

A. FEATURES OF LIVING ORGANISMS (MR. SHENG)

Living organisms carry out **seven** life processes:

Metabolism – carry out essential **chemical reactions** using **enzymes**

Reproduction – produce **offspring**, either **sexually** or **asexually**

Sensitivity – are **responsive** to internal and external **stimuli**

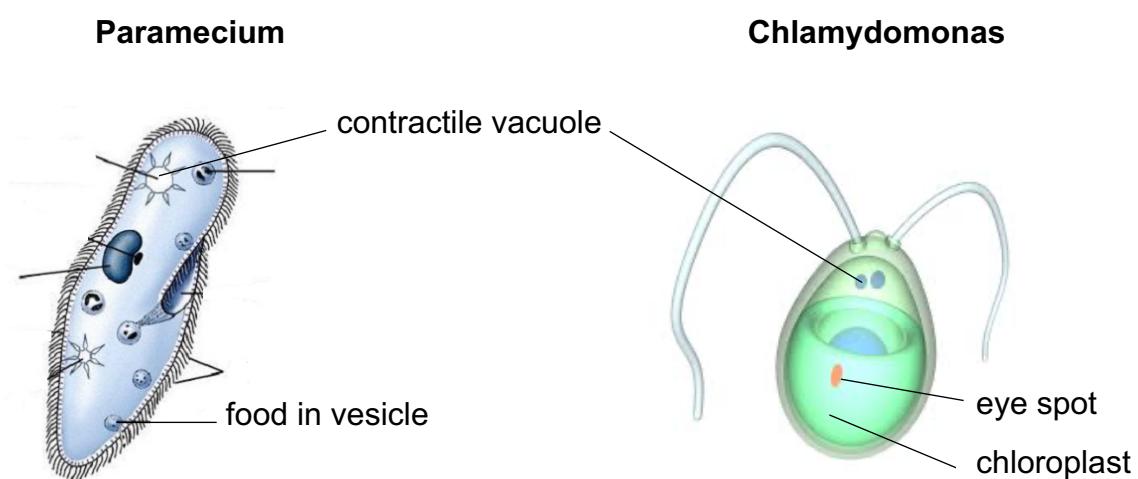
Homeostasis – maintain a **stable internal environment**

Excretion – remove **toxic waste products**

Nutrition – feeds on **other organisms** or makes its **own food** using **photosynthesis**

Growth – move and change its **size or shape**

Two **unicellular** organisms:



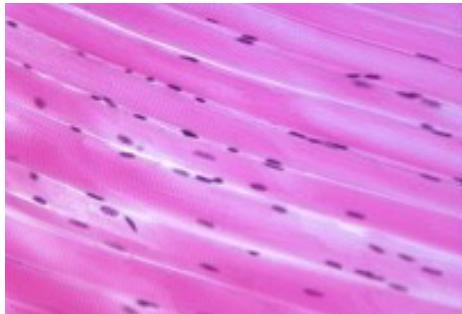
	Paramecium	Chlamydomonas
Metabolism	Both produce enzymes that catalyse chemical reactions	
Reproduction	Both reproduce asexually by mitosis or sexually by meiosis using gametes	
Sensitivity	Reverses its direction of movement when it touches a solid object	Its eyespot detects where the brightest light is so it can then swim towards it
Homeostasis	Both maintain a stable environment e.g. contractile vacuole expels excess water	
Excretion	Both excrete CO₂ from respiration	
Nutrition	Feed on smaller organisms by ingesting and digesting them in vesicles (endocytosis)	Feed by producing its own food by photosynthesis using a chloroplast
Growth	Increases in size and dry mass by accumulating organic matter and minerals from food	Increases in size and dry mass by photosynthesis and absorption of minerals

B. CELL THEORY

1. All living things are made up of **one or more cells**.
2. Cells are the **smallest units of life**.
3. All cells **come from pre-existing cells**.

C. THREE EXCEPTIONS TO CELL THEORY

SKELETAL MUSCLE



- Muscle fibres, like cells, are surrounded by a **plasma membrane**.
- However, they **fuse** to form **fibres** that can be very long.
- Therefore, muscle fibres contain **many nuclei (=multinuclear)**, despite being surround by a single plasma membrane.
- Challenges the idea that cells always function as autonomous units.

ASEPTATE FUNGI



- Have many **undivided** sections of **hyphae** (threads).
- **Not** separated by internal walls.
- They form a **continuous** tube
- They contain **many nuclei** (**=multinuclear**).
- Challenges the idea that organisms are composed of discrete cells

GIANT ALGAE (*Acetabularia*)



- Classed as a **single giant cell**.
- With **one** nucleus.
- It has **not divided** into **separate cells**.
- (So) **not** multicellular.
- May **grow** to very **large** sizes.
- Challenges the idea that larger organisms are always made of microscopic cells.

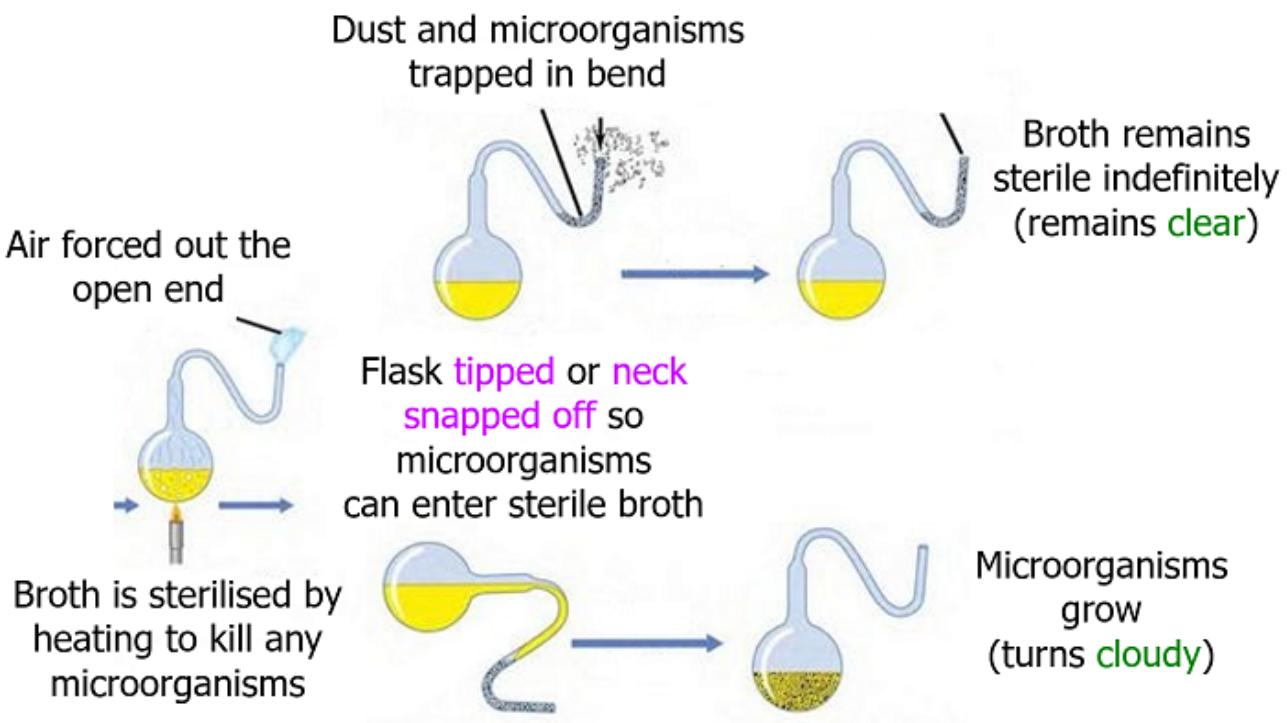
hyphae

D. OTHER RELEVANT POINTS TO INCLUDE IN AN ESSAY

- Red blood cells have **no nucleus** but most eukaryotic cells have one nucleus.
- **Viruses** have some characteristics of living organisms but are **not cells**.
- If all cells come from **pre-existing** cells, **where did the first cell come from?**

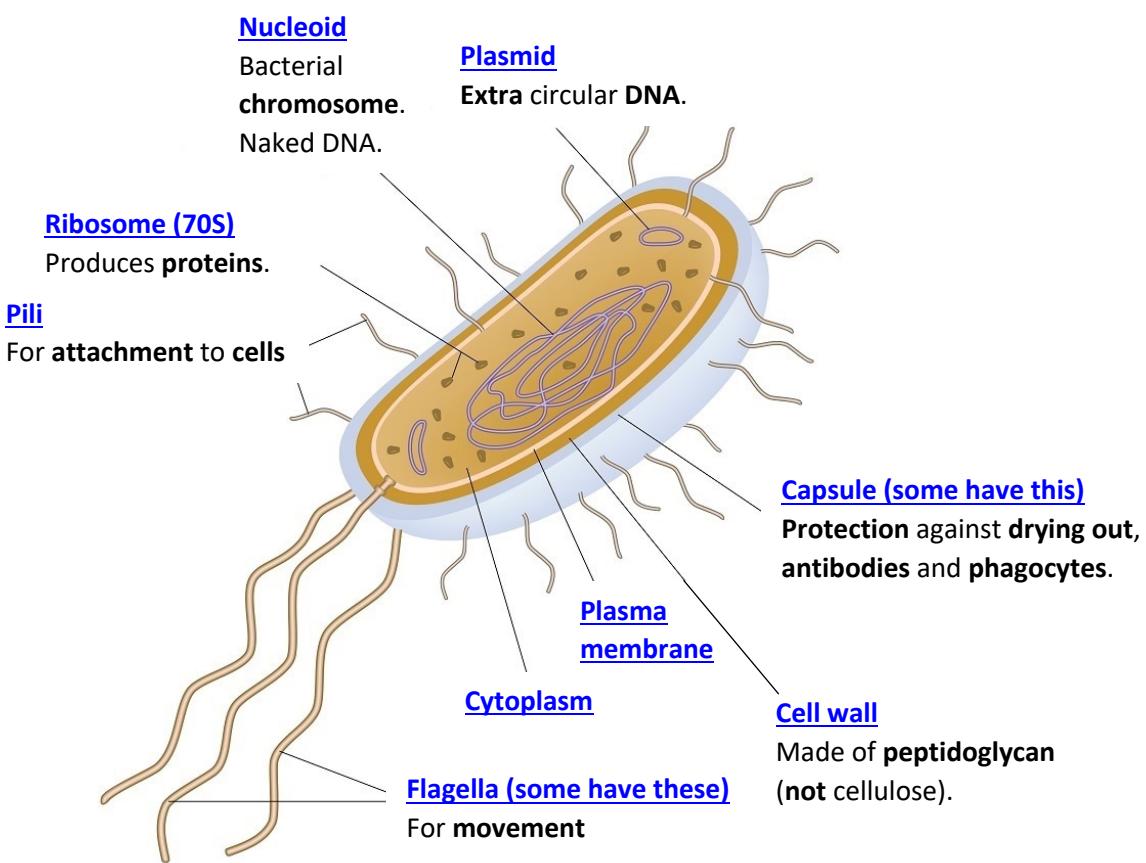
E. HOW PASTEUR DISPROVED THE SPONTANEOUS GENERATION HYPOTHESIS

- Spontaneous generation = **life** appears from **nothing** or **non-living things**

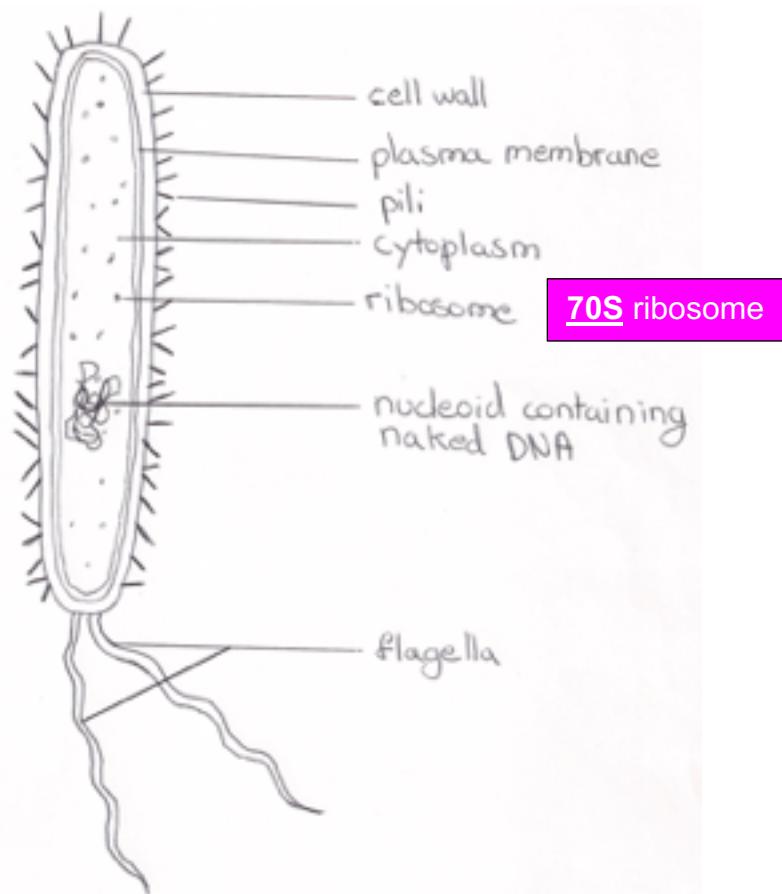


- Broth is placed in **flasks** and **sterilised** to kill microbes.
- Broth remained **clear** when **boiled**, showing **no microbes** were present.
- If **necks of flasks** were **snapped off**, **broth** became **cloudy**, showing **microbes** from the air had **entered** and **grown**.
- Curved necks of flasks allowed **exposure** to air but **prevented** the entry of **microbes** in air.
- He concluded that **cells must come from pre-existing cells** as **no organisms** appeared **spontaneously**.

F. PROKARYOTIC CELLS (BACTERIA)



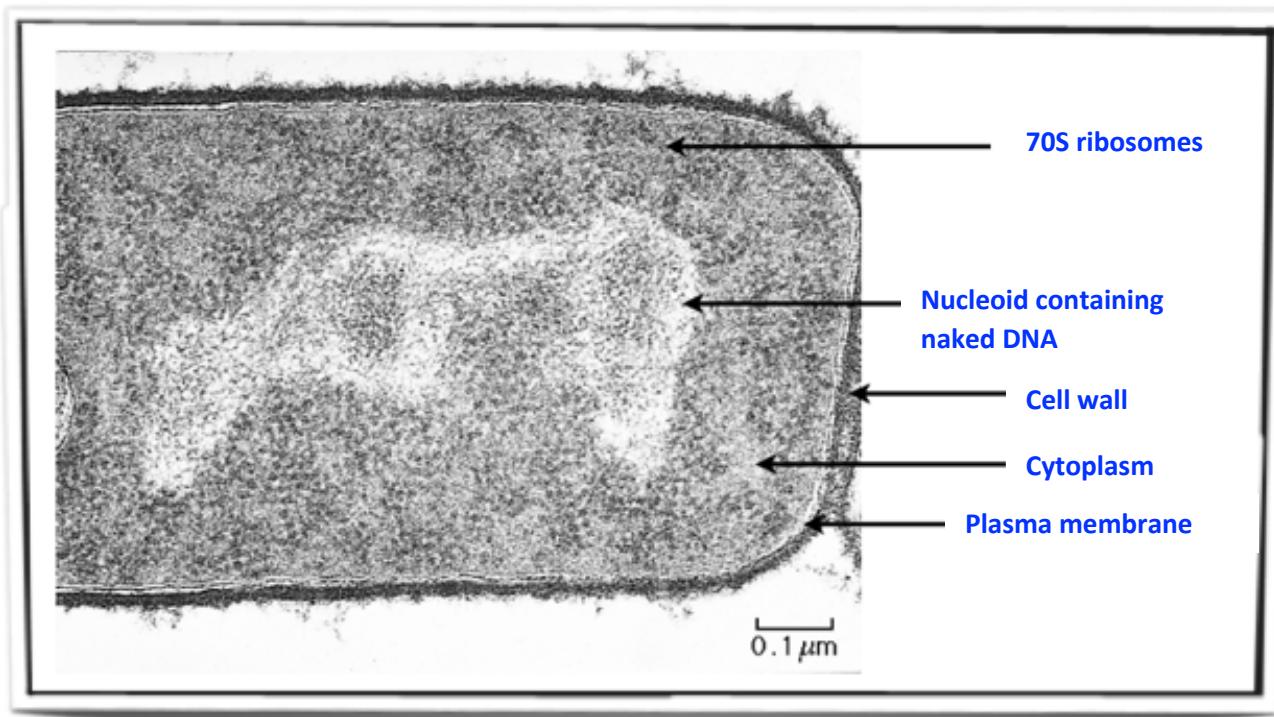
Note:
How the **cell wall** and **plasma membrane** are drawn



Note:
Label lines should **touch** the structures and do **not** need arrow heads

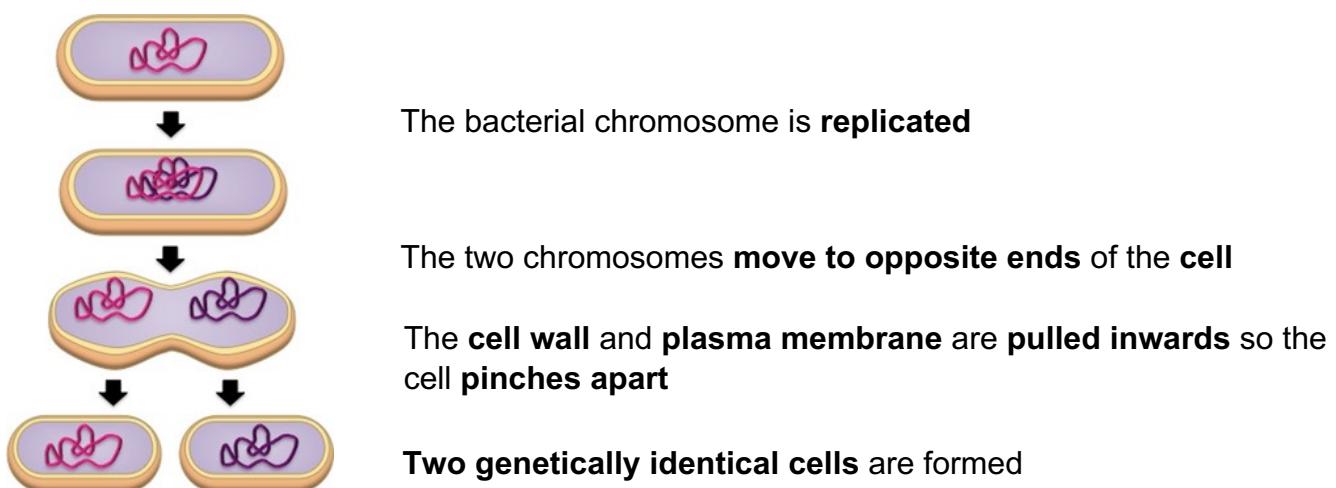
Note:
A **plasmid** could also be shown and labelled

Ultrastructure of a prokaryotic cell (bacterium)



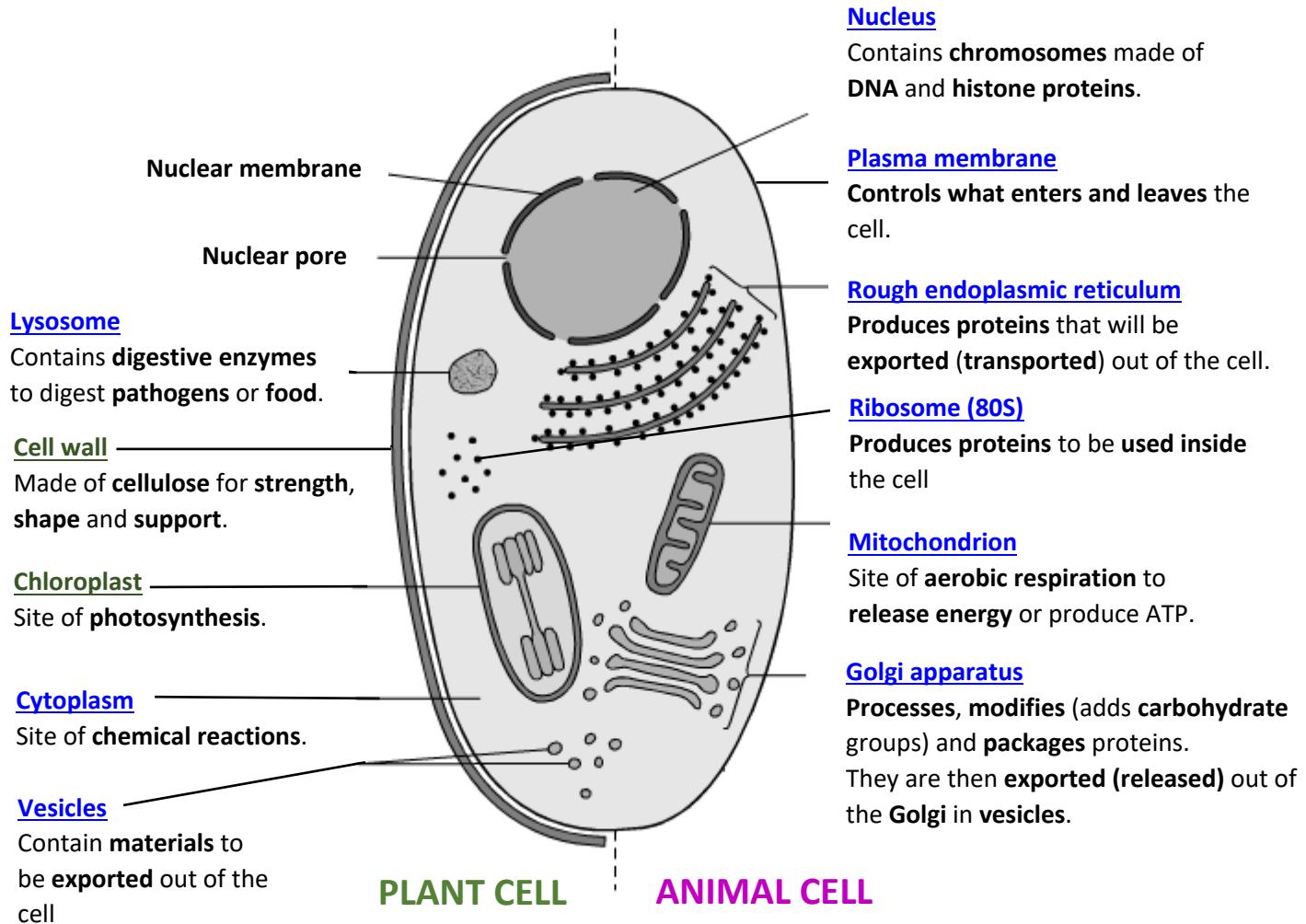
Bacteria divide by binary fission – they do **not** divide by mitosis.

- This is **asexual reproduction** and produces **genetically identical cells** (clones).



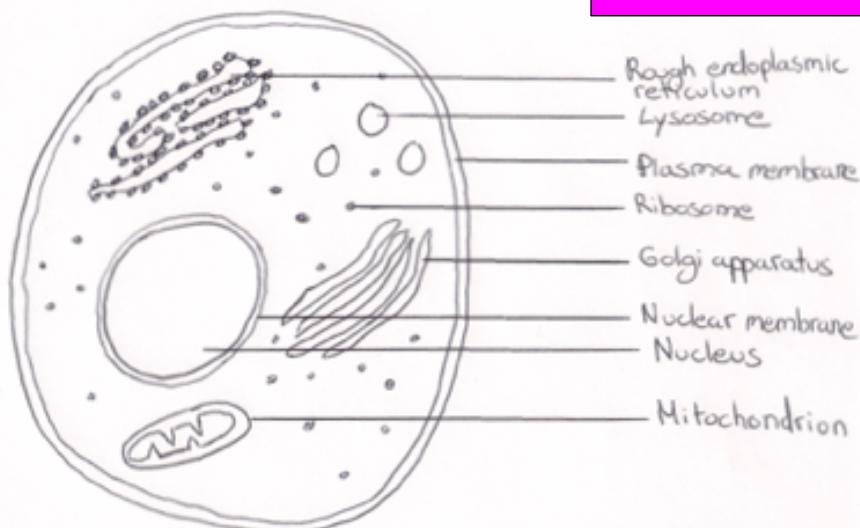
G. EUKARYOTIC CELLS (PLANT AND ANIMAL)

- Organelles that have a **double membrane**: Nucleus; Mitochondrion; Chloroplast.
- Mitochondria** and **chloroplasts** also contain their **own DNA** and **ribosomes (70S)**.



Liver cell

The plasma membrane would be best drawn using a **single line**, not two lines



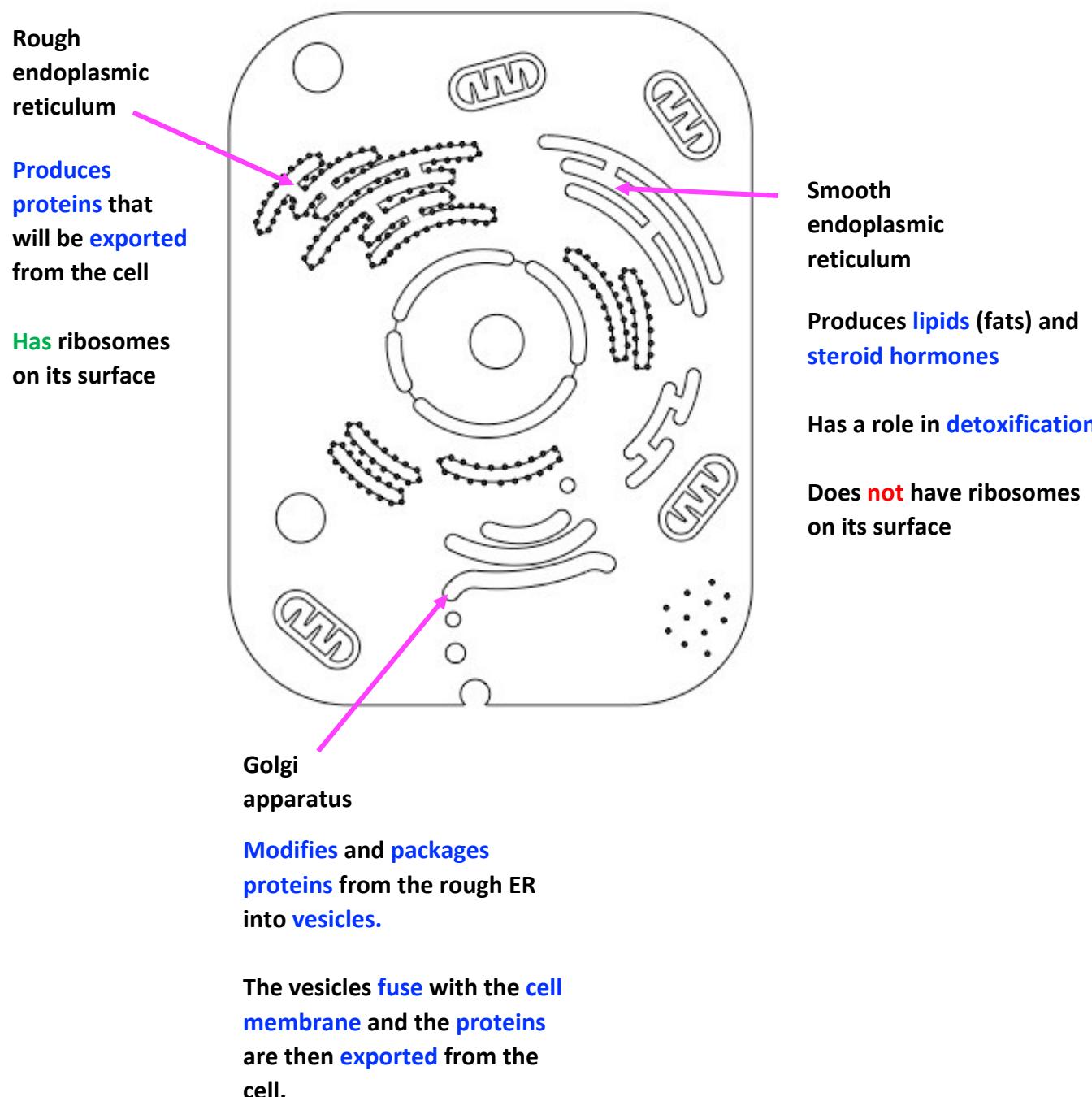
The **nuclear membrane** is correctly shown as a **double membrane** but the **pores** (holes) are missing

80S ribosome

The **Golgi apparatus** should show secretory **vesicles** breaking off from it

H. FINAL WORD ON CELL STRUCTURE

- Eukaryotic cells have a **rough endoplasmic reticulum** and a **smooth endoplasmic reticulum**.
- You are **not** expected to know about the smooth endoplasmic reticulum and **no questions or mark schemes** have ever featured it
- However, for **completeness**, please see below for a summary of three organelles that can easily be confused:

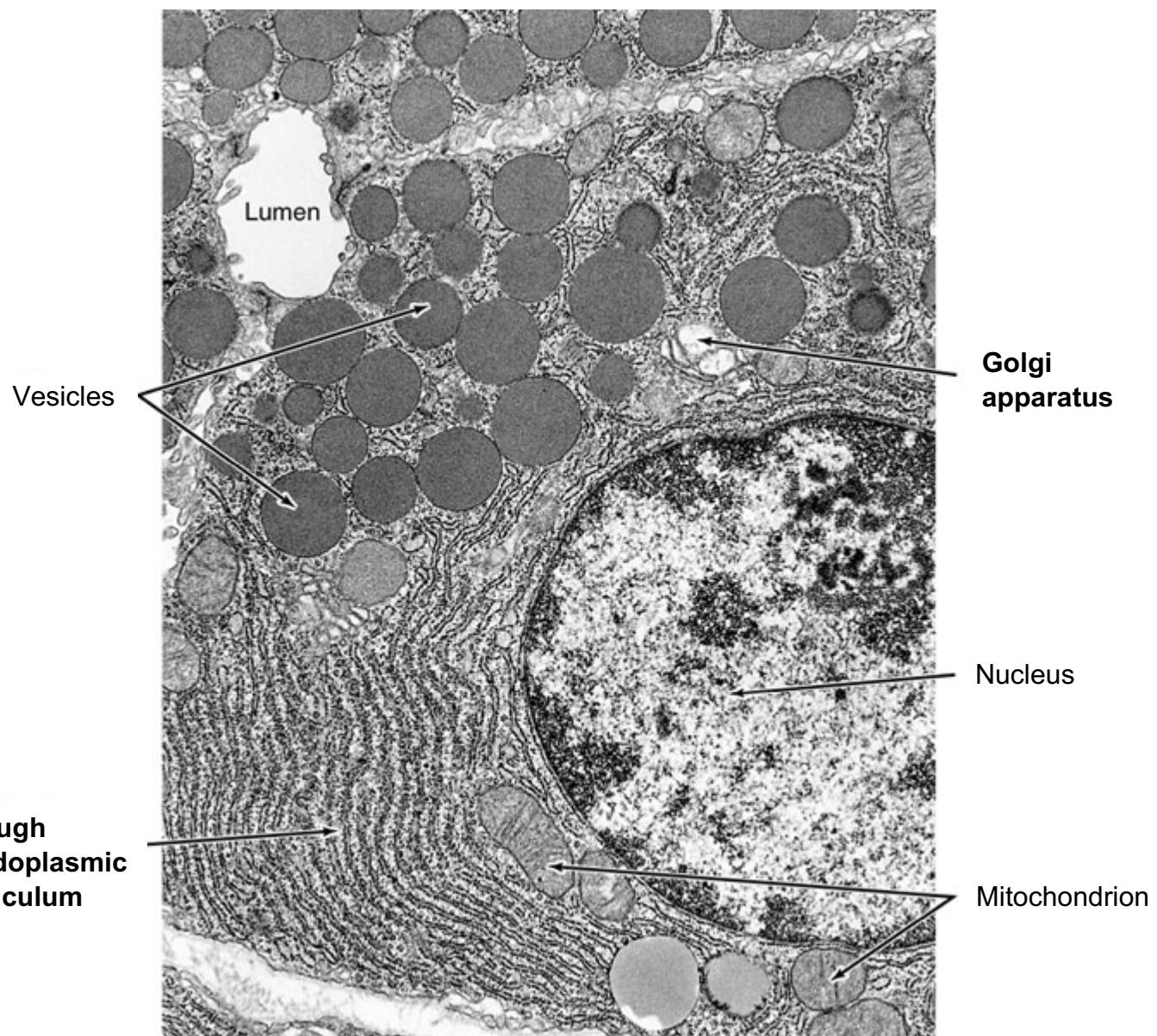


- The pathway for **secreting** products from a cell is:

Rough endoplasmic reticulum → Golgi Apparatus → Vesicle → Cell Membrane

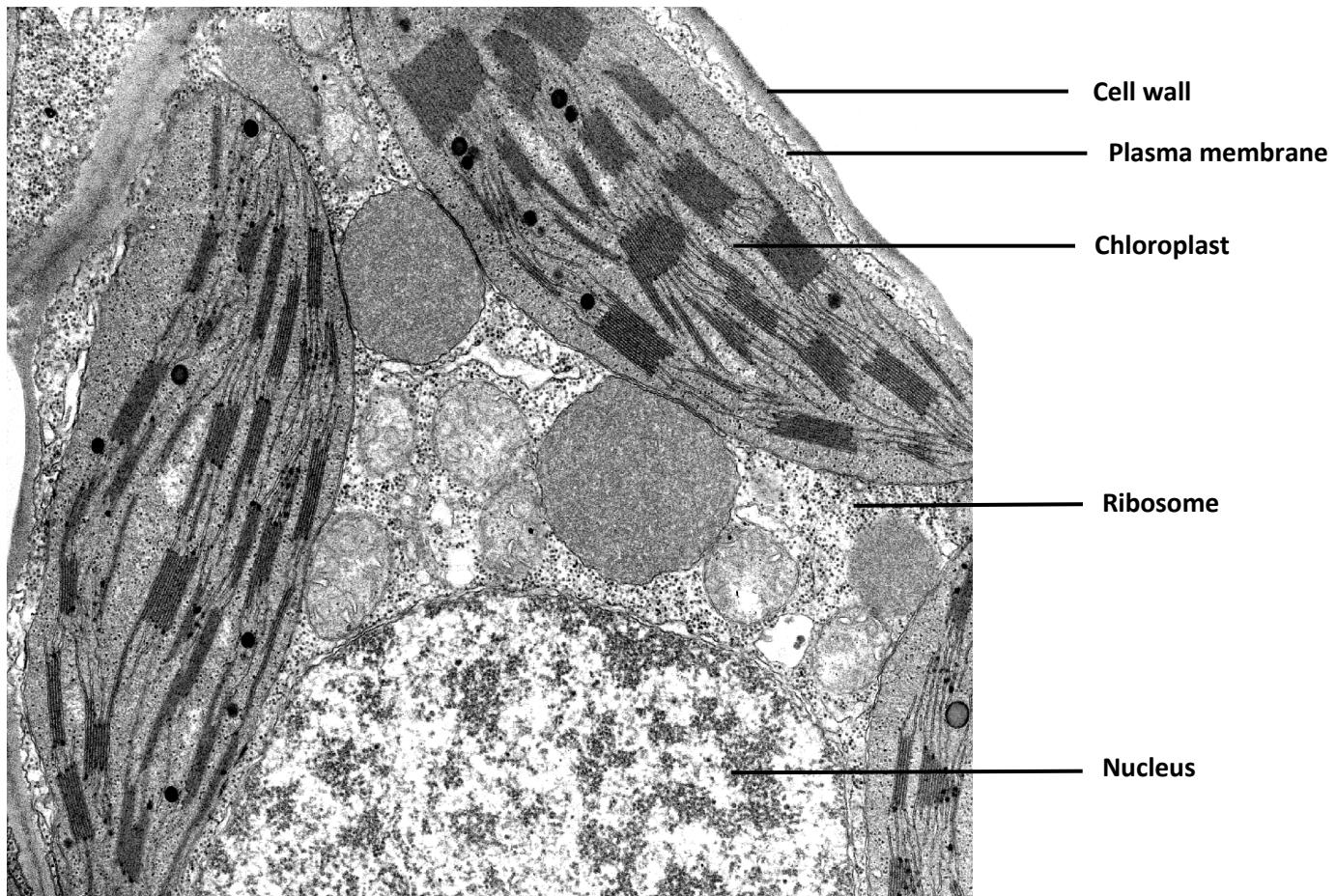
I. NAMING ORGANELLES IN ELECTRON MICROGRAPHS

Ultrastructure of a pancreas secretory cell



- **Secretory cells**, such as in the **pancreas**, have **large amounts of**:
 - **rough endoplasmic reticulum**
to produce **proteins** such as **digestive enzymes** and **hormones**
 - **Golgi apparatus**
to **modify proteins** and **package them** into **vesicles** for **export** from the cell
 - **mitochondria**
to **release energy** by **aerobic respiration** for **secretion of proteins** from the cell by **exocytosis**

Ultrastructure of a palisade (leaf) cell



J. CONTRASTING PROKARYOTIC CELLS & EUKARYOTIC CELLS

Prokaryotic cells	Eukaryotic cells
No nucleus / has a nucleoid	Nucleus
DNA is not associated with histones /proteins	DNA is associated with histones /proteins
Circular DNA	Linear DNA
One chromosome	Many chromosomes
No mitochondria	Mitochondria
70S /smaller ribosomes	80S /larger ribosomes
No membrane-bound organelles / no Golgi apparatus/rough ER/lysosomes	Membrane-bound organelles / Golgi apparatus/rough ER/lysosomes
No compartmentalisation	Compartmentalisation
Cell wall present	Cell wall is in plant cells but not animal cells
Non-cellulose/peptidoglycan cell wall	Cellulose cell wall in plant cells

Only **EUKARYOTIC** cells show **COMPARTMENTALIZATION**

Different **organelles** have their own **separate compartments**

ADVANTAGE of this:

Enzymes and substrates used in a reaction can be **concentrated in a small area**, at optimum temperature and pH, with **no other enzymes** that might disrupt the reaction

K. THE ENDOSYMBIOTIC THEORY

Early
Anaerobic host cell Aerobic bacterium



- Host cell that respires **anaerobically** took in a **bacterium** that respired **aerobically** by **endocytosis** (but it **did not digest** the bacterium).
- This benefited **both** cells (= **symbiosis**).
 - **aerobic bacterium** given **food**
 - **aerobic respiration** releases **more energy** than **anaerobic respiration**, so **host cell** is supplied with **more energy**

Heterotrophic eukaryote

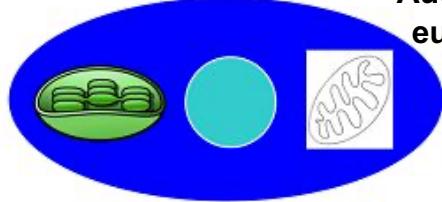


Photosynthetic bacterium

Mitochondrion

- Gradually
 - the **aerobic bacterium** evolved into a **mitochondrion**
 - the **anaerobic host cell** evolved into a **heterotrophic eukaryotic cell**, such as an **animal cell**

Autotrophic eukaryote



Chloroplast

- The **heterotrophic eukaryotic cell** took in a **photosynthetic bacterium (cyanobacterium)** by **endocytosis**.
- This benefited **both** cells (=symbiosis):

- Gradually
 - the **photosynthetic bacterium** evolved into a **chloroplast**
 - the **heterotrophic eukaryotic cell** evolved into an **autotrophic eukaryotic cell**, such as a **plant cell**

Evidence for the endosymbiotic theory (DR. MAD)

- Mitochondria and chloroplasts both:

D	Have their own circular DNA (like bacteria)
R	Have their own 70S ribosomes for making proteins (like bacteria)
M	Have double membranes - expected if they had been taken into a vesicle by endocytosis
A	Antibiotics can prevent them from functioning (like bacteria)
D	Divide and grow by fission (like bacteria)

- This **supports** the idea that **mitochondria** and **chloroplasts** evolved from **bacteria**.

L. MICROSCOPY

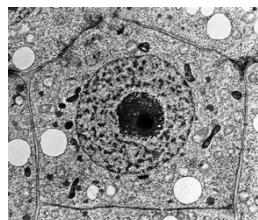
- **Magnification** is by **how many times** the image has been **enlarged**, relative to its **actual size**.
- **Resolution** is the ability of microscopes to show **two close objects separately** in the image. The **lower the distance** that this can be done, the **better (higher)** the resolution.

Types of microscope

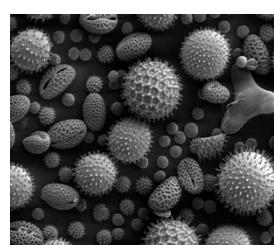
	Light microscope	Electron microscope
Radiation used	Light	Electrons
Focused By	Glass lenses	Electromagnets
Magnification	Lower (2,000 x)	Higher (1,000,000 x)
Resolution	Lower (0.25 µm)	Higher (0.25 nm) Can see them as two separate objects when even closer together
Specimens	Living or dead (As in air)	Dead only (As in a vacuum)
Can View Specimens In	Natural colour	Black & White Although false colour rendering can be applied

There are two types of electron microscope:

- **Transmission electron microscopes (TEM)** **pass** electrons **through** a specimen to generate a **thin cross-section** of tissue.



- **Scanning electron microscopes (SEM)** **scatter** electrons **over a surface** to differentiate **depth** and **map** in **3-D**.



Calculating magnification and actual length

$$\text{MAGNIFICATION} = \frac{\text{IMAGE SIZE}}{\text{ACTUAL SIZE}}$$

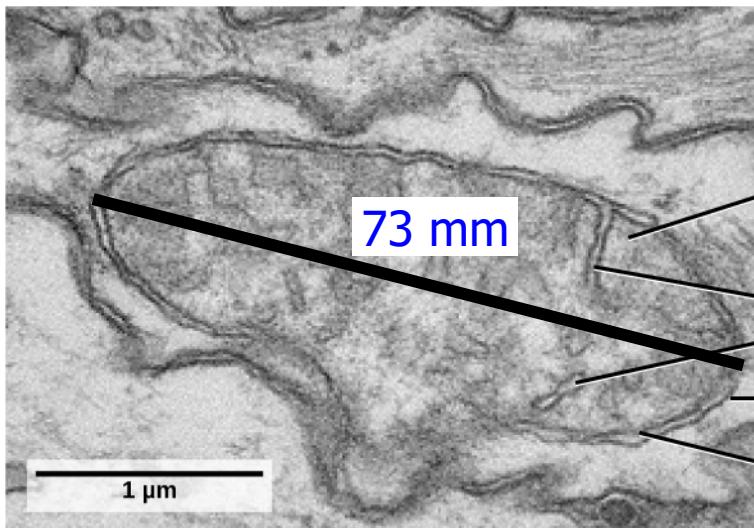
$$1 \text{ mm} = 1000 \mu\text{m}$$

$$1 \mu\text{m} = 1000 \text{ nm}$$

- Keep the **units the same** all the way through.

Worked Example

The picture shows a mitochondrion.



(a) Calculate the magnification of the picture.

From the **slide bar**: $1 \mu\text{m} = 25 \text{ mm}$

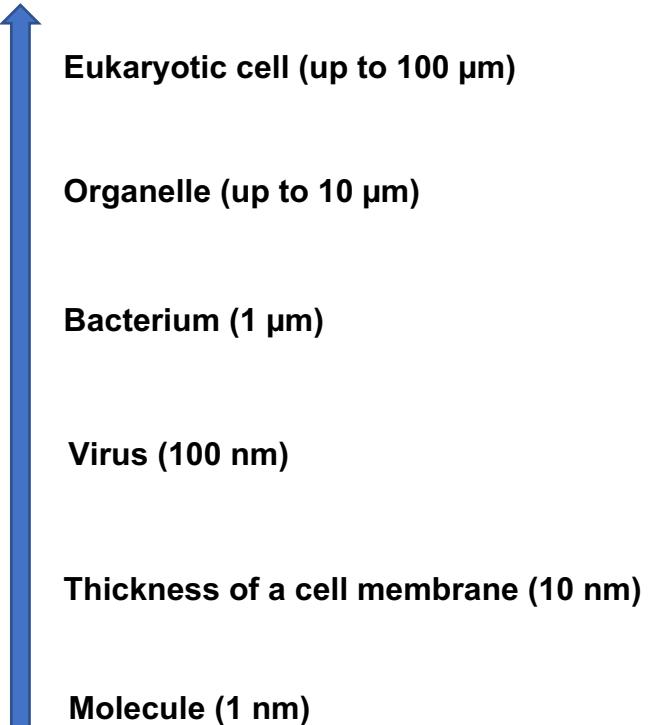
$$\text{Magnification} = \frac{\text{image size}}{\text{actual size}} = \frac{25 \text{ mm}}{1 \mu\text{m}} = \frac{25,000 \mu\text{m}}{1 \mu\text{m}} = 25,000$$

(b) Calculate the actual length of the mitochondrion in μm .

$$\text{Magnification} = \frac{\text{image size}}{\text{actual size}} \text{ so: } 25,000 = \frac{73 \text{ mm}}{\text{actual size}} \text{ so: actual size} = \frac{73 \text{ mm}}{25,000} = 0.00292 \text{ mm}$$
$$= 2.92 \mu\text{m}$$

**M. THE RELATIVE SIZE OF MOLECULES, CELL MEMBRANE THICKNESS,
VIRUSES, BACTERIA, ORGANELLES AND CELLS, USING THE APPROPRIATE SI UNIT**

LARGEST



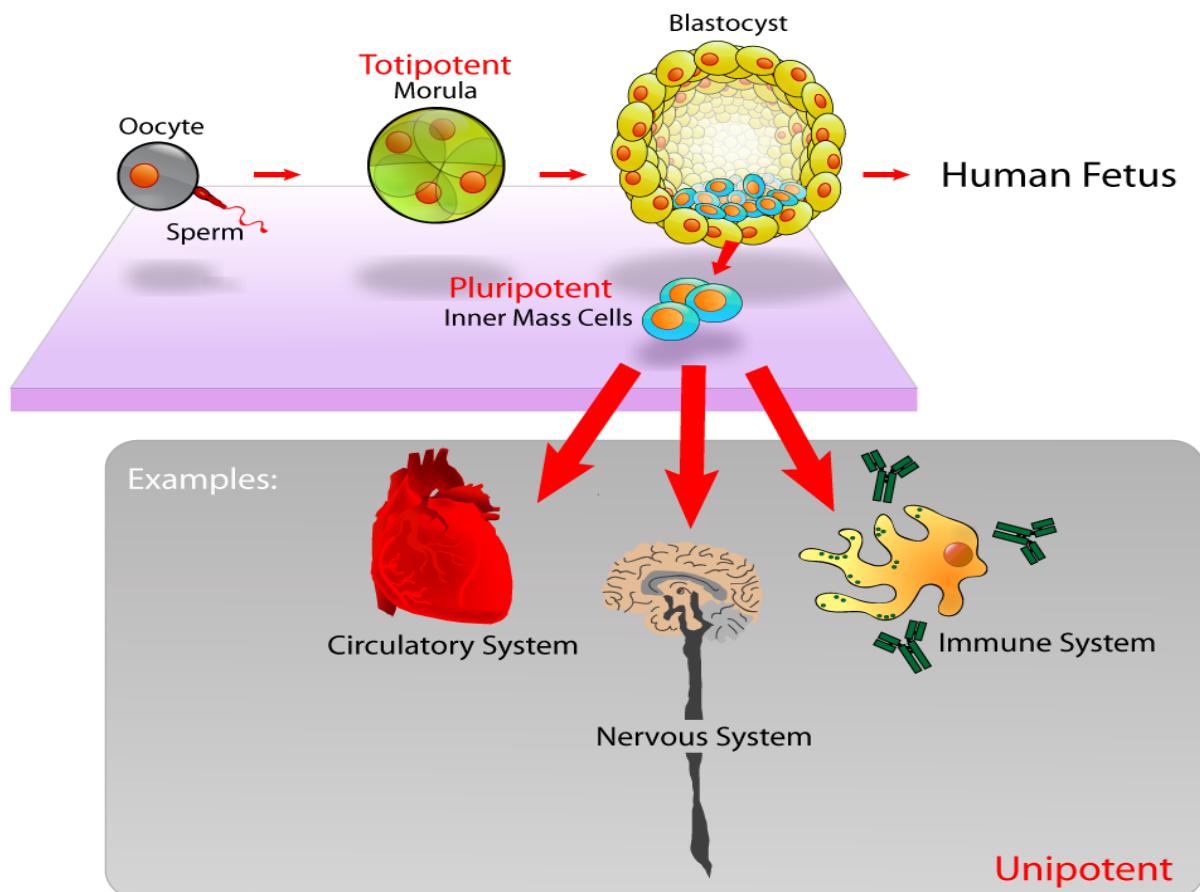
SMALLEST

N. STEM CELLS

WHAT THEY ARE

- **Undifferentiated, unspecialised** (do not have a **specific function**), **self-replicating** cells.
- They have the **potential to develop** into **different cell types**.
- Cells in an **embryo** are **genetically identical** but they **differentiate** and **develop** into **different cell types**.
- They **differentiate by expressing** (switching on) **specific genes**. This allows them to produce **specific proteins** to become a **specific cell type**.
- **Differentiation** causes **specialisation**.

TYPES OF STEM CELL



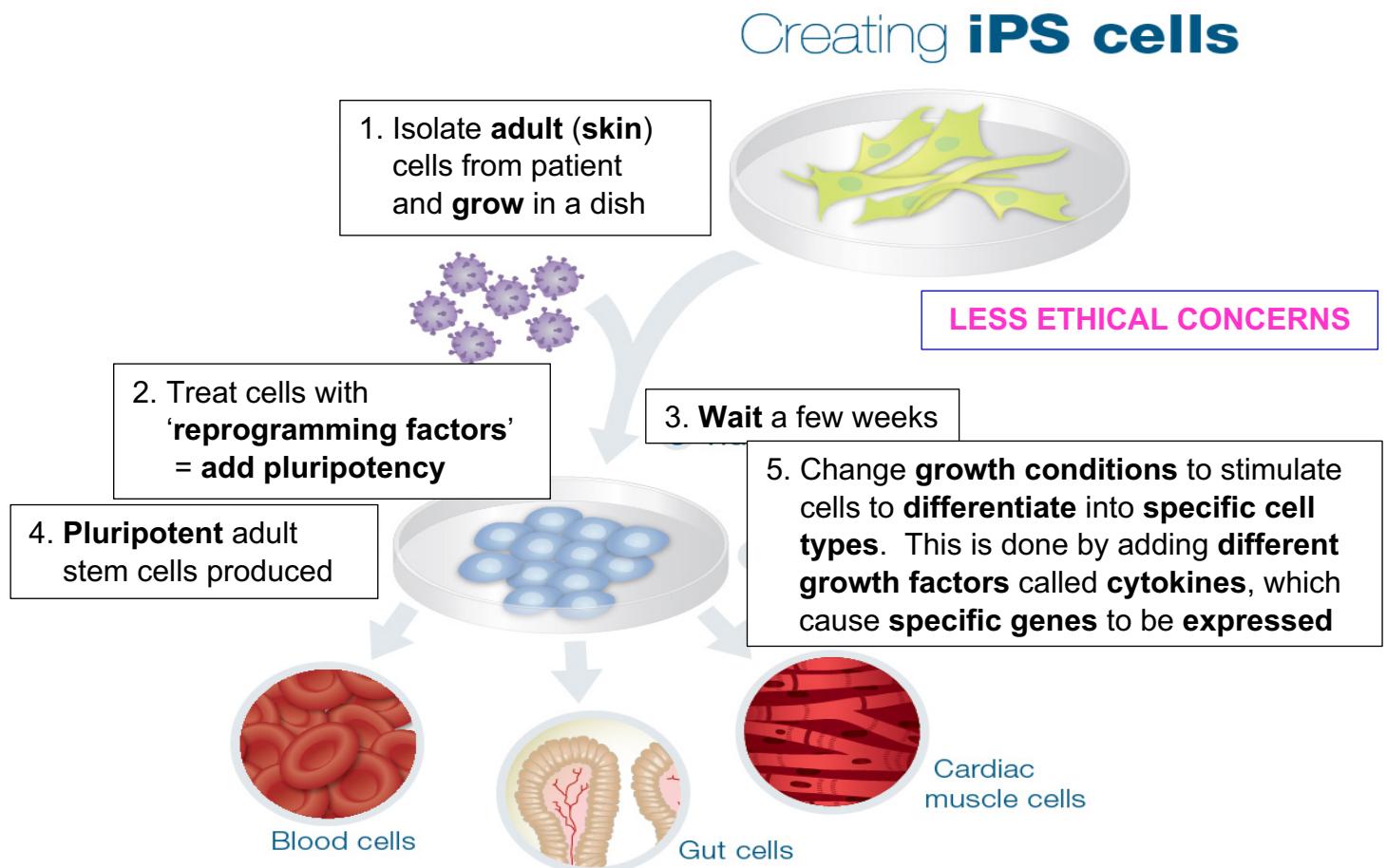
- The **first few divisions** after **fertilisation** produces a structure called a **morula**. Its cells are **totipotent** and can develop into **any cell type** including **placental cells**.
- **Further divisions** produce an **embryonic** structure called a **blastocyst**. Its **inner mass** of cells is **pluripotent** and can develop into **most cell types** but not **placental cells**.
- **Bone marrow cells** are **multipotent** and can develop into a **restricted range of cell types**. It produces **all types of blood cell**.
- **Skin cells** are **unipotent** and can only develop into **one cell type – skin cells**.

Type of stem cell	Can Develop Into	Example
Totipotent	Any cell type	Morula – all cell types including placental
Pluripotent	Most cell types	Embryo – all cell types apart from placental
Multipotent	A restricted range of cell types	Bone marrow – all blood cells
Unipotent	One cell type	Skin cell – only skin cells

- Two functions: to **replace/repair** existing cells (produce **large numbers of identical cells**) or to **differentiate into specific cell types**.

IPS CELLS (INDUCED PLURIPOTENT STEM CELLS)

- Makes **adult cells pluripotent** to avoid the **ethical** arguments of using **embryo** stem cells.



DIFFERENCES BETWEEN EMBRYO AND ADULT STEM CELLS

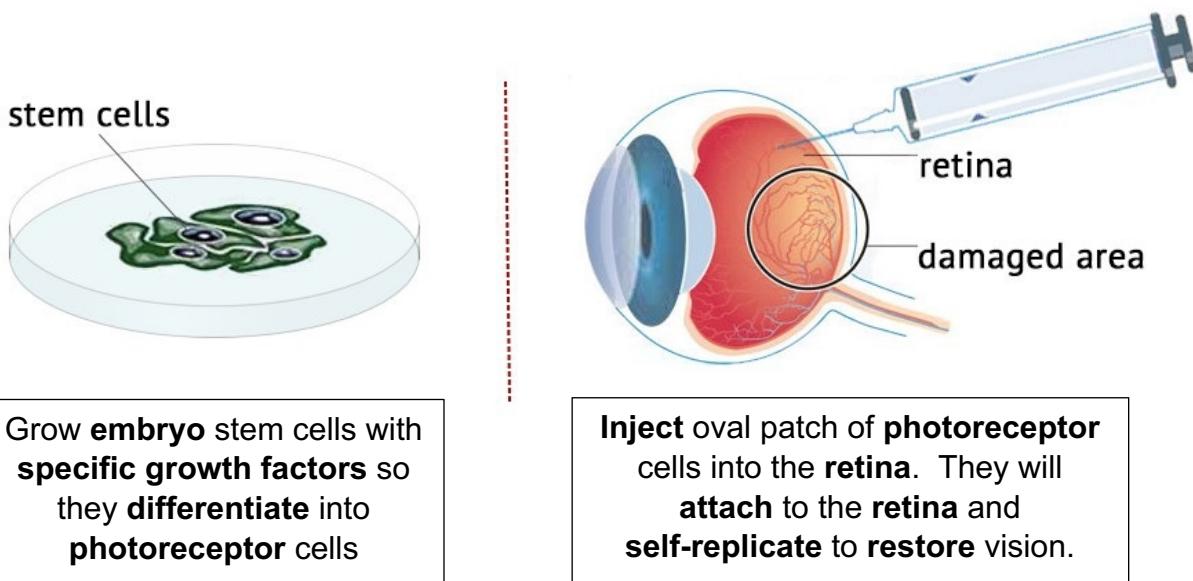
	EMBRYO	ADULT
Potency	Pluripotent	Multipotent
Main use in the body	Differentiation into specific cell types	Replacing and repairing existing body cells
Source	Inner mass of cells from the embryo (blastocyst)	Developed, specialised tissue
Replication rate	Can double up to 300x	More limited replication
Chance of forming tumours	Possible if transplanted when undifferentiated	Unknown
Ease of culturing	Easy	More difficult
Main obstacle	Ethics	Owner's consent
Chances of rejection after transplantation	Unknown	Less likely
Medical use	They need to be induced (started off)	Directly transferable

ADVANTAGES AND DISADVANTAGES OF USING ADULT STEM CELLS

ADVANTAGES	DISADVANTAGES
Can divide endlessly/differentiate	Differentiate into fewer cell types than embryo stem cells (but IPS cells can also be made now)
Can be used to repair/regenerate tissue	Some tissues do not contain stem cells
Fewer ethical objections than with embryo stem cells	Difficult to collect/find in an adult body
Adults can give informed consent for using their stem cells	
Adult source is not killed/would not have developed into a new human	
No rejection problems as patient's own cells are used	
Less chance of cancer/tumours	
Most tissues in adults contain some stem cells	

THERAPEUTIC USE OF STEM CELLS 1: STARGARDT'S DISEASE

- The most common form of inherited **blindness** in young people.
- Caused by **photoreceptors** in the **retina** not working.
- Due to a **mutation** that causes a **membrane protein** to **malfunction**.



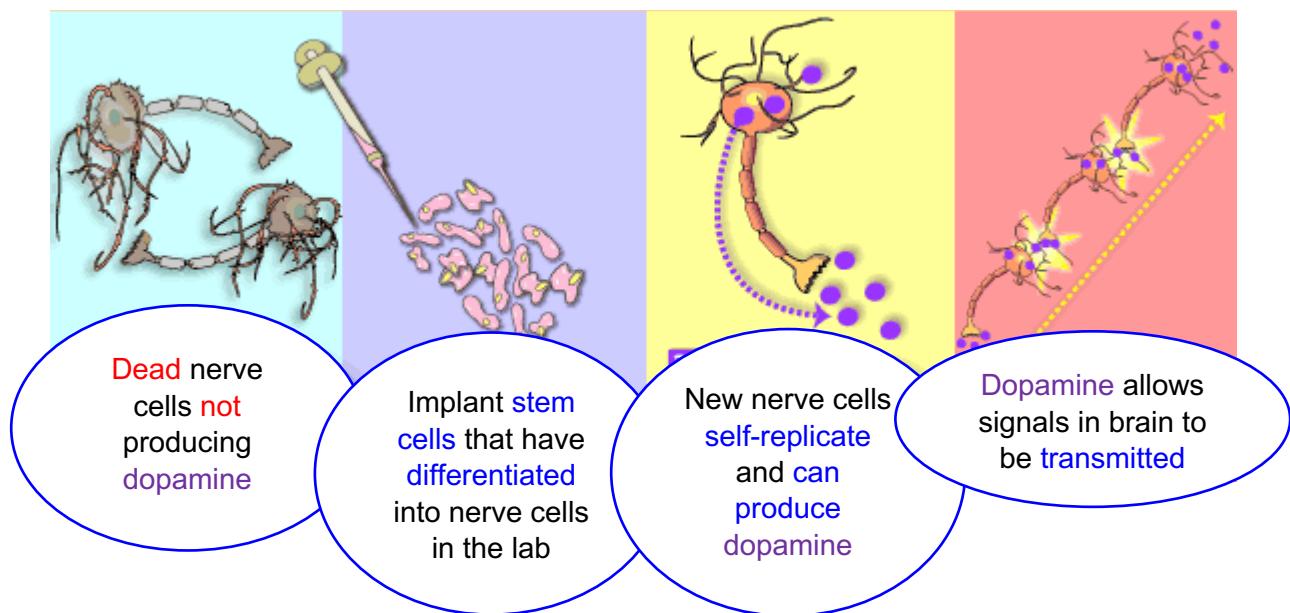
- The current **main uses** of **stem cells** are:

(a) **growing tissues or organs;**

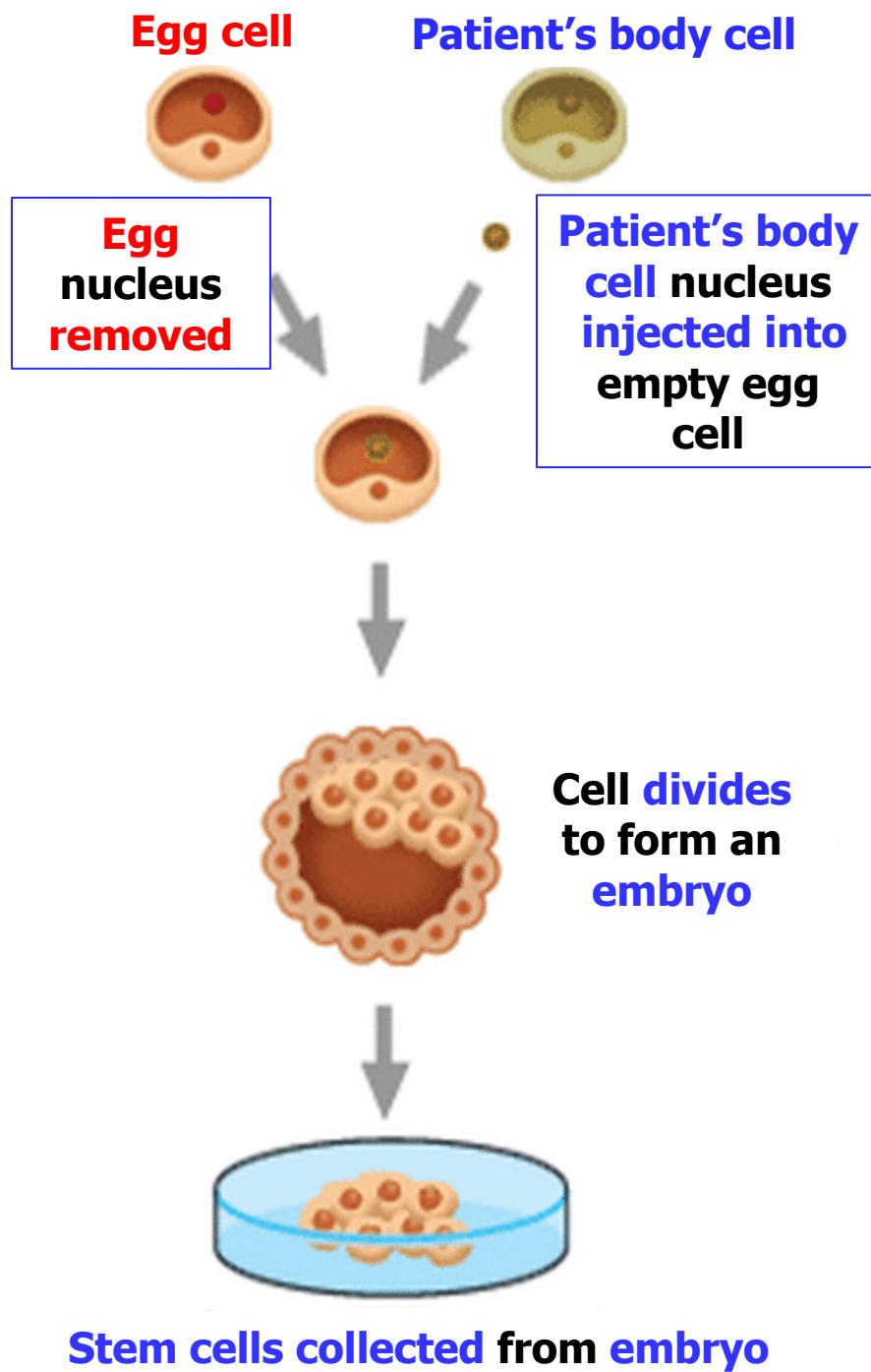
(b) **differentiating** stem cells into a **specific cell type** and **injecting** these into a **specific area** of the **body**, where they will **self-replicate**;

THERAPEUTIC USE OF STEM CELLS 2: PARKINSON'S DISEASE

- A disorder of the **central nervous system**.
- Caused by the **death of dopamine-secreting cells** in the **brain**.
- Dopamine is a **neurotransmitter** responsible for **transmitting signals** involved in the production of **smooth, purposeful movements**.
- People with Parkinson's disease typically show **tremors, stiffness, and slow movement**.



THERAPEUTIC CLONING TO PRODUCE EMBRYO STEM CELLS FOR MEDICAL USE



Therapeutic cloning involves producing embryos from which embryonic stem cells can be collected for medical use.

It is not about cloning a full organism.

- Low risk of rejection as they are the patient's own stem cells.
- If the embryo was implanted into the uterus of a surrogate mother, a clone of the donor would be born!
- The embryo is not allowed to grow past 14 days.

ETHICAL ISSUES OF THERAPEUTIC CLONING (= USING EMBRYONIC STEM CELLS FOR MEDICAL USE)

Benefit	Concern
Can replace organs/tissues that have been damaged	Embryo cells are no longer needed due to iPS cells
Any procedure that reduces pain/suffering is ethically justified	Any procedure that harms/kills a potential life is ethically wrong
Cells can be removed from embryos that would have stopped developing/ would have died anyway	Every embryo is a potential human life with the right to develop
Cells are removed at a stage when no pain would be felt by the embryo	More embryos may be produced than can be used and so some would be killed
Use embryos from IVF that would otherwise be destroyed	Danger of embryo stem cells developing into tumour cells

O. SURFACE AREA:VOLUME RATIO

WHAT IT IS

- The **rate of EXCHANGE** by which **materials enter or leave** a cell depends on the **SURFACE AREA**.
- The **rate of METABOLISM** by which **materials are used or produced** by a cell depends on the **VOLUME**.
- HIGHER SA:VOL RATIO = FASTER EXCHANGE/DIFFUSION.**

As a cell **grows**,
Volume (units³) **increases faster** than surface area (units²)
 Leading to a **decreased SA:VOL**

- If the rate of **metabolism** is > rate of **exchange**, the cell will **die**.
- (So) when growing cells reach a **certain size**, **mitosis** is **stimulated** and the **cell divides**.
- This ensures that cells **remain small**, within **size limits**.
- (So) a **high SA:VOL** is **maintained** for **survival**.

TADPOLES AND FROGS

- Tadpoles **do not** need **lungs** but frogs **do**. Why is this?

Tadpole



Frog



Volume increases faster than surface area

(So) as an organism gets **larger**, its **SA:VOL decreases**

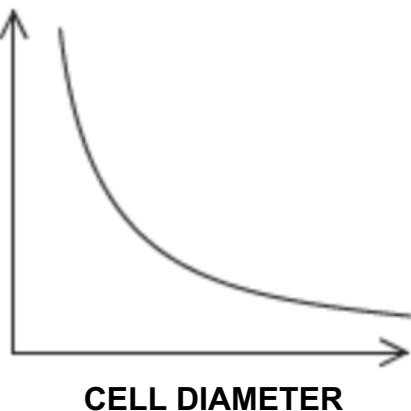
(So) **slower exchange/diffusion of oxygen**

Through the **skin**

(So) **lungs** are needed to **compensate**

- **NOTE:** **HIGHER SA:VOL = FASTER HEAT LOSS** too.

SURFACE AREA : VOLUME



HOW SA:VOL RATIO LIMITS THE SIZE OF A CELL

RECAP:

- The **rate of EXCHANGE** by which **materials enter or leave** a cell depends on the **SURFACE AREA**.
- The **rate of METABOLISM** by which **materials are used or produced** by a cell depends on the **VOLUME** (**LARGER** cells will have **INCREASED METABOLISM**)
- **HIGHER SA:VOL RATIO = FASTER EXCHANGE/DIFFUSION.**
- As a cell gets **LARGER**, its **VOLUME INCREASES** to a **MORE/FASTER** than its **SURFACE AREA**



SMALL SIZE

- **Food/oxygen enters** through the cell **surface**
- **Wastes leave** through the cell **surface**
- **Rate of exchange/substance entering/leaving cells** depends on **surface area**

LARGE SIZE:

Problems with a **larger volume**:

- slower diffusion of substances**
- more wastes produced**
- more metabolism** so more glucose and oxygen needed
- more excess heat** generated that can't be easily lost

SO: THE SA:VOL STIMULATES MITOSIS AT A CRITICAL VALUE

SO: THE SIZE OF THE CELL IS REDUCED AND KEPT WITHIN SIZE LIMITS

SO: CELLS DIVIDE WHEN MAXIMUM (ALLOWED) SIZE IS REACHED

P. MULTICELLULAR ORGANISMS

Show **EMERGENT PROPERTIES**

These are properties that can only result from the **INTERACTION** of **MANY CELLS**