OXFORD IB DIPLOMA PROGRAMME

SECOND EDITION

BIOLOGY

COURSE COMPANION

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OXFORD

Biology: 2nd edition

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- **TOK is integrated** throughout to help keep your teaching in line with the Learner Profile
- *Thinking about science* sections help students **make connections between the theory and the real world**, in line with the Learner Profile

Contents

3 Cell division

All living organisms need to produce new cells. They can only do this by division of pre-existing cells.

Cell division in prokaryotic cells is called binary fission and it is used for asexual reproduction. It involves the replication of the single circular chromosome. The two copies of the chromosome move to opposite ends of the cell. Division of the cytoplasm to form two cells quickly follows. This process is called cytokinesis.

In eukaryotic cells, division of the nucleus to form two genetically identical nuclei is termed mitosis. DNA replication before mitosis converts all of the chromosomes from a single DNA molecule into two identical DNA molecules, called chromatids. During mitosis, one of these chromatids passes to each daughter nucleus. The daughter nuclei are therefore genetically identical to each other and to the original parent nucleus. Mitosis occurs before the cytoplasm is split by cytokinesis, so the two daughter cells can therefore each receive one of the nuclei.

Mitosis is involved whenever cells with genetically identical nuclei are required in eukaryotes: during growth, embryonic development, tissue repair and asexual reproduction.

Although mitosis is a continuous process, cytologists have divided the events into four phases: prophase, metaphase, anaphase and telophase. The events that occur in these phases are described on pages 40 and 41.

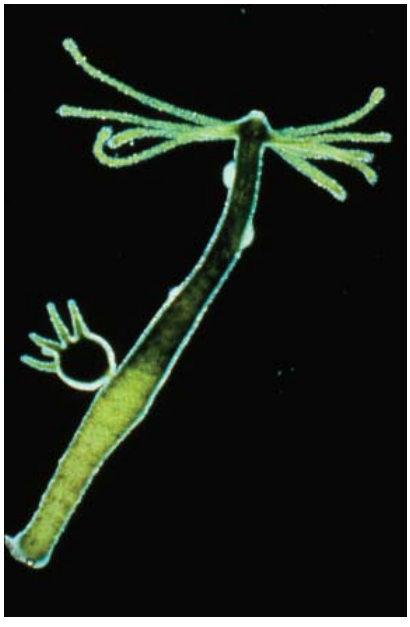


Figure 1 *Hydra viridissima* with a small new polyp attached, produced by asexual reproduction involving mitosis

Rediscovering biology: determining the mitotic index

- Obtain a prepared slide of an onion root tip. Find and examine the meristematic region, i.e. a region of rapid cell division.
- Create a tally chart. Classify each of about 100 cells in this region as being either in interphase or in any of the stages of mitosis.
- Use this data to calculate the mitotic index; i.e. the fraction of cells undergoing mitosis per 1000.

The mitotic index is an important diagnostic signal in the classification of tumours.

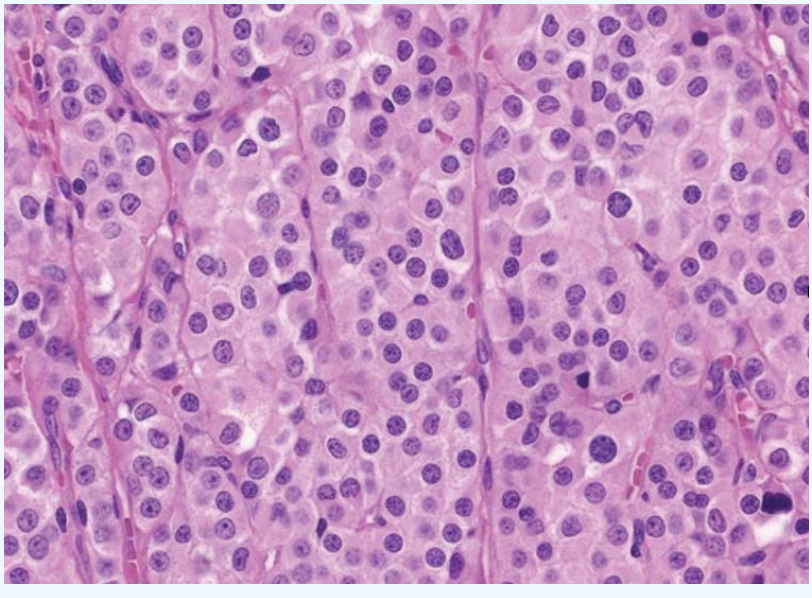


Figure 2 Cells undergoing mitosis in a Leydig cell tumour

Interphase and the cell cycle

The life of a cell can be thought of as an ordered sequence of events, called the cell cycle. The cell cycle refers to the events between one cell division and the next in a eukaryotic cell. It can be roughly divided into interphase and cell division. Interphase is an active period in the life of a cell when many metabolic reactions occur, including protein synthesis, DNA replication and an increase in the number of mitochondria and/or chloroplasts. It is not necessarily a period of preparation for mitosis, as a cell can remain in interphase indefinitely.

Interphase consists of three phases, the G1 phase, S phase and G2 phase. During the S phase the cell copies all genetic material, so that after mitosis both new cells have a complete set of genes.

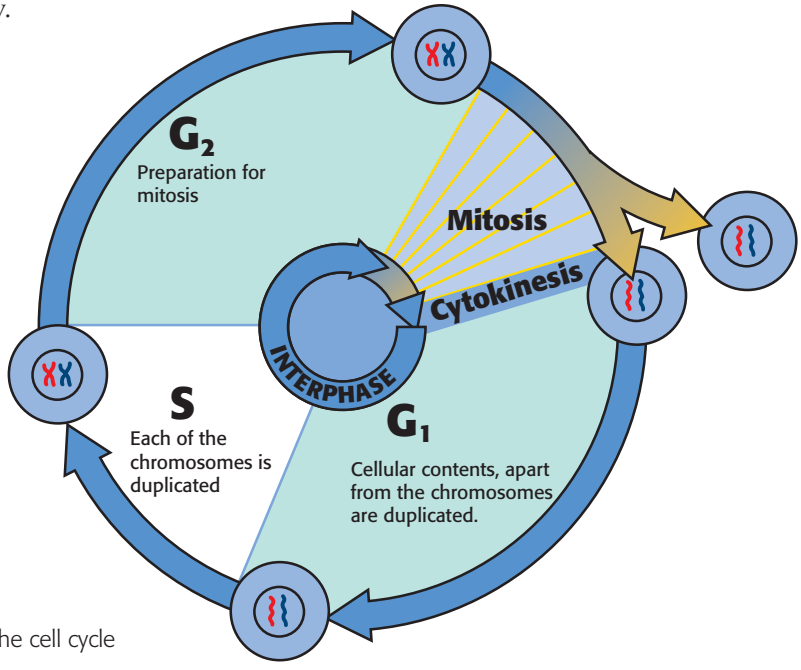


Figure 3 The cell cycle

Data-based question: *cell size and the cell cycle*

Figure 4 shows the daily life cycle pattern of *Emiliania huxleyi* (a species of phytoplankton) as observed under laboratory conditions. The hypothesis is that the cell cycle appears to be timed so that the light period can be used for photosynthesis linked to growth whereas energy consuming processes can occur in the dark, the daughter cells being prepared for photosynthesis by the onset of the next day.

1 State the time of day when:

a) most DNA replication occurs

b) when mitosis is most likely to occur. [2]

2 Identify the cell cycle stage when most of the increase in cell size is occurring. [1]

3 Evaluate the claim that the timing of the cell cycle in *Emiliania huxleyi* is an adaptation to take advantage of light resources. [3]

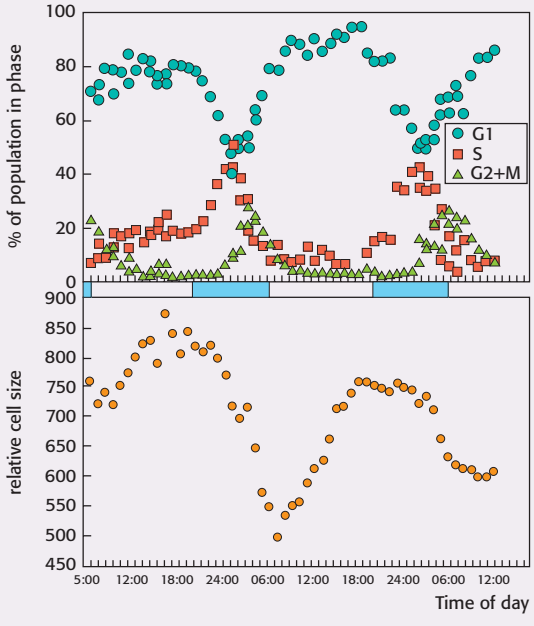
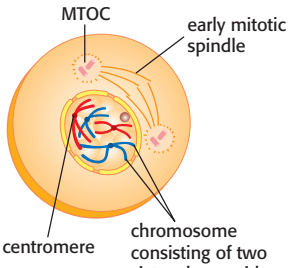
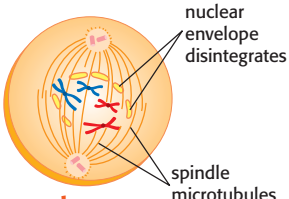


Figure 4 The cell cycle in *Emiliania huxleyi* follows a daily pattern

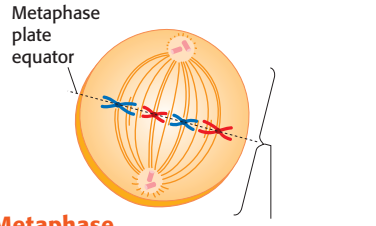
Mitosis - prophase and metaphase



Early prophase



Late prophase



Metaphase

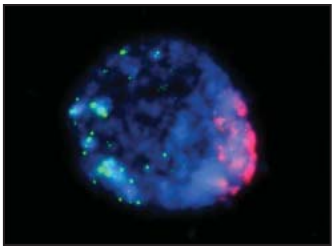
Prophase

The chromosomes become shorter and fatter by coiling. To become short enough they have to coil repeatedly. This is called supercoiling. At the end of prophase the nuclear membrane breaks down.

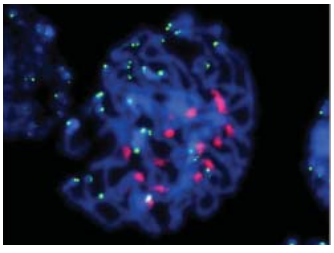
Microtubules grow from the poles of the cell from a structure called the microtubule organizing centre (MTOC) to the chromosomes. These microtubules form a spindle shape and so the MTOCs together with the microtubules are referred to as the mitotic spindle.

Metaphase

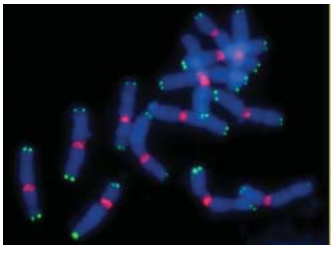
Spindle microtubules attach to the centromeres.Chromosomes are moved to the equator of the cell, with a spindle microtubule attached to one of the sister chromatids from one pole and another spindle microtubule attached to the opposite sister chromatid from the other pole.



Interphase



Prophase



Metaphase

Data-based question: *centromeres and telomeres*

Figure 5 and the other micrographs on this page and page 41 show cells undergoing mitosis. The DNA has been stained blue. The centromeres have been stained with a red fluorescent dye. At the ends of the chromosomes there are structures called telomeres. These have been stained with a green fluorescent dye.

Figure 5 shows a cell that has been squashed to burst it so that the chromosomes spread and are easier to see.

1 Deduce the stage of mitosis that the cell was in, giving reasons for your answer. [3]

2 The cell has an even number of chromosomes.

a) State how many chromosomes there are in this cell. [1]

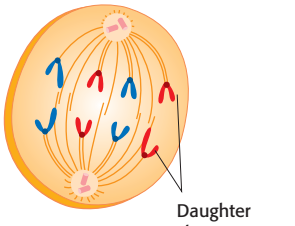
b) Explain the reason for body cells in plants and animals having an even number of chromosomes. [2]

c) In the micrograph of a cell in interphase, the centromeres are on one side of the nucleus and the telomeres are on the other side. Suggest reasons for this. [2]

d) An enzyme called telomerase lengthens the telomeres, by adding many short repeating base sequences of DNA. This enzyme is only active in the germ cells that are used to produce gametes. When DNA is replicated during the cell cycle in body cells, the end of the telomere cannot be replicated, so the telomere becomes shorter. Predict the consequences for a plant or animal of the shortening of telomeres. [2]

Figure 5 Cell in mitosis

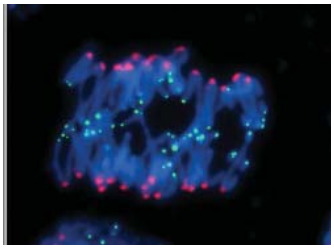
Mitosis - anaphase and telephase



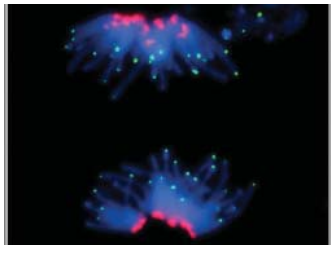
Anaphase

Anaphase

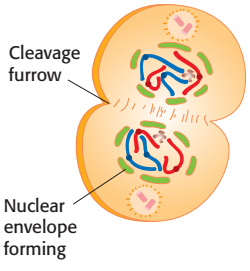
At the start of anaphase, the pairs of sister chromatids separate and the spindle microtubules pull them towards the poles of the cell. Until then the centromeres had held them together. Mitosis produces two genetically identical nuclei because sister chromatids are pulled to opposite poles. To ensure this, the centromeres of sister chromatids must be attached in metaphase to spindle microtubules from different poles.



Early anaphase



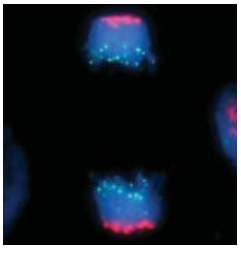
Late anaphase



Telophase

Telophase

Nuclear membranes reform around the chromatids, now called chromosomes, at each pole. The chromosomes uncoil, the cell divides and the two daughter cells enter interphase again.



Telophase

Working with data: using Excel to construct a pie graph

1. To estimate the relative length of each stage of the cell cycle, the number of cells in each stage can be counted, as in the sample data in Table 1.
2. To construct a pie graph of the data, open an Excel spreadsheet.
3. Enter the names of the phases of the cell cycle in the first column.
4. Enter the total number of cells in the corresponding phase in the second column. Your table should look like Table 1. Enter the total number of cells in the corresponding phase in the second column.
5. Highlight both columns and then click on the "Insert" menu.
6. For a colour pie chart (Figure 6), choose "Pie" from the "Chart type" list. For black and white, click on the "Custom type" tab and choose "B&W Pie".
7. Click "Next" and then from the "Data Range" window, press "Next" again.
8. Give the chart a title by choosing the "Title" tab and typing a title in the "Chart title" field. A suitable title might be "Fraction of total cells in each of the phases of the cell cycle".
9. Choose the "Legend" tab, click "Show legend" and for the "Placement" choose "Right". Alternatively you can have labels rather than a key, as in the diagram on the right. For this option, choose the "Data labels" tab and click on "percentage". Choose "Category name" as well.

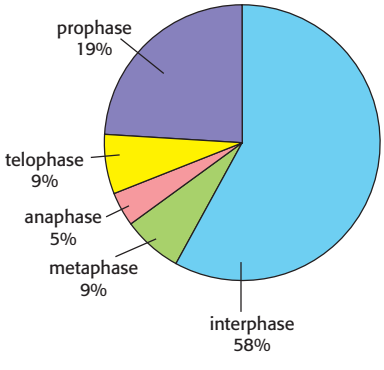


Table 1	
metaphase	20
anaphase	10
telophase	20
prophase	40
interphase	125

Figure 6 Fraction of total cells in each of the phases of the cell cycle.

Cancer

The cell division cycle is regulated in a number of ways. Agents such as ultraviolet light, chemicals called carcinogens, and viruses can damage the cycle. When this happens, uncontrolled cell division can occur resulting in the formation of tumours. This can happen in any organ or tissue. If a tumour is malignant, cells can become detached and move to other parts of the body, where they develop into secondary tumours.

Thinking about science

Abridged from "The Median is not the Message" by Steven Jay Gould, *Discover* magazine, 1985.

This is a personal story of statistics, properly interpreted, as profoundly nurturant and life-giving. It declares war on the downgrading of intellect by telling a small story about the utility of dry, academic knowledge about science. Heart and head are focal points of one body, one personality.

In July 1982, I learned that I was suffering from abdominal mesothelioma, a rare and serious cancer usually associated with exposure to asbestos. When I revived after surgery, I asked my first question of my doctor and chemotherapist: "What is the best technical literature about mesothelioma?" She replied, with a touch of diplomacy… that the medical literature contained nothing really worth reading.

As soon as I could walk, I made a beeline for Harvard's Countway medical library and punched mesothelioma into the computer's bibliographic search program. An hour later, surrounded by the latest literature on abdominal mesothelioma, I realized with a gulp why my doctor had offered that humane advice. The literature couldn't have been more brutally clear: mesothelioma is incurable, with a median mortality of only eight months after discovery. I sat stunned for about fifteen minutes, then smiled and said to myself: so that's why they didn't give me anything to read.

If a little learning could ever be a dangerous thing, I had encountered a classic example. Attitude clearly matters in fighting cancer… Match people with the same cancer for age, class, health, socioeconomic status, and, in general, those with positive attitudes, with a strong will and purpose for living, with commitment to struggle, with an active response to aiding their own treatment and not just a passive acceptance of anything doctors say, tend to live longer.

Hence the dilemma for humane doctors: since attitude matters so critically, should such a sombre conclusion be advertised, especially since few people have sufficient understanding of statistics to evaluate what the statements really mean? From years of experience with the small-scale evolution of Bahamian land snails treated quantitatively, I have developed this technical knowledge – and I am convinced that it played a major role in saving my life. Knowledge is indeed power, in Bacon's proverb.

The problem may be briefly stated: What does "median mortality of eight months" signify in our vernacular? I suspect that most people, without training in statistics, would read such a statement as "I will probably be dead in eight months" – the very conclusion that must be avoided, since it isn't so, and since attitude matters so much…

When I learned about the eight-month median, my first intellectual reaction was: fine, half the people will live longer; now what are my chances of being in that half. I read for a furious and nervous hour and concluded, with relief: damned good. I possessed every one of the characteristics conferring a probability of longer life: I was young; my disease had been recognized in a relatively early stage; I would receive the nation's best medical treatment; I had the world to live for; I knew how to read the data properly and not despair.

My technical knowledge had helped. I had read the graph correctly. I had asked the right question and found the answers. I had obtained, in all probability, the most precious of all possible gifts in the circumstances - substantial time. I didn't have to stop and immediately follow Isaiah's injunction to Hezekiah – set thine house in order for thou shalt die, and not live. I would have time to think, to plan, and to fight.

1. What evidence does Gould offer that we should not separate heart (emotions) and head (mind) ?
2. Gould realized that although median mortality was eight months, mean mortality is significantly longer. Why is this and why did it comfort him?
3. What can be meant by the statement, "Knowledge is power"?

Chapter 3 questions

1 In each of the following combinations of words or phrases, one word or phrase does not belong. Identify which it is and explain why it does not belong.

a) spindle microtubule formation, replication, growth

b) spindle microtubule formation, supercoiling of chromosomes, attachment of microtubules to centromeres

c) maintenance, repair, formation of gametes.

2 Define the following terms:

a) diploid **b)** cytokinesis **c)** S phase. [3]

3 Draw diagrams to show the four stages of mitosis in an animal cell with four chromosomes. [5]

4 Which phases of mitosis are shown in Figure 7? [6]

Figure 7 Stages of mitosis

5 The amount of DNA present in each cell nucleus was measured in a large number of cells taken from two different cultures of human bone marrow (Figure 8).

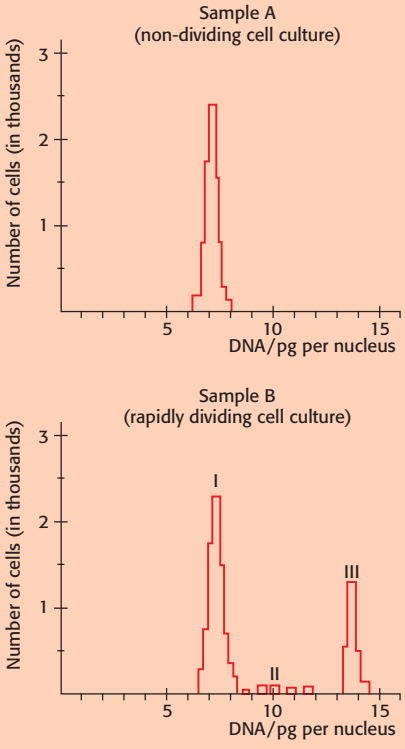


Figure 8

a) For each label (I, II and III) in the Sample B graph, deduce which phase of the cell cycle the cells could be in; i.e. G1, G2 or S. [3]

b) Estimate the approximate amount of DNA per nucleus that would be expected in the following human cell types:

i) bone marrow at prophase

ii) bone marrow at telophase. [2]

6 Identify stages I–IV.

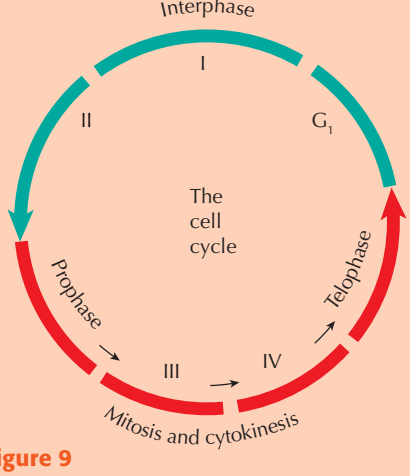


Figure 9