BIOZONE

Student Workbook

IB BIOLOGY

SECOND EDITION

FREE SAMPLE for classroom trial

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Topic 1

Cell Biology

Key terms

active transport
amphipathic
binary fission
cell cycle
cell differentiation
cell theory
cyclin
diffusion
electron microscope
endocytosis
endosymbiotic theory
eukaryotic cell
exocytosis
facilitated diffusion
fluid mosaic model
interphase
ion pump
light microscope two lines look like this
metastasis
mitosis
mitotic index
multicellular
mutagen
oncogene
organelle
osmosis
phospholipid
plasma membrane
prokaryotic cell
specialized cell
stem cell
tumour

1.1 Introduction to cells

Understandings, applications, skills

Activity number

☐ 1 Outline the cell theory and the evidence supporting it. Use examples to show that the cell theory is a generalization that applies to most but not all organisms. — 1

TOK *How do we distinguish living from non-living environments?*

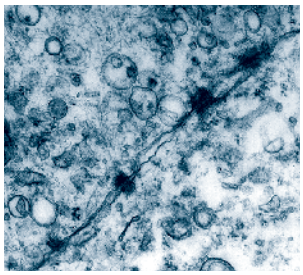
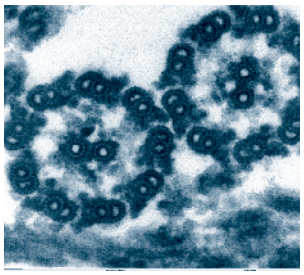
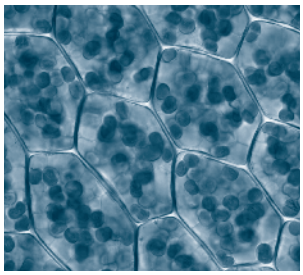
☐ 2 Describe the criteria for life as demonstrated by unicellular organisms. Investigate life functions using *Paramecium* and *Scenedesmus*. — 1 2

☐ 3 Explain the significance of surface area to volume ratio to cell size. — 3

☐ 4 Calculate the magnification of drawings and the size of cell structures in light and electron micrographs and in drawings. — 4 5

☐ 5 Explain how multicellularity results in the emergence of new properties. Explain how specialized tissues develop by cell differentiation during development. — 6 7

☐ 6 Describe the properties of stem cells and explain their role in embryonic development. Explain how stem cells can be used to treat disease. Discuss the ethics of producing and using stem cells for therapeutic use. — 8 9

1.2 Ultrastructure of cells

Understandings, applications, skills

Activity number

☐ 1 Describe the structure and function of a prokaryotic cell, e.g. *E. coli.* Draw the ultrastructure of a prokaryotic cell based on electron micrographs. — 10 12

☐ 2 Describe the process and purpose of binary fission in prokaryotes. — 13

☐ 3 Describe the structure and function of a eukaryotic cell, e.g. liver cell. Compare and contrast the structure of typical plant and animal cells. — 10 14 15

☐ 4 Explain the higher resolution of electron microscopes relative to light microscopes and relate this to the greater cellular detail that can be seen. Draw the ultrastructure of a eukaryotic cell based on electron micrographs. Use electron micrographs to identify cellular structures and deduce the function of specialized cells. — 11 16 17

TOK *Are knowledge claims based on observations made using technology as valid as those made without technological assistance?*

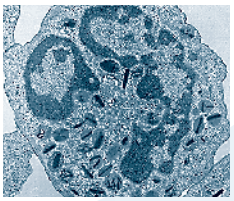
1.3 Membrane structure

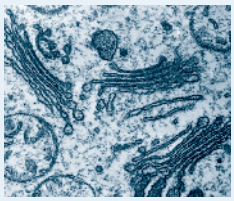
Understandings, applications, skills

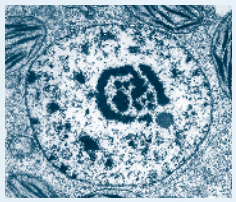
Activity number

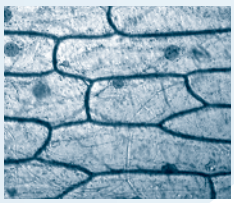
☐ 1 Describe the fluid mosaic model of the plasma membrane, explaining why the phospholipids form a bilayer. Draw a diagram to illustrate the fluid mosaic model including cholesterol and embedded proteins. — 18

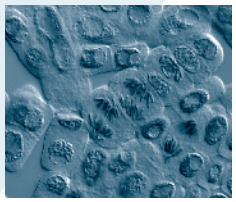
☐ 2 Describe the diversity and roles of proteins in the plasma membrane. — 18











- ☐ 3 Describe how cholesterol regulates membrane fluidity and permeability — 18
- ☐ 4 Analyze evidence from electron microscopy supporting the current fluid mosaic model of membrane structure (and falsification of previous models). — 19

TOK *The models for plasma membrane structure have changed as a result of new evidence and ways of analysis. Why learn about discredited models?*

1.4 Membrane transport

Understandings, applications, skills

Activity number

- ☐ 1 Describe and explain how particles move across membranes by diffusion, facilitated diffusion, osmosis, and active transport. — 20 21 23
- ☐ 2 Explain why tissues used in medical procedures must be bathed in solutions with the same osmolarity as the cytoplasm. — 21
- ☐ 3 Demonstrate the effect of osmosis using hypertonic and hypotonic solutions. — 22
- ☐ 4 Describe active transport using the sodium-potassium pump and facilitated diffusion using potassium channels in axons. — 20 24 26
- ☐ 5 Describe how endocytosis and exocytosis are possible because of the fluid nature of the plasma membrane. Describe how vesicles move material around within the cell. — 25 26

1.5 Origins of cells

Understandings, applications, skills

Activity number

- ☐ 1 Understand that cells can only form by division of pre-existing cells. Explain how Pasteur's experiments dispelled the idea of spontaneous generation — 1 27
- ☐ 2 Explain how the first cells might have originated and describe any supporting evidence. — 28
- ☐ 3 Explain the endosymbiotic theory for the origin of eukaryotic cells and the evidence for it. Know that almost universal nature of the genetic code indicates a common origin of life. — 29 30

1.6 Cell division

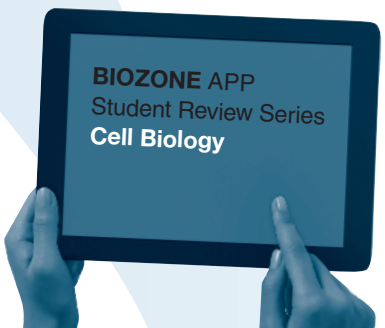
Understandings, applications, skills

Activity number

- ☐ 1 Describe the outcome of mitotic division and explain its role in eukaryotes. — 31
- ☐ 2 Describe mitosis as a continuous process, with distinct stages. Recognize and describe the events in the following stages in mitosis: prophase, metaphase, anaphase, telophase. — 32
- ☐ 3 Recognize stages in the eukaryotic cell cycle: interphase, mitosis, cytokinesis. Describe the events occurring during interphase stages: G1, S, and G2. — 32
- ☐ 4 Identify phases of mitosis from micrographs. Determine the miotic index of a cell from micrographs. — 33
- ☐ 5 Explain the regulation of the cell cycle by cyclins. — 34

TOK *Cyclins were discovered by 'accident' when researchers were studying development in marine invertebrates. To what extent are new discoveries the result of intuition rather than luck?*

- ☐ 6 Explain how mutagens, oncogenes, and metastasis are involved in tumor development. Discuss the correlation between smoking and the incidence of cancer. — 35



2 Unicellular Eukaryotes

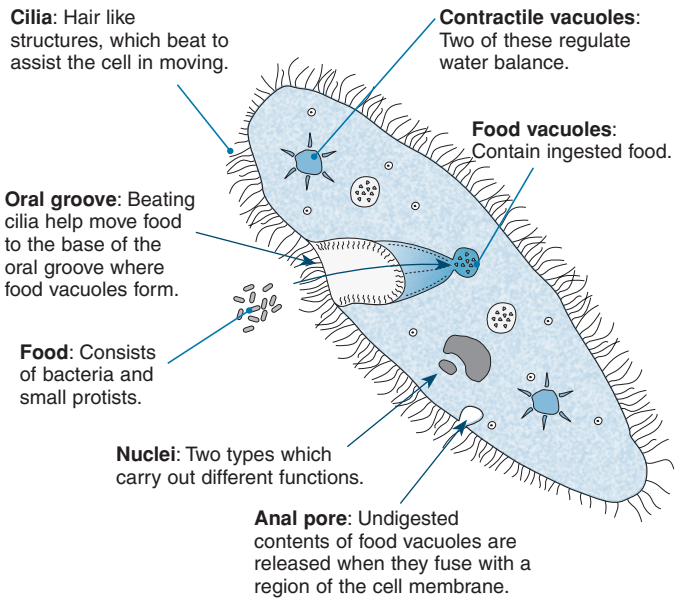
Key Idea: Unicellular organisms are able to perform all life functions, although there is a large amount of diversity in the way they do so.

Unicellular (single-celled) **eukaryotes** comprise the majority of the diverse kingdom, **Protista**. They are found almost anywhere there is water, including within larger organisms (as parasites or symbionts). The protists are a very diverse group, exhibiting some features typical of generalized eukaryotic cells, as well as specialized features, which may be specific to one genus. *Paramecium* (below left) is **heterotrophic**, ingesting food particles. *Scenedesmus* (below right) is autotrophic. The typical mode of reproduction in most of the major protistan taxa is asexual **binary fission**. Most can also reproduce sexually, most commonly by syngamy (fusion of gametes to produce a zygote).

Paramecium

Paramecium is a common protozoan in freshwater and marine environments. It feeds on bacteria, algae, and yeasts, sweeping them into the oral grove with its cilia. There are numerous species of Paramecium which range in size from 50 µm to 300 µm long.

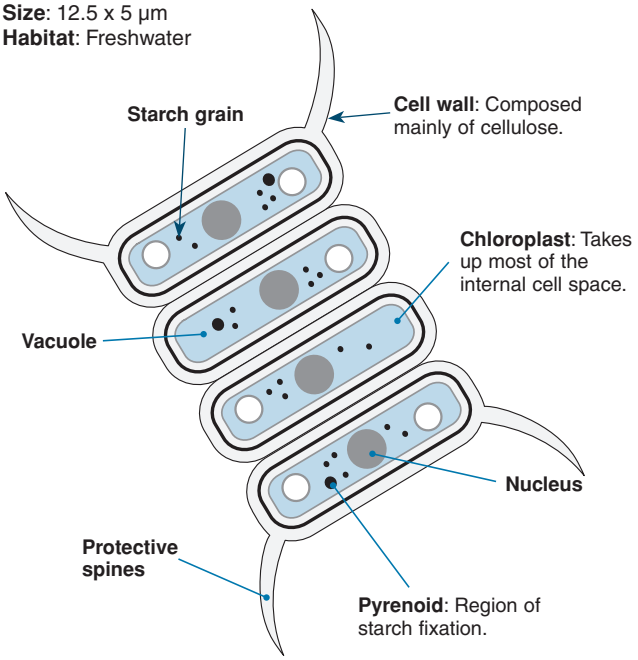
Size: 240 x 80 µm
Habitat: Freshwater, sea water



Scenedesmus

Scendesmus is a freshwater algae that forms colonies of 4, 8, or sometimes 16 cells. Its colonial existence and the outer spines give it protection from predators (e.g. *Daphnia*). Spines normally only grow from the outer most cells in the colony.

Size: 12.5 x 5 µm
Habitat: Freshwater



1. Identify two ways *Scenedesmus* defends against predators: _____

2. Suggest why *Scenedesmus* colonies commonly consists of 4, 8 or 16 cells: _____

3. Explain how the life function of nutrition is carried out by:

   (a) *Paramecium*: _____

   (b) *Scenedesmus*: _____

4. Suggest why *Paramecium* needs to be particularly mobile: _____

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5 Calculating Linear Magnification

Key Idea: Magnification is how much larger an object appears compared to its actual size. It can be calculated from the ratio of image height to object height.

Microscopes produce an enlarged (magnified) image of an object allowing it to be observed in greater detail than is possible with the naked eye. **Magnification** refers to the number of times larger an object appears compared to its actual size. **Linear magnification** is calculated by taking a ratio of the image height to the object's actual height. If this ratio is greater than one, the image is enlarged, if it is less than one, it is reduced. To calculate magnification, all measurements should be converted to the same units. Most often, you will be asked to calculate an object's actual size, in which case you will be told the size of the object and given the magnification.

Calculating Linear Magnification: A Worked Example

1. Measure the body length of the bed bug image (right). Your measurement should be 40 mm (***not*** including the body hairs and antennae).

2. Measure the length of the scale line marked 1.0 mm. You will find it is 10 mm long. The magnification of the scale line can be calculated using equation 1 (below right).

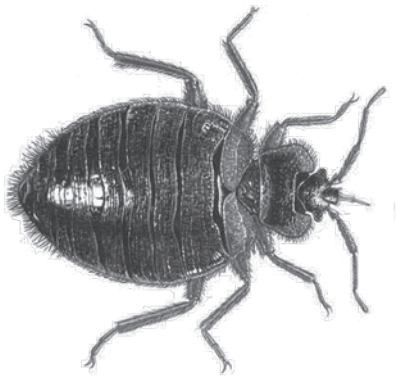
   The magnification of the scale line is **10** (10 mm / 1 mm)

   **NB: The magnification of the bed bug image will also be 10x because the scale line and image are magnified to the same degree.*

3. Calculate the actual (real) size of the bed bug using equation 2 (right):

   The actual size of the bed bug is **4 mm**
   (40 mm / 10 x magnification)

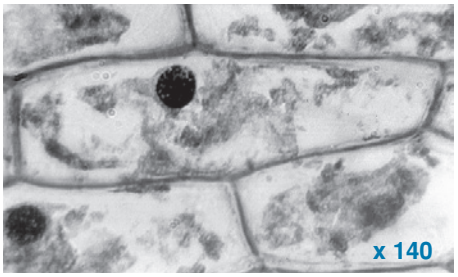
1.0 mm



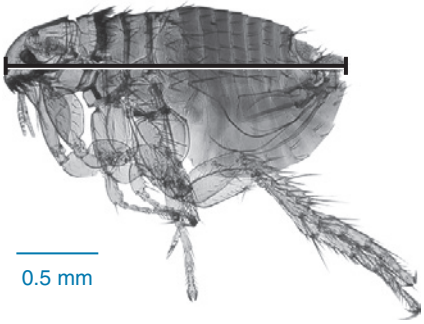
Microscopy Equations

1. **Magnification = size of the image / actual size of object**

2. **Actual object size = size of the image / magnification**



1. The bright field microscopy image on the left is of onion epidermal cells. The measured length of the onion cell in the centre of the photograph is 52,000 µm (52 mm). The image has been magnified 140 x. Calculate the actual size of the cell:

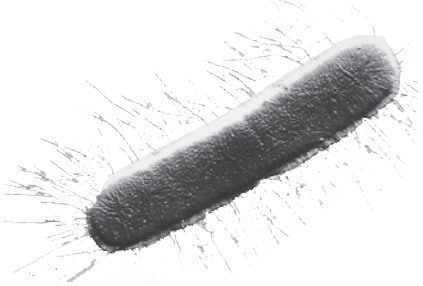


0.5 mm

2. The image of the flea (left) has been captured using light microscopy.

   (a) Calculate the magnification using the scale line on the image:

   (b) The body length of the flea is indicated by a line. Measure along the line and calculate the actual length of the flea:



3. The image size of the *E.coli* cell (left) is 43 mm, and its actual size is 2 µm. Using this information, calculate the magnification of the image:

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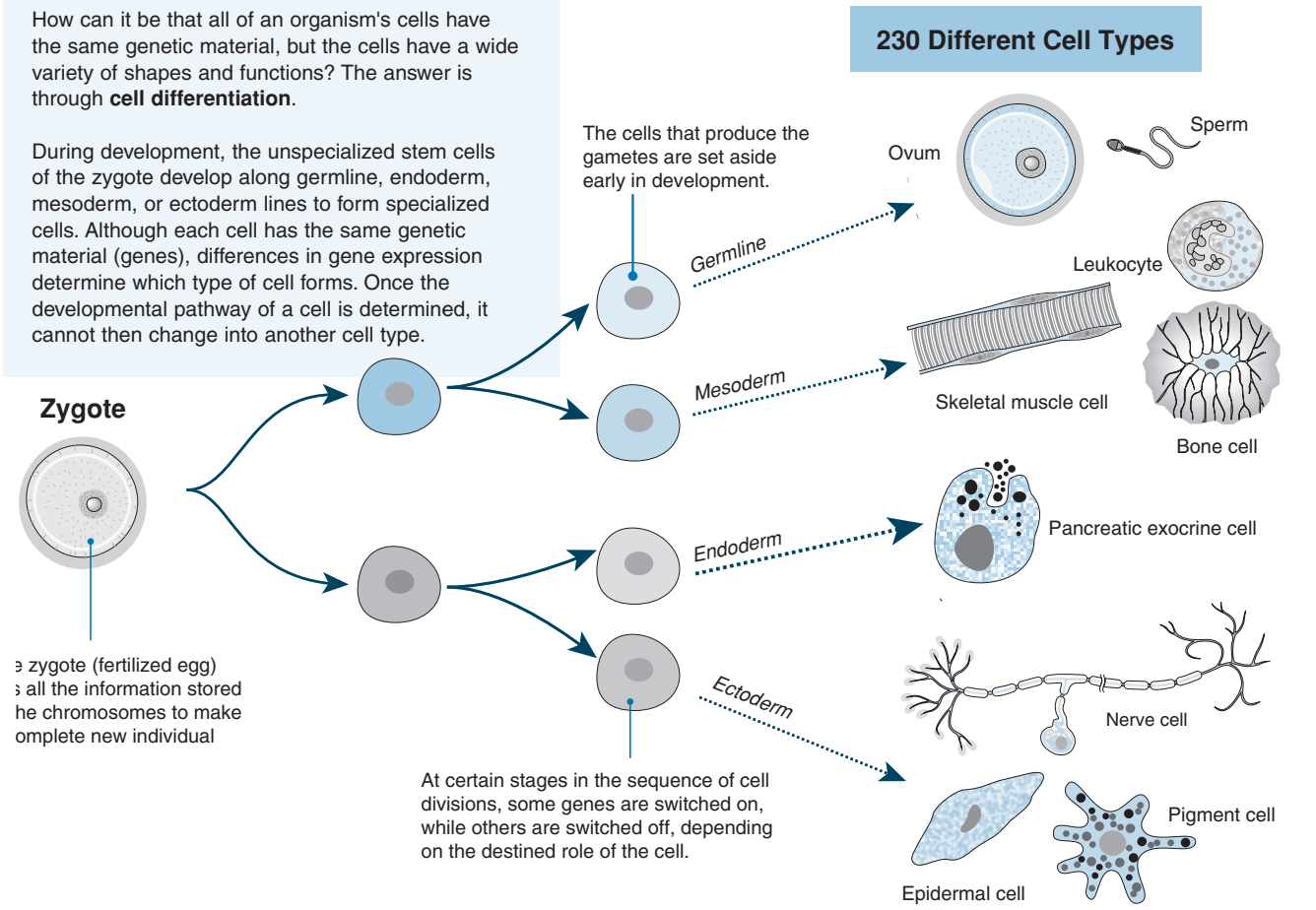
6 Multicellularity

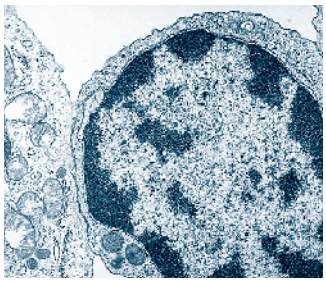
Key Idea: Specialized cells and tissues arise through cell differentiation, which is regulated through differential gene expression. The complex interactions of cells in multicellular organisms results in the emergence of new properties.

The cell is the site of life. It is the functioning unit structure from which living organisms are made. In multicellular organisms, specialized cells with specific functions are produced by cell differentiation. Those with related functions associate to form tissues and tissues are organized into organs. With each step in this hierarchy of biological order, new properties emerge that were not present at simpler levels of organization. Life is an emergent property of billions of chemical reactions that are driven by the input of energy that produces work and results in decreased entropy (disorder) within the system.

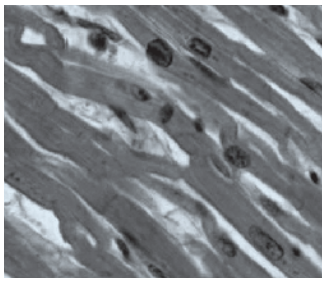
How can it be that all of an organism's cells have the same genetic material, but the cells have a wide variety of shapes and functions? The answer is through **cell differentiation**.

During development, the unspecialized stem cells of the zygote develop along germline, endoderm, mesoderm, or ectoderm lines to form specialized cells. Although each cell has the same genetic material (genes), differences in gene expression determine which type of cell forms. Once the developmental pathway of a cell is determined, it cannot then change into another cell type.

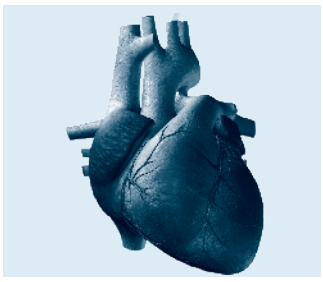




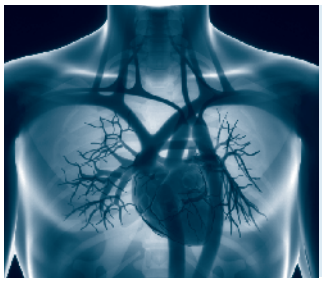
The continuous biochemical reactions in all cells produce the emergent property of metabolism.



Muscle tissue displays the emergent properties of forceful contraction and elasticity (recovery to original shape).



Muscle and other tissues associate to form organs. The heart shows properties of contraction and relaxation and control of blood flow.



Organs work together as organ systems. The circulatory system show the emergent properties of circulation and exchange.

1. Using examples, explain the concept of emergent properties: _____

2. Explain how cellular differentiation allows a multicellular organism to carry out complex functions: _____

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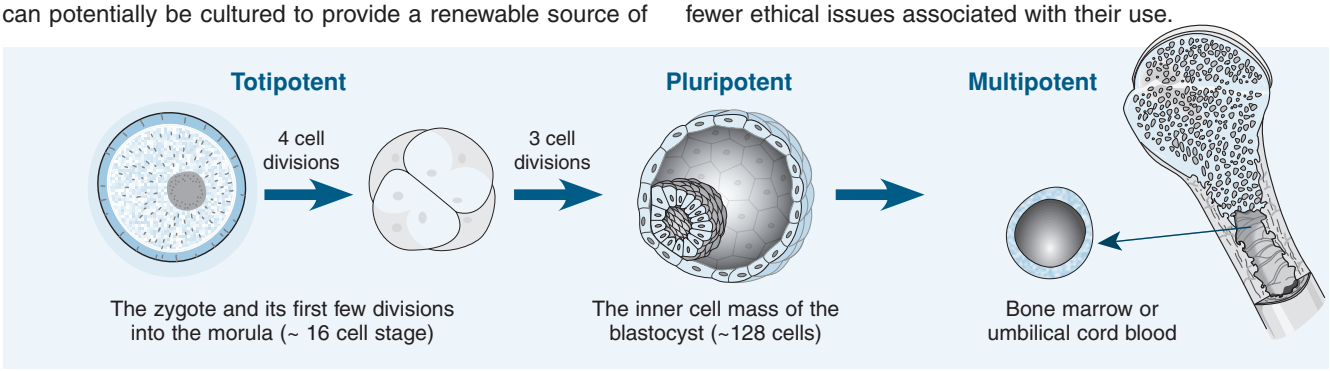
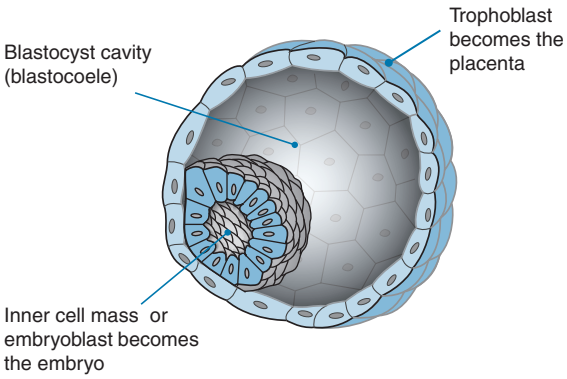
8 Types of Stem Cells

Key Idea: The potency of stem cells depends on their origin. Both embryonic and adult stem cells can be used to replace diseased and damaged tissue.

The properties of self renewal and potency make stem cells suitable for a wide range of applications. Stem cells from early stage embryos (embryonic stem cells) are pluripotent and can potentially be cultured to provide a renewable source of cells for studies of human development and gene regulation, for tests of new drugs and vaccines, for monoclonal antibody production, and for treating any type of diseased or damaged tissue. Adult stem cells from bone marrow or umbilical cord blood can give rise to a more limited number of cell types. Although their potential use is more restricted, there are fewer ethical issues associated with their use.

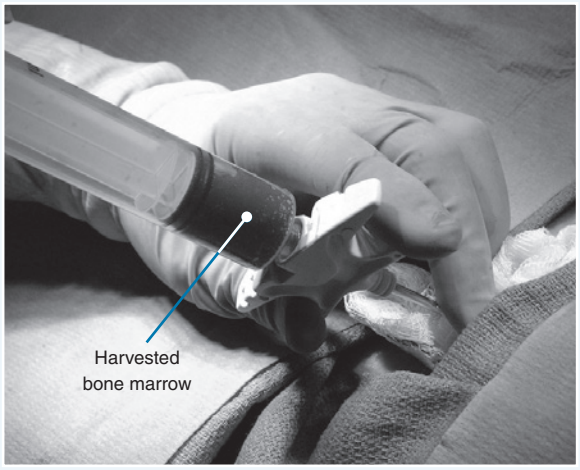


Embryonic Stem Cells



Embryonic stem cells (**ESC**) are derived from the inner cell mass of blastocysts (above). Blastocysts are embryos that are about five days old and consist of a hollow ball of 50-150 cells. Cells derived from the inner cell mass are **pluripotent**. They can become any cells of the body, with the exception of placental cells. When cultured without any stimulation to differentiate, ESC retain their potency through multiple cell divisions. This means they have great potential for therapeutic use in regenerative medicine and tissue replacement. However, the use of ESC involves the deliberate creation and destruction of embryos and is therefore unacceptable to many.

Adult Stem Cells



Adult stem cells (ASC) are undifferentiated cells found in several types of tissues (e.g. brain, bone marrow, fat, and liver) in adults, children, and umbilical cord blood. Unlike ESCs, they are **multipotent** and can only differentiate into a limited number of cell types, usually related to the tissue of origin. There are fewer ethical issues associated with using ASC for therapeutic purposes, because no embryos are destroyed. For this reason, ASC are already widely used to treat a number of diseases including leukemia and other blood disorders.

1. (a) Distinguish between embryonic stem cells and adult stem cells with respect to their **potency**:

(b) What is the significance of this difference to their use in the treatment of disease:

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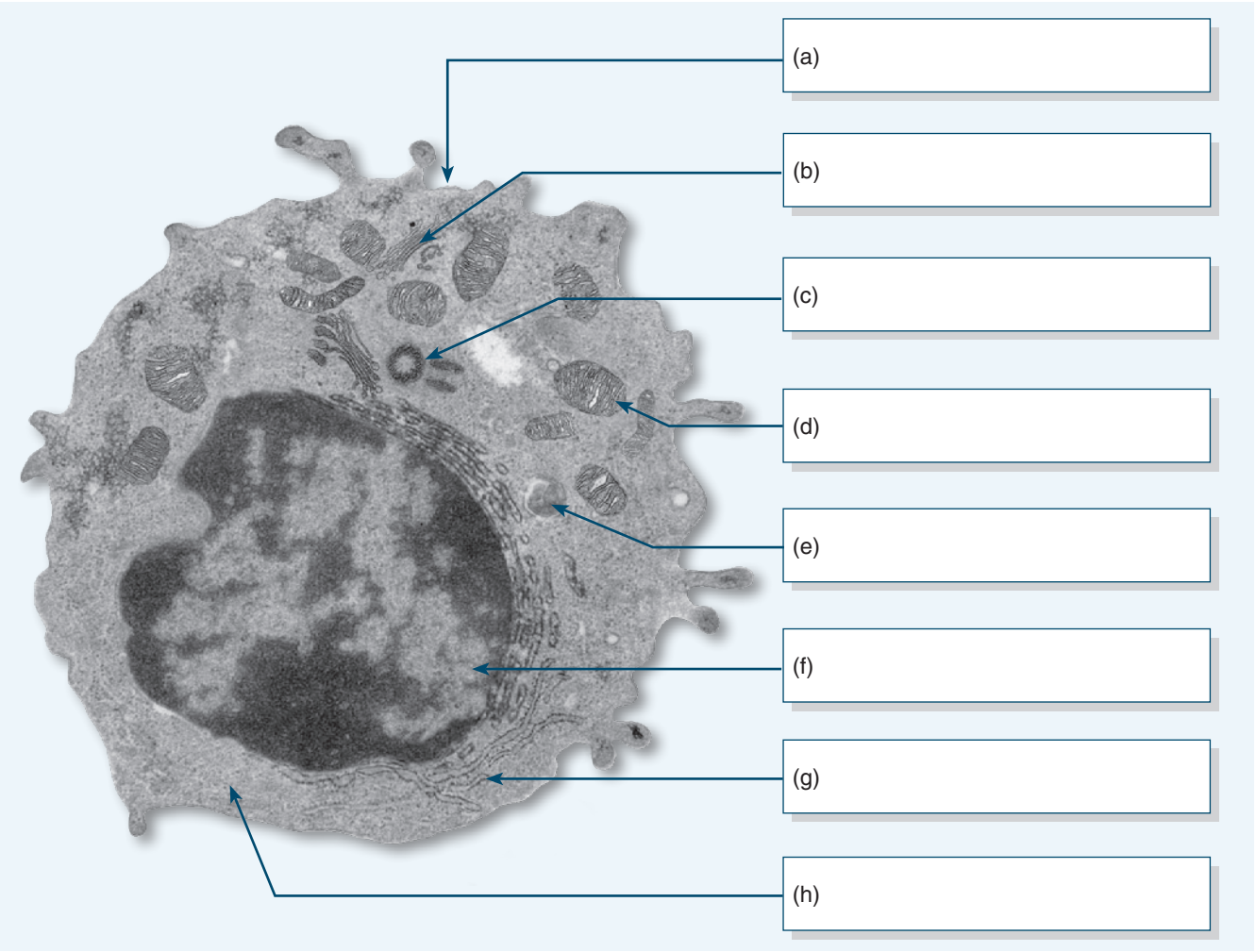
16 Identifying Structures in an Animal Cell

Key Idea: The position of the organelles in an electron micrograph can result in variations in their appearance.

Our current knowledge of cell ultrastructure has been made possible by the advent of electron microscopy. Transmission electron microscopy is the most frequently used technique for viewing cellular organelles. When viewing TEMs, the cellular organelles may appear to be quite different depending on whether they are in transverse or longitudinal section.



1. Identify and label the structures in the cell above using the following list of terms: *cytoplasm, plasma membrane, rough endoplasmic reticulum, mitochondrion, nucleus, centriole, Golgi apparatus, lysosome*

2. Which of the organelles in the EM above are clearly obvious in both transverse and longitudinal section?

3. Why do plants lack any of the mobile phagocytic cells typical of animals?

4. The animal pictured above is a lymphocyte. Describe the features that suggest to you that:

   (a) It has a role in producing and secreting proteins:

   (b) It is metabolically very active:

5. What features of the lymphocyte cell above identify it as eukaryotic?

6. Draw a generalized animal cell to include the features noted above. Staple it into your workbook.

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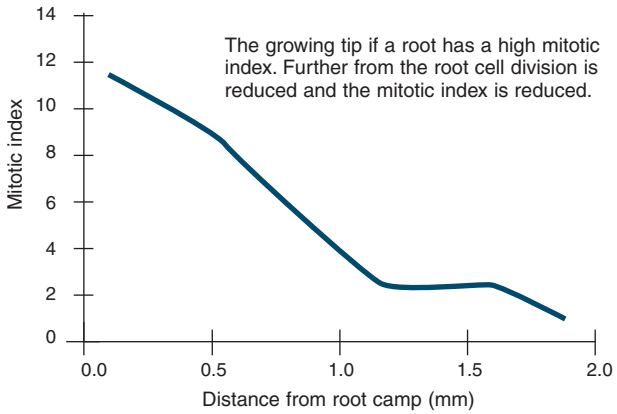
33 Recognizing Stages in Mitosis

Key Idea: The stages of mitosis can be recognized by the organization of the cell and chromosomes.
Although mitosis is a continuous process it is divided into four stages (prophase, anaphase, metaphase, and telophase) to more easily describe the processes occurring throughout mitosis.

The Mitotic Index

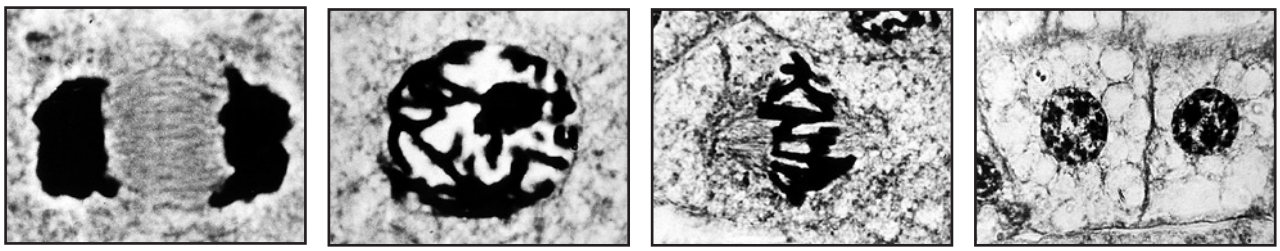
The mitotic index measures the ratio of cells in mitosis to the number of cells counted. It is a measure of cell proliferation and can be used to diagnose cancer. In areas of high cell growth the mitotic index is high such as in plant apical meristems or the growing tips of plant roots. The mitotic index can be calculated using the formula:

$$\text{Mitotic index} = \frac{\text{Number of cells in mitosis}}{\text{Total number of cells}}$$



The growing tip if a root has a high mitotic index. Further from the root cell division is reduced and the mitotic index is reduced.

1. Use the information on page 40 to identify which stages of mitosis is shown in each of the photographs below:



Photos: RCN

(a) _____ (b) _____ (c) _____ (d) _____

2. (a) The light micrograph (right) shows a section of cells in an onion root tip. These cells have a cell cycle of approximately 24 hours. The cells can be seen to be in various stages of the cell cycle. By counting the number of cells in the various stages it is possible to calculate how long the cell spends in each stage of the cycle. Count and record the number of cells in the image which are undergoing mitosis and those that are in interphase. Estimate the amount of time a cell spends in each phase.

Stage	No. of cells	% of total cells	Estimated time in stage
Interphase			
Mitosis			
Total		100	

(b) Use your counts from 2(a) to calculate the mitotic index for this section of cells.

_____

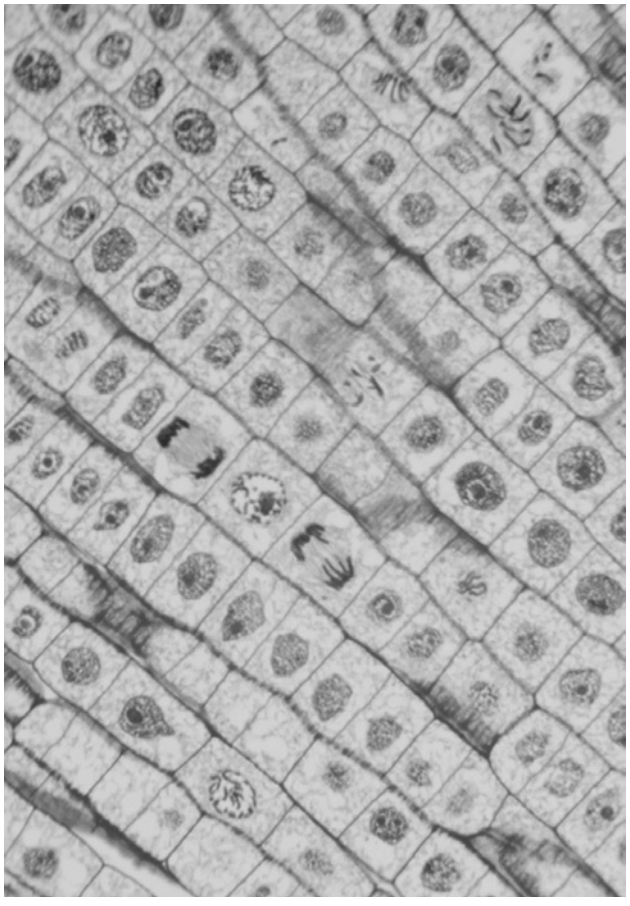
_____

3. What would you expect to happen to the mitotic index of a populations of cells that loses the ability to divide as they mature?

_____

_____

Onion root tip cells



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