ADVANCED BIOLOGY

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Preface

In recent years there has been a change in emphasis in the content of GCE Advanced Level syllabuses in biological sciences. As well as traditional topics, students are now expected to cope with the complexities of biochemistry and the molecular basis of genetics. Most Examination Boards have also altered their style of assessment. Less weight is now placed on memorising facts and more on understanding principles and interpreting data. The applications of biology are currently stressed more than ever. It is with these changes in mind that this book has been written.

The major topics of all GCE Advanced Level syllabuses in Biology are included. The contents are also relevant to courses leading to the Technical Education Council Diploma in Sciences. Technician students enrolled for TEC Certificate programmes will find the objectives of the Standard Units Biology II, Cell Biology II, Mammalian Physiology II and III, and Biochemistry III well covered. Our many years' experience in teaching and examining at this level have been instrumental in determining the appropriate depth of treatment of the subject matter.

We have consciously attempted to write in a style and language which the average sixth former can readily understand. The chapters can be read in any order. However, in our opinion the subject matter is more intelligible if the topics are studied in the order in which they are set out. The first seven chapters provide a foundation in biological, biochemical and physical knowledge and principles which should make it easier to understand the topics in the remainder of the book. Key words have been presented in bold type to emphasise important facts and concepts and for ease of revision.

Biology is a practical subject but in the space available we could not include details of practical work. However, second-hand evidence from experimental work is quoted extensively in the text and in a number of the questions. It is hoped that this will encourage students to realise that factual evidence is essential if valid conclusions are to be arrived at in biological science. Where we have written about debatable issues an attempt has been made to strike a reasonable balance in the conflicting evidence available. The practical uses to which biological knowledge can be put have been mentioned where appropriate.

J.S.
J.I.W.
Nottingham, 1983.

Units, Symbols and Quantities

SI and SI derived units, symbols and quantities

Système International (SI) and SI-derived units, symbols and quantities have been used throughout the text. Non-SI units have been given in addition where it is anticipated that the SI system may not be adopted in the near future.

Non-SI units and their conversion to SI units are given in brackets under each section.

LENGTH

1 metre (m) = 1000 millimetres (mm)
1 mm (10^{-3}m) = 1000 micrometres (μm)
1 μm (10^{-6}m) = 1000 nanometres (nm)
(1 in = 25·4 mm)

ENERGY

1 kilojoule (kJ) = 1000 joules (J)
(1 calorie = 4·187 J)

PRESSURE

1 kilopascal (kPa) = 1000 pascals (Pa)
(1 atm = 760 mm Hg = 101·325 kPa)

MASS

1 kilogram (kg) = 1000 grams (g)
1 g (10^{-3}kg) = 1000 milligrams (mg)
1 mg (10^{-6}kg) = 1000 nanograms (ng)
1 ng (10^{-9}kg) = 1000 picograms (pg)
(1 lb = 0·454 kg)

VOLUME

1 cubic decimetre (dm^3) = 1000 cubic centimetres (cm^3)
1 cubic centimetre (10^{-3} dm^3) = 1000 cubic millimetres (mm^3)
(1 in^3 = 16·38 cm^3)

ELECTRICAL POTENTIAL DIFFERENCE

1 volt (V) = 1000 millivolts (mV)

TIME

1 second (s) = 1000 milliseconds (ms)

TEMPERATURE

thermodynamic temperature kelvin (K)
degree Celsius = °C
(t °Fahrenheit = $\frac{5}{9}$(t − 32) °C)

Chemical Nomenclature

In recent years the International Union of Physics and Chemistry (IUPAC) and the International Union of Biochemistry (IUB) have reached agreement on the rules of nomenclature for many compounds of biological interest. The systematic names of most biochemicals are extremely cumbersome and require a knowledge of chemistry beyond what is expected of GCE Advanced Level Biology students. We have used systematic names where students should reasonably be able to cope with them or where they present little or no more difficulty than the trivial names. Trivial names have been given where it is not anticipated that the systematic names will be used at this level of study in the near future. Because some students may wish to know the systematic names of some of the biochemicals given trivial names in the text the following list has been drawn up. The list may also be useful for those who are not familiar with the systematic names used in the text.

Table A2.1

Trivial name	Systematic name
acetaldehyde	ethanal
acetic acid	ethanoic acid
acetone	propanone
alanine	2-aminopropanoic acid
aniline	phenylamine
benzoic acid	benzenecarboxylic acid
carbon tetrachloride	tetrachloromethane
chloroform	trichloromethane
citric acid	2-hydroxypropane, 1,2,3-tricarboxylic acid
ethylene	ethene
formaldehyde	methanal
fumaric acid	trans-butenedioic acid
glyceraldehyde	2,3-dihydroxypropanal
glycerol	propane-1,2,3 triol
glycine	aminoethanoic acid
glycollic acid	hydroxyethanoic acid
hippuric acid	N-benzoylglycine
lactic acid	2-hydroxypropanoic acid
malic acid	2-hydroxybutanedioic acid
malonic acid	propanedioic acid
ornithine	2,5-diaminovaleric acid
phosphoenolpyruvic acid	2-hydroxy-2-propanoic acid
pyruvic acid	2-oxopropanoic acid
succinic acid	butanedioic acid
urea	carbamide
xylene	dimethylbenzene

The names of mammalian hormones have recently been revised by the IUB and the revised names have been used in the text. Abbreviations for the old names have also been included as these are in such wide use.

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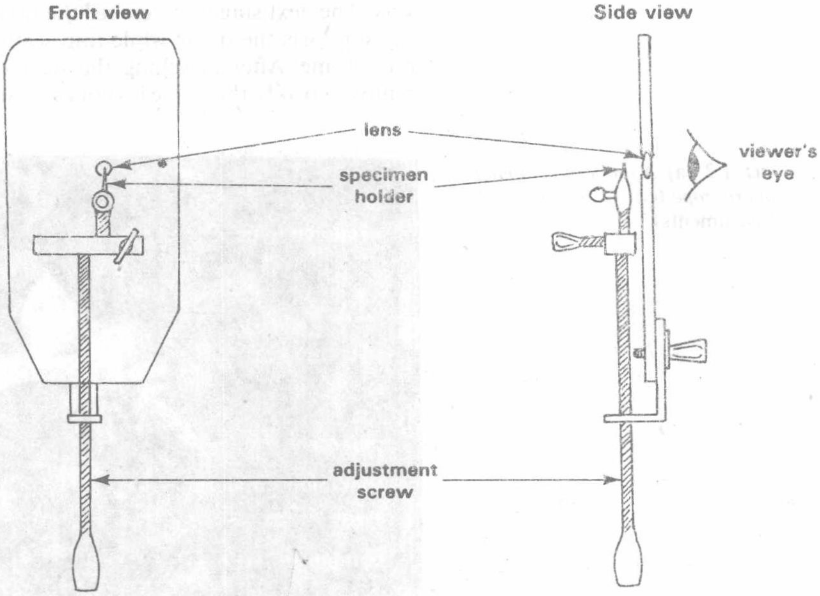
Chapter 1

The structure of cells

What is known about cell structure has largely depended on the development of microscopes and microscopical techniques. A simple microscope was invented by Galileo in 1610 but there are no reports that he used it to examine living organisms. In 1676 a Dutch draper, Antonie van Leeuwenhoek, whose hobby was the grinding of lenses, used one of his **simple microscopes** (Fig. 1.1) to examine rainwater in which grains of pepper had been soaked. He observed a variety of unicellular organisms which he called animalcules. It is now known that the organisms he saw were bacteria. A decade earlier Robert Hooke in England had made a **compound microscope** with which he examined, among other things, thin slices of cork tissue. He saw that the cork was porous, rather like a honeycomb, consisting of a great many small compartments which he called **cells**. Such are the origins of cell biology.

FIG. 1.1 *Van Leeuwenhoek's simple microscope*

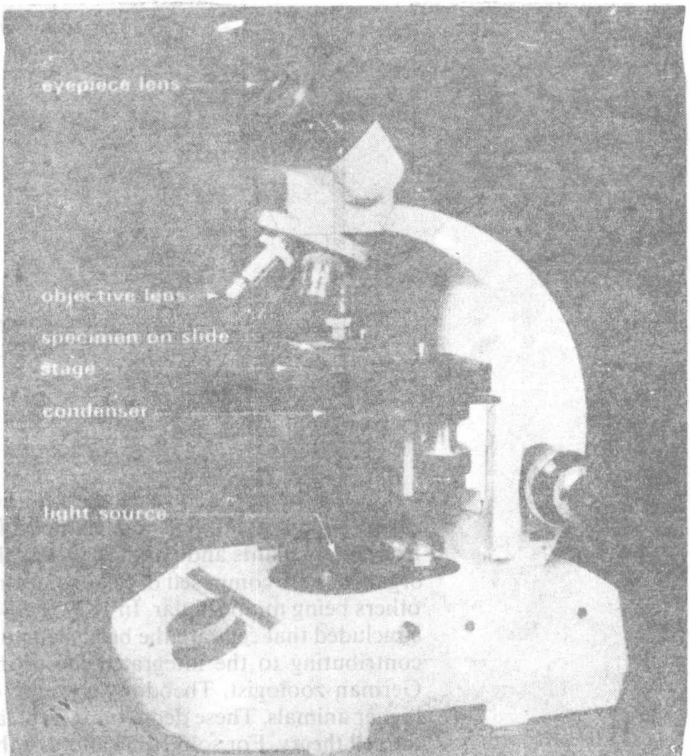


During the next 150 years, with further improvement of the compound microscope a great deal was learned of the structure of cells and tissues from many plants and animals. Gradually it was recognised that all living organisms are composed of cells, some organisms consisting of a single cell, others being multicellular. In 1839 the Belgian botanist Mathias Schleiden concluded that cells are the basic structural units of higher plants, each cell contributing to the integrated life of the organism. At the same time a German zoologist, Theodor Schwann, came to the same opinion about higher animals. These deductions were later formulated into what is called the **cell theory**. For some time after the theory was first proposed there was a tendency for biologists to emphasise the importance of individual cells, the structure and activity of which were thought to mirror that of the whole organism. Recently there has been more interest in the ways in which different types of cells interact in the functioning and development of multicellular organisms.

1.1 Cell structure as interpreted by the light microscope

The compound microscope is still used by most biologists to examine cells and tissues (Fig. 1.2(a)). With this instrument it is possible to observe living material. Good images showing much detail can be obtained, especially if the microscope is of the **phase-contrast** type (Fig. 1.2(b)). A phase-contrast microscope exaggerates small differences in refractive index of cell components to create an image in which the components are more clearly distinguished by the human eye. Nevertheless, most of what was known about the structure of cells up to the 1940s was obtained from observations on dead tissue which had been treated with preservatives. The technique, which had been developed for over a hundred years, first involves immersing the tissue in a fixative such as methanal or ethanol in order to prevent deterioration and to keep the structure as life-like as possible. Following **fixation** the tissue is **dehydrated** with ethanol and then **cleared** with an organic solvent such as dimethylbenzene which is miscible with paraffin wax. The next stage is to **embed** the tissue in molten wax which on hardening supports the tissue while thin sections, 2–10 μm thick, are cut using a microtome. After attaching the sections to microscope slides the wax is removed before the tissue is **stained**. Staining changes the refractive index of

FIG. 1.2 (a) *A modern compound microscope* (courtesy Vickers Instruments)



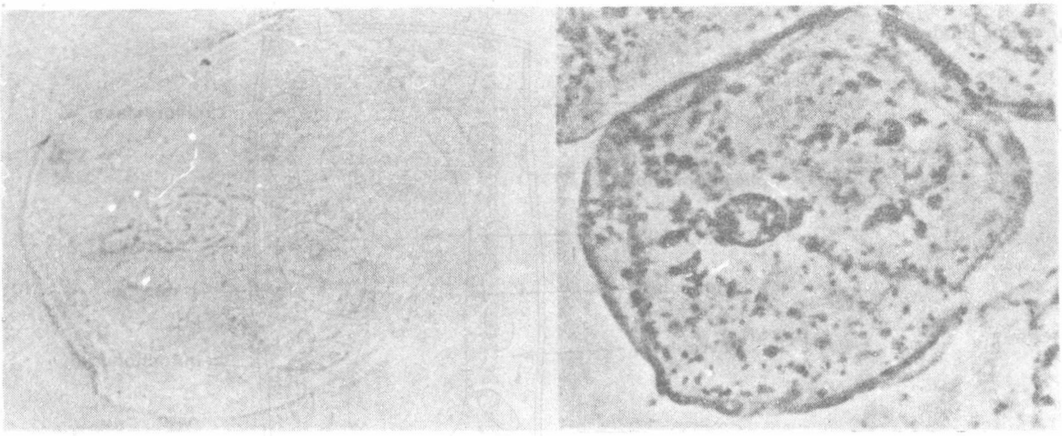


FIG. 1.2 (b) *An epithelial cell from the mouth lining*

(i) *as seen with a conventional light microscope, ×900*
(ii) *as seen with a phase-contrast microscope, ×900*

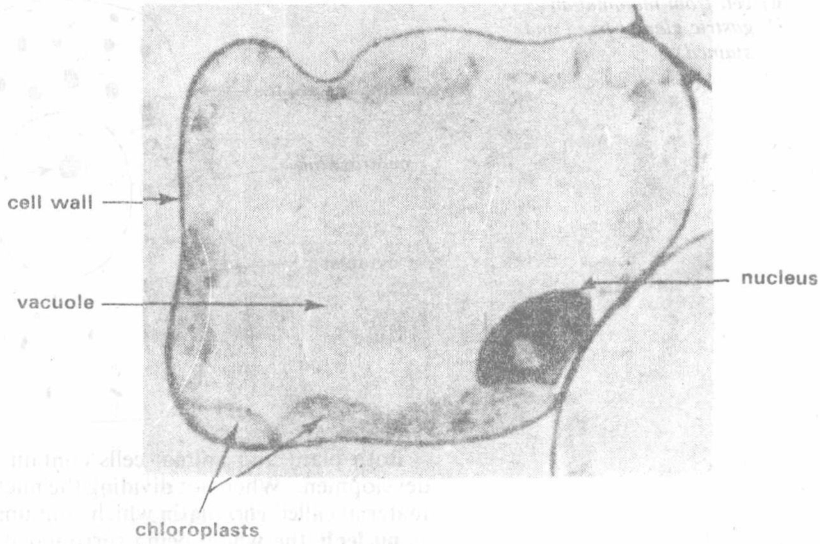
cell components so that they are more easily seen when the material is examined microscopically. Any of the above steps can lead to distortion of the specimen, so it is necessary to guard against artificial structures, called **artefacts**, which appear in the specimen during treatment but are not present in living cells.

Using such methods, coupled with observations on living cells, it is possible to build up a fairly detailed picture of cell structure (Fig. 1.3(a) and (b)).

The living material of cells is called **protoplasm** and is enclosed in a **plasma membrane**, an elastic outer layer. In plant cells the protoplast, the unit of protoplasm found in a single cell, is surrounded by an inert **cell wall**. The main ingredient of plant cell walls is a glucose polymer called cellulose. Adjacent plant cells are held together by a thin layer composed mainly of calcium pectate and known as the **middle lamella**. Another distinctive feature of many plant cells is the presence of pigment-containing bodies called plastids, the most common of which are the green **chloroplasts**. Large sap-filled **vacuoles** are also frequent.

FIG. 1.3 *Structure of cells as revealed by a compound microscope*

(a) (i) *section of a leaf mesophyll cell as seen with a light microscope × 1200*



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