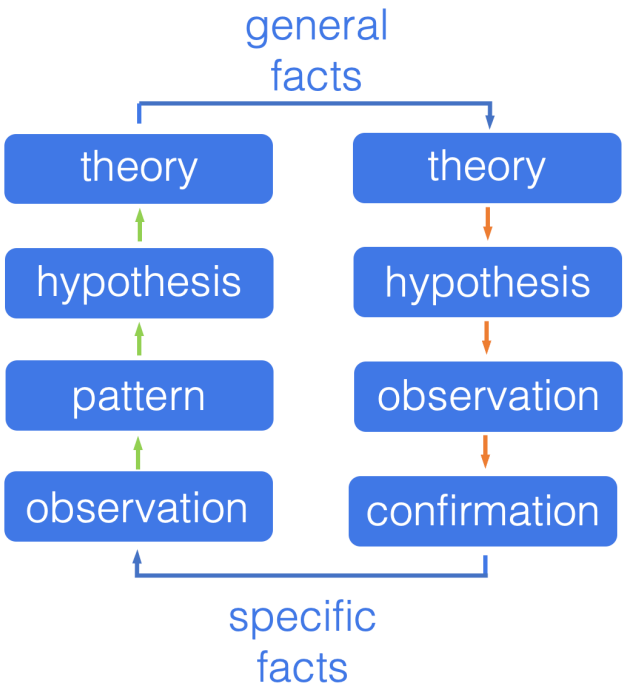
A2.2
Cell Structure

What are the features common to all cells and the features that differ?
How is microscopy used to investigate cell structure?

© biocode.co

NOS: Deductive reasoning



inductive reasoning

specific observations:
swan 1, 2, 3, … are white

pattern:
every swan seen is white

general conclusion:
likely all swans are white

falsification:
a black swan

conclusion
- has uncertainty due to limited observations
- can be 100% falsified

- useful to form theories

deductive reasoning

general premises:
- swans are birds
- all birds have feathers

IF A = B and B = C then A = C

A: swans B: birds C: feathers

specific conclusion:
swans have feathers

confirmation:
check swans for feathers

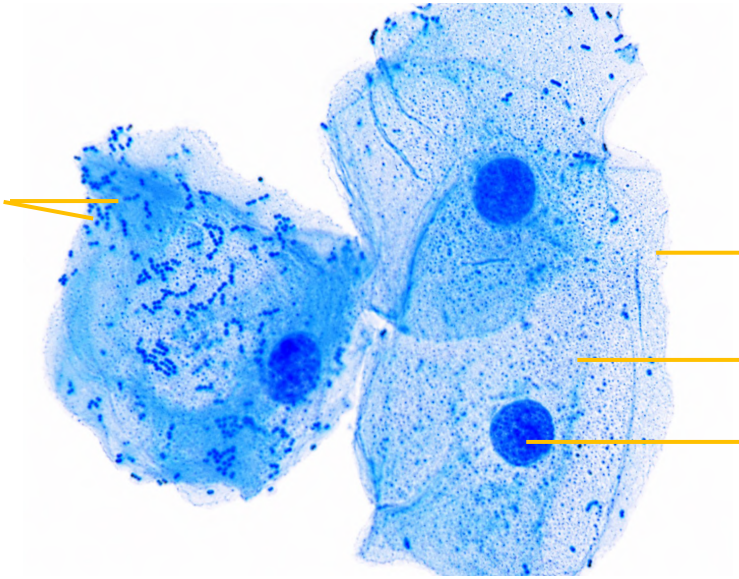
conclusion
- is certain if premises are true
- falsifiable if premises are testable

- useful to confirm theories

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Microscopy skills

Animal cell
Light Microscope 400x



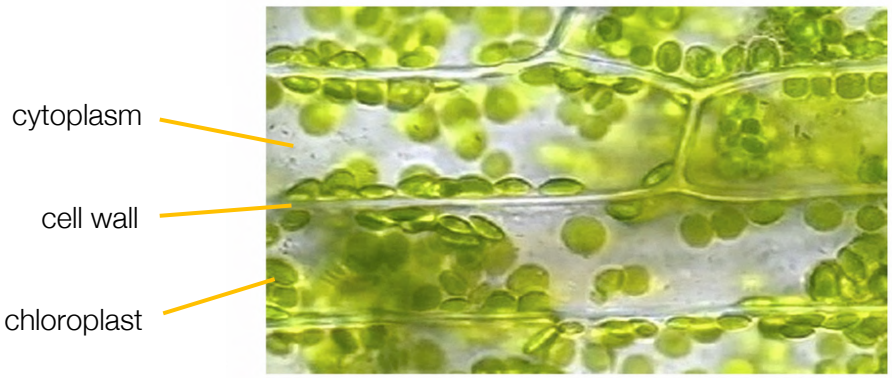
cheek epithelial cells



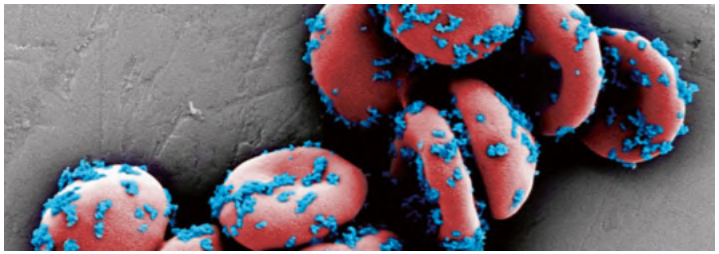
onion cell cytoplasmic streaming

by germiury

Plant cell
Light Microscope 100x



Elodea pond weed leaf cells

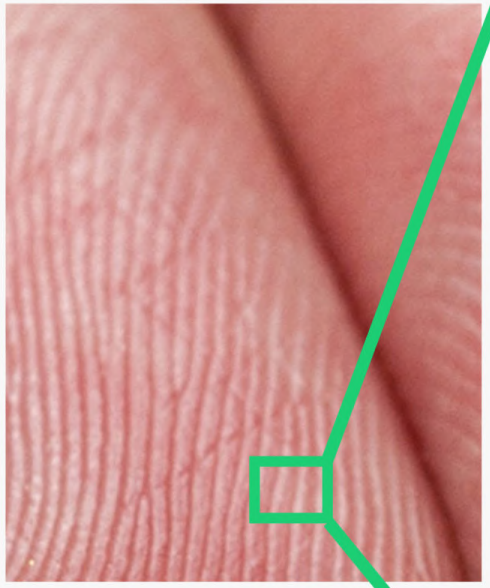


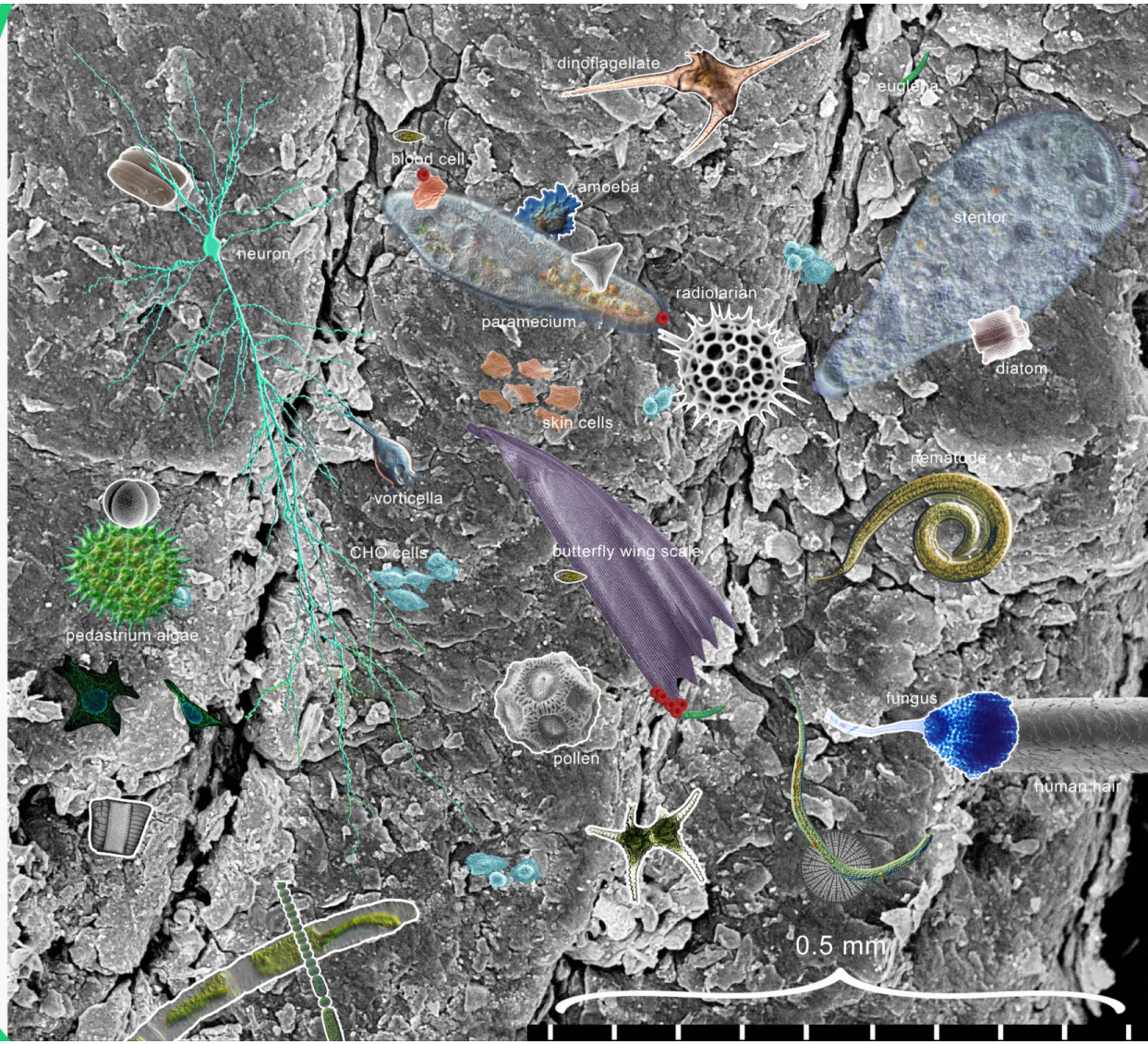
Winkler

Red blood cells covered in synthetic particles.
Scanning Electron Microscope (SEM) False Colour Image

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Microscopy skills

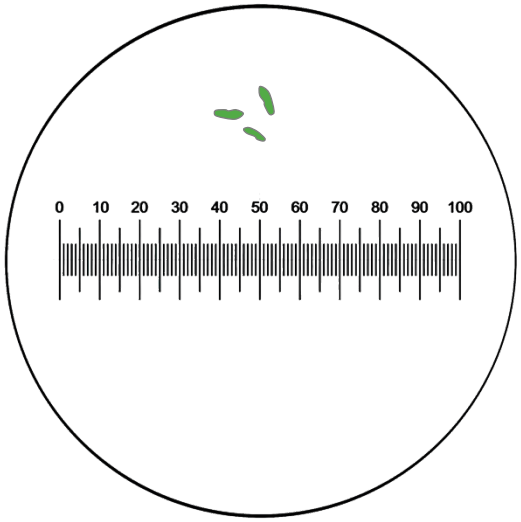


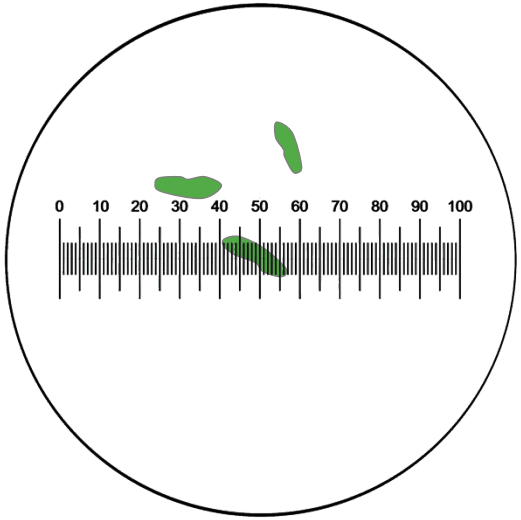


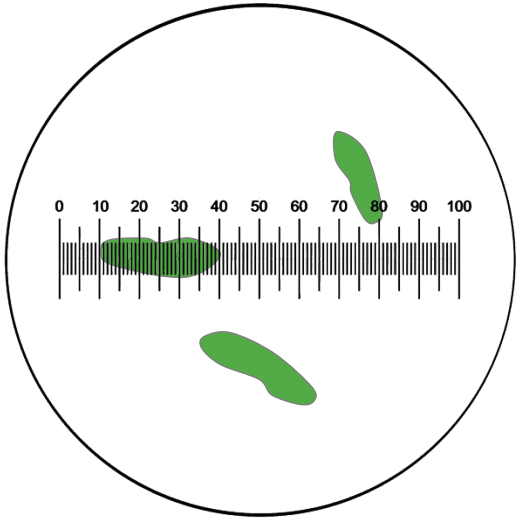
Used with Permission Jess Holz

Cell Size and Scale Interactive

Microscopy skills







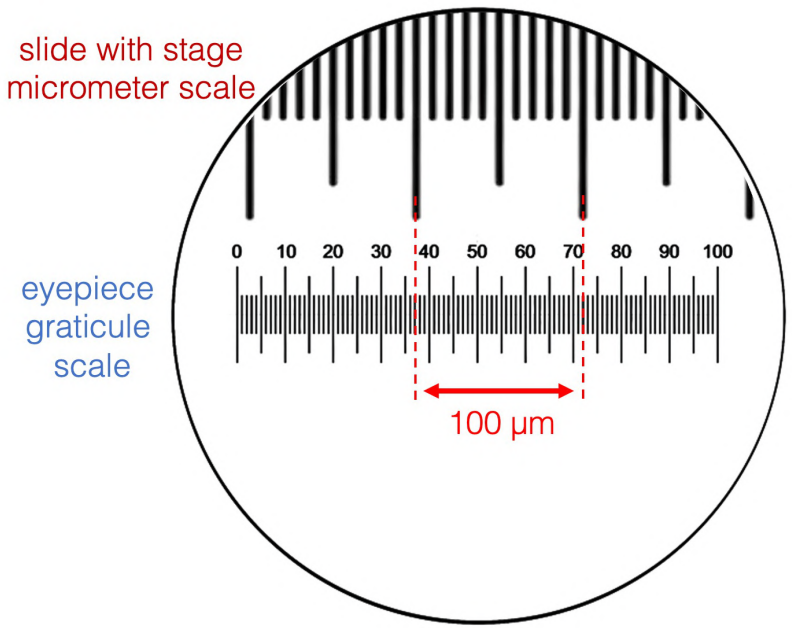
Adapted from Giles Bolduc

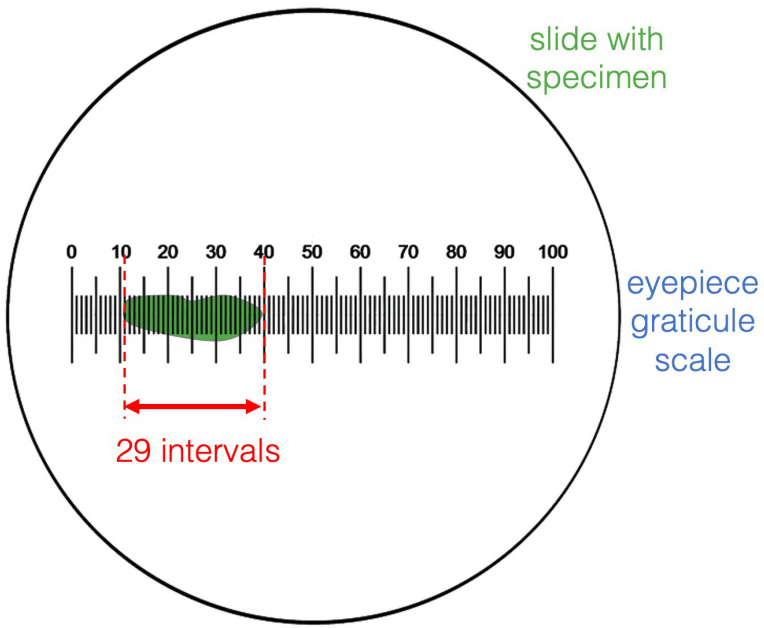
eyepiece lens	10x	10x	10x
objective lens	4x	10x	40x
sample magnification	40x	100x	400x
eyepiece scale magnification	10x	10x	10x

Virtual Microscope: The Open University

See video by Gilles Bolduc

Microscopy skills





Adapted from Giles Bolduc

One interval on the eyepiece scale
at 400x magnification is found by:

= 100 µm ÷ (72-37)
= 100 µm ÷ 35 intervals
= 2.9 µm

Length of cell
at 400x magnification is found by:

= 40 – 11 = 29 intervals
= 29 x 2.9 µm
= 84.1 µm

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Microscopy skills



Daniel Boone Native Gardens Flickr



UWDC



Donald Ott

Tradescantia stamen filament cells showing cytoplasmic streaming by Donald Ott

Developments in microscopy

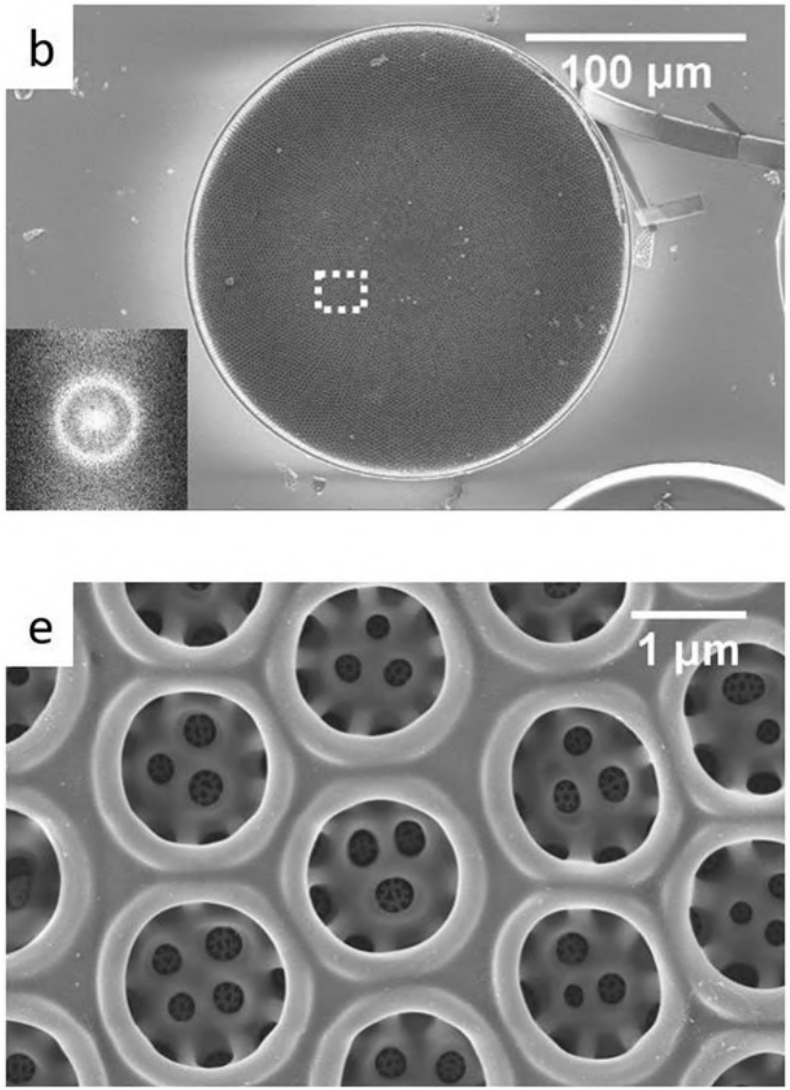


John Ray 1627 – 1705
Father of Natural History

The Observations which have been made in these latter times by the help of the Microscope, since we had the use and improvement of it, discover a vast difference between Natural and Artificial Things. Whatever is natural beheld through that appears exquisitely formed, and adorned with all imaginable Elegancy and Beauty. There are such inimitable gildings in the smallest Seeds of Plants, but especially in the parts of Animals, in the Head or Eye of a small Fly; such Accuracy, Order, and Symmetry in the frame of the most minute Creatures, a Louse, for Example, or a Mite, as no Man were able to conceive without seeing of them. Whereas the most curious Works of Art, the sharpest and finest Needle doth appear as a blunt rough Bar of Iron, coming from the Furnace or the Forge: the most accurate engravings or embossments seem such rude, bungling and deformed Work, as if they had been done with a Mattock or a Trowel, so vast a difference is there betwixt the Skill of Nature, and the Rudeness and Imperfection of Art. I might add, that the Works of Nature the better Lights and Glasses you use, the more cleaver and exactly formed they appear; whereas the effects of human Art the more curiously they are viewed and examined, the more of Deformity they discover.

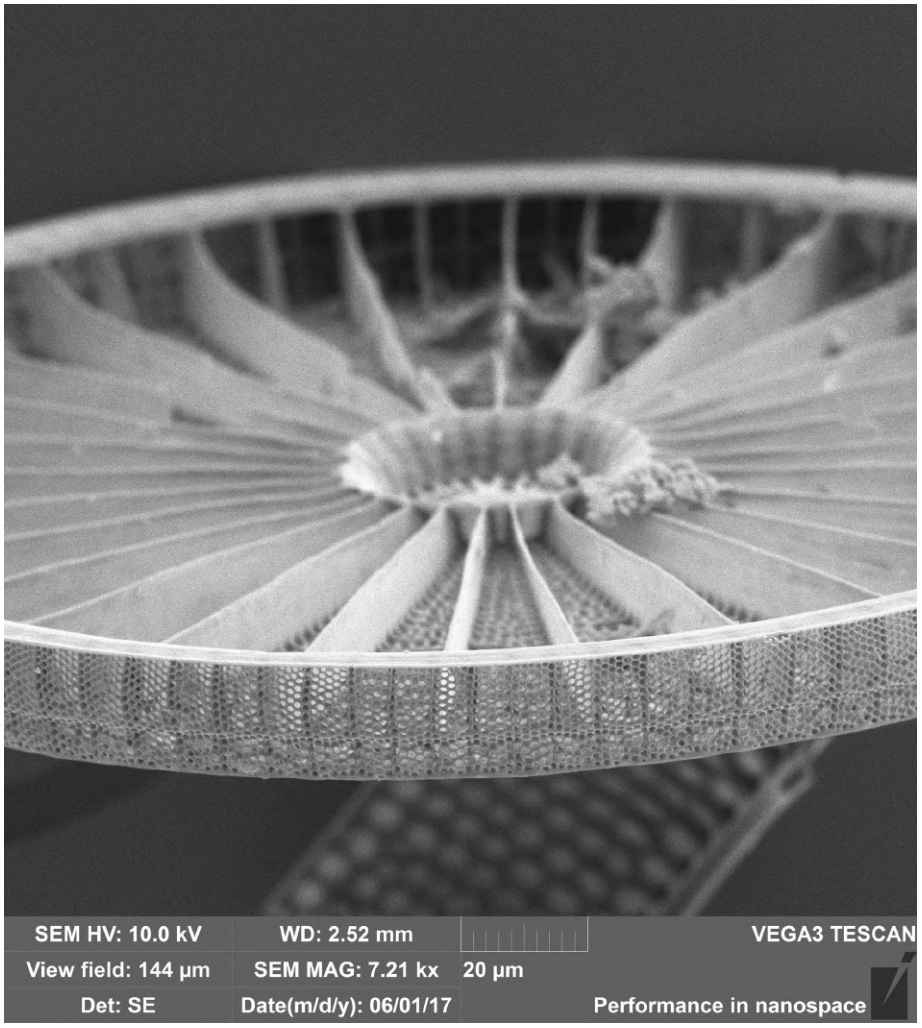
biocode.co

Developments in microscopy



Aguirre et. al 2018 Nature

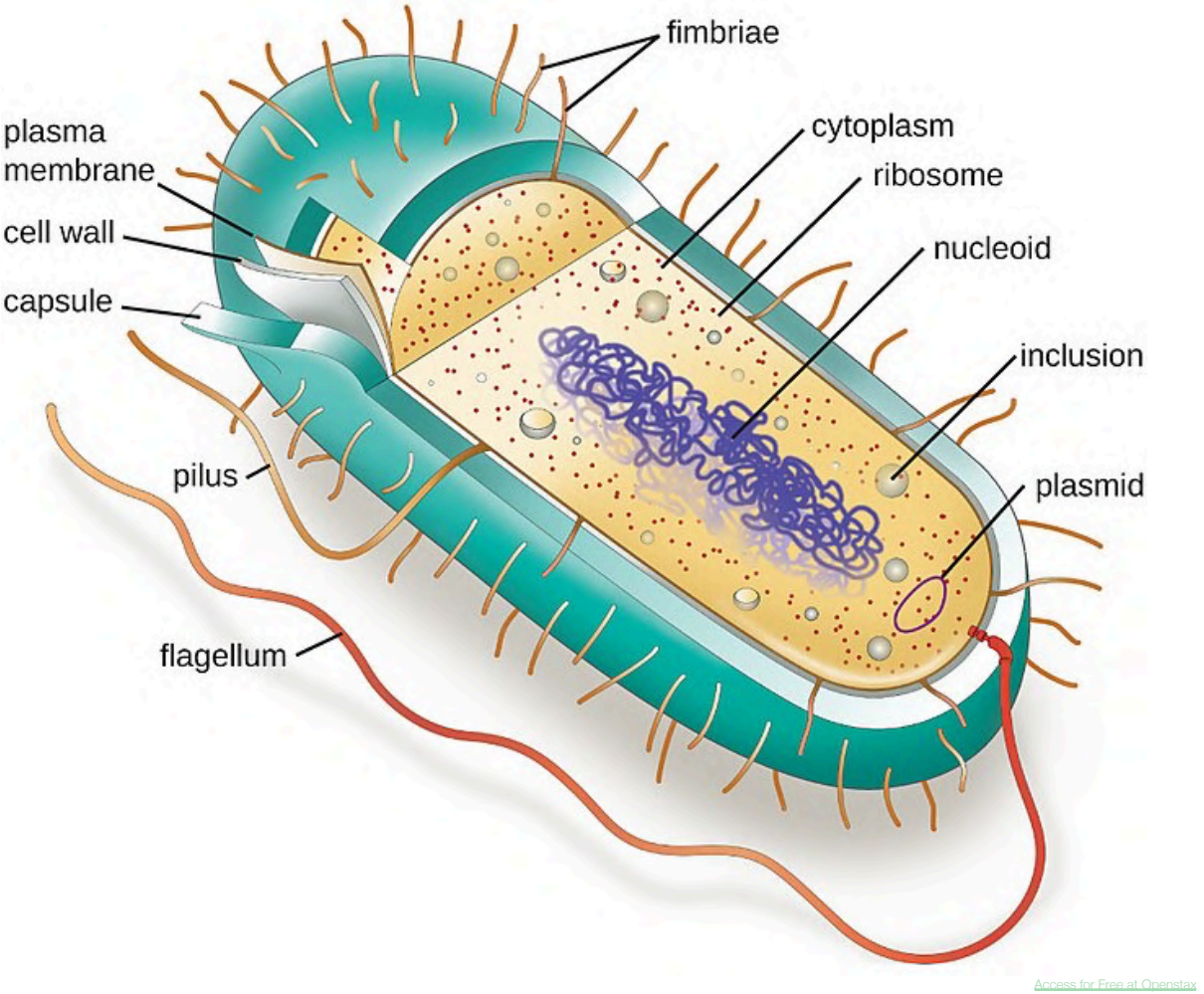
Closeup of a unicellular diatom frustule.



Wikimedia humanosmexicanos

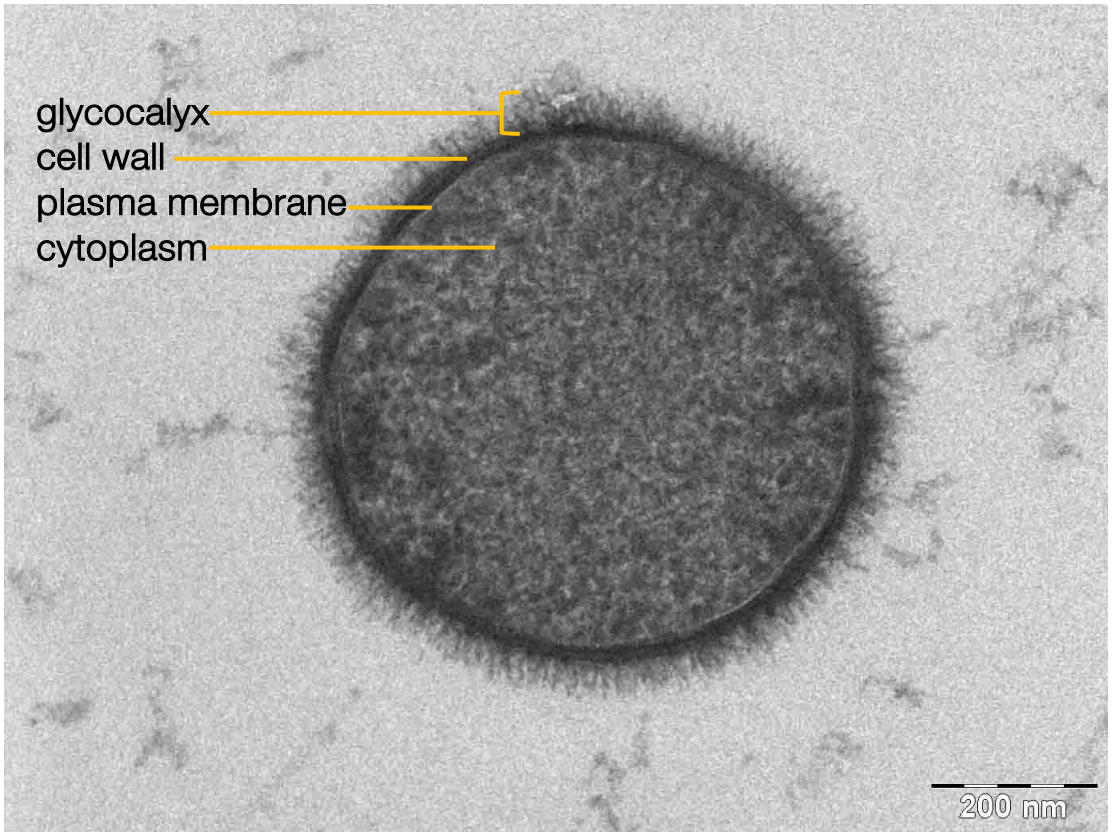
Closeup of a unicellular diatom frustule.

Prokaryote cell structure



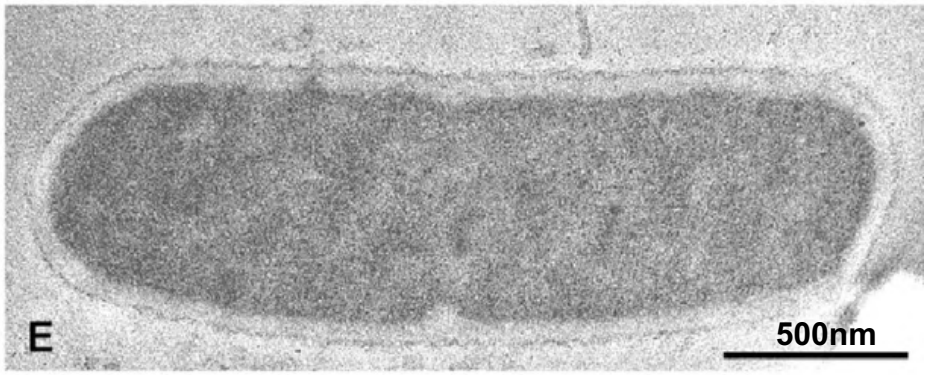
biocode.co

Prokaryote cell structure



Public Domain: Allon Weiner, The Weizmann Institute of Science

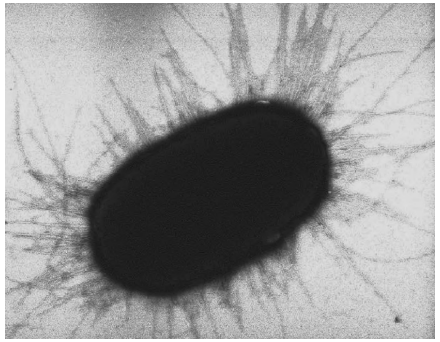
Bacillus subtilis TEM cross section – some bacteria have a glycocalyx.



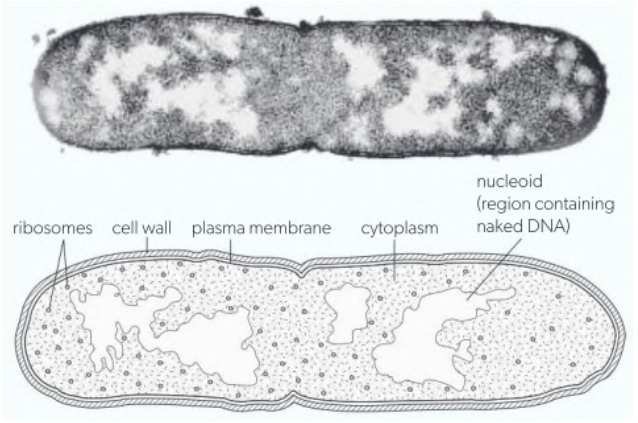
Bacillus subtilis TEM longitudinal section

Holzinger et al 2011

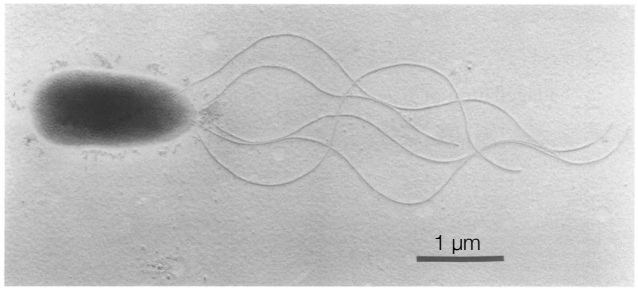
Prokaryote cell structure



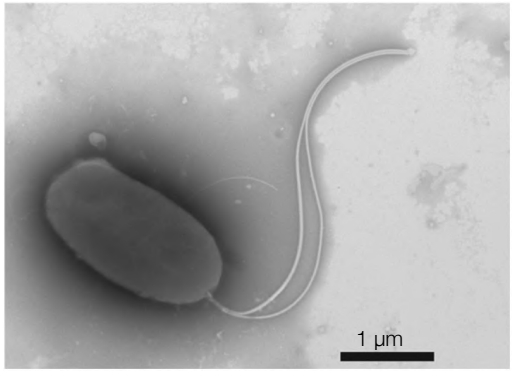
Forero 2006



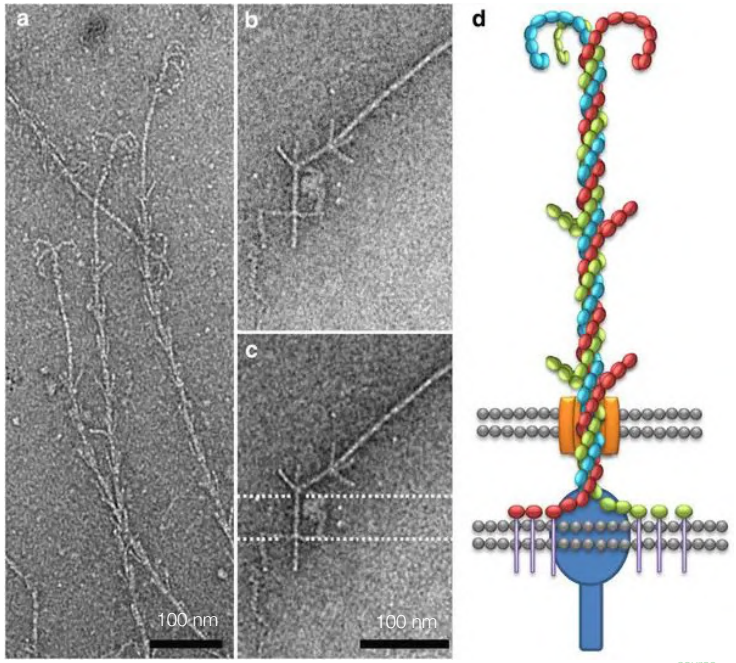
source



Harwood and Fosnaugh et al 1989



Brennan et al 2014 eLife



source

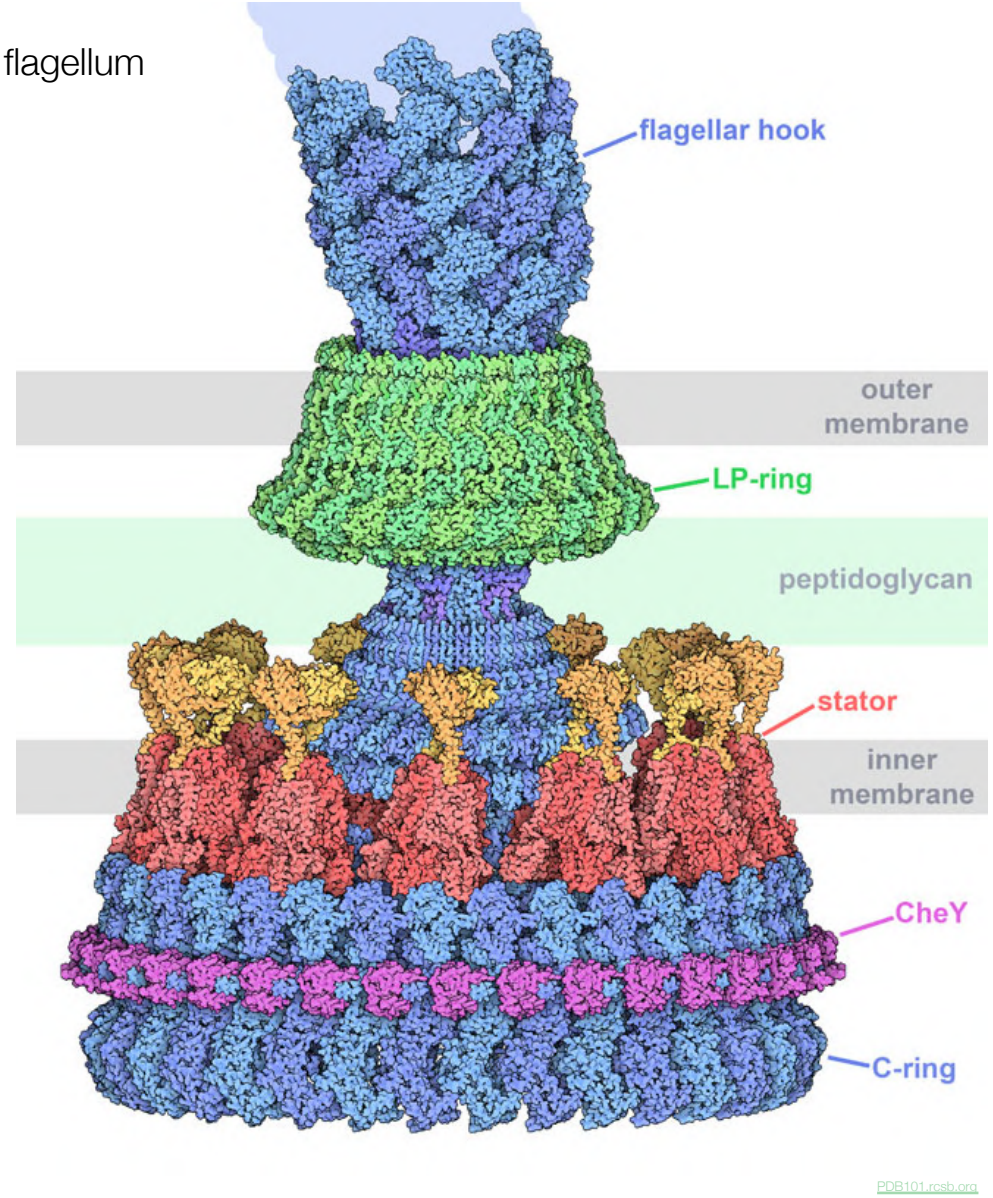
Hamus – grappling hook found in Archea for attachment.

Optional extra - prokaryote rotary flagellum

Early Research in Japan

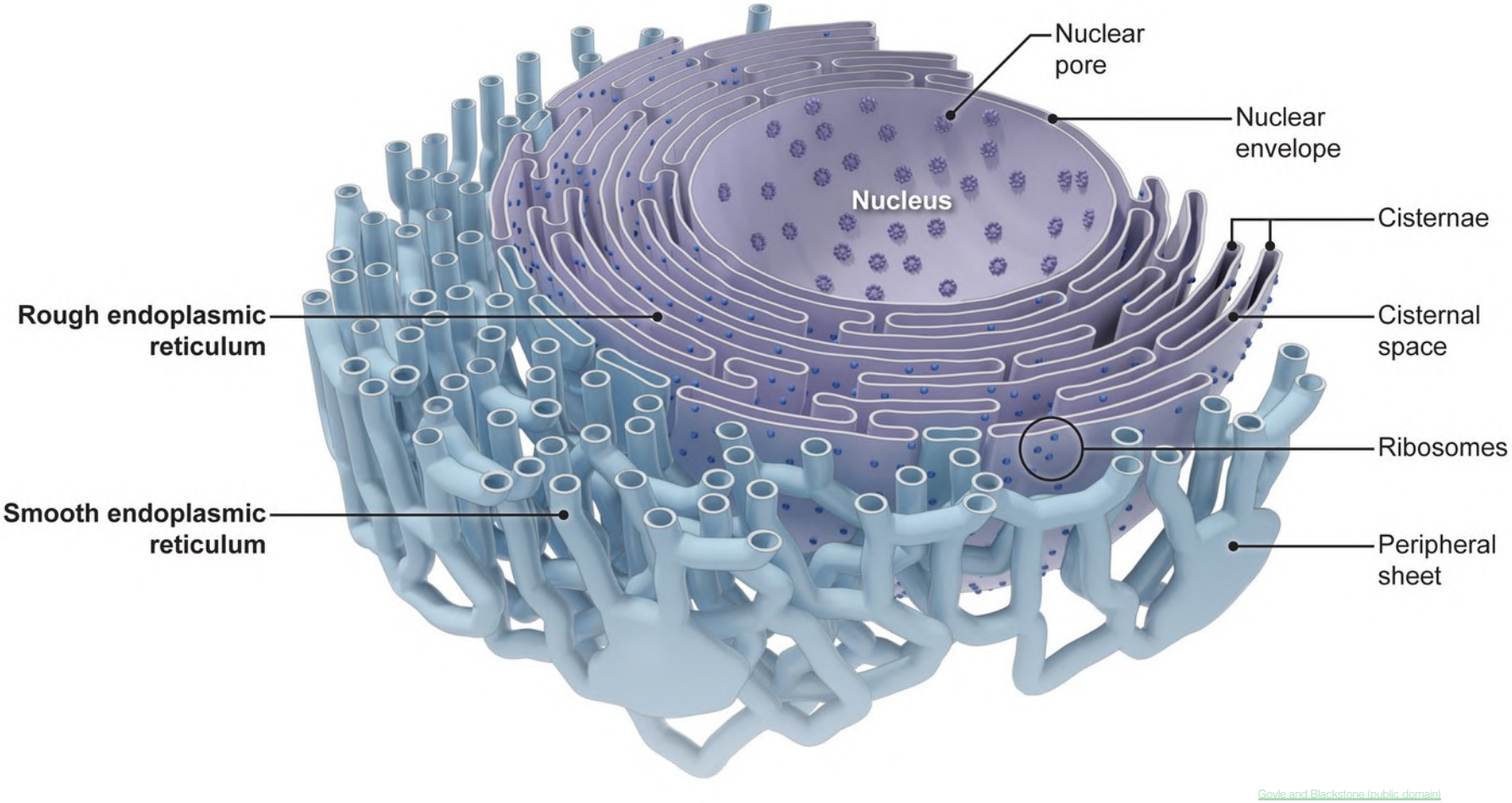
We show that magnetotactic cocci with two flagella bundles on one pole swim faster than 500 μm·s^{-1} along a double helical path, making them one of the fastest natural microswimmers.
Bente et al 2020

"Flagellar motors are molecular nanomachines with a diameter of roughly 45 nm and an energy conversion efficiency of approximately 100%. Our findings are a big step to clarify their torque-generation mechanisms, which would be essential for the engineering of nanoscale molecular motors,"
Tatsuro Nishikino



Is the bacterial flagellum motor an example of irreducible complexity.

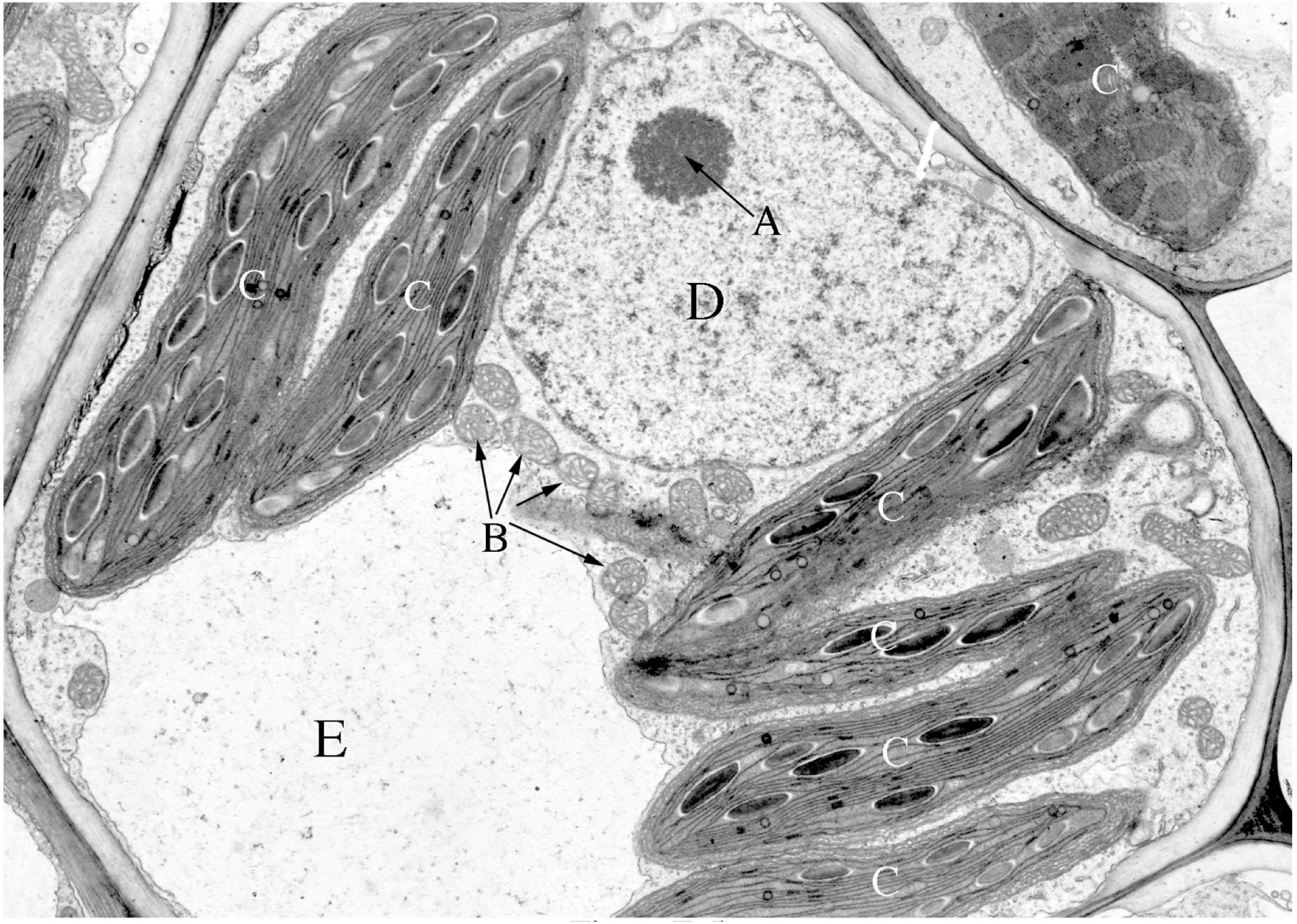
Eukaryote cell structure nucleus and endoplasmic reticulum



The endoplasmic reticulum is the largest single structure in eukaryote cells.

biocode.co

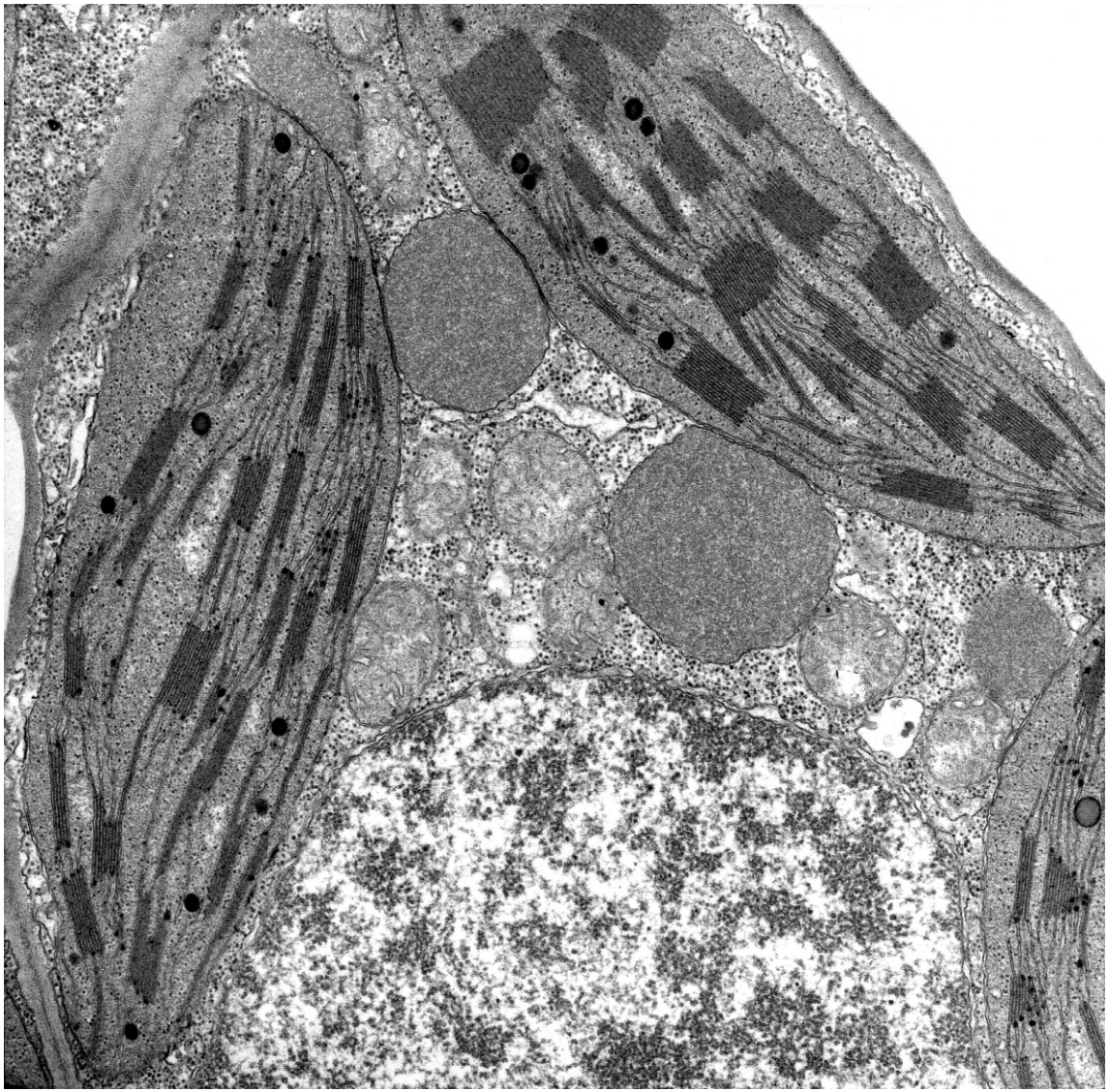
Eukaryote cell structure mitochondria, chloroplasts and vacuole



Botany UWC

biocode.co

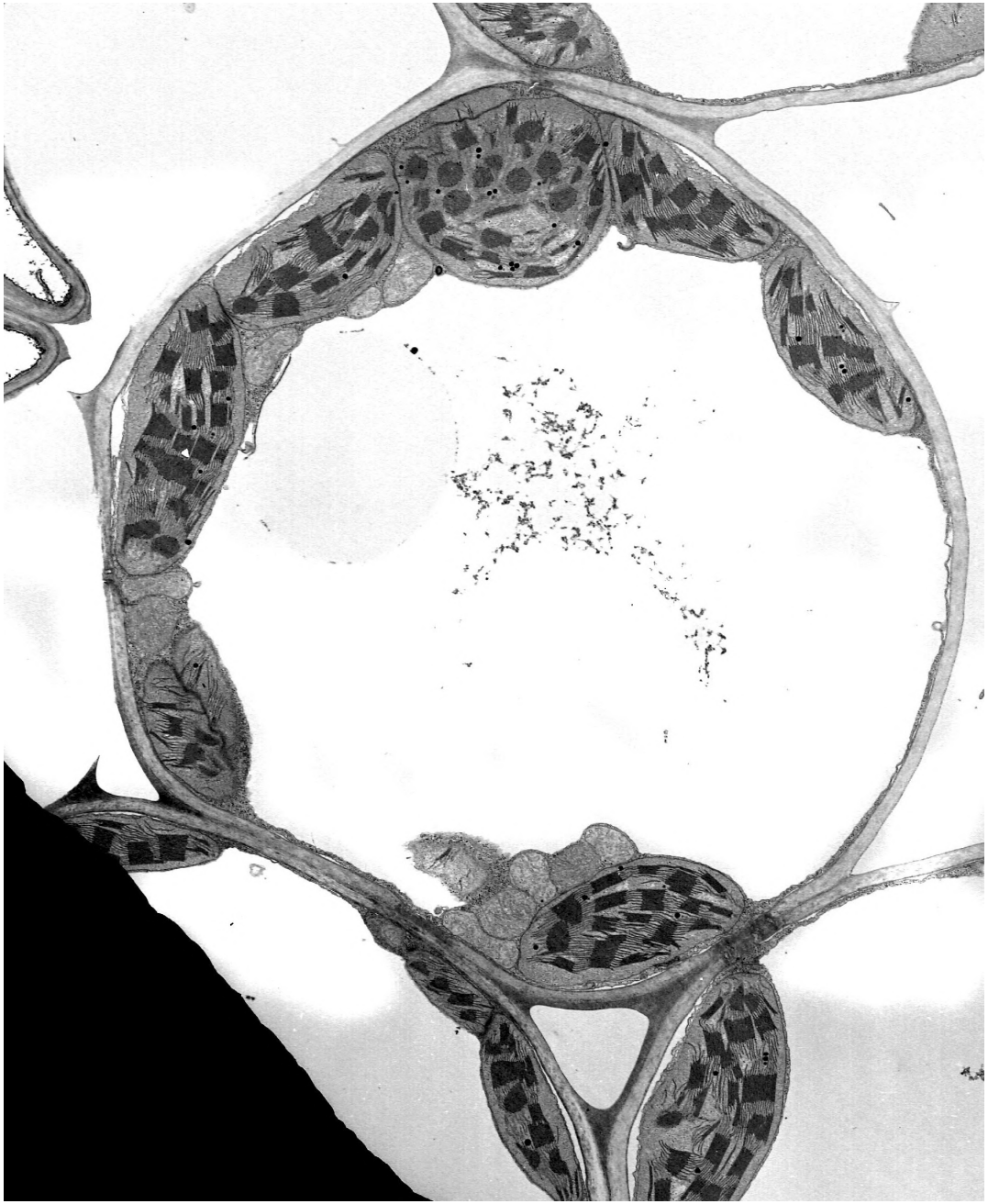
Eukaryote cell structure lysosomes



Newcomb UWDC

biocode.co

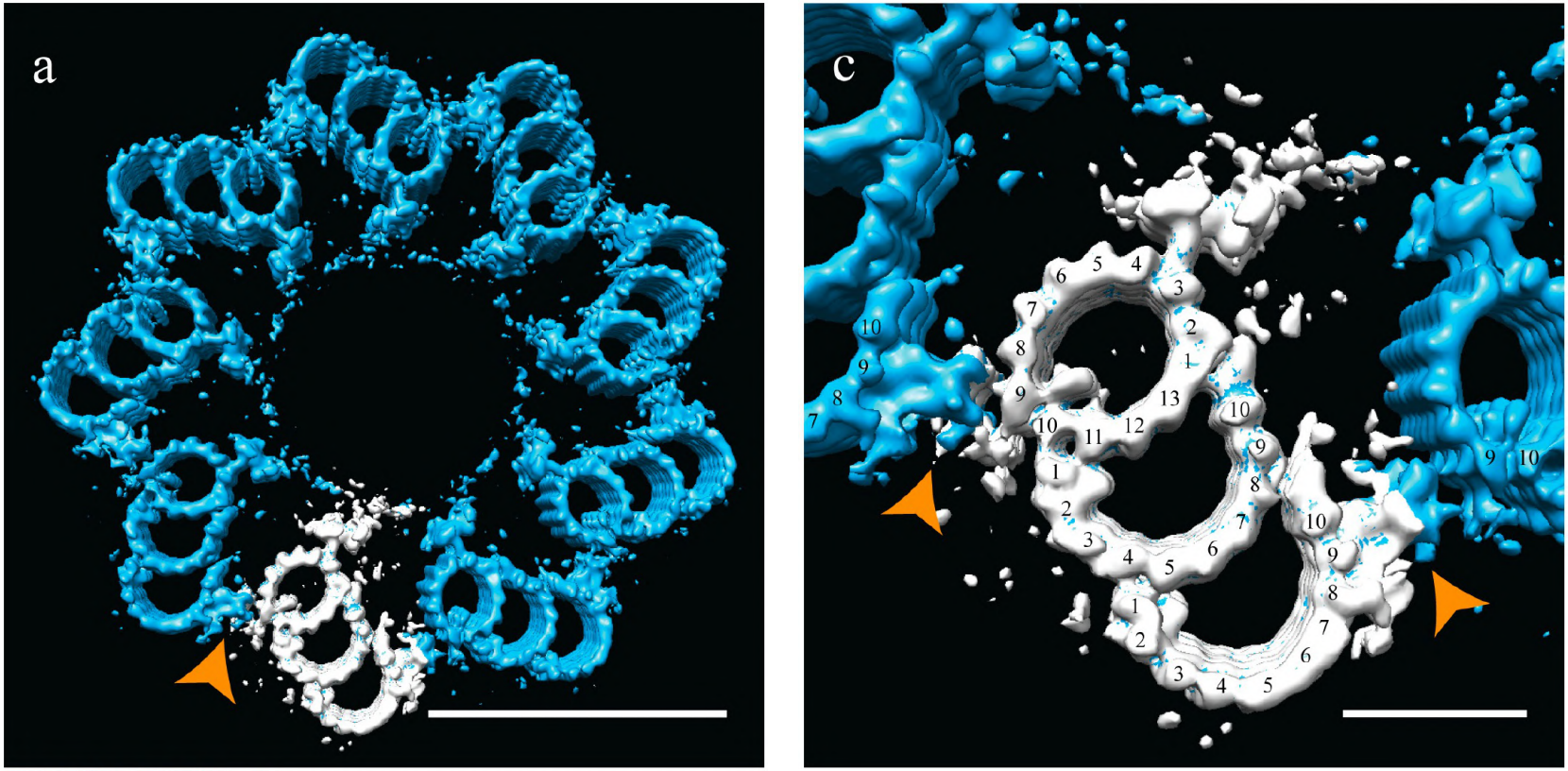
Eukaryote cell structure cell wall



biocode.co

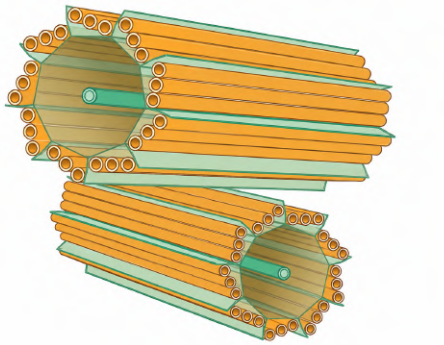
Newcomb UWDC

Eukaryote cell structure centrioles



Scale bar is 100nm in (a) and 25nm in (c)

Greenan et al 2018



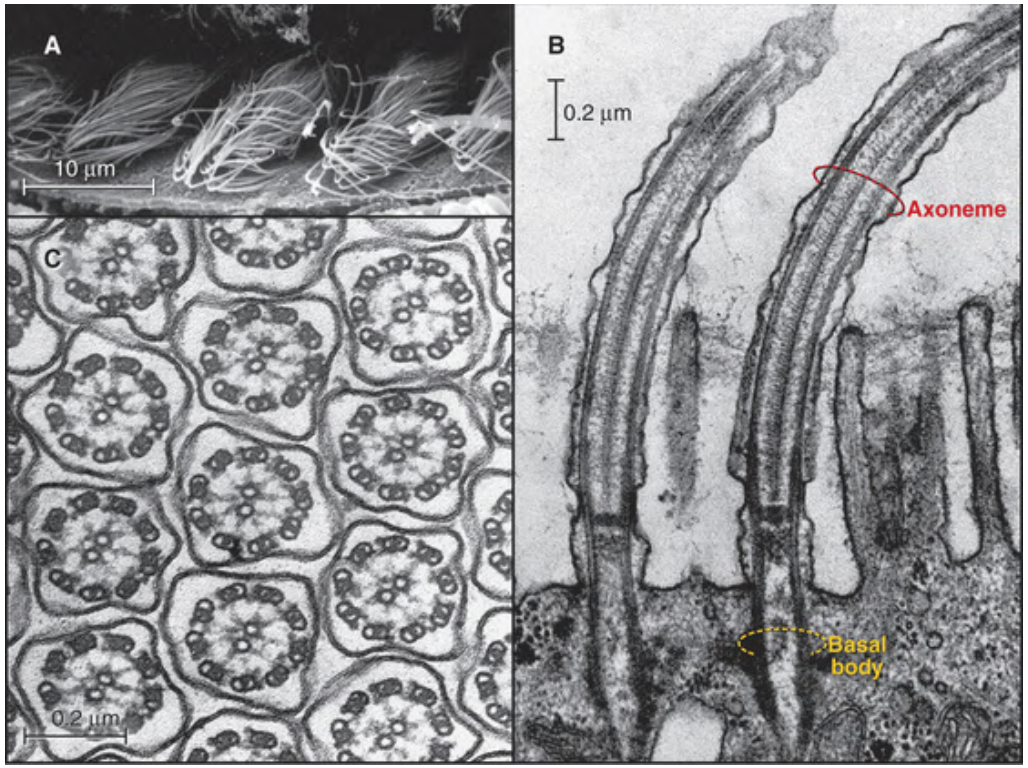
OpenEd.CUNY

a pair of centrioles

biocode.co

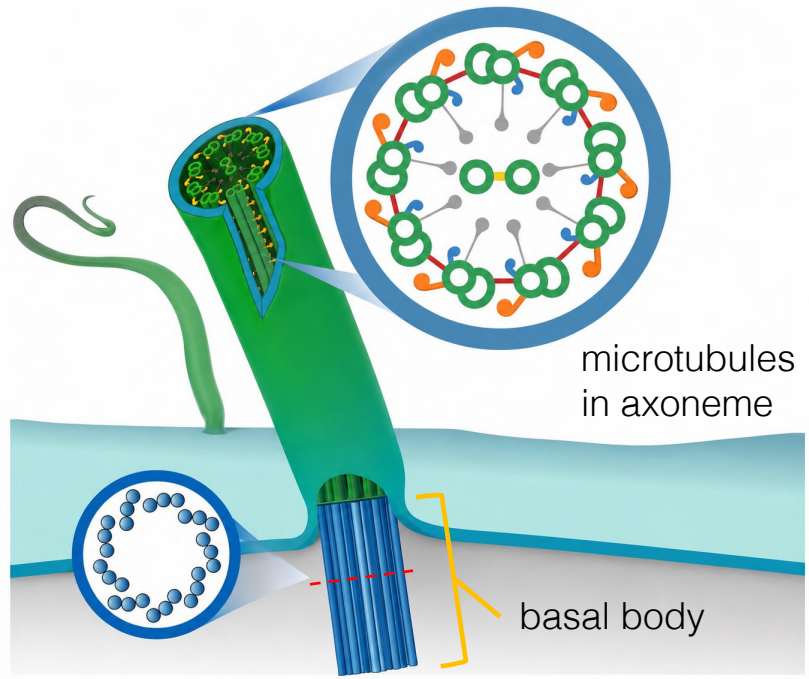
Eukaryote cell structure

eukaryote flagella and cilia



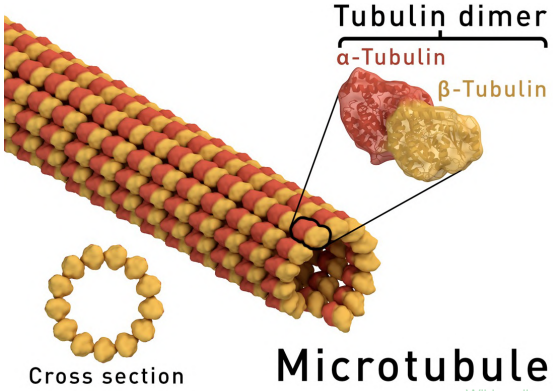
Satir 1974

A – cilia on mussel gills
B – cilia longitudinal section
C – cilia cross section of axoneme

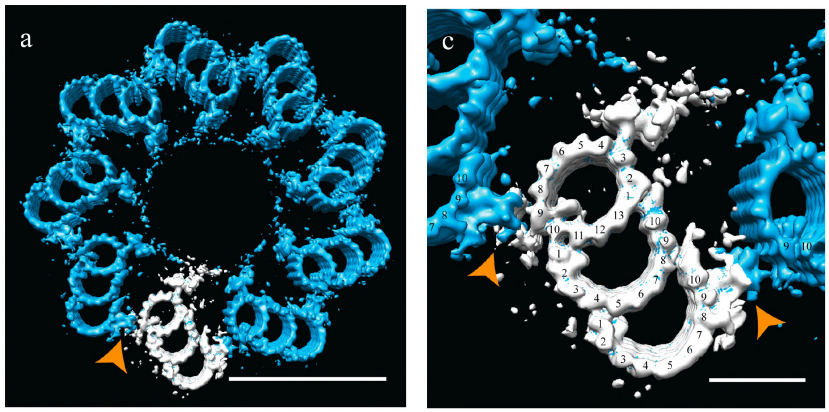


Public domain

animation



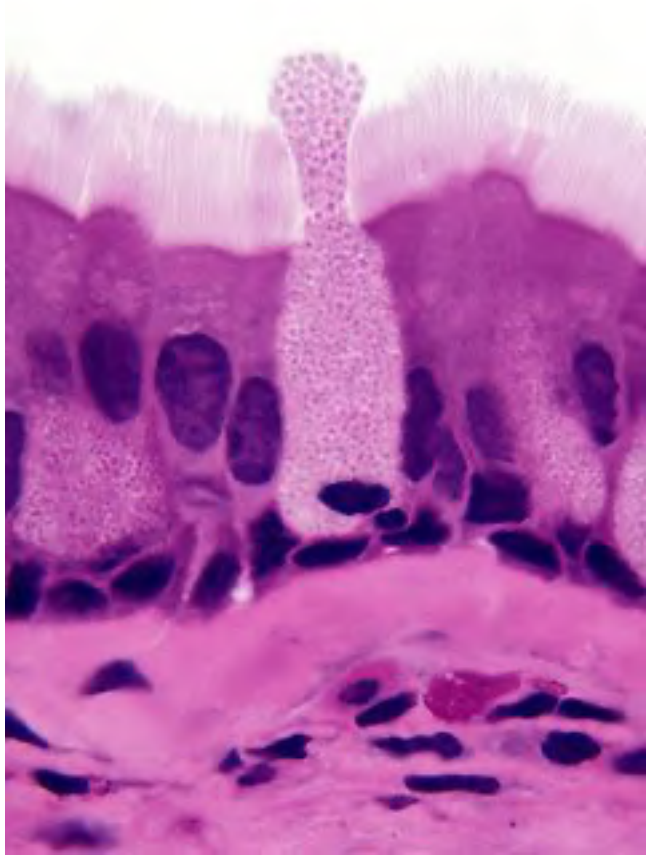
Wikimedia



Scale bar is 100 nm in (a) and (b)

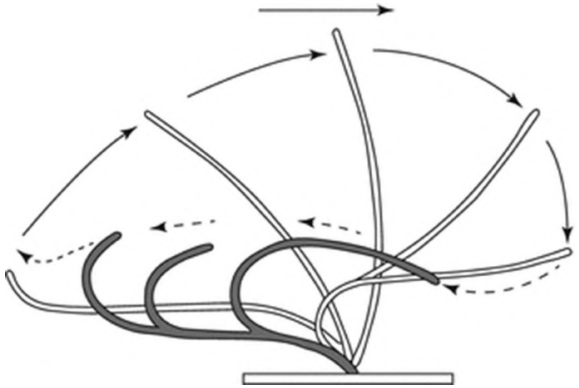
Greenan et al 2018

Eukaryote cell structure motile cilia



source

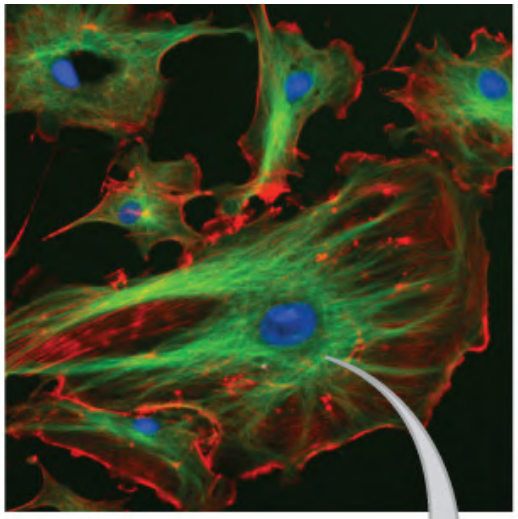
Cilia lining the lungs - a goblet cell is secreting mucus to trap particles.

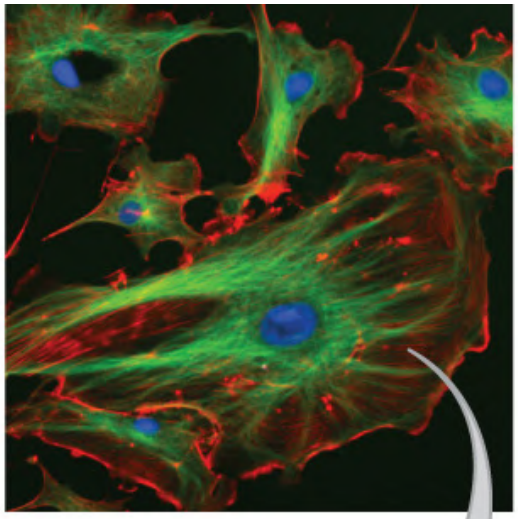


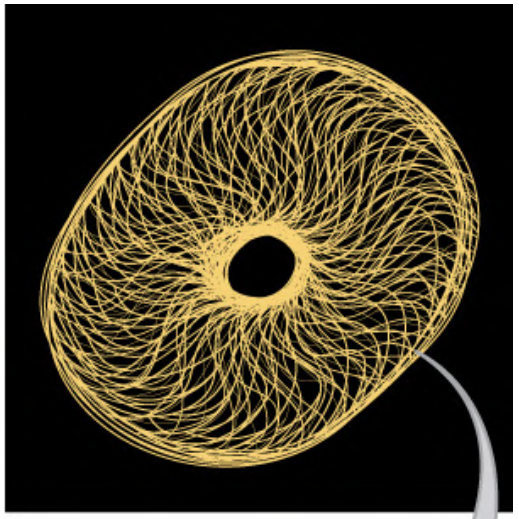
Jorissen and Jaspers 2023

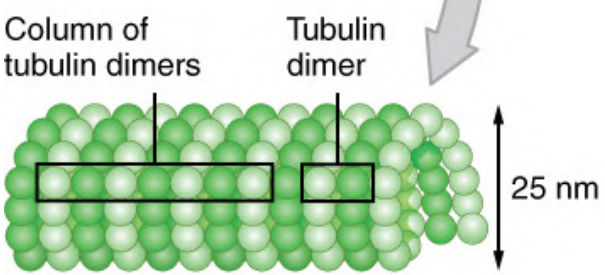
Cilia do not move back and forth like wind shield wipers but as shown above in the diagram.
Cilia beat together in a coordinated Mexican wave to sweep particles in one direction.

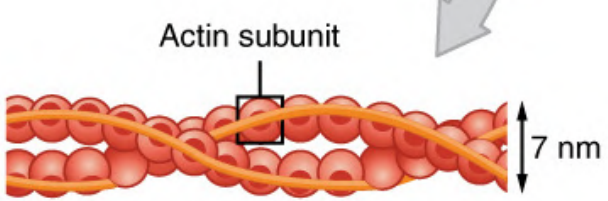
Eukaryote cell structure cytoskeleton





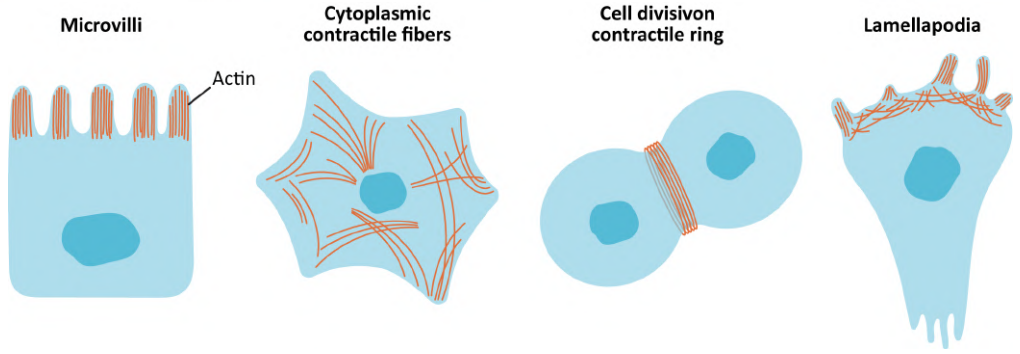






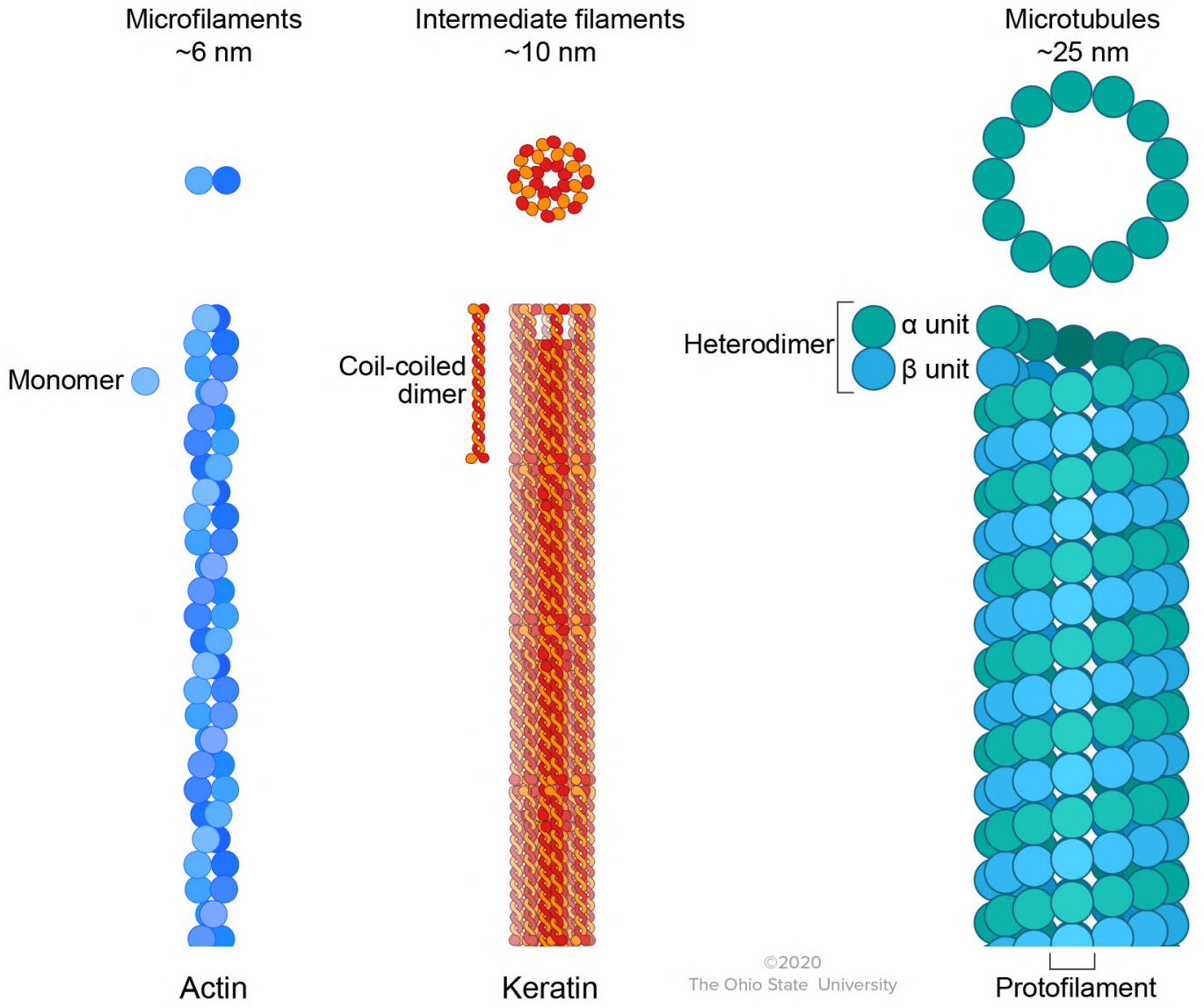


wikipedia



Heather Ng-Cornish

Eukaryote cell structure cytoskeleton

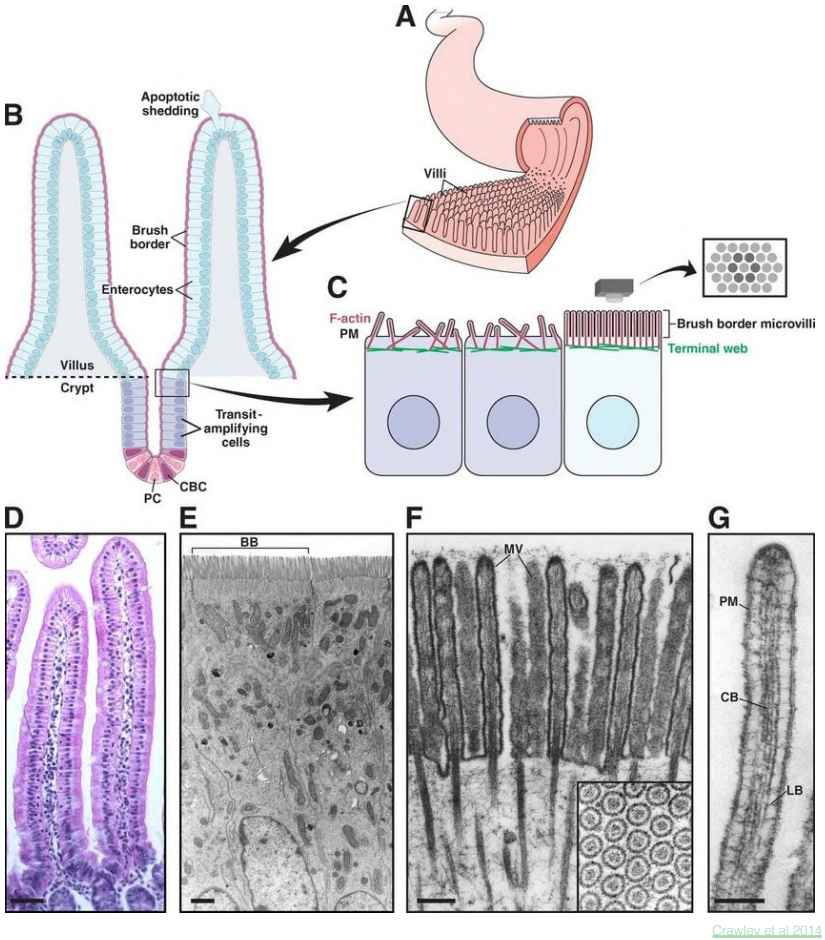


Veterinary Histology 2017 Jennings and Premanandan Ohio State University

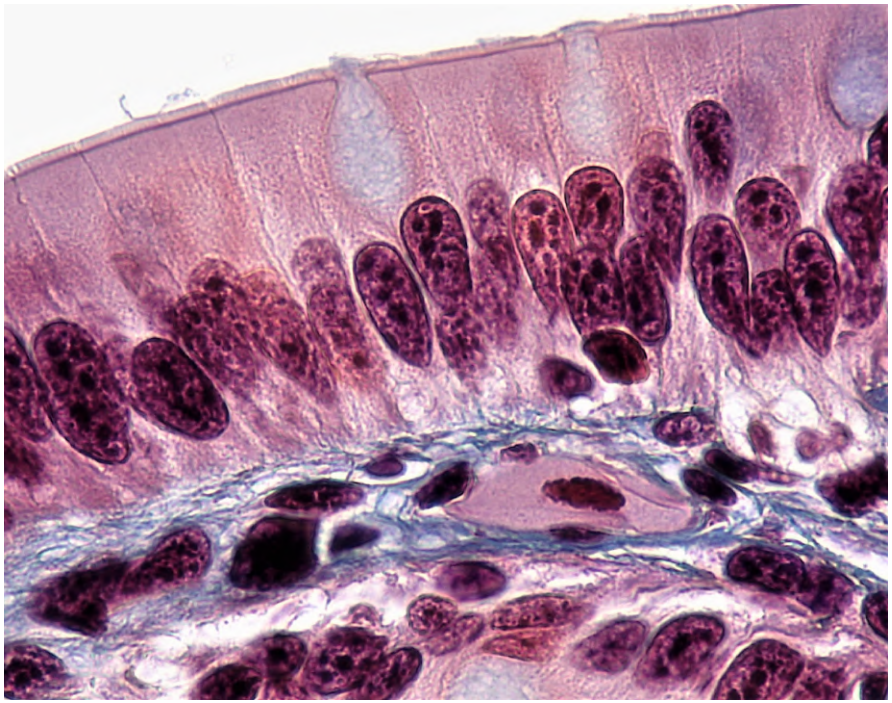
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Eukaryote cell structure

villi / microvilli



Crawley et al 2014



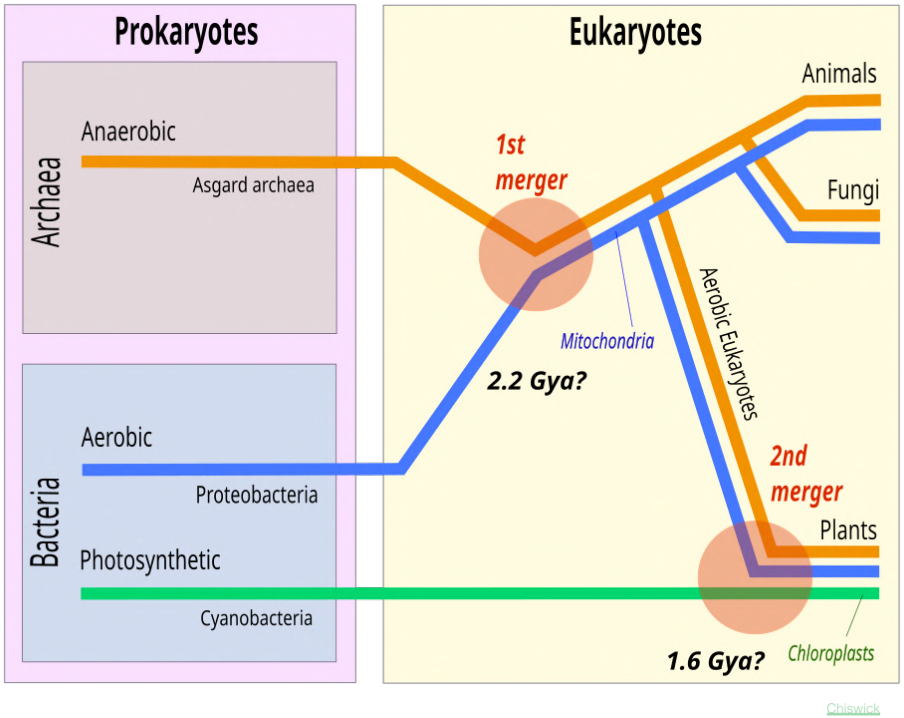
stained epithelial cells of the gut with a brush border on their surface
light microscope

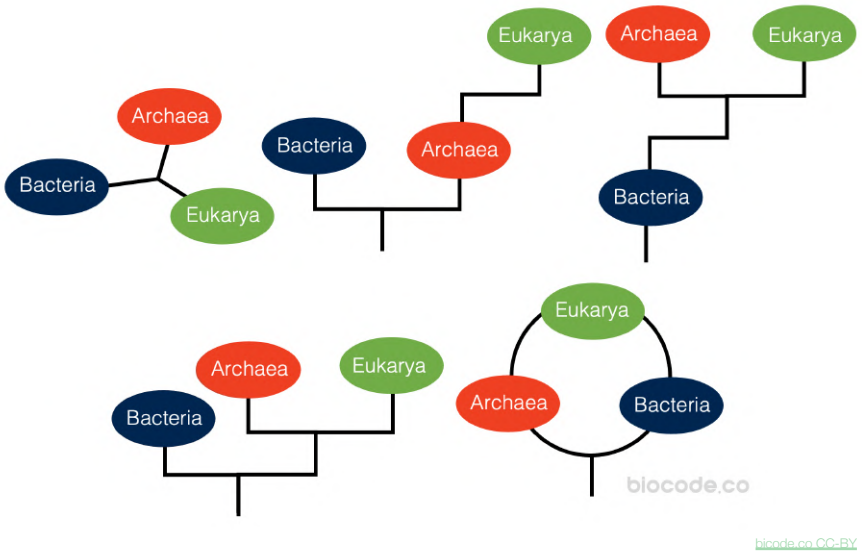
A - small intestine **B** - two villi **C** - epithilial cells
D - two stained villi cross section light microscope
E – epithilial cells with microvilli brush border of one cell labelled TEM
F - microvilli close up and cross section TEM
G – one microvillus TEM

Scale Bars: **D** 50µm **E** 1µm **F** 0.2µm **G** 0.1µm

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Origin of eukaryotes





The origin of eukaryotes has a number of possible scenarios.

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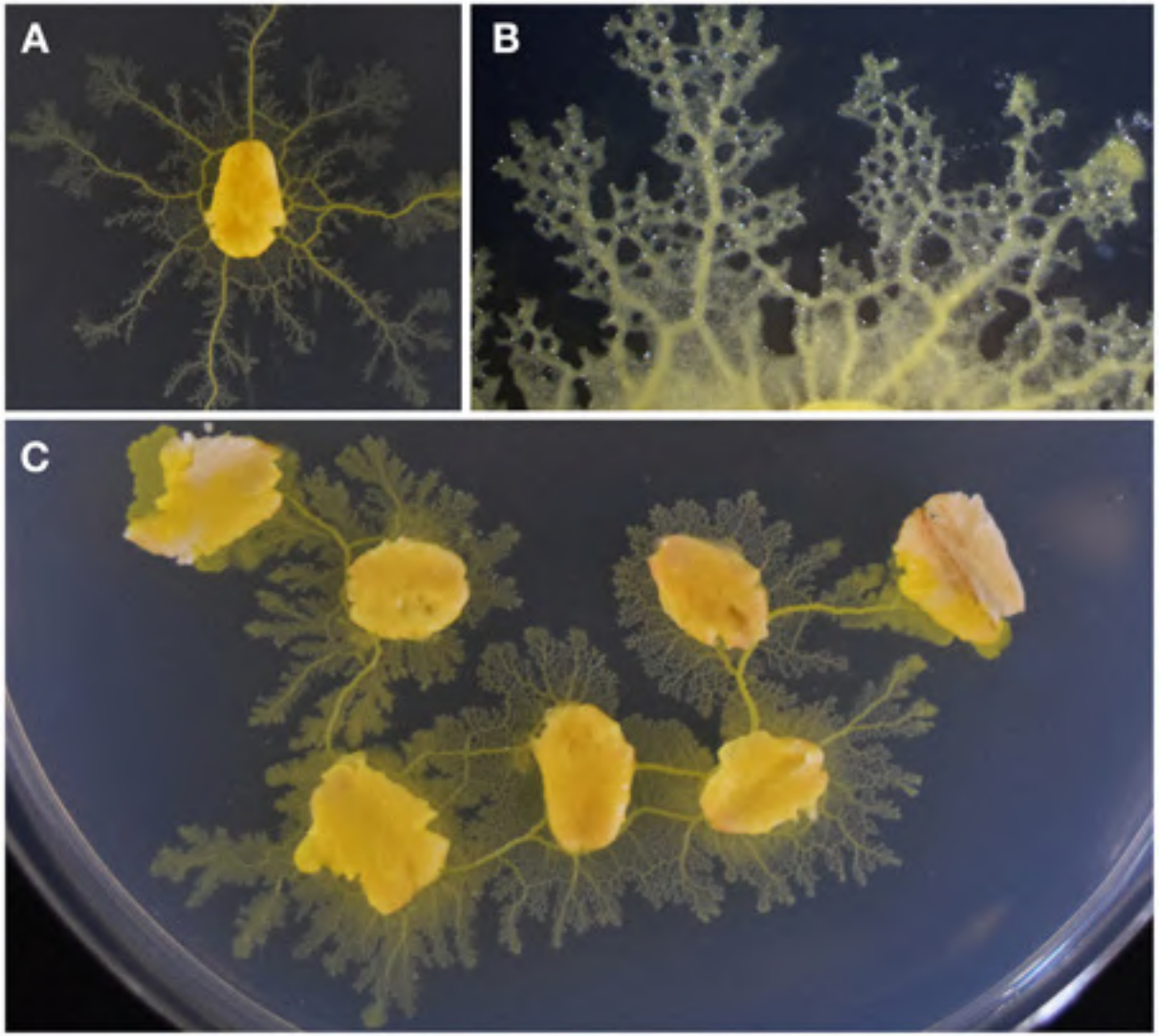
Origin of eukaryotes



© Kittisak Songprakob; istock

Costasiella kuroshimae the Sea Leaf Sheep
It is not a true symbiont as it can only temporarily retain chloroplasts taken from ingested algae.

Evolution of multicellularity



Bicigliano et al 2015 Frontiers in Microbiology

Physarum plasmodium spreading onto oat flakes on an agar plate.

biocode.co

Painting of Antony van Leeuwenhoek
By Jan Verkolji
completed between 1680 -1686



biocode.co

Optional Extension
(not required for IB exams)

The Messenger
Painting by Jan Verkolji.



biocode.co

Optional Extension (not required for IB exams)

The origin of eukaryotes is one of the most daunting and captivating problems in all biology...
Mills 2020

Testing the Endosymbiotic Theory

The endosymbiont theory is not directly testable and difficult to falsify as it occurred in the distant past but it can be tested indirectly from cell biology, genetics and phylogenetics.

Currently the microbial fossil record lacks clear transitional fossils of these cells – they may not have been preserved.

Prokaryotes cannot carry out phagocytosis.
Phagocytosis requires a cytoskeleton and actin filaments - when this evolved is not clear.
The host cell may have been an early prokaryote that lost the cell wall or the host cell may have engulfed the prokaryote by outward blebbing of the membrane through a hole in the cell wall.

What mechanism prevented the host cell from digesting the endosymbiont?

Mitochondrial genes are predicted to be left-overs from prokaryotes however:

- they have many unique sequences and contain introns which bacteria do not have
- 90% of proteins used by the mitochondria are coded by the cell nucleus, therefore it is thought numerous genes of the endosymbiont made their way into the nucleus
- over 96% of the original bacterial genes would need to be lost over time
- mitochondrial ribosomes were predicted to be 70S as they came from a prokaryote, however:
  mammalian mitochondrial ribosomes are 55S – thought due to reductive evolution
  plant mitochondrial ribosomes are 78S – thought due to constructive evolution

Like the nuclear-encoded COX subunits, the majority of genes required for mitochondrial function are encoded by the nuclear genome. … Although the evolutionary origin of the nuclear-encoded subunits remains a mystery, they have subsequently evolved specialized functions.
Das et al 2004

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Microscopicall observations (1661)

In Comendation of ye Microscope
Dr Henry Power

Of all th' Inventions none there is Surpasses
the Noble Florentine's Dioptrick-glasses.
For what a better, fitter, guift Could bee
in this world's Aged Luciosity.
To Helpe our Blindnesse so as to devize
a paire of new & Artificiall eyes.
By whose augmenting power wee now see more
then all the world Has ever donn Before.
Thy Atomes (Brave Democritus [)] are now
made to appeare in bulk & figure too.
When Archimide by his Arithmatick,
numbred the sands, had hee But knowne this trick.
Hee might have seene each corn a massy stone,
& counted them distinctly one by one.
Veiw[!] but the wonders in a Louse through whose
tralucent Body all Her entrayles shows.
As through a Chrystall watch I have often seene
the Counter-motions of the wheeles within.
There yow may see the pulsing Heart drive on
the Blood in it's due Circulation.

If Natures skill in optick's yow would trye
then take a Flea & looke mee at her eye.
Where in an Emarauld Iris shee hath sett,
(empaled with white) a pupill all of jett.
Change but your object Looke at common flyes
how theire soules peepe through Lattices of eyes.
In the gray flye is lively to bee Seene
an eye Dauncettad all of Black & greene.
As if ye nett work of her eyes were made
of Irish-stick a greene with a dark shade.
In the wood mite or -Louse yow may behold,
an eye of Trellice-Worke in Burnisht Gold.
Wich with a rare Contrivance Shee can move
inwards or outwards as her objects prove.
Nay to the Spider providence hath given
plurality. of eyes Some Six or Seaven.
Wich Like a Lockett of pure Diamonds Show
or like a Constellation in her Brow.
Here Argus eyes are fix'd & doe remaine
cleerer by farr then in the Peacock's Traine.

Nay lett mee Screw your Inquisition higher
looke but at mites & then you'le most admire.
How Nature could to Such a nothing Sett
both Heade, & Tayle, & Leggs, & mouth compleate.
Besides ye stomach, gutts, & Heart, & Spleene
wch lye within this Hollow mote unseene
To wch adde nerves, & Sinews & all these
cask'd in those Liveing exiguityes.

Oh for an otacousticon to Heare
the vocall Noyse of this throng[ed] Theater.
And sett of Animalls for who can tell
but they have Severall cryes though inaudible.
Wee want thine eares Melampus that could Heare
when thou was cag'd up a close-Prisoner.
The Language that the Timber worme did speake
when they foretould thee yt ye Beame would Breake.

Looke into Liquors who would thinke that there
should Quick's breed in the keenest Viniger.
Wich though so vastly magnified appeare
noe bigger then ye smallest chire of Haire.
Here are the Curious Mathematick's Here
lyes ye rare skill of theire Artificeere.
All things hee made of nothing, but in this
hee made a thinge that lesse then Nothing is.
Who can the old Phylos[o]p[he]r renounce
that sd a thousand Soules might dance at once.
Upon a needles point, when wee see Here
as many in one dropp of Viniger.
This to our mind the a'theriall wisdome bringes
how God is greatest in ye Least of things
And in the smallest print wee gather hence
the world may Best reade his omnipotence.
Goe on Dioptrick Artist's still goe on
may your glass-eyes even Vie pfection.
With natures Noblest sense: from yow wee hope
such rare Emprovements of ye Microscope.
That ye Magnetick fluors of ye stone
shall bee as cleerely Seene as now there's none.
Nay then yow pretty sprit's & fairy Elves
that hover in ye aire Looke to your selves.
For with such prying Spectacles as these
wee shall see yow in yr owne essences.
Then shall I see a soule just when tis gone
as cleere as now I doe our will: & John.

Hen: Power Dr of Physick.

*probably Galileo was the noble Florentine



Replica of Hookes Microscope 1665 (AI generated)

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