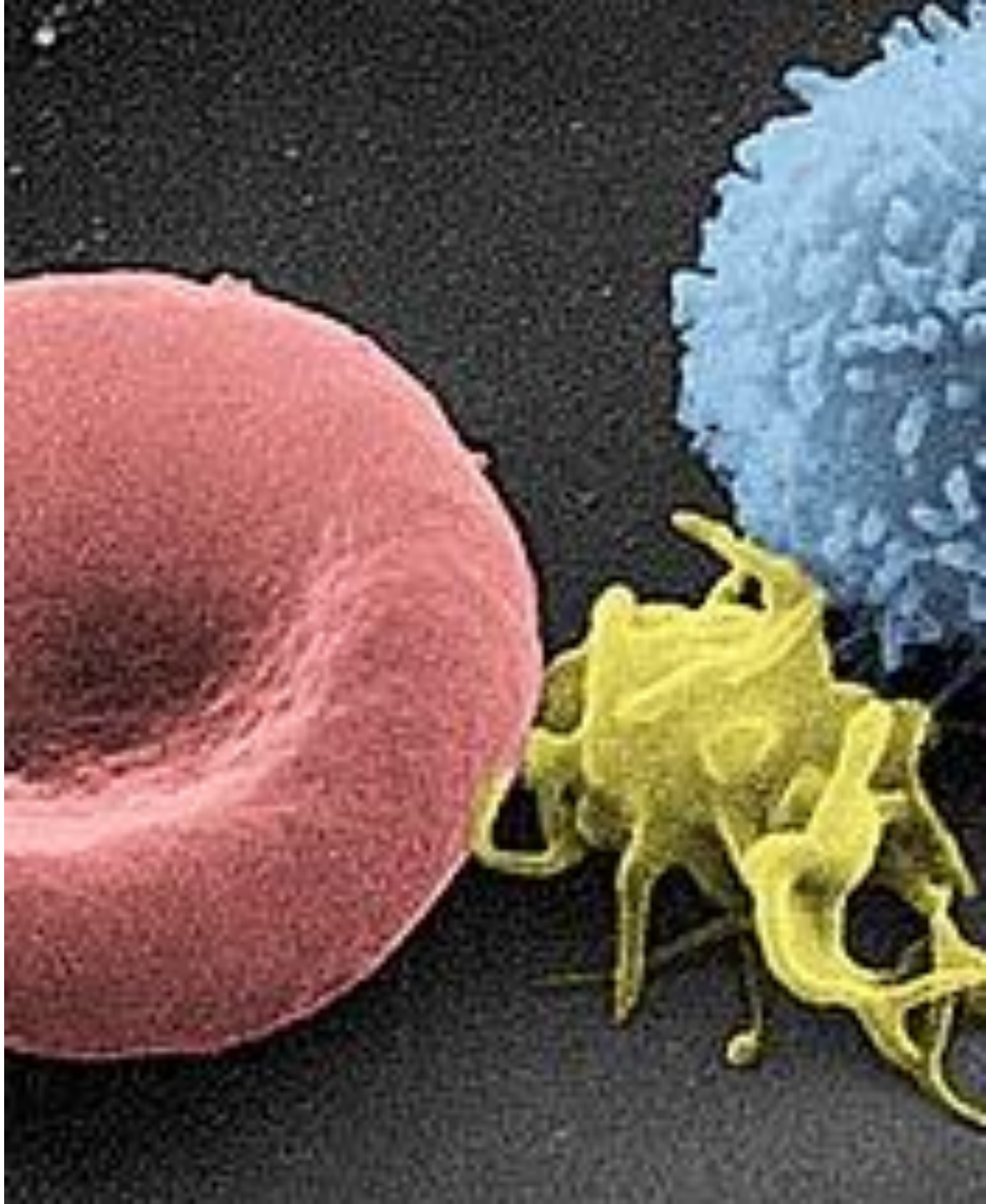
DP Biology – B2.3

Cell specialization

- What do stem cells do in multicellular organisms?
- How do differentiated cells suit their specialized roles?

SL statements B2.3.1–6. Textbook pp. 256–264. Further specialized cell examples are at HL.
Image: red and white blood cells. Electron Microscopy Facility, NCI, public domain.



Objectives for each class

Class	Statements	By the end of the class, you can...
1	B2.3.1–4	Explain how unspecialized cells differentiate, what stem cells are, where stem cell niches are, and the levels of potency
2	B2.3.5–6	Compare specialized cell sizes, and calculate surface area-to-volume ratios to explain limits on cell size

From a zygote to specialized cells

B2.3.1

- After fertilization, repeated cell division produces a group of **unspecialized**, genetically identical cells
- Cells then **differentiate**: they follow a pathway and become specialized for a role
- All cells have the same genes, and different genes are expressed in each cell type

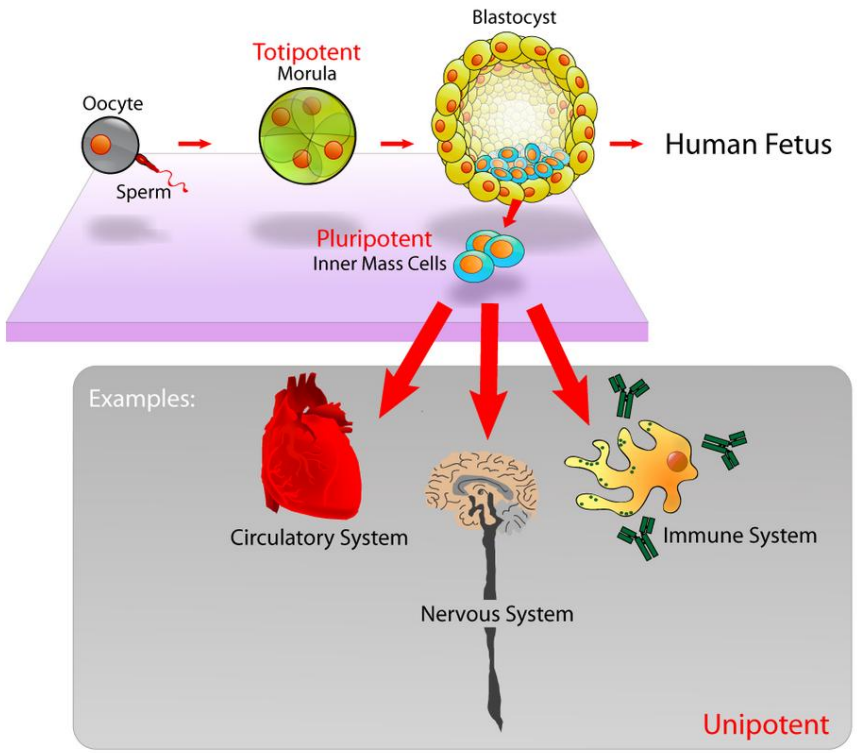
Key idea

Signalling chemicals called **morphogens** form gradients in an early embryo. The concentration a cell receives tells it where it is, and this affects which genes it expresses.

Common mistake

Differentiation does not remove genes. A neuron and a skin cell in one person have the same genome. They differ because of gene expression, which you met in the protein synthesis chapter (D1.2).

What makes a cell a stem cell?



- They can **keep dividing** many times without limit
- They can **differentiate** along different pathways

Key idea

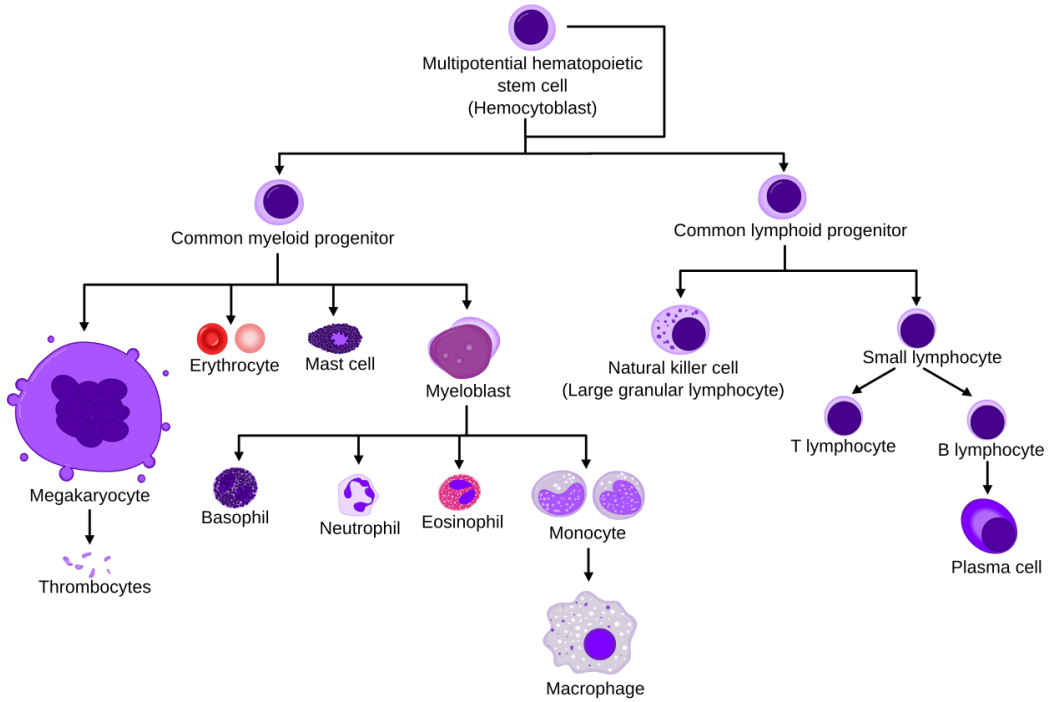
When a stem cell divides, some daughter cells stay as stem cells, while others differentiate. This maintains a supply of both.

Stem cells. Mike Jones, CC BY-SA 2.5.

Stem cells are used in medicine: for example, bone marrow transplants replace the blood-forming cells of patients treated for leukaemia.

Stem cell niches in the adult body

B2.3.3



Blood cells from stem cells. A. Rad and M. Haggstrom, CC BY-SA 3.0.

Niche	What the stem cells do
Bone marrow	Produce all types of blood cell
Hair follicles	Produce new hair and help repair skin

Definition

A **niche** is a location that keeps stem cells alive, and it controls their activity.

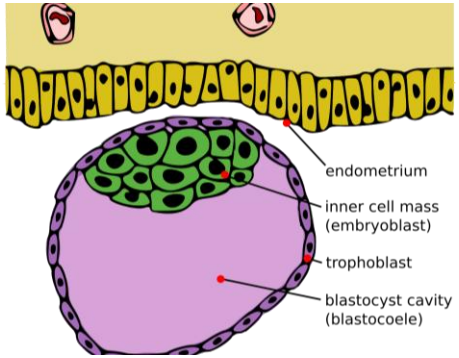
Key idea

A niche can maintain stem cells in an undivided state, or it can promote their division and differentiation, depending on what the body needs.

Three levels of potency

B2.3.4

Type	Can become	Where found
Totipotent	Any cell type, including those of the placenta	Zygote and earliest embryo cells
Pluripotent	Any cell type of the body, but not a whole organism	Early embryo, after a few days
Multipotent	A limited range of related cell types	Adult tissues such as bone marrow



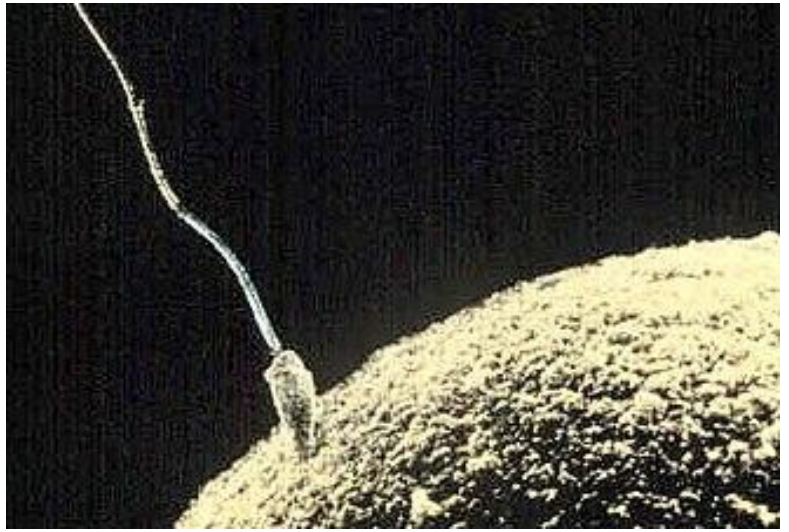
Remember

Potency falls as development goes on. Early embryo cells are totipotent, then soon become pluripotent. Stem cells in adult tissue are multipotent. Image: a blastocyst. Seans Potato Business, CC BY-SA 3.0.

Cell size as part of specialization

B2.3.5

Cell	Approximate size	Why
Red blood cell	About 8 µm	Fits through capillaries
White blood cell	12–17 µm	Engulfs pathogens
Sperm	About 55 µm long	Small and able to swim
Egg	About 100 µm	Stores food
Neuron	Up to 1 m long	Carries signals far
Muscle fibre	Several centimetres	Contracts along its length



A sperm and an egg. Unknown author, public domain.

Discussion

Why does an egg need to be so much larger than a sperm?

Learn the pattern rather than the exact figures. Each size suits what the cell does.

Surface area and volume

B2.3.6

- **Exchange** across the cell surface depends on **surface area**
- The **need** for exchange depends on **volume**, where metabolism takes place
- As a cell grows, its volume rises faster than its surface area

Side of cube	Surface area	Volume	SA:V ratio
1 unit	6	1	6 : 1
2 units	24	8	3 : 1
3 units	54	27	2 : 1

Key idea

The bigger the cell, the smaller its surface area-to-volume ratio.

Why cells stay small

B2.3.6

- If the ratio is too low, materials cannot enter or leave quickly enough
- Waste can build up, and heat may be lost too slowly
- So a growing cell either divides or becomes multicellular tissue

Activity

A cube has sides of 5 units. Calculate its surface area, its volume and its ratio. Then explain how flattening or folding a cell would change the ratio.



At the scale of a whole animal

Small animals have a high ratio and lose heat quickly. A hummingbird has a very high metabolic rate to make up for this. Image: Anna’s hummingbird. MesoComet, CC0.

Practical: agar cubes

B2.3.6

1. Cut agar containing a pH indicator into cubes of different sizes
2. Put them in dilute acid, which diffuses in and changes the colour
3. Time how long each cube takes to change colour all the way through
4. Compare the time with the surface area-to-volume ratio

Safety and control

Wear eye protection with acid. Keep the temperature and the acid concentration the same for every cube.

Discussion

In what ways is an agar cube a good model of a cell? In what ways is it a poor one? Think about membranes and active transport.

Check that you can explain

1. How differentiation depends on gene expression and gradients
2. The two properties of stem cells
3. Two stem cell niches in the adult body
4. Totipotent, pluripotent and multipotent cells
5. How cell size suits a role
6. How to calculate surface area-to-volume ratio, and why it limits cell size

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. State the two properties of a stem cell.
2. Distinguish between pluripotent and multipotent stem cells.
3. A cube has sides of 4 units. Calculate its surface area-to-volume ratio.

Image credits

Red White Blood cells.jpg – Electron Microscopy Facility at The National Cancer Institut – Public domain

Stem cells diagram.png – Mike Jones – CC BY-SA 2.5

Hematopoiesis simple.svg – A. Rad and Mikael Häggström, M.D. Author info – Reusing imag – CC BY-SA 3.0

Blastocyst English.svg – Seans Potato Business (derivative of the source cited above) – CC BY-SA 3.0

Sperm-egg.jpg – Unknown author – Public domain

Hovering Calypte anna.jpg – MesoComet – CC0

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