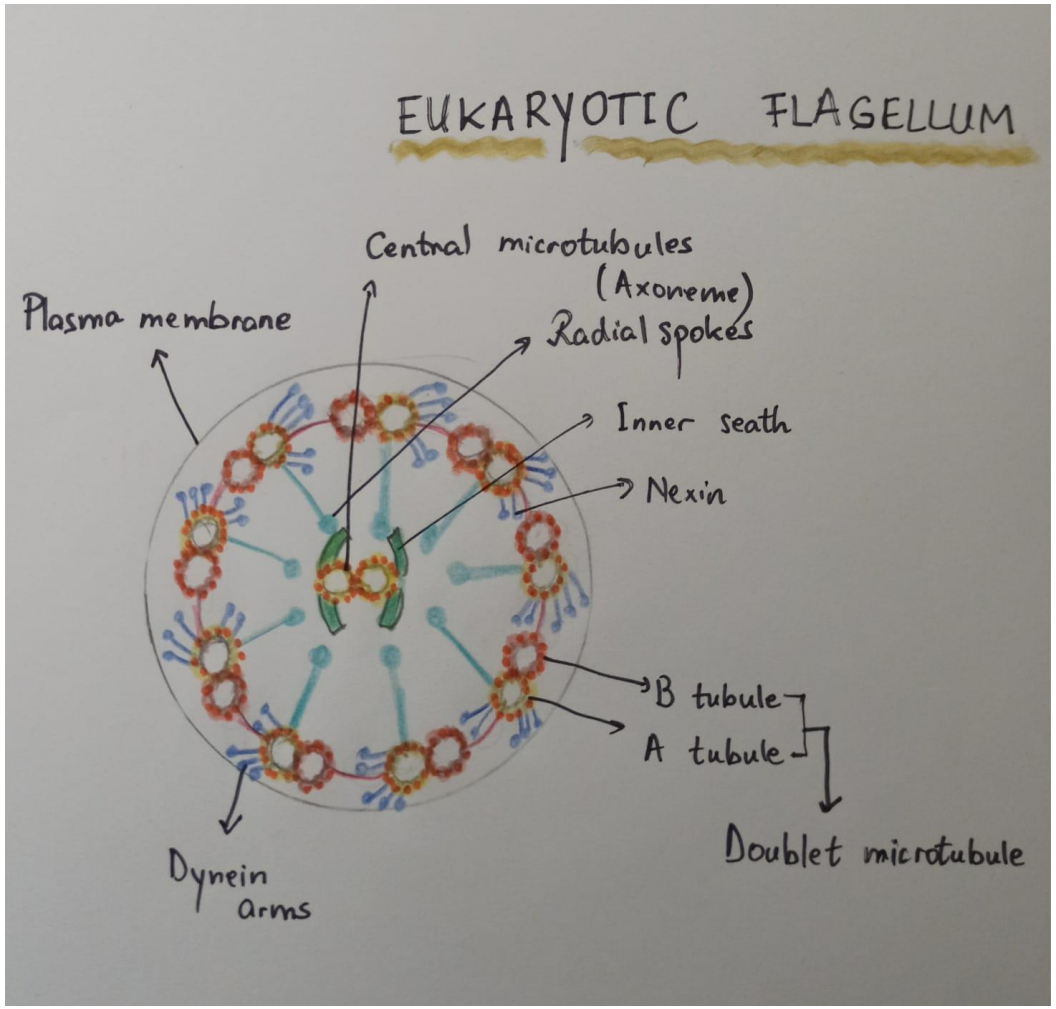
Eukaryotes

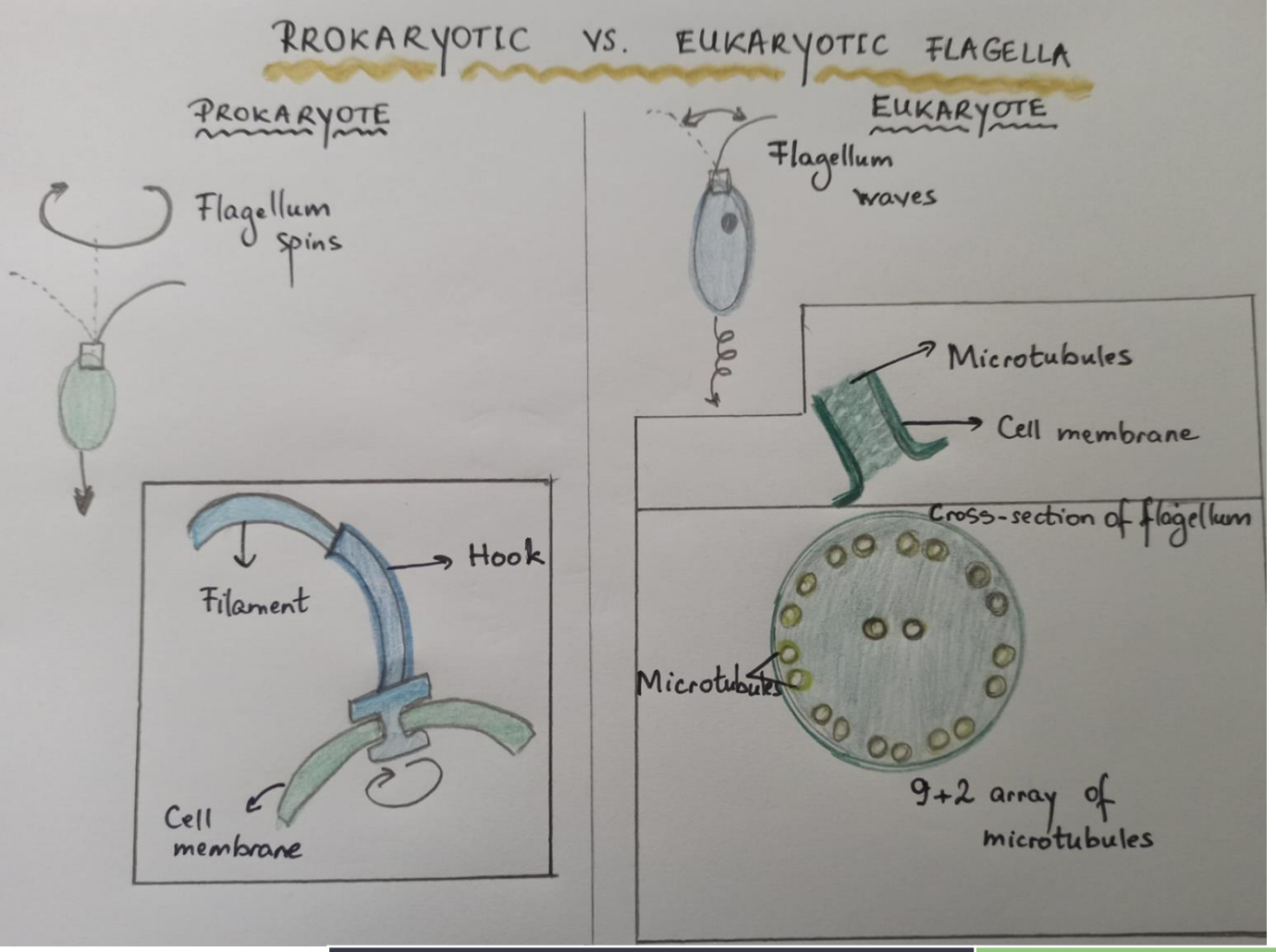
– organisms whose cells have a nucleus enclosed within a nuclear envelope:

Paramecium, *Euglena*, *algae Chlamydomonas*, *jellies*, *worms*, *flying and hovering insects*, *mollusks*, *fish*, *amphibians*, *birds*, *seals*

Eukaryotic flagella

- **larger and complex structure**
- **nine doublet pairs of microtubules arranged in a circular fashion around two central microtubules (9 + 2 arrangement)**
- **the dynein motor proteins utilize ATP (adenosine triphosphate)**
- **bending movement**





Prokaryotic flagella	Eukaryotic flagella
• made of protein subunits • protrude through cell wall and cell membrane • stiff, twirling like a propeller	• a bundle (9+2) of microtubules (made of protein) • covered by cell membrane • whipping action

	EUKARYOTIC	PROKARYOTIC
Motion	bending	rotation
Energy	ATP pump	proton pump
Structure	9+2	helical / hollow
Protein	microtubules	flagellin

Flagellates - types of movement

1. planar undulatory waves
2. traveling helical waves
3. interrupted helical waves, base to tip, anterior, pushing backward
4. spiral wave, tip to base, anterior, pulling
5. lateroposterior beat, whole flagellum or distal portion only

- contraction waves that pass either from the base to the tip of the flagellum or in the reverse direction to produce forward or backward movement

Peranema Trichophorum (Protozoa)

a colorless, cigar-shaped flagellate, a hardy, sluggish creature

a close relative of Euglena

near the anterior end→ a contractile vacuole→ where a heavy flagellum, nearly as long as the body, is projected

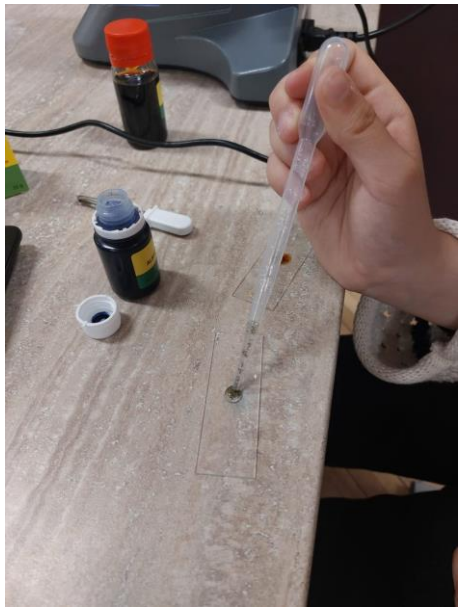
scarcely 0.05 mm long and a little more than 0.01 mm in diameter

found in stagnant water which contains a considerable amount of organic matter

it has two flagella, one of them being used for swimming, the other functioning as a sensory organ

Peranema trichophorum, photo credit - *Science Photo Library*

Experimental part of the study



Required materials:

- microscope
- slides and blades
- spatula needle
- pipettes
- tweezers
- culture with protozoa
- 3% gelatin solution
- methylene blue, solution (1 %)
- iodine, solution (2 %)

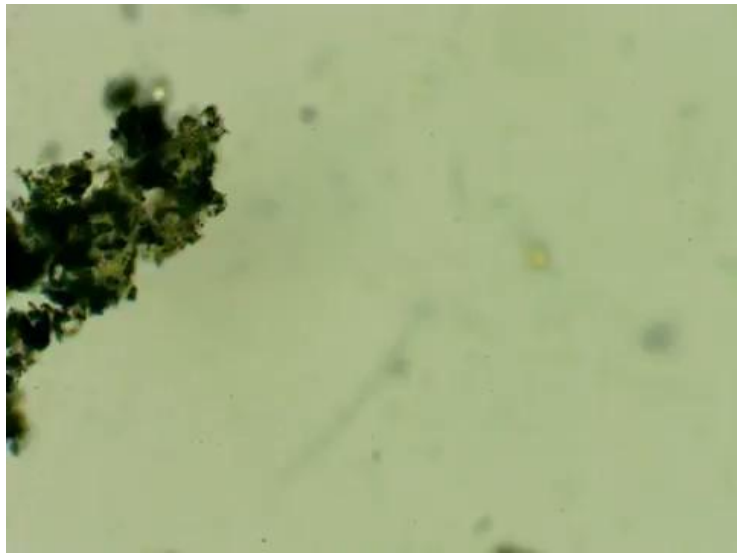
Experiment 1

Cell culture microscope - recording observations:

Task: take pictures and make conclusions based on the theory and on the experiment

Hypotheses:

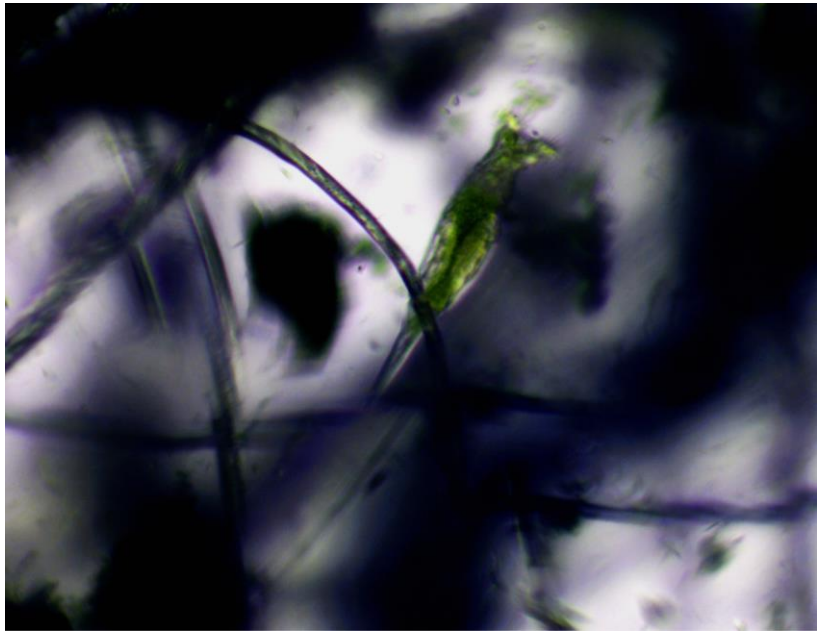
1. **Flagellum is a hairlike structure that acts primarily as an organelle of locomotion.**
2. **Eukaryotic flagella facilitate a bending movement to perform the locomotion in all directions.**



My discoveries:

- elongated, with a broad rounded or truncated posterior end during the locomotion
- peranema performs both swimming and a gliding movement, although the latter is less frequent
- the locomotion pattern is from tip to base, pulling
- peranema rapidly deforms in shape and is very effective at capturing and eating prey
- it is highly flexible, especially when it changes direction of locomotion
- the flagellum extends straight forward
- the flagellum vibrates rapidly, striking backward and forward, describing an ellipse
- when the flagellum beats, it causes the entire cell to wriggle or to bend

Obs.: During this experiment, I also observed the movement of other flagellates species: *Euglena viridis*, *Paramecium caudatum*, *Spirostomum*, the green alga *Chlamydomonas reinhardtii*, with all of them using filaments that ondulate or rotate.



Hypothesis 1: true ✓

Hypothesis 2: true ✓

Experiment 2

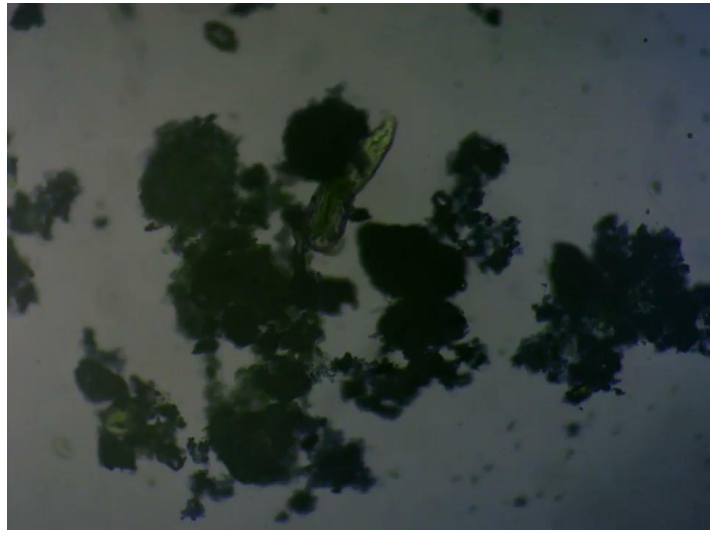
Reactions to contact stimuli

Tasks:

- to study the responses of Peranema to mechanical stimuli
- to determine whether the flagellum is sensitive to this type of stimuli

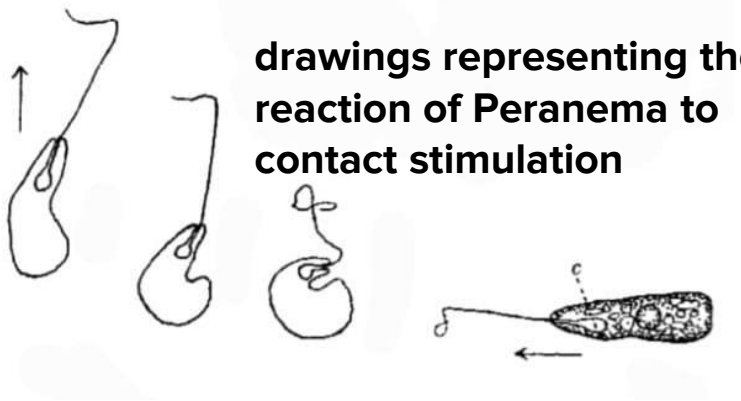
Hypotheses:

1. This eukaryote is responding to mechanical stimuli.
2. The flagellum is sensitive to contact.



My discoveries:

- in contact with physical stimuli, the tip of the flagellum usually strikes the object first
- the first response seen after a specimen gets into a fibrous mass which affords some obstruction is an increase in the activity of the flagellum
- there is no response to this when the object is small, the Peranema sliding by or through the obstruction
- when the mechanical resistance requires it, the organism stops and the body bends sharply, avoiding the objects
- the response results in a change in the direction of motion of approximately 90 °



drawings representing the reaction of Peranema to contact stimulation

Hypothesis 1: true ✓

Hypothesis 2: true ✓

Experiment 3

Reactions to chemicals

Task:

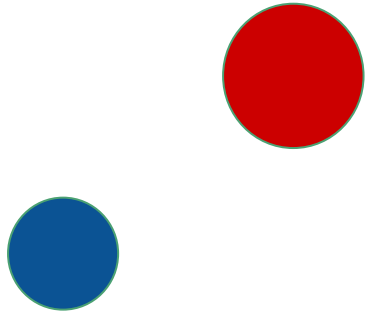
- to study the responses of Peranema to chemicals
- to ascertain whether the flagellum is sensitive to colored chemical stimuli

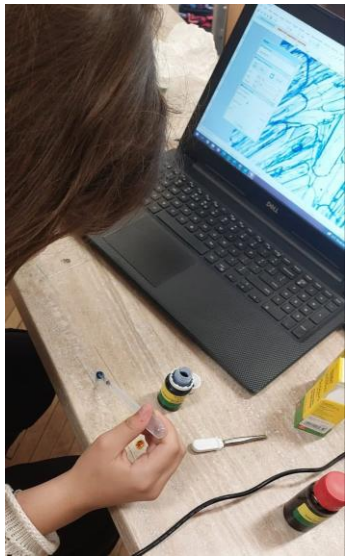
Hypotheses:

1. **Peranema is responding to chemicals.**
2. **The flagellum is sensitive to chemicals.**

Methylene blue, solution (1 %)

Iodine, solution (2 %)

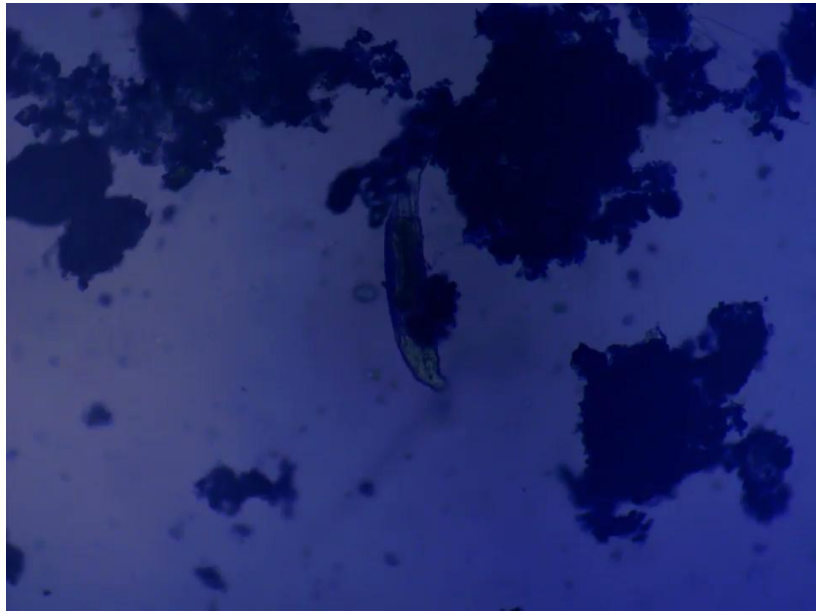


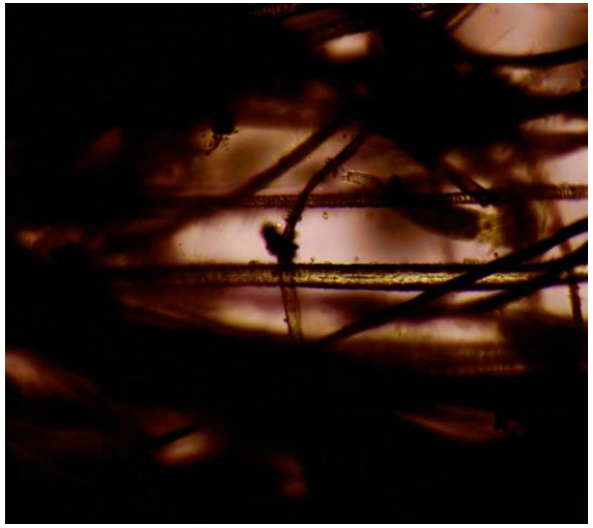


- **colored substances were introduced under the cover-glass in solution by means of a fine capillary pipette**

My discoveries:

- the Peranema swam towards the colored substance which gradually spread out in the process of diffusion
- a sharp bending of the body and an abrupt change in the direction of motion just as in the reaction of the mechanical stimuli
- the colored substances not only induce marked contractions in the body, they also induced a much more vigorous action of the flagellum
- the rate of locomotion - almost double than ordinarily observed in crawling specimens
- in one case, the Peranema responded before the tip of the flagellum reached the colored portion of the solution ➡ the sensitiveness is not evident



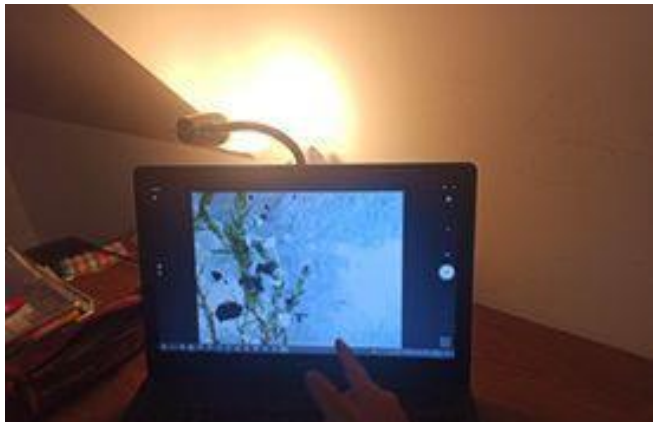


Hypothesis 1 - true ✓

Hypothesis 2 - inconclusive evidence ?

Experiment 4
Reactions to light

Task: to observe how does light affect the swimming of Peranema



Hypothesis: **Peranema only responds to light.**

- specimens of Peranema under the microscope were at different times suddenly exposed to light varying in intensity

My discoveries:

- the cells had the fastest response after approximately 30 to 60 min of light followed by 30 min of darkness
- longer light exposures reduced the specific bending movement
- having a dark adaptation period after the light period also increased the response
- so, both light and dark adaptation increased the response to light
- Peranema cells glide, turn and curl spontaneously in either light or dark
- the frequency of curling behavior is apparently enhanced by an increase in light, as shown by a shortening of the time before next curl

Hypothesis: false ✗

Experiment 5

Movement of Peranema in a denser environment

Task: to observe the movement of Peranema in a gelatin solution

Hypothesis: The movement of this eukaryotic organism is slower in a denser environment.

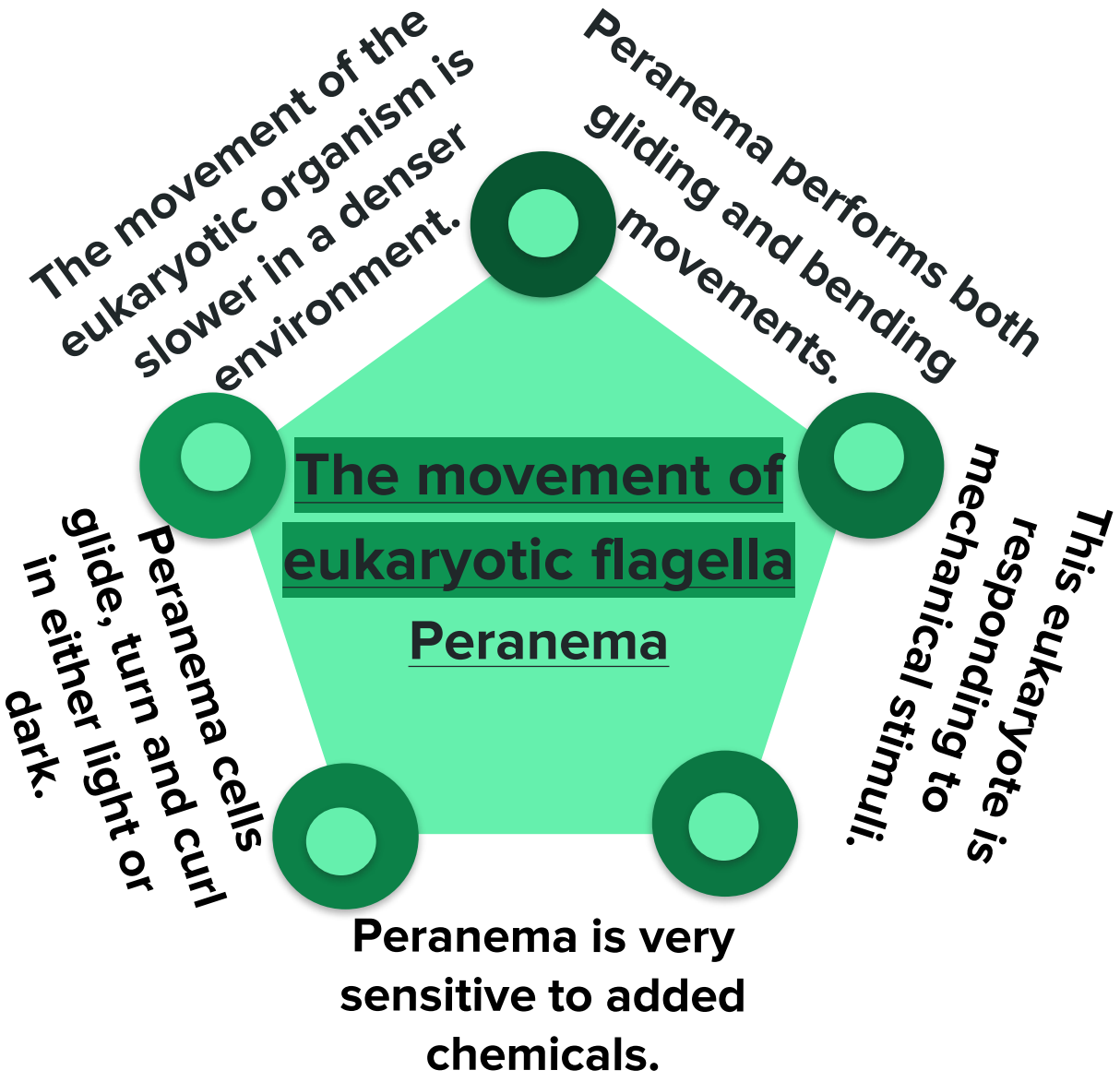
- to slow down the movements, I applied the protozoa culture on a denser medium - in a drop of 3% gelatine solution

My discoveries:

- the peranema flagella move slower in a denser medium, which allows the movements to be traced: they originate from the tip to base, performing body pulling
- when organisms are incapacitated because of imprisonment in gelatin, they move a little forward by a peristaltic type contraction

Hypothesis: true ✓

Conclusions



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Thank you for your attention!