

Differentiation and Organization

Learning outcomes

- ☒ understand how a cell's structure is related to its function
- ☒ deduce a cell's function from its structure
- ☒ understand the role and importance of stem cells in differentiation
- ☒ understand how the following specialized cells are adapted to their function:

a) Nerve cell

b) Red blood cell

c) Intestinal epithelial cell

d) Skeletal muscle cell

e) sperm cell

f) ovum

g) ciliated cell

h) leaf palisade cell

i) root hair cell

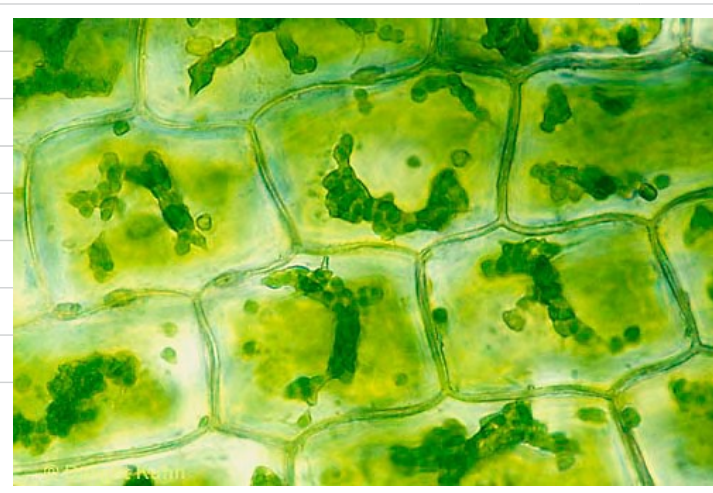
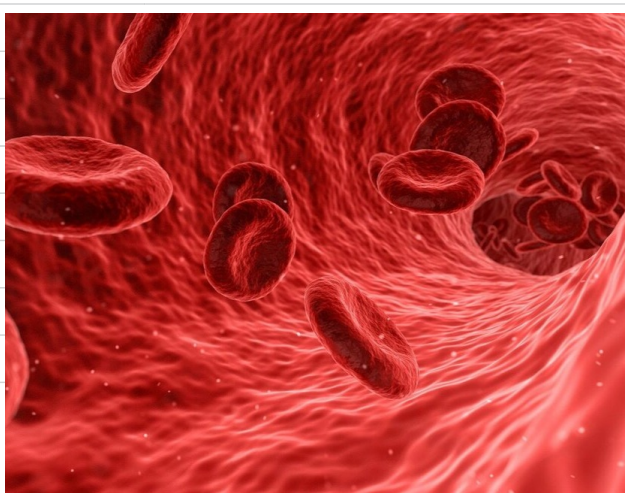
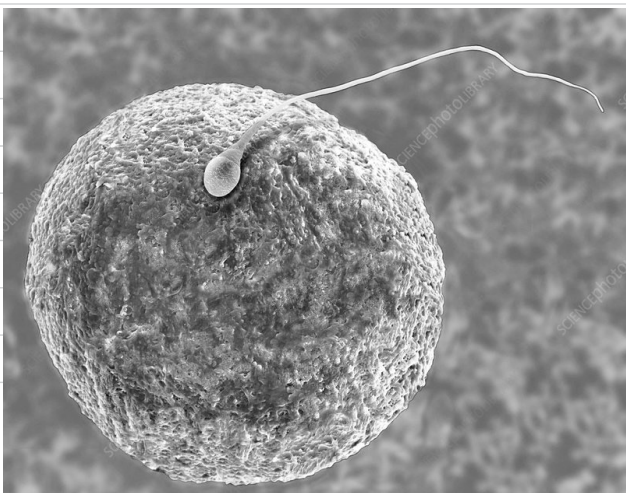
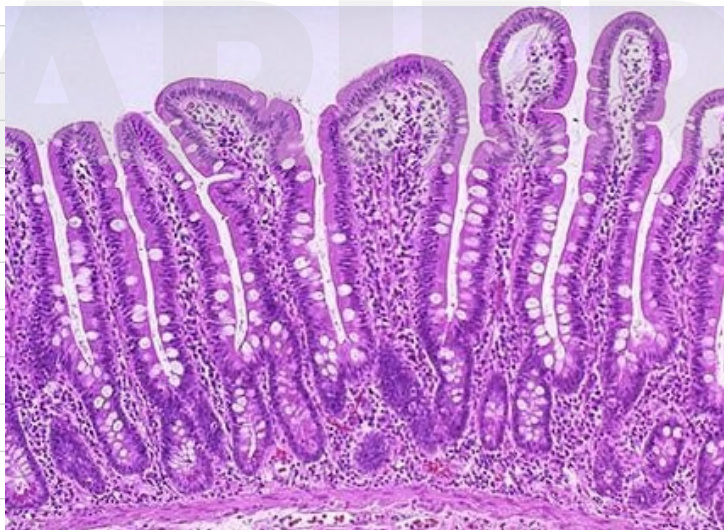
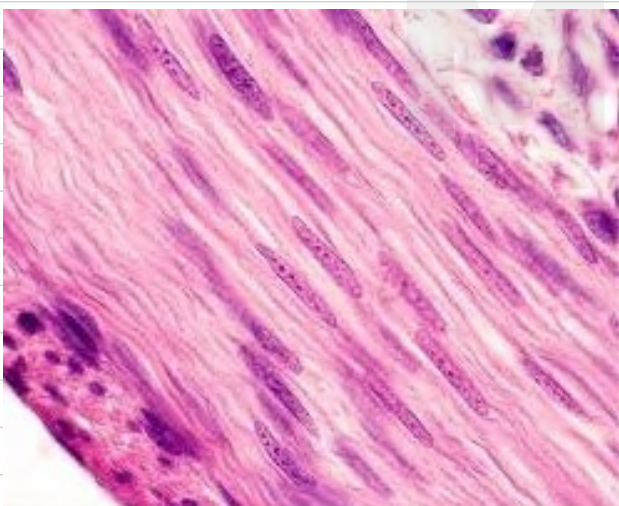
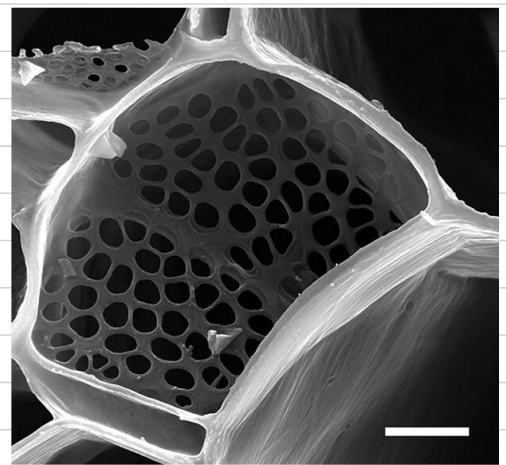
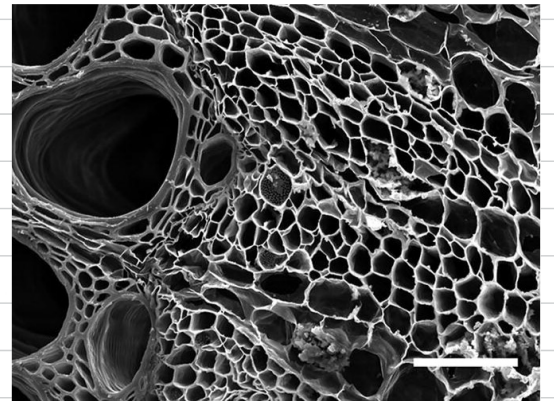
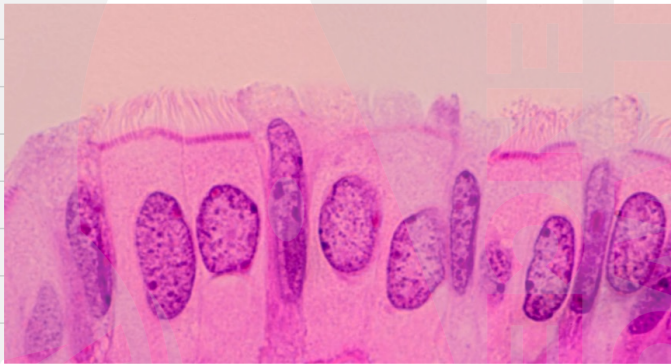
j) xylem cell

k) phloem cell

- ☒ understand how things are organised from atom → organism
- ☒ understand how multicellular organisms have emergent properties with examples

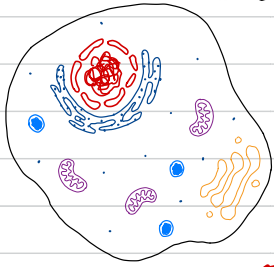
Key terms

- stem cell
- differentiation
- gene
- specialized cell
- square cube law
- Nerve cell
- Red blood cell
- Intestinal epithelial cell
- Skeletal muscle cell
- sperm cell
- ovum
- leaf palisade cell
- root hair cell
- xylem cell
- phloem cell
- anatomy
- tissue
- organ
- organ system
- organism
- emergent property
- physiology

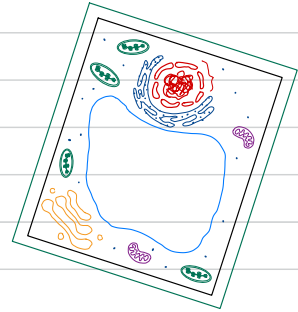


Cell Differentiation

Do all animal cells look like this?



Do all plant cells look like this?



Why not?

Just like society, different cells have different roles and functions

∴ cells will have different adaptations + structures that allow them to carry out their roles

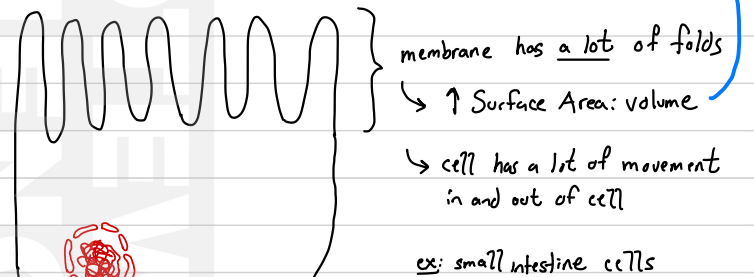
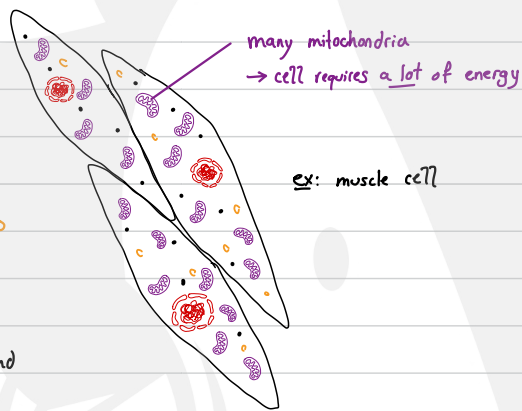
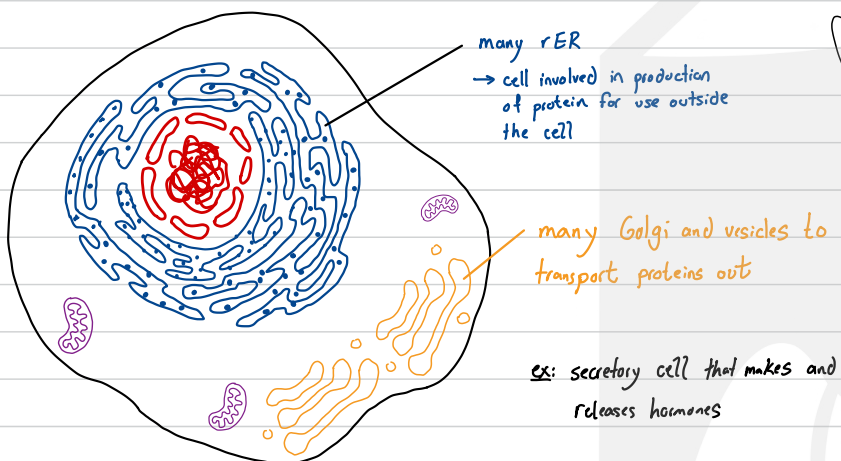
"Form follows function"

meaning the way a cell looks and is structured is directly linked to its function

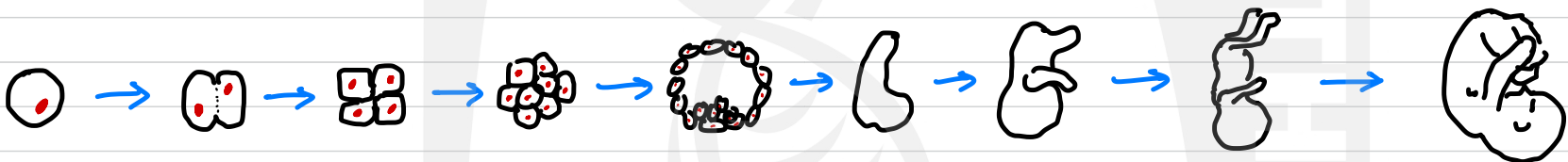
Examples:

If a cell has a lot of a particular ultrastructure it can indicate its function

* more info later



Multicellular organisms can have > 200 different types of cells but they started as one!

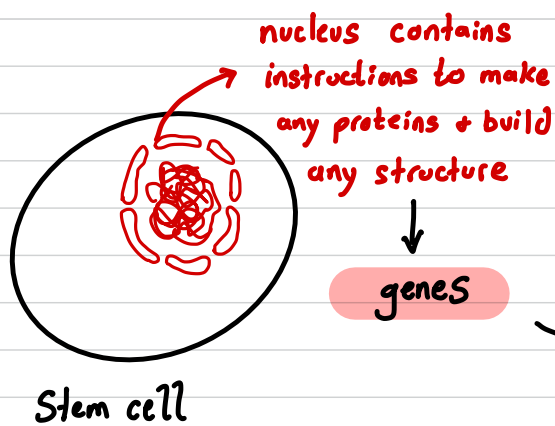


so how can all these different cells come from one?

Stem cells: cells that can grow + replicate themselves indefinitely + can **differentiate** into a specialized cell

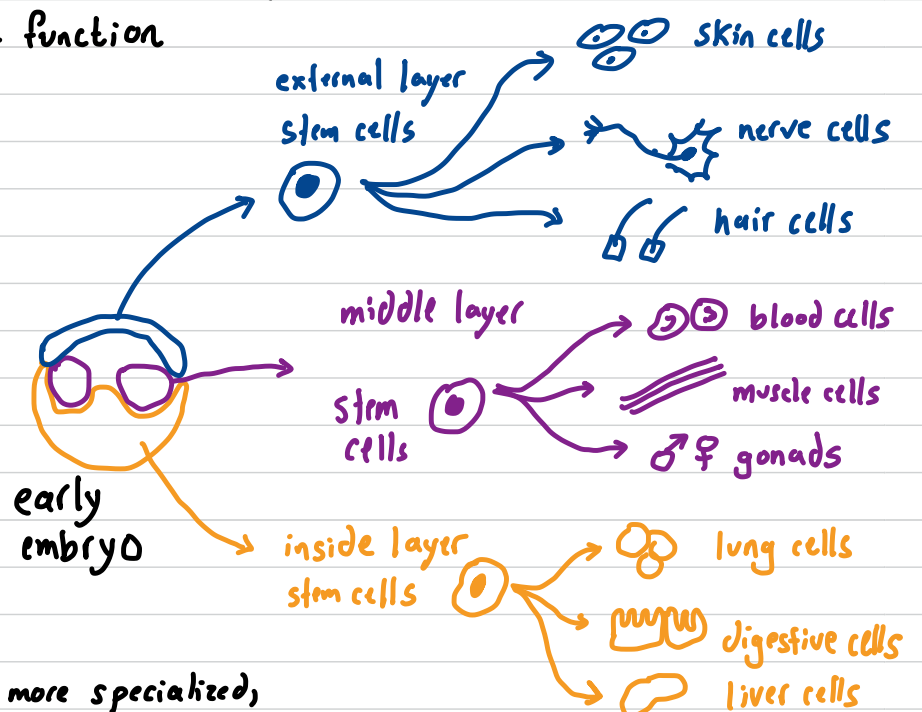
when a cell develops special features to help them carry out a specific function

How?

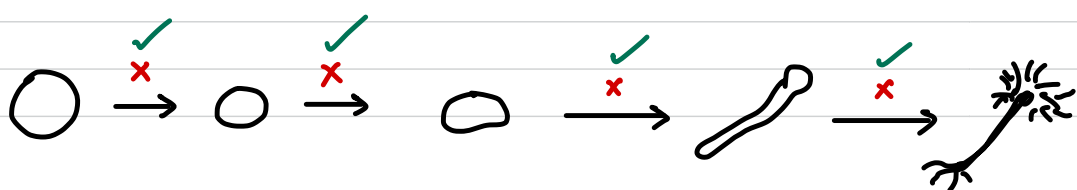


genes that are needed are 'turned on' or expressed ✓

genes that are not needed are 'turned off' ✗



the more specialized, the more genes are turned off + specific genes expressed



Specialized Cells

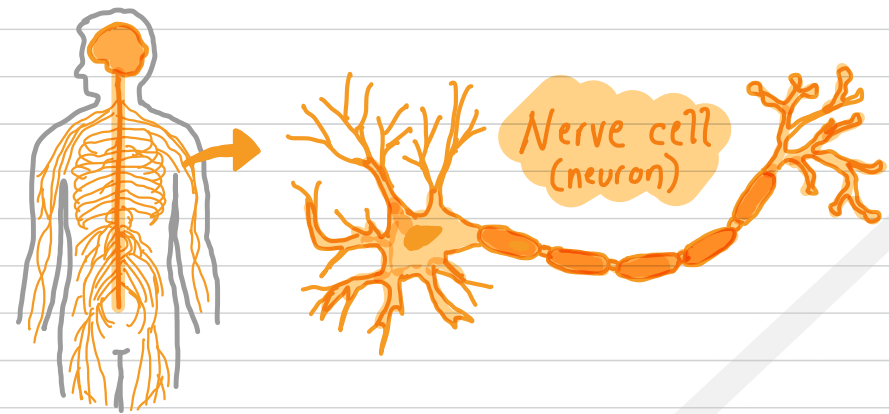
Why do multicellular cells specialize? Efficiency!

→ it is more efficient for many different cells to do few jobs really well than for every cell to do every job ok.

ex: a school, hospital, orchestra — people specialize in their career fields to do a specific role really well and work together

Specialized cell: cells that carry out a specific function

for each cell type, ask yourself: "How is the structure adapted to its function?"



Nerve cell (neuron)

function: carry electrical signals

structure: long ▶ carry signal faster over long distances
insulated ▶ signal is not lost and travels faster
branched ▶ able to receive from many sources + transmit to many



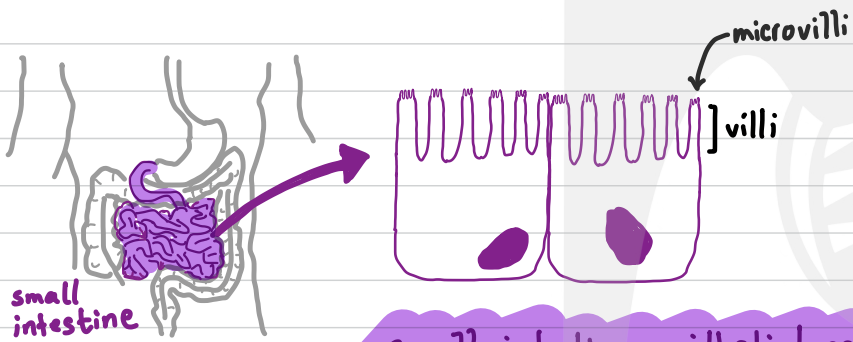
Red Blood cells



side view

function: carry oxygen through blood vessels

structure: a lot of haemoglobin ▶ protein that binds O_2
biconcave shape ▶ ↑ SA:vol allows more O_2 to bind
no nucleus ▶ more room for haemoglobin and O_2

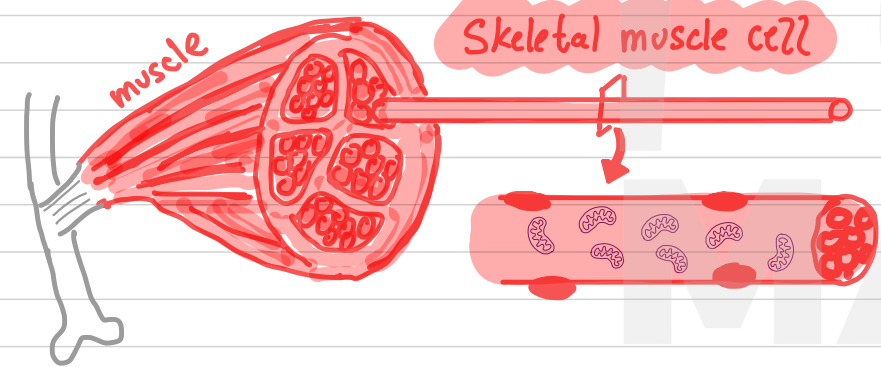


small intestine

small intestine epithelial cells

function: absorb broken-down nutrients from small intestine into blood

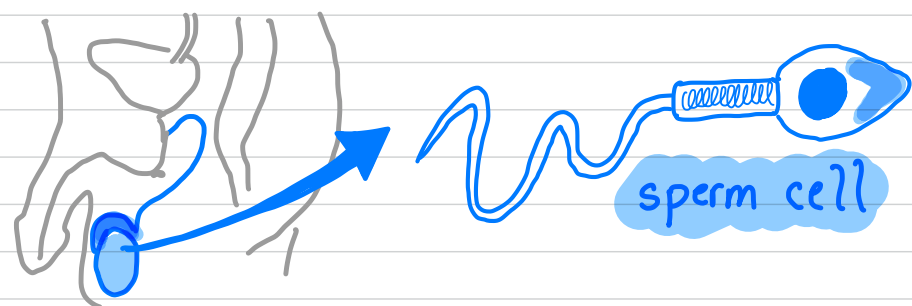
structure: a lot of folds (villi) } ↑ SA:vol allows faster transport
folds have more folds (microvilli)



Skeletal muscle cell

function: contract and relax in order to move bones

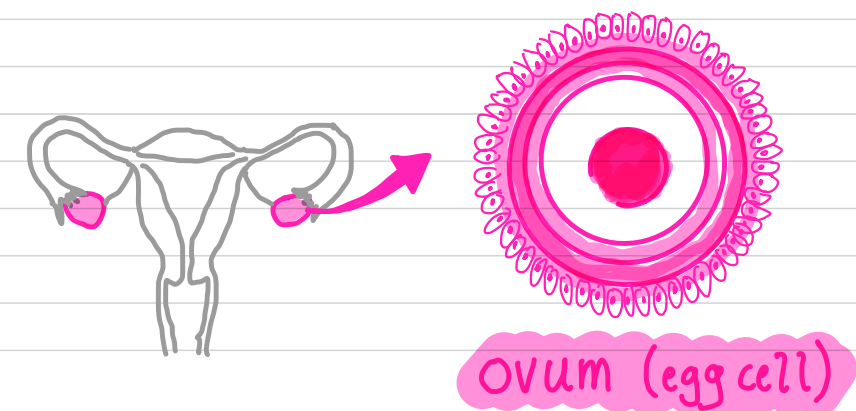
structure: very long ▶ allows contraction to occur over long distances
many mitochondria ▶ a lot of energy produced for contractions
many nuclei on outside ▶ more efficient for long cells + out of the way
bundles of fibres ▶ very strong (like cables)



sperm cell

function: carry genetic material to ovum (egg) and fuse

structure: nucleus has $\frac{1}{2}$ genetic material ▶ proper amount when it fuses
flagellum ▶ allows it to move toward egg cell
tip has enzymes ▶ break down outer layer of egg, allows fusion
very small ▶ allows many to be produced easily

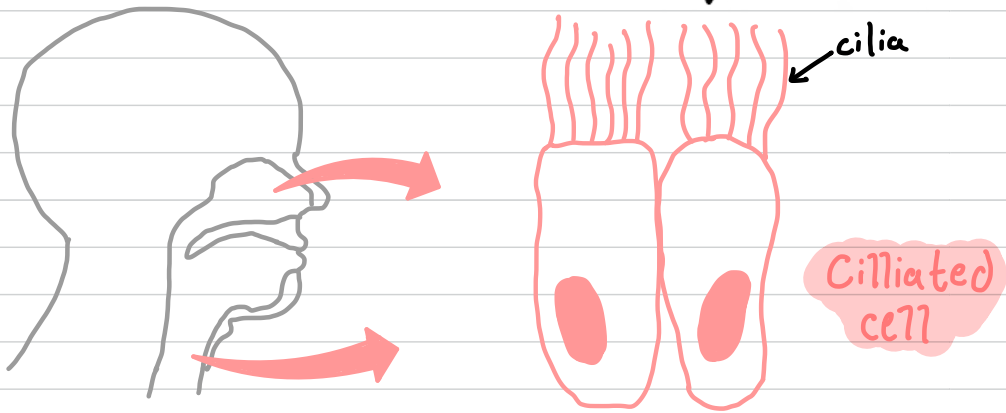


ovum (egg cell)

function: fuse with 1 sperm cell and then divide

structure: nucleus has $\frac{1}{2}$ genetic material ▶ proper amount when it fuses
large cytoplasm ▶ provides a lot of nutrients + enzymes for growth
protective outer coat ▶ makes it difficult for multiple sperm to fuse

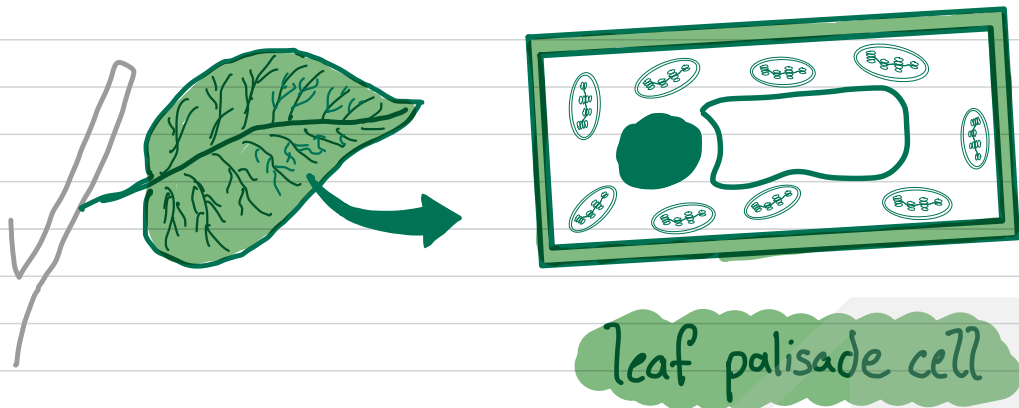
Specialized Cells



function: move particles above cells (mucus, dust, ova)

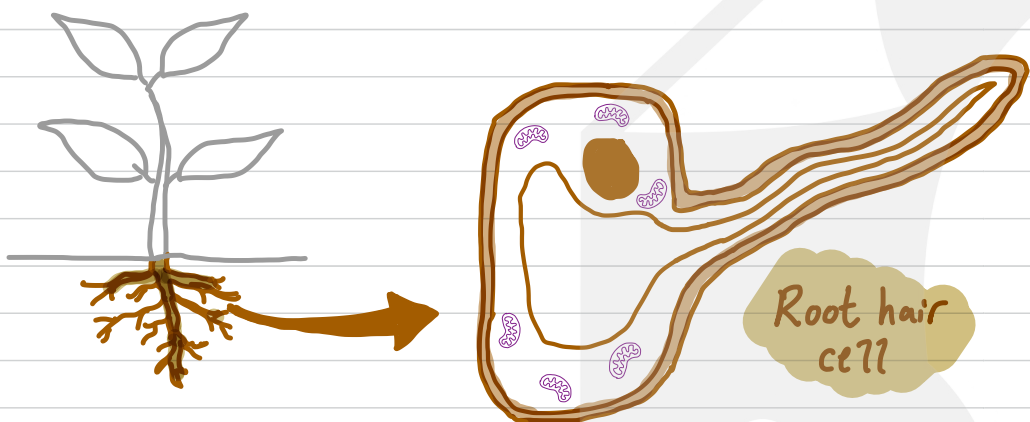
structure: many hair-like cilia ▶ move in waves to push material on surface of cell ▶ above them (like crowd surfing)

*note, these are not villi or flagella



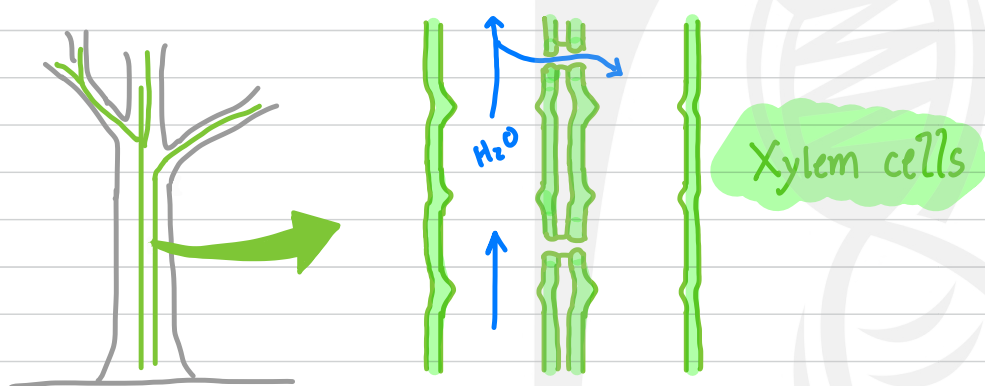
function: absorb sunlight for photosynthesis

structure: a lot of chloroplasts ▶ full of chlorophyll (absorb light) site of photosynthesis
long shape ▶ can be layered, maximizing absorption



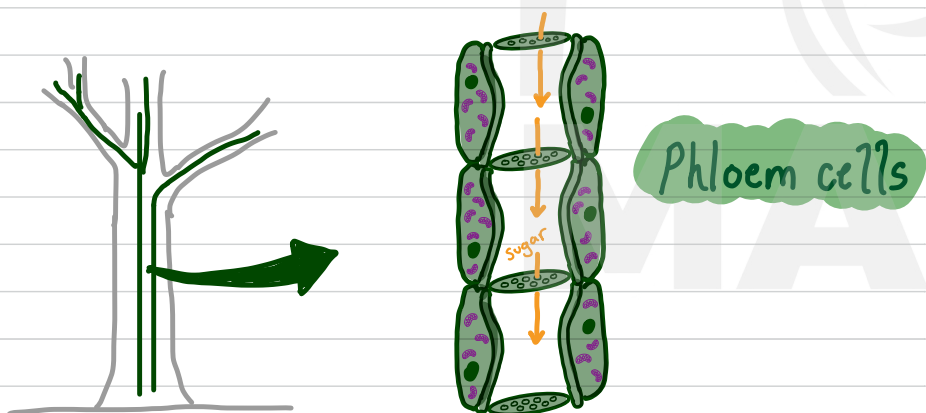
function: takes in water and minerals

structure: long thin projection ▶ ↑SA:vol allows faster transport
a lot of mitochondria ▶ Energy needed for transport



function: transport **water** throughout plants

structure: stacks of dead cells ▶ long continuous tube
strengthened by lignin ▶ keeps tube strong and water-proof
no cytoplasm ▶ easier for water to pass through
gaps between tubes ▶ allows water to pass horizontally



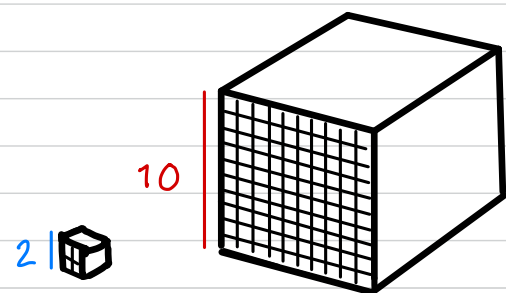
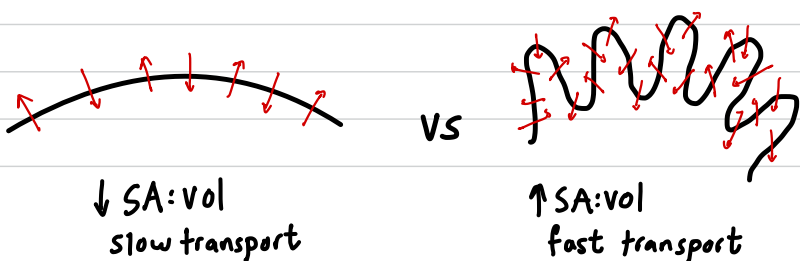
function: transport **sugars** throughout plants

structure: cells connected with perforated end ▶ cytoplasm of cells connected in order to provide easy transport
companion cells nearby ▶ provide Energy for transport with a lot of mitochondria

* A note about surface area (SA) to Volume ratio :

Square - Cube Law: volume increases faster than SA

cells can take advantage of this in order to maximize transport in & out

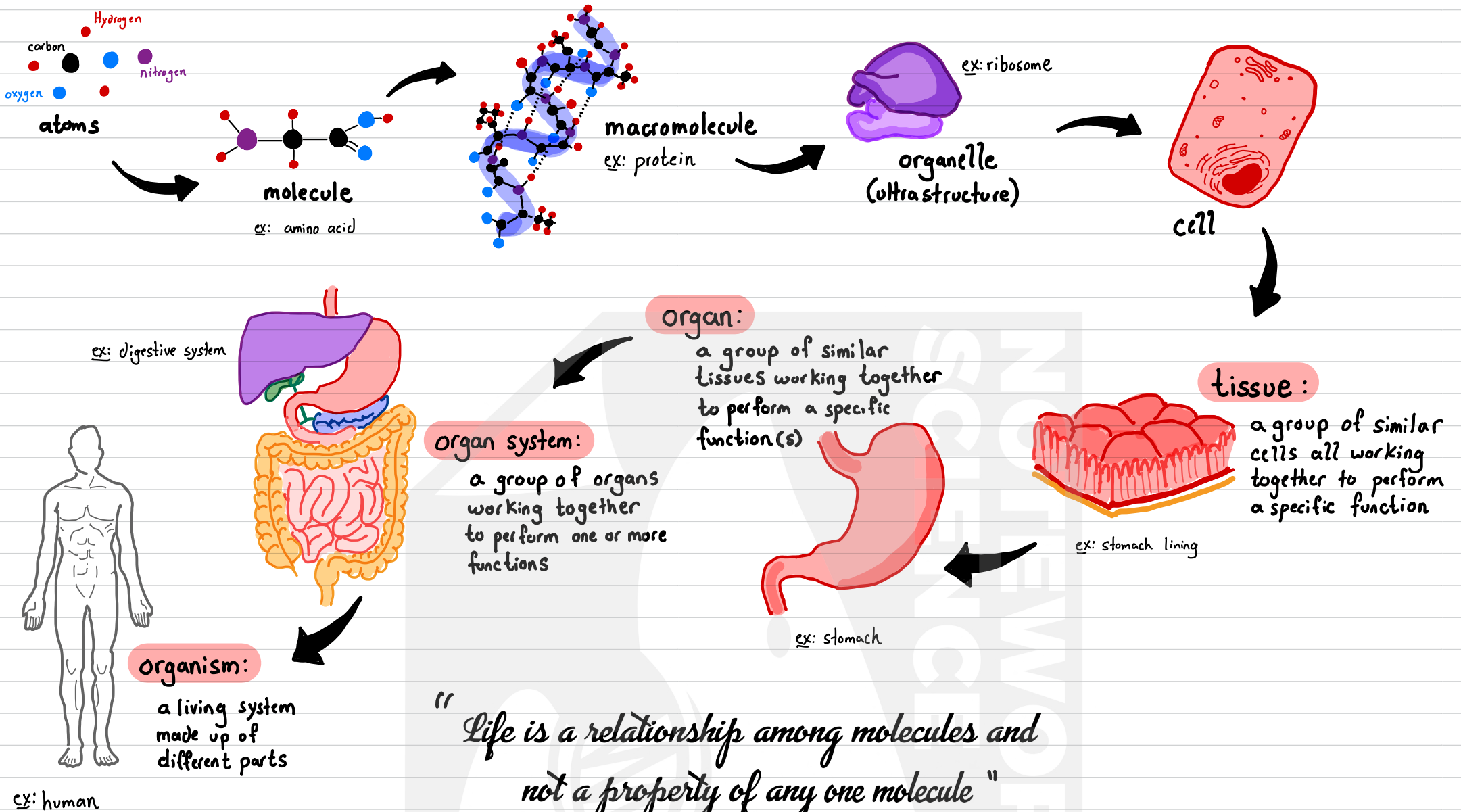


length	2	10
area	4 2^2	100 10^2
volume	8 2^3	1000 10^3

Biological Organization

Anatomy: the study of how organisms are structured and organized

Biology can be studied by examining how things are organized in a hierarchy



"Life is a relationship among molecules and not a property of any one molecule"

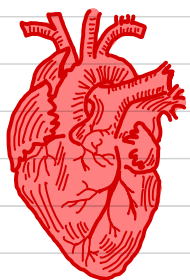
— Pauling & Zuckerkandl

life is defined in terms of **interactions, relationships, and collective properties** of many systems and their parts

Emergent property: a property which a collection or system has, but which individual members do not have

examples:

aka "the whole is greater than the sum of its parts"



heart is made up of heart cells. The heart can pump blood but individual heart cells cannot



human emotions (joy, anger) or memories are formed and stored in the brain. No individual neuron can form these

salt (NaCl) has the property of 'saltiness' and edible but Na and Cl are dangerous and not salty



► at every higher level of complexity, new emergent properties appear

i.e. tissues have properties that cells do not, organs have properties that tissues do not ... etc.

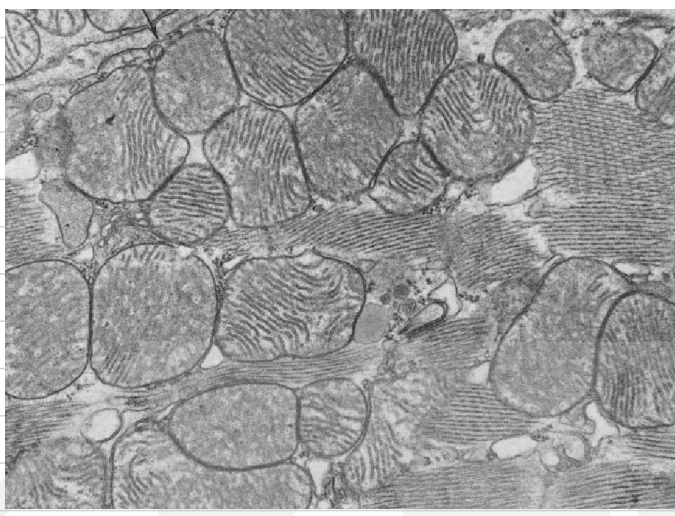
Physiology: the study of functions and mechanisms in a living body

< Anatomy looks at how something is structured, >
Physiology looks at how those structures work

Assessment Tasks

Answer the following questions:

- ① Look at the images of cell's below. Based on their structure, deduce what their role may be
(Bonus: state where the cell is found in an organism and its name)



- ② Stem cells are undifferentiated cells, i.e. they are unspecialized.
- a) Why are these cells common during development but much more rare in adults?
 - b) How can these cells be used in medical treatments? Give an example.
- ③ Do all specialized cells with a nucleus have the same genes? Explain.
- ④ Choose two specialized cells not found in this lesson.
- For each, explain how their structure is adapted to their function.
- ⑤ For atom to organism, research an example for each