Students' Manual

Biology A Functional Approach

M. B. V. Roberts MA PhD

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Nelson

Equipment and Materials

Most of the laboratory equipment and materials specified in this manual are obtainable from Philip Harris Biological Ltd. (Oldmixon, Weston-super-Mare, Somerset BS24 9BJ) with whom the author and publisher have been in consultation during the preparation of the manual. However, many of the items can be obtained from alternative sources and the teacher is advised to shop around. Useful pieces of apparatus can sometimes be scrounged from research laboratories.

General biological suppliers in the United Kingdom, apart from Philip Harris Biological Ltd., include Griffin and George Ltd. (Head Office: 285 Ealing Road, Wembley HA0 1HJ), and Gerrard and Haig Ltd. (Gerrard House, Worthing Road, East Preston, Sussex BN16 1AS). Gerrard and Haig Ltd. are sole agents in the United Kingdom for the Carolina Biological Supply Company, U.S.A.

Media for chick tissue culture can be obtained from Flow Laboratories, Victoria Park, Heatherhouse Road, Irvine, Scotland.

Marine specimens are generally available from Marine Biological Laboratories such as those at Plymouth and Oban.

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Note to Teachers and Students

The purpose of this manual is to provide a repertoire of practical laboratory investigations and homework questions, and a source book of further information suitable for Advanced Level biology students in schools and colleges. It is a sequel to, and is designed to be used in conjunction with, my textbook *Biology: A Functional Approach* and its complementary series of slides (*see* Appendix). However, the manual is self-contained and can be used independently of its parent book.

In compiling this manual I lay little claim to originality. Most of the laboratory investigations have been attempted before and many of the questions and problems have featured in past examination papers. In selecting material I have been greatly influenced by what we, at Marlborough College, have found useful, since we adopted a functional approach some years ago.

Broadly speaking, laboratory work in biology falls into four categories: direct observation, dissection, microscopic study, and experimental work. There are, of course, no hard and fast distinctions between these disciplines, and a full investigation of a biological problem often involves all four. I believe that in a practical biology course all have an important part to play and should be given the right emphasis. I hope that in this manual I have achieved the correct balance. I make no apology for including a fair amount of morphological work, for a functional approach is only meaningful if it is based on sound structural principles, and nowhere can these principles be better acquired than in the laboratory.

Whatever the approach and whatever the techniques, the ultimate purpose of laboratory work is to explore and investigate the world of living things. Wherever possible, I have tried to present each unit of laboratory work in such a way that it can be seen as a genuine scientific investigation and not merely as a practical exercise to be done for the purpose of passing an examination.

All the investigations are designed to fit into clearly defined periods of time. Most of the experimental investigations can be carried out in 1½ hours. The times for microscopic work and dissection will vary according to the aptitude and ability of the student. I have deliberately reduced experiments that are unduly time-consuming, expensive or capricious to a minimum.

It would, of course, be impossible for all the laboratory work suggested here to be completed in a two-year course, but I have included more than can be covered in the time so as to give teachers and students some degree of choice. The same applies to the questions and problems.

A common criticism of laboratory exercises, particularly experimental investigations that are tailor-made to fit into a prescribed period of time, is that they are contrived. This is bound to be so, but I hope that some of the investigations in this manual may stimulate the student to carry out project work on his own.

I strongly urge that the student should make his own drawings and notes and record his own observations and write up the experiments which he, himself, carries out. Advice on this is given in the appendix.

Many of the homework questions involve interpretation of biological phenomena and analysis of data. In the belief that learning to express ideas clearly and succinctly is an essential part of a biologist's training, I have also included a number of questions requiring the writing of a short essay. On the other hand, I have not included many questions demanding purely descriptive answers, on the grounds that such questions can easily be set by individual teachers.

In preparing this manual I have not had any one syllabus in mind, but the range of laboratory investigations and homework questions should make it suitable for students following the Advanced Level syllabuses of the various universities and examining boards in Great Britain and the Commonwealth, and for students pursuing introductory biology courses in universities and colleges of further education. It is envisaged that in the United States and Canada the manual would be suitable for students doing introductory biology courses in the first and second years at colleges and universities.

Acknowledgments

In preparing a book of this kind one is more than ever dependent on the constructive advice of one's friends. For their continual help and encouragement I must thank, first and foremost, my colleagues at Marlborough College: Mr Jack Halliday, Mr John Emmerson, Mr Malcolm Hardstaff and Mr Roderick Putman. Our present course is as much a result of their endeavours as mine, and without their help this manual would have been impossible. Mr Peter Holway of St Dunstan's College kindly commented on some of the problems, for which I wish to record my thanks; and for their helpful comments on the text I am grateful to Mr Beverley Heath and Mrs Morag Putman. I am also indebted to many of my students for testing the investigations, questions and problems, and for their valuable comments on the text. They include Mr David Howard, Mr Robert Wright, Mr Graham Fergusson, Mr Nigel Bruce, Mr Robin Bertaut, Mr Paul Goldsmith, Mr Mark Davies, and Mr Tony Brown, to all of whom I owe warm thanks. I am grateful to our laboratory staff, Mr Charles Hughes, Mr Ivor Radford, Mr Michael Ward, and Miss Lynn Thompson, for their technical assistance, and to Mr John Haller and Mr Stephen Wood of Philip Harris Biological Ltd. for their useful suggestions and cooperation over the provision of laboratory materials. For bearing the burden of typing the manuscript I am indebted to Mrs Jeanette Radford and also to my wife for her support and assistance. Finally I wish to thank my publishers, Thomas Nelson and Sons Ltd., particularly Miss Elizabeth Johnston and Mr David Worlock for their encouragement and courtesy at all times during the preparation of this manual.

In thanking all these helpers, I must make it clear that I alone am responsible for the many imperfections which doubtless remain. I hope that teachers and students will not hesitate to point these out to me as they use the manual at home and in the laboratory.

M. B. V. Roberts
June, 1974.

Examination questions

The author and publisher wish to thank the following examining bodies for permission to reproduce, either direct or in modified form, certain questions from their past examination papers. The sources are acknowledged in the manual by the abbreviations shown in parentheses. The questions are all A level or the equivalent.

Associated Examining Board (*AEB*); Biological Sciences Curriculum Study of the American Institute of Biological Sciences (*BSCS*); Cambridge Colleges Joint Examination (*CCJE*); Cambridge Local Examinations Syndicate (*CL*); Joint Matriculation Board (*JMB*); New South Wales Department of Education (*NSW*); Oxford and Cambridge Schools Examination Board (*O and C*); Oxford Colleges Joint Examination (*OCJE*); Oxford Delegacy of Local Examinations (*OL*); Public Examinations Board of South Australia (*SA*); Schools Board of Tasmania (*SBT*); University of London (*UL*); Victorian Universities and Schools Examinations Board (*VUS*); Joint Matriculation Board—Nuffield (*JMB—N*); Hong Kong University (*HK*).

Contents

1 Introducing Biology

Background Summary

1 **Biology**, the study of life and living organisms, is divided into numerous subjects which include **zoology, botany, microbiology** (bacteriology and virology), **anatomy, physiology, biochemistry, cytology** (cell biology), **heredity** (genetics), **molecular biology, behaviour** and **ecology**.

2 Properties shared by all living organisms are: **movement** (which may be internal), **responsiveness, growth** by internal assimilation, **reproduction** (involving replication of nucleic acid), **release of energy** by breakdown of adenosine triphosphate, and **excretion.**

3 **Scientific method** starts with an observation which leads to the formulation of an **hypothesis**. Predictions made from the hypothesis are tested by **experiment.** Every experiment must be accompanied by the appropriate **controls**.

4 Animal and plant species run into millions, so a system of classification (**taxonomy, systematics**) is essential.

5 Organisms as a whole are divided into the **animal** and **plant kingdoms**, within each of which they are further divided into **phyla, classes, orders, families, genera** and **species**. Bacteria, viruses and certain other microorganisms do not fit readily into either the animal or plant kingdoms and may be classified separately.

6 Basic biological concepts include survival, adaptation, a close relationship between structure and function, and evolution.

Investigation 1.1

Construction of an identification key

The diversity of organisms is prodigious and it is therefore necessary for each organism to be classified and named. They are classified according to their similarities with one another. Once a system of classification has been constructed, a method must be devised whereby other people can quickly determine the name of a particular organism. This is done by constructing an **identification key** based on the classification.

Principles involved

To illustrate how a classification and identification key can be constructed, consider the following example.

Nine students, all belonging to the same class in a school, have the following features. They are listed in alphabetical order:

Alan — dark hair, blue eyes
Ann — auburn hair, brown eyes
David — dark hair, brown eyes
Elizabeth — auburn hair, blue eyes
Jane — fair hair, hazel eyes
John — fair hair, brown eyes
Pamela — auburn hair, green eyes
Philip — fair hair, blue eyes
Susan — fair hair, blue eyes

It would be possible to classify these students in various ways. A **dichotomous classification** is one which splits them into successive **pairs** of sub-groups of approximately equal size. Such a classification is given below and from it a dichotomous key can be constructed.

This enables a stranger, unfamiliar with the class, to quickly determine the name of any student.

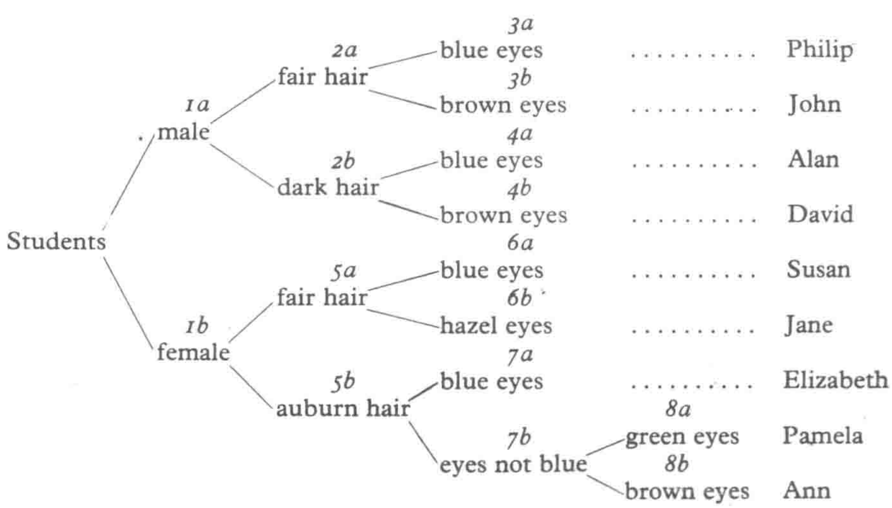
1a male . . . . go to 2
1b female . . . . go to 5
2a fair hair . . . . go to 3
2b dark hair . . . . go to 4
3a blue eyes . . . . Philip
3b brown eyes . . . . John
4a blue eyes . . . . Alan
4b brown eyes . . . . David
5a fair hair . . . . go to 6
5b auburn hair . . . . go to 7
6a blue eyes . . . . Susan
6b hazel eyes . . . . Jane
7a blue eyes . . . . Elizabeth
7b eyes not blue . . . . go to 8
8a green eyes . . . . Pamela
8b brown eyes . . . . Ann

Using the key, determine the name of the brown-eyed boy with dark hair, and the blue-eyed girl with fair hair.

Exactly the same principles apply to the construction and use of an animal or plant key, as you will see if you consult a **flora**, that is a key to the plant kingdom.

Construction of classification

With these principles in mind, try classifying one of the groups of objects laid out before you. Each group contains between 15 and 20 objects, each identified by a **letter**. Using *visible* characteristics, arrange the objects into two sub-groups of approximately equal size. Then divide each of these sub-groups into two further groups. Continue to split the groups until each individual object is in a group of its own.



Requirements

For each group of students: approximately 16 objects, animate or inanimate, each labelled with a letter. The range of objects should be such that they can be readily classified dichotomously.

Construction of key

Now construct a dichotomous key based on your classification. As other people must be able to use your key, it should be based on visible characteristics which can be readily observed by anyone looking at the specimens. Resist the temptation to place specimens in a given group because you happen to know they belong there: i.e. do not use ready-made taxonomic groups such as 'plant', 'insect', 'bird', 'reptile', etc.

If there is any ambiguity about the meaning of a term used in describing a specimen, write out a definition and incorporate it into your key.

When completed, invite someone to test your key: choose a specimen at random, cover its identifying letter, and see if the specimen can be identified correctly, using only the key you have constructed.

For Consideration

Animals and plants in existence today are believed to have evolved from pre-existing ancestors by a process of gradual change. A natural classification is designed to show how closely, or distantly, organisms are related to each other in evolution. With this in mind, try to answer these questions:

(1) To what extent do you think your classification reflects evolutionary relationships?

(2) What explanation can you offer of the fact that some organisms are strikingly similar, others different?

(3) How would you explain the fact that in a natural classification some organisms that appear to be similar are placed in different groups?

Investigation 1.2

Animal and plant classification

In the previous investigation you based your classification on easily observable features. Although this is satisfactory for purposes of 'pigeon-holing' and identification, it can be scientifically misleading for it may result in some organisms being grouped together on the basis of some superficial similarity when, in fact, they have little in common.

Animals and plants are believed to have arisen by a process of **evolution**. Those that are closely related in this evolutionary process would be expected to share certain fundamental features in common, whereas those that are distantly related would not be expected to do so.

In classifying organisms a biologist aims to group them according to their evolutionary closeness to one another. The science of classification is known as **taxonomy**.

THE TAXONOMIC HIERARCHY

Organisms which share detailed features in common, but which do not normally interbreed, are grouped together as a **species**. A **genus** is a somewhat larger group which includes additional organisms, similar to one another in many respects, but not sufficiently close to merit putting them in the same species. It is customary to name organisms by their genus and species: the **generic name** is written first, followed by the **specific name**. Both are normally printed in italics, or underlined. The generic name begins with a capital letter, the specific name with a lower case letter. Thus, the proper name for man in *Homo sapiens*, the earthworm is *Lumbricus terrestris*, and the common buttercup is *Ranunculus acris*.

Organisms are grouped together into progressively larger groups, creating a kind of hierarchy. Thus genera are grouped together into **families**, families into **orders**, orders into **classes**, classes into **phyla**, and phyla into **kingdoms**. Intermediate divisions are sometimes used, for example, between a phylum and class, but we will not concern ourselves with those here.

Two kingdoms are generally recognized: the **animal kingdom** and **plant kingdom**.

It follows that, as one progresses *down* the hierarchy, the smaller the number of organisms belonging to each group and the more they have in common. Thus a phylum may contain a large number of organisms, held together by certain fundamental features but at the same time displaying a wide range of variety. On the other hand, the different members of a genus may be so similar as to be virtually indistinguishable except by an expert.

Taxonomic group	Plant example	Animal examples	
Kingdom	Plant	Animal	Animal
Phylum	Angiospermae/Tracheophyta	Annelida	Chordata
Class	Dicotyledon/Angiospermae	Oligochaeta	Mammalia
Order	Ranales	Terricolae	Primates
Family	Ranunculaceae	Lumbricidae	Hominidae
Genus	Ranunculus	Lumbricus	Homo
Species	bulbosus	terrestris	sapiens
Common name	bulbous buttercup	earthworm	man

Table 1.1 Three examples of classification from the plant and animal kingdoms.

EXAMPLES OF CLASSIFICATION

Three examples of classification are given in Table 1.1. The features on which the main phyla and classes of the animal and plant kingdoms are based are summarized in the classification of the animal and plant kingdoms (*see* pp. 400–417).

There is sometimes dispute as to what features a group should be based on. Thus some botanists consider that the phylum to which the buttercup belongs should be the **Angiospermae**, characterized by the possession of **flowers**; others consider that such plants should be placed in a phylum called the **Tracheophyta**, characterized by the possession of **vascular tissues** (*see* p. 406). Although, in the last analysis, this is a matter of opinion, it does make a difference because the former would embrace *only* the flowering plants, whereas the latter would also include the conifers and ferns (*see* p. 416).

CLASSIFICATION OF A PLANT GROUP

Examine different species of a common plant growing in your part of the world. As an example we can take the genus *Ranunculus* which includes the buttercup and its relatives.

Twelve species of *Ranunculus*, together with their common names, times of flowering, and occurrence, are listed in Table 1.2. Examine specimens of some or all of these species, noting their similarities and differences. From your observations can you say what features cause them to be placed by botanists in the same genus? What are the differences which cause them to be placed in separate species?

Ranunculus belongs to the family **Ranunculaceae** (*see* Table 1.1). This contains a number of other genera besides *Ranunculus*. These include:

Anemone, e.g. *A. nemorosa*: wood anemone

Caltha, e.g. *C. palustris*: marsh marigold*

Clematis, e.g. *C. vitalba*: traveller's joy, old man's beard

Delphinium, e.g. *D. ambiguum*: larkspur

Helleborus, e.g. *H. viridis*: green hellebore

Paeonia, e.g. *P. mascula*: paeony

Examine specimens of some or all of the above genera. What features do they have in common with *Ranunculus*, and how do they differ from it? The various members of the Ranunculaceae are in fact held together by the structure of their flowers. What features of the flowers do they all have in common?

* *C. palustris* is also known as king-cup, golden cup, brave celandine, horse-blob, mare-blob, may-blob, Mary-bud, soldier's button, and publicans and sinners. In parts of the U.S.A. it is called cowslip, a name which elsewhere is applied to *Primula veris*, a member of the Primulaceae. This is a splendid example of how misleading the use of common names can be.

Proper name	Common names	Time of flowering	Occurrence
R. acris	Meadow buttercup Common meadow buttercup Tall buttercup Common buttercup	April–September	sloping meadows
R. aquatilis	Water crowfoot	May–August	rivers
R. arvensis	Corn buttercup	May–July	cornfields in calcareous soil
R. auricomus	Goldilocks Wood crowfoot	April–July	thickets and woods
R. bulbosus	Bulbous buttercup	May–August	dry fields and meadows
R. flammula	Lesser spearwort	May–September	wet areas
R. ficaria	Lesser celandine	March–May	shade
R. fluitans	Water crowfoot River crowfoot	June–August	fast-flowing streams
R. lingua	Great(er) spearwort	June–September	marshes, fens, ditches
R. parviflorus	Small-flowered buttercup	May–July	short grass, arable land
R. repens	Creeping buttercup	May–August	wet meadows in valleys
R. sceleratus	Celery-leaved buttercup	May–September	sides of ponds and ditches

Table 1.2 Names, times of flowering, and occurrence of 12 species of *Ranunculus*.

The Ranunculaceae is a family within the phylum **Angiospermae**. This contains many other families besides the Ranunculaceae. These include the following:

- Compositae (daisy, etc.)
- Convolvulaceae (bindweed, etc.)
- Cruciferae (wallflower, etc.)
- Geraniaceae (geranium, etc.)
- Labiatae (deadnettle, etc.)
- Leguminosae (pea, bean, etc.)
- Primulaceae (primrose, etc.)
- Rosaceae (rose, etc.)
- Scrophulariaceae (snapdragon, etc.)
- Violaceae (violet, etc.)

Examine representatives of some or all of the above families. In what respects do they differ from the Ranunculaceae, and from each other? What features hold them together and cause them to be placed in the same phylum?

CLASSIFICATION OF OTHER ORGANISMS

What you have done in this exercise is to look at a **genus**, then at the **family** to which that genus belongs, and finally at the **phylum**.

This can be done with any organism, though the procedure is easier for some organisms than for others. By way of contrast, try it with the earthworm (*see* Table 1.1). In this case the genus is *Lumbricus*. First look at different species of *Lumbricus*; then look at other worms belonging to the same

Requirements
Ranunculus species (*see* Table 1.2)
Selection of genera of Ranunculaceae
Selection of angiosperms
Other organisms and groups as required.

class (**Oligochaeta**). Then broaden your survey further to include the whole phylum (**Annelida**). This includes leeches, fanworms, ragworms and lugworms, as well as the earthworm and its relatives (*see* p. 404). What features do the various groups have in common? How do they differ?

For Consideration

(1) It is a basic biological principle that organisms are adapted to their environments. In what respects are the various species of *Ranunculus*, which you have examined, adapted to their respective environments?

(2) Construct a dichotomous key enabling the different species of *Ranunculus* to be identified (*see* Investigation 1.1).

(3) What problems might arise if animals and plants were only called by their common names? (Consult Table 1.2 and the footnote on p. 4).

Investigation 1.3

Who's who in the animal and plant kingdoms

Requirements
Live and/or preserved animals and plants belonging to the phyla listed above. (*See also* Classification of the Animal Kingdom, pp. 400–412, and Classification of the Plant Kingdom, pp. 413–417).

The animal and plant kingdoms are subdivided into **phyla**, which in turn are subdivided into smaller groups. The members of each phylum, though often displaying considerable diversity of form, are held together by certain features which they all possess.

The purpose of this investigation is to examine representatives of each major phylum of the animal and plant kingdoms. In doing this, you are urged to notice the variety within each phylum, but also the more obvious features uniting its various members.

Classifications of the animal and plant kingdoms are given on pp. 400–417. Compare your observations with the information given in these classifications.

Procedure

ANIMAL KINGDOM

Examine several representatives of each of the following phyla: **Protozoa** (single-celled animals), **Porifera** (sponges), **Coelenterata** (*Hydra*, etc.), **Platyhelminthes** (flatworms), **Nematodes** (thread worms, round worms), **Rotifera** ('wheel animalcules'), **Annelida** (ringed worms, earthworms, etc.), **Mollusca** (snails, etc.), **Arthropoda** (insects, etc.), **Echinodermata** (starfish, etc.), **Chordata** (vertebrates, etc.).

From your own observations try to determine the criteria upon which each group of animals are combined into one phylum. Then check against the classification in Appendix 1.

PLANT KINGDOM

Examine several representatives of each of the following phyla: **Thallophyta** (including representative **Algae** and **Fungi**), **Bryophyta** (mosses, etc), **Pteridophyta** (ferns, etc.), **Spermatophyta** (including representative **gymnosperms** and **angiosperms**, coniferous and flowering plants respectively).

As with the animal kingdom, try to determine, *from your own observations*, the criteria on which the different plants are grouped together into phyla.

For Consideration

(1) How would you explain the similarities that exist between the members of a phylum?

(2) How would you explain the fact that some phyla appear to have more in common than others?

(3) From the organisms which you have looked at, give examples of cases where the animal or plant is clearly adapted to its particular habitat and way of life.

(4) Give examples of cases where there is a clear correlation between a specific structure possessed by an organism, and its function.

Questions and Problems

1 What are the basic properties of living things? What arguments would you present to show that (a) a crystal, and (b) a candle flame are not alive, and that an oak tree is alive?

2 What characteristics of life are exploited in:
(a) the use of flashing signs;
(b) giving a green plant extra light;
(c) manuring soil;
(d) the use of a carrier pigeon;
(e) making wine?

3 'The body was found in the neighbouring water meadows. Beside it was a rusty and bloodstained iron bar. At the inquest it was stated that the victim was Fortescue-Watson, a member of Merlberry College, and that death resulted from a series of blows on the back of the head with a blunt instrument.

'The police searched the area of the crime and the only clue they found was two sets of footprints in the mud; one of these fitted the victim's shoes, while the other had been made by shoes with steel quarter heels and a hole in the left sole. A search was made, and a pair of shoes belonging to Snooks, a member of the same school, was found to fit the footprints.

'An examination of Snook's clothes was then made and showed recent mud stains on the trousers, seeds of a weed currently in flower in the water meadows in the turn-ups, and on the jacket bloodstains which had been treated, but not obliterated, by the application of ammonia.'

Discuss how far the police investigations in this story illustrate the method of science, and point out any differences in method between these investigations and those carried out by a scientist studying natural phenomena in a laboratory.

Do you consider that, on the evidence given, Snooks' guilt is proved? If not, explain why you consider the evidence to be insufficient. What other investigations should the police carry out?

4 Put forward hypotheses to explain the following observations, and suggest how you might test your hypotheses experimentally:
(a) Plants are sometimes seen to droop.
(b) Woodlice are generally found under logs or stones, rarely in the open.
(c) The cut shoot of a water weed often exudes a continuous stream of bubbles.
(d) Mosses occur in greater abundance on north-facing than south-facing walls.
(e) In a certain type of malaria fever occurs at regular 48-hour intervals.

5 Explain fully how you would test the hypothesis that:
(a) the apical bud is essential for vertical growth of the main stem of a flowering plant;
(b) vitamin B_1 (thiamine) is required for the growth of hens.

6 In answering the following question refer, if necessary, to the classification of the animal and plant kingdoms on pp. 400–417.

Place each of the following organisms into its correct kingdom, phylum and sub-group within the phylum. In each case state what you consider to be the most easily observed characteristic which shows what phylum and sub-group the organism belongs to.

Clam, man, bread mold, crab, pine, fanworm, buttercup, *Amoeba*, moss, bee.

7 From your own observations give one example of (a) an animal, and (b) a plant that is strikingly adapted to a particular way of life.

2 Structure and Function in Cells

Background Summary

1 Cells were first described in 1665 by Robert Hooke and are now known to be of almost universal occurrence in organisms. The **cell theory** states that the cell is the basic unit of an organism, the whole organism being little more than a collection of independent cells; the rival **organismal theory** states that the whole organism is the basic unit, the cells being incidental sub-units with no independent life of their own.

2 Cells may be observed with various kinds of **microscope**, e.g. optical (light); phase-contrast, polarizing and electron microscopes. A typical light microscope magnifies about 800 times and has a resolving power of approximately 0.2 μm. The electron microscope can magnify objects 300,000 times and has a resolving power of approximately 1.0 nm. (Compare the naked eye whose resolving power is about 0.1 mm.)

3 Structures characteristic of animal cells: **nucleus** with nuclear membrane perforated by pores; nucleolus and chromatin granules; **cytoplasm** with endoplasmic reticulum, food granules (glycogen, lipids), ribosomes and/or polyribosomes (polysomes), Golgi body, secretory vesicles and granules, mitochondria, lysosomes, centrioles and microtubules; **cell membrane** (**plasma membrane**) from which may project microvilli, cilia, or flagella with basal bodies.

4 Typical plant cells differ from animal cells in lacking cilia, flagella and centrioles; and in possessing chloroplasts, starch grains (instead of glycogen), sap vacuole and cellulose wall. The cellulose is laid down on the inside of a primary wall consisting largely of calcium pectate, the latter being represented in mature cells by the middle lamella. The secondary wall may sometimes be absent locally, giving rise to a pit, and adjacent cells are linked by plasmodesmata.

5 The **plasma membrane**, approximately 7.5 nm thick, is thought to consist of a layer of lipid sandwiched between two layers of protein. There is evidence that it is perforated by pores of less than 1.0 nm diameter.

6 Though containing much in common, cells show considerable diversity in their contents, shape and functions. In all cases there is a close relationship between cell structure and function.

Investigation 2.1
Structure of cells

The various structures that often are seen crammed into a theoretical diagram of a generalized cell are not all visible in any one cell. So to piece together the structure of a 'typical' cell—animal or plant—it is necessary to look at more than one type of cell.

To see a particular structure it may be necessary to stain the cell. The choice of stain is important because certain stains are specific to certain structures; thus aceto-carmine stains the nucleus and its contents, iodine stains starch grains, and so on.

Procedure

(1) Gently scrape the inside of your cheek with a spatula and mount the scrapings in a drop of water on a microscope slide. Cover with a coverslip. Observe under the microscope. (If you have not used a microscope before, consult Appendix 7). Locate a **single cell** and examine it under high power. Many of the cells will be crumpled and irregular in outline because the cell membrane is extremely thin and delicate.

Make out as much as you can of the **nucleus** and **cytoplasm**. You will find this fairly easy provided you don't let too much light through the microscope. Try dark ground illumination and, if available, phase contrast. How do these different techniques affect what you observe?

To get a better picture of the nucleus, stain with methylene blue. The stain may be introduced by a technique called **irrigation** (Fig. 2.1). A drop of stain is placed on the slide so it just touches the edge of the coverslip. Fluid is then withdrawn from the opposite side of the coverslip by a piece of absorptive paper and the stain flows in, replacing the fluid removed by the paper.

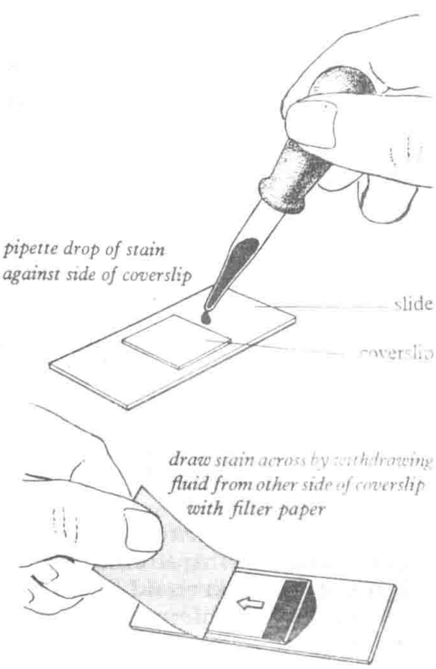


Fig. 2.1 The technique of irrigation.

Sketch the cell, putting in as many structures as you have been able to observe. Label: **nucleus**, **nuclear membrane**, **chromatin granules**, **nucleolus**, **granular cytoplasm**, **cell membrane**.

(2) Strip off a piece of epidermis from one of the inner 'fleshy scales' of an onion, mount in iodine and observe one cell under low and high powers. In addition to the nucleus, observe the distribution of granular cytoplasm surrounding the **vacuole**. Also notice: **cellulose cell wall**, **nucleoli** (how many?), **chromatin granules**. The onion is a plant organ but it does not contain chloroplasts: explain. What can you say about the 3-dimensional shape of the cells?

(3) Mount a small leaf of Canadian pondweed, *Elodea*, in water and examine its cells under high power. The cells are so packed with **chloroplasts** that little else can be seen. Look for **cytoplasmic streaming** resulting in circulation of the chloroplasts. What do you suppose the function of this is?

(4) Streaming of the cytoplasm can be seen more clearly in cells of the staminal hairs of *Tradescantia*. Open up one of the flowers and remove a stamen. Mount the stamen in water and examine a hair under high power. Adjust the illumination carefully or, better still, use phase contrast. What might be the function of streaming in this case? Make sketches to illustrate.

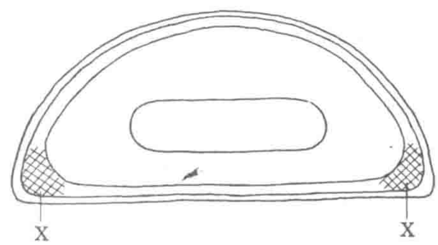


Fig. 2.2 Transverse section of pine needle. The cells at the corner (marked X in the diagram) have thick cellulose walls perforated by channels connecting adjacent cells.

(5) Examine the large cells at the corners of a transverse section of a pine needle (Fig. 2.2). Notice the thick **cellulose walls** which have been laid down in layers. The thin line separating the cellulose walls of adjacent cells, the **middle lamella**, is clearly visible. What does it represent? Fine channels in the cellulose walls connecting adjacent cells may be seen. What do they represent?

These observations can be performed either on prepared slides or on sections which you have cut yourself (*see* p. 96). If you are cutting your own sections mount them in either fresh Schultz' solution or FABIL. Both stain cellulose purple.

(6) Many plant cells store starch in the form of **starch grains**. Nowhere can this be better seen than in a potato, a swollen stem (stem tuber) specially adapted as a plant storage organ. Scrape some tissue from the cut surface of a potato and mount in water. Observe starch grains under high power.