DP Biology – B2.3 (HL extension)

Specialized cells

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

HL statements B2.3.7–10. Textbook pp. 265–272.

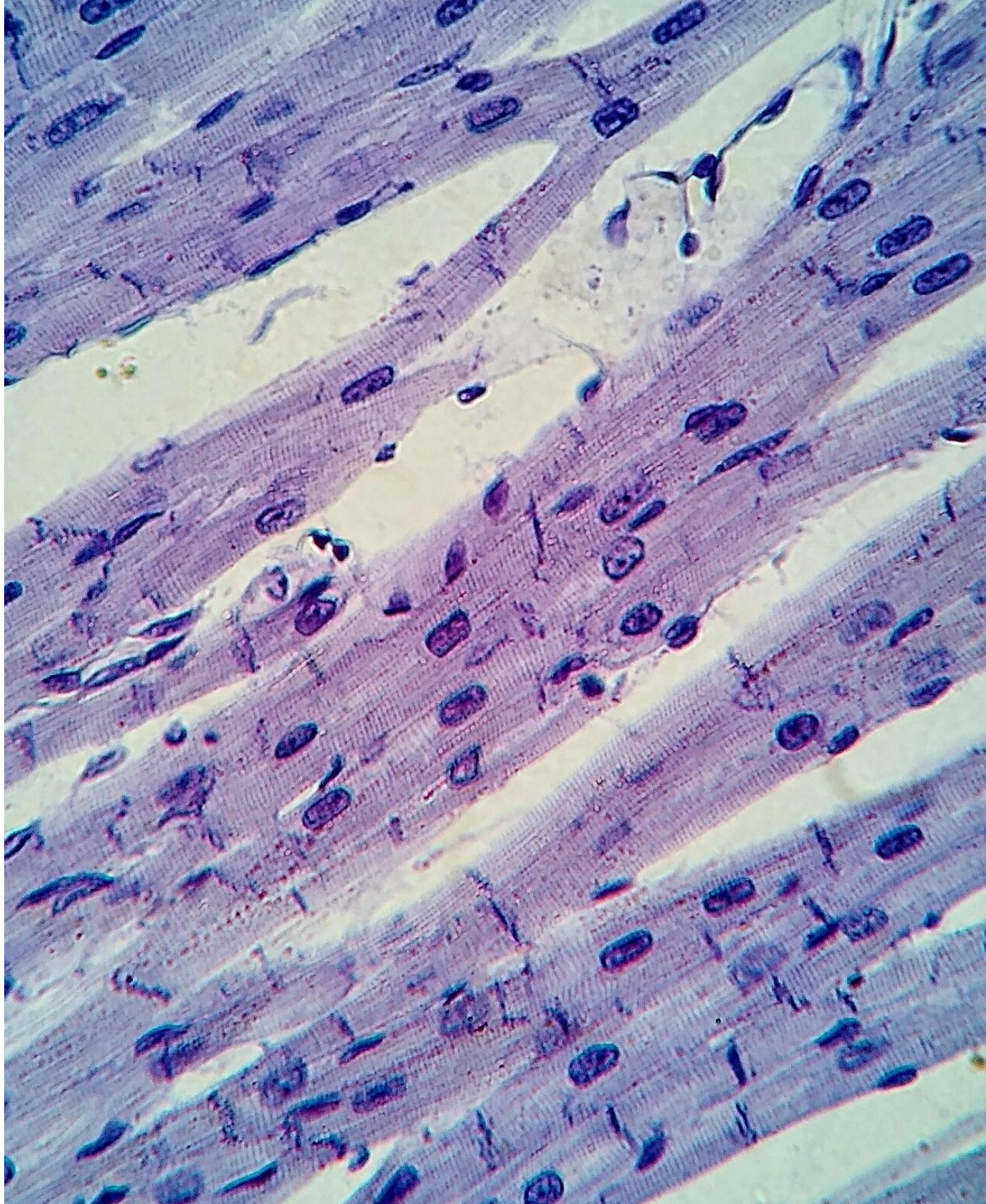


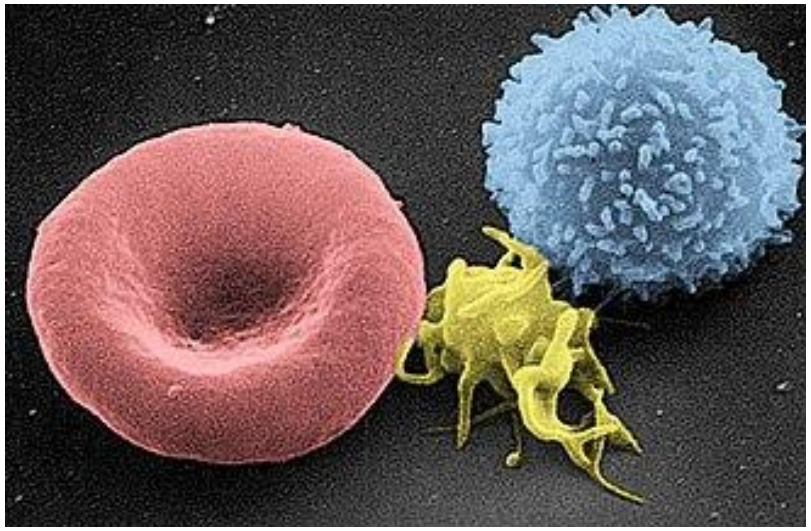
Image: heart muscle cells (light micrograph). A. G. Cheroske, CC BY-SA 4.0.

Objectives for each class

Class	Statements	By the end of the class, you can...
1	B2.3.7–8	Explain how cells increase their surface area-to-volume ratio, and how the two kinds of pneumocyte suit their roles
2	B2.3.9–10	Compare heart muscle cells with skeletal muscle fibres, and explain the adaptations of human sperm and egg cells

More surface for the same volume

B2.3.7



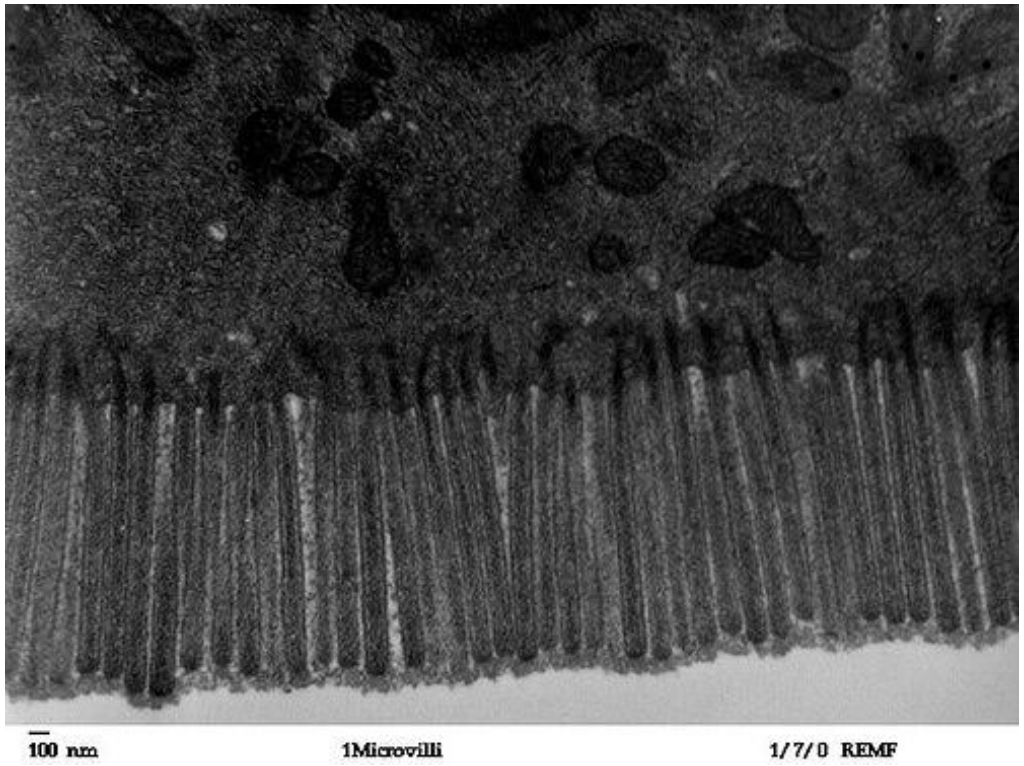
Red blood cell (left) and white blood cells (SEM). NCI, public domain.

Adaptation	How it raises surface area-to-volume ratio
Flattening	A thin cell has more surface per unit volume, and short distances inside
Microvilli	Finger-like projections of the plasma membrane form a brush border
Invagination	Infolding of the plasma membrane, often where active transport happens

Red blood cells

About 8 µm across and biconcave. With no nucleus, the cell can be thin in the middle, so oxygen diffuses a short distance to every haemoglobin molecule. The shape also lets it bend through capillaries. Why do large cells divide, or change shape, rather than just growing?

Proximal convoluted tubule cells



Microvilli forming a brush border (TEM). L. Howard and K. Connollly, public domain.

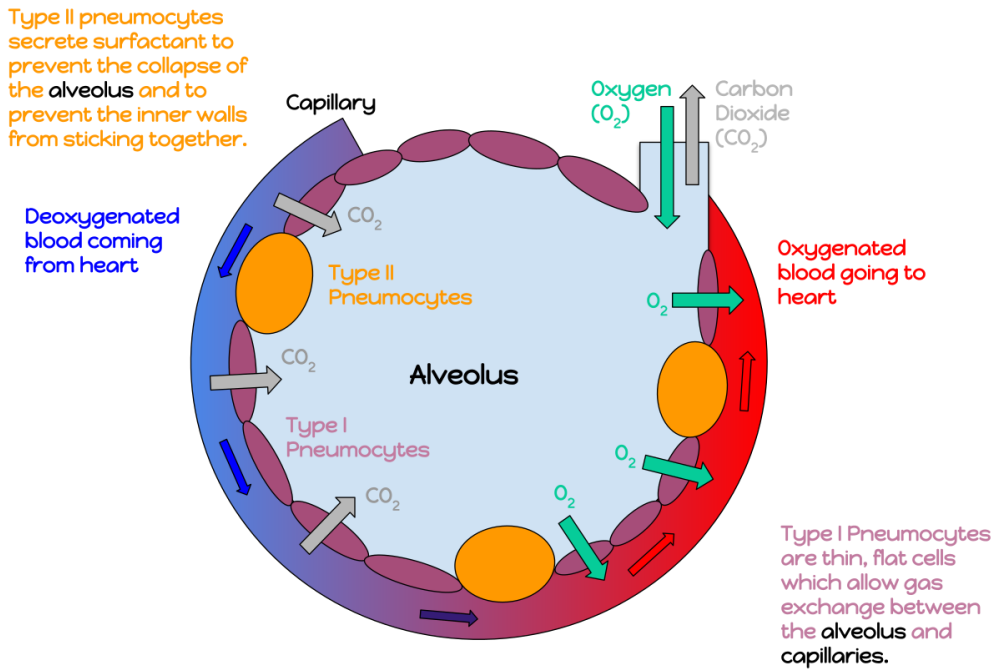
- The tubule reabsorbs glucose, amino acids, ions and water from the filtrate
- The surface facing the filtrate has **microvilli**: a large area for cotransporters
- The surface facing the blood has **invaginations**: a large area for pumps
- Many mitochondria between the infoldings supply ATP for active transport

Link

The same features occur in cells lining the small intestine. Both tissues absorb glucose using sodium-potassium pumps and sodium-dependent cotransporters (B2.1).

Two cell types line each alveolus

B2.3.8



	Type I	Type II
Shape	Very thin and flat	Cuboidal
Share of surface	About 95%	About 5%
Key feature	Little cytoplasm; few organelles	Many lamellar bodies, rough ER, Golgi
Role	Short diffusion distance for gas exchange	Secrete surfactant by exocytosis

Alveolus and its cell types. Katherinebutler1331, CC BY-SA 4.0.

A tissue with two cell types

The alveolar epithelium needs two jobs done that no single cell could do well: very thin walls, and a supply of surfactant.

Why surfactant matters

B2.3.8

- Water lining the alveoli has surface tension, which pulls the walls inwards
- Surfactant (phospholipids and proteins) spreads over this water and lowers surface tension
- So alveoli do not collapse or stick together when we breathe out, and reinflate easily
- Lamellar bodies store surfactant until it is released by exocytosis

Case study

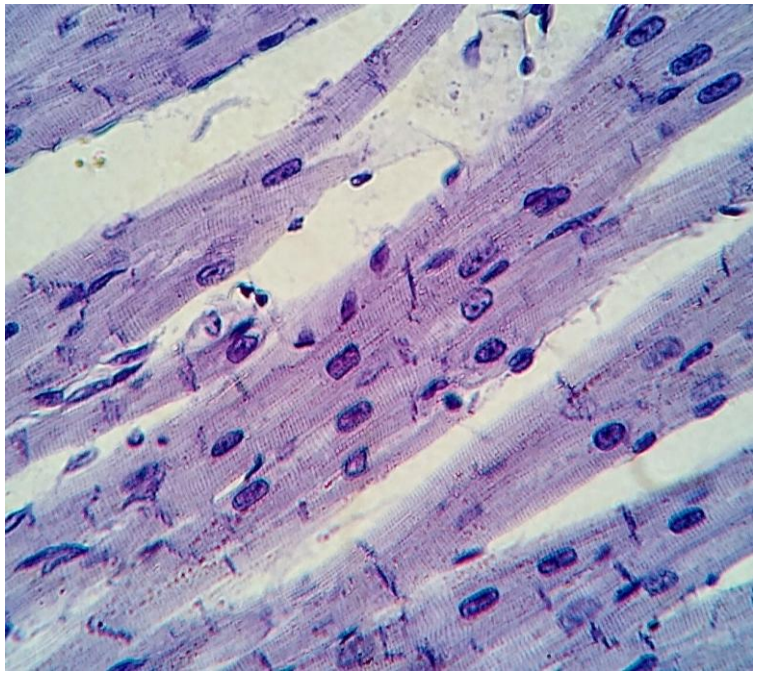
Babies born very early may not yet have enough type II pneumocytes making surfactant. Their alveoli collapse, and breathing is hard (respiratory distress). Treatment includes giving artificial surfactant into the lungs.

Think about it

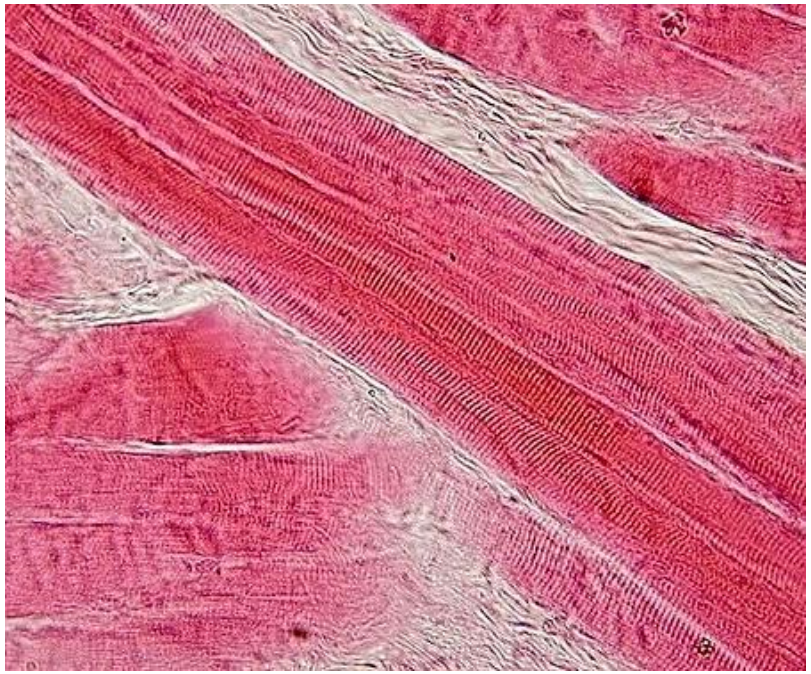
Suggest why type II pneumocytes have more mitochondria and rough ER than type I cells.

Heart muscle and skeletal muscle compared

B2.3.9



Cardiac muscle (light micrograph). A. G. Cheroske, CC BY-SA 4.0.



Striated (skeletal) muscle. CC BY-SA 3.0.

Shared

Both are striated, because myofibrils of actin and myosin are packed in repeating sarcomeres. Both have many mitochondria.

	Cardiac muscle cell	Striated muscle fibre
Shape	Short and branched	Long (up to many cm) and unbranched
Nuclei	One (sometimes two)	Many: formed by fusion of cells
Junctions	Intercalated discs with gap junctions	None between fibres

Why the differences? Is a fibre a cell?

B2.3.9

Feature	Hypothesis
Branching in heart	Spreads the signal in many directions so the heart contracts together
Long fibres	Can shorten a long way along one line of pull
Many nuclei	Enough DNA to supply proteins to a huge volume of cytoplasm

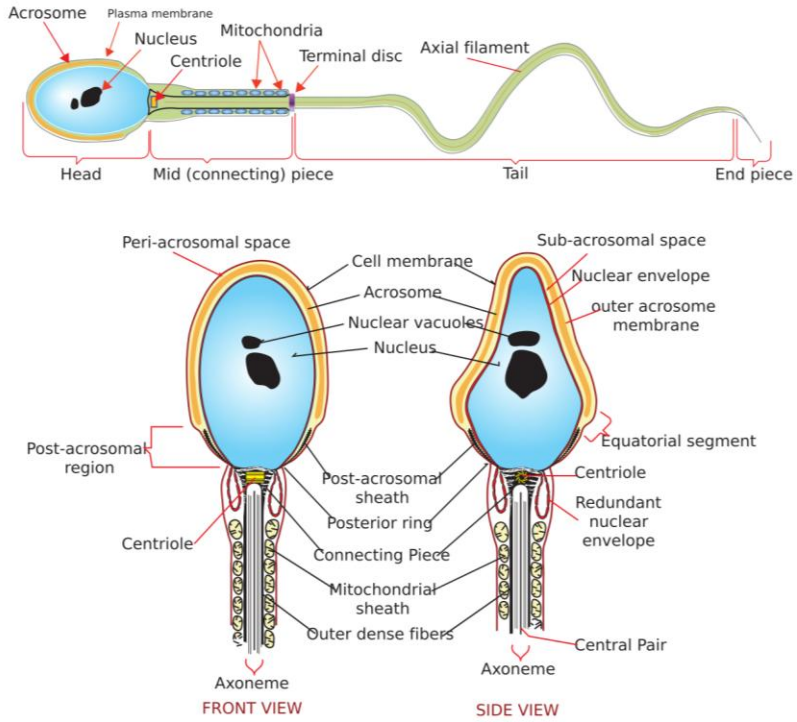
Is a cell	Is not a typical cell
One continuous plasma membrane	Many nuclei
Has usual organelles	Formed by fusion of many cells
Works as one unit	Far larger than most cells

Discuss

Cell theory says cells are the units of life. Does a muscle fibre break the rule, or show that the theory needs careful wording? Decide, and give your best evidence.

The human sperm cell

B2.3.10



Human sperm cell. Mariana Ruiz Villarreal, public domain.

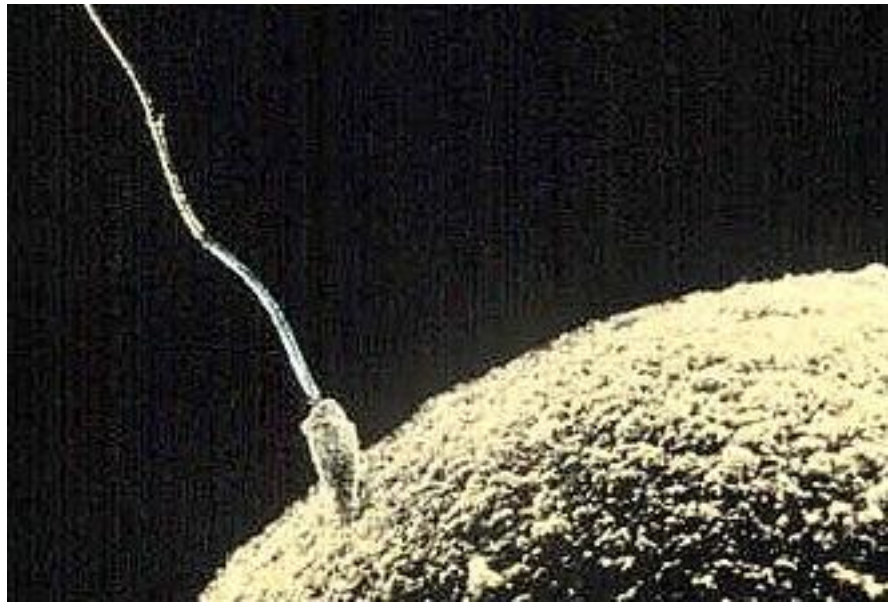
Structure	Adaptation
Acrosome	Enzymes digest the zona pellucida
Haploid nucleus	Half the chromosomes; DNA tightly packed so the head is small
Mid-piece	Many mitochondria supply ATP for swimming
Flagellum	Microtubules (9 + 2) move the cell
Small size, little cytoplasm	Streamlined; many millions can be made

Fate of the mid-piece

The whole sperm usually enters the egg, but its mitochondria are destroyed. So mitochondrial DNA is inherited from the mother.

The human egg cell

B2.3.10



Sperm meeting an egg (SEM). Public domain.

Structure	Adaptation
Large cytoplasm	Nutrients, organelles and mRNA for early development
Haploid nucleus	Arrested in metaphase II until fertilization
Zona pellucida	Sperm bind to it; it hardens to block extra sperm
Cortical granules	Release enzymes that harden the zona after one sperm enters
Follicle cells	Protect and feed the egg

Compare

The egg is about 0.1 mm across, roughly 20 times the length of a sperm head. Explain why the two gametes are so different in size and number.

Check that you can explain

1. Three ways cells raise surface area-to-volume ratio, using red blood cells and PCT cells
2. How the two kinds of pneumocyte differ, and why both are needed
3. Why surfactant prevents alveoli collapsing
4. Similarities and differences between cardiac and striated muscle, with hypotheses for them
5. Whether a striated muscle fibre is a cell
6. Adaptations of human sperm and egg cells

Exit activity: 5 minutes

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

1. State two features of type I pneumocytes that suit gas exchange.
2. Give two differences between heart muscle cells and skeletal muscle fibres.
3. State the role of the acrosome and of cortical granules.

Image credits

Cardiac muscle histology 400x.jpg – Alexander G. Cheroske – CC BY-SA 4.0

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

Human jejunum microvilli 1 – TEM.jpg – Louisa Howard, Katherine Connollly – Public domain

An annotated diagram of an alveolus.svg – Katherinebutler1331 – CC BY-SA 4.0

Skeletal muscle – longitudinal section.jpg – Author not stated – CC BY-SA 3.0

Complete diagram of a human spermatozoa en.svg – Mariana Ruiz Villarreal – Public domain

Sperm-egg.jpg – Unknown author – Public domain

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