Senior

Biology 1

Student Resource & Activity Manual

Model Answers: 2004

This model answer booklet is a companion publication to provide answers for the exercises in the **Senior Biology 1 Student Resource and Activity Manual** 2004 edition. These answers have been produced as a separate publication to keep the cost of the manual itself to a minimum, as well as to prevent easy access to the answers by students. In most cases, simply the answer is given with no working or calculations described. A few, however, have been provided with greater detail because of their more difficult nature.

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Forming a Hypothesis (page 18)

1. (a) The hypothesis is given as a definite statement, not a question.
   (b) The hypothesis contains only one (independent) variable that changes.
   (c) The hypothesis is testable by experimentation.

2. (a) The amount of air movement (wind) around plant A influences its transpiration rate.
   (b) The angle of the slope influences the rate at which snail species A moves.

3. (a) **Bacterial cultures**:
   Hypothesis: Temperature influences the rate of growth of bacterial strain A.
   Outline of the investigation: Set up agar plates of bacterial strain A, using the streak plating method. Place 4 plates in a 37°C incubator and 4 on the lab bench. Leave all 8 plates for the same length of time (e.g. 24 hours), with all other conditions identical. Measure the coverage of the agar plates with bacteria (as a percentage).
   (b) **Plant cloning**:
   Hypothesis: The concentration of hormone A influences the rate of root growth in plant A.
   Outline of the investigation: Set up 6 agar plates infused with increasing concentrations of hormone A (e.g. 1 mgl^{-1}, 5 mgl^{-1}, 10 mgl^{-1}, 50 mgl^{-1}, 100 mgl^{-1}, 500 mgl^{-1}), and each plate with 12 clones of plant A. Measure root length each day for 20 days.

Planning an Investigation (page 20)

1. Aim: To investigate the effect of temperature on the rate of catalase activity.

2. Hypothesis: The rate of catalase activity is dependent on temperature.

3. (a) Independent variable: Temperature.
   (b) Values: 10-60°C in uneven steps: 10°C, 20°C, 30°C, 60°C.
   (c) Unit: °C
   (d) Equipment: A means to maintain the test-tubes at the set temperatures, e.g. waterbaths; equilibrate all reactants to the required temperatures in each case, before adding enzyme to the reaction tubes.

4. (a) Dependent variable: Height of oxygen bubbles.
   (b) Unit: mm
   (c) Equipment: Ruler; place vertically alongside the tube and read off the height (directly facing as you would a meniscus).

5. (a) Each temperature represents a treatment.
   (b) No. of tubes at each temperature = 2
   (c) Sample size: for each treatment = 2
   (d) Times the investigation repeated = 3

6. It would have been desirable to have had an extra tube with no enzyme to determine whether or not any oxygen was produced in the absence of enzyme.

7. Variables that might have been controlled (a-c):
   (a) Catalase from the same batch source and with the same storage history. Likewise for the H_2O_2. Storage and batch history can be determined.
   (b) Equipment of the same type and size (i.e. using test-tubes of the same dimensions, as well as volume). This could be checked before starting.
   (c) Same person doing the measurements of height each time.This should be decided beforehand.
   Note that some variables were controlled: the test-tube volume, and the volume of each reactant. Control of measurement error is probably the most important after these considerations.

8. Controlled variables should be monitored carefully to ensure that the only variable that changes between treatments (apart from the biological response variable) is the independent (manipulated) variable.

Experimental Method (page 22)

1. Increasing the sample size is the best way to take account of natural variability. In the example described, this would be increasing the number of plants per treatment. **Note**: Repeating the entire experiment as separate trials (as described) is a compromise, usually necessitated by a lack of equipment and other resources. It is not as good as increasing the sample size in one experiment run at the same time, but it is better than just the single run of a small sample size.

2. If all possible variables except the one of interest are kept constant, then you can be more sure that any changes you observe in your experiment (i.e. differences between experimental treatments) are just the result of changes in the variable of interest.

3. Only single plants were grown in each pot to exclude the confounding effects of competition between plants (this would occur if plants were grown together).

4. Physical layout can affect the outcome of experimental treatments, especially those involving growth responses in plants. For example, the physical conditions might vary considerably with different placements along a lab bench (near the window vs central). Arranging treatments to minimize these effects is desirable.

   Checklist to be completed by the student.

Recording Results (page 24)

1. See the results table at the top of the next page. Student's may use a separate sheet and staple it in.

2. The table would be three times as big in the vertical dimension; the layout of the top of the table would be unchanged. The increased vertical height of the table would accommodate the different ranges of the independent variable (full light, as in question 1, but also half light, and low light. These ranges would have measured values attached to them (they should be quantified, rather than subjective values).

Variables and Data (page 25)

1. (a) Leaf shape: qualitative
   (b) Number per litter: quantitative, discontinuous
   (c) Fish length: quantitative, continuous

2 (a) Quantitative data are more easily subjected to statistical tests. Statistical tests are a requirement to

		Trial 1 (CO_2 concn in ppm)											Trial 2 (CO_2 concn in ppm)											Trial 3 (CO_2 concn in ppm)										
		Minutes											Minutes											Minutes										
	Set up no.	0	1	2	3	4	5	6	7	8	9	10	0	1	2	3	4	5	6	7	8	9	10	0	1	2	3	4	5	6	7	8	9	10
Full light conditions	1																																	
	2																																	
	3																																	
	Av.																																	

being able to properly test a hypothesis.
Note: Qualitative data can be tested statistically but the tests are very complex and generally not very powerful (their ability to detect differences between data sets is sometimes limited).

(b) Many variables could be chosen: examples include: gender, viability (dead or alive), species, presence or absence of a feature, flower color.

3. (a) and (b) any two of the following: thickness of the zygomatic arch, thickness of the brow ridge, height of the sagittal crest, width and thickness of the jawbone, skull depth and width.

Transforming Raw Data (page 26)

1. (a) Transforming data involves performing calculations using the raw data to determine such properties as rates, percentages, and totals.
   (b) The purpose of data transformation is to convert raw data into a more useful form.

2. (a) **Transformation**: Percentage (percentage cover)
   Reason: Abundance alone might not reflect the importance of a species in terms of its dominance in the habitat.
   (b) **Transformation**: Relative value (ml per unit weight)
   Reason: this transformation allows animals of different body size to be compared meaningfully without the interfering influence of actual body size.
   (c) **Transformation**: Reciprocal
   Reason: Provides a measure of rate where the data have been recorded over very different time periods (time taken for precipitation to occur). It is difficult to compare values where the time scale is different for each recording.
   (d) **Transformation**: Rate
   Reason: Data may have been recorded over different time periods. A rate allows the production of CO_2 to be compared per unit of time over all temperatures (removes the confounding effect of different time periods as well as different temperatures).

3. Performing data transformations:
   (a) Incidence of cyanogenic clover in different regions:

	Frost free No.	Frost free %	Frost prone No.	Frost prone %	Totals
Cyanogenic	124	78	26	18	150
Acyanogenic	35	22	115	82	150
Total	159	100	141	100	300

   (b) Plant transpiration loss:

Time	Pipette arm reading (cm^3)	Plant water loss ($cm^3\ min^{-1}$)
0	9.0	-
5	8.0	0.20
10	7.2	0.16
15	6.2	0.20
20	4.9	0.26

   (c) Photosynthetic rate at different light intensities:

Light intensity	Average time (min)	Reciprocal of time (min^{-1})
100	15	0.067
50	25	0.040
25	50	0.020
11	93	0.011
6	187	0.005

   (d) Frequency of size classes of eels:

Size class (mm)	Frequency	Relative frequency (%)
0-50	7	2.6
50-99	23	8.5
100-149	59	21.9
150-199	98	36.3
200-249	50	18.5
250-299	30	11.1
300-349	3	1.1
Total	**270**	**100.0**

Data Presentation (page 29)

1. Any of: • Presents numerical data in a concise, accurate and structured form • Condenses numerical data for display (especially if totals or averages are displayed) • Allows meaningful comparisons between numerical data.

2. (a) Scales that *are not* appropriate may leave all the plotted data in a small corner of the graph or not allow the data to be accurately interpreted. Appropriate scales prevent this and allow the data to convey all the available information clearly.
   (b) A floating scale enables data points to be plotted away from the axis (this make interpretation of these points easier). A broken scale allows a graph to fill the entire space provided (without condensing it to one corner). (Again, data interpretation is easier).

Drawing Bar Graphs (page 30)

1. (a) Table as below:

Species	Site 1	Site 2
Ornate limpet	21	30
Radiate limpet	6	34
Limpet sp. A	38	-
Limpet sp. B	57	39
Limpet sp. C	-	2
Catseye	6	2
Topshell	2	4
Chiton	1	3

(b) Bar graph: *see next page of graph solutions.*

Drawing Histograms (page 31)

1. (a) Tally chart totals as below:

Weight group	Total
45-49.9	1
50-54.9	2
55-59.9	7
60-64.9	13
65-69.9	15
70-74.9	13
75-79.9	11
80-84.9	16
85-89.9	9
90-94.9	5
95-99.9	2
100-104.9	0
105-109.9	1

(b) Histogram: *see next page of graph solutions.*

Drawing Pie Graphs (page 32)

1. (a) Tabulated data:

Food item in diet	Ferrets		Rats		Cats	
	% in diet	Angle (°)	% in diet	Angle (°)	% in diet	Angle (°)
Birds	23.6	85	1.4	5	6.9	25
Crickets	15.3	55	23.6	85	-	-
Insects	15.3	55	20.8	75	1.9	7
Voles	9.2	33	-	-	19.4	70
Rabbits	8.3	30	-	-	18.1	65
Rats	6.1	22	-	-	43.1	155
Mice	13.9	50	-	-	10.6	38
Fruits	-	-	40.3	145	-	-
Leaves	-	-	13.9	50	-	-
Unid.	8.3	30	-	-	-	-

(b) Pie graphs: *see next page of graph solutions.*

Drawing Kite graphs (page 33)

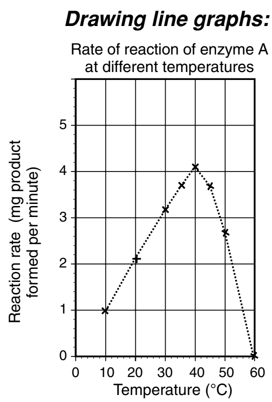
1. (a) Table:

Distance from mouth (km)	Wet weight (g m^{-2})		
	Stm A	Stm B	Stm C
0	0.4	0.4	0
0.5	0.5	0.6	0.5
1.0	0.4	0.1	0
1.5	0.3	0.5	0.2
2.0	0.3	0.4	-
2.5	0.6	0.3	-
3.0	0.1	-	-
3.5	0.7	-	-
4.0	0.2	-	-
4.5	2.5	-	-
5.0	0.3	-	-

(b) Kite graph: *see next page of graph solutions.*

Drawing Line Graphs (page 34)

1. (a) Line graph:



(b) Rate of reaction at 15°C = 1.6 mg product min^{-1}

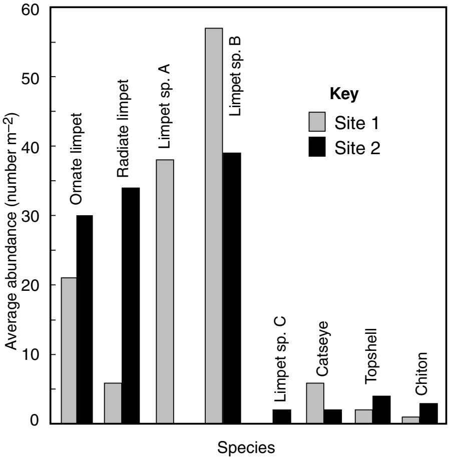
2. Line graph: *see next page of graph solutions.*

Interpreting Line Graphs (page 36)

1. (b) **Slope**: Negative linear relationship, with constantly falling slope.
   Interpretation:Variable Y decreases steadily with increase in variable X
   (c) **Slope**: Constant, level slope
   Interpretation: Increase in variable X does not affect variable Y
   (d) **Slope**: Slope rises and then becomes level
   Interpretation: Variable Y initially increases with increase in variable X, then levels out (no further increase with increase in variable X)
   (e) **Slope**: Rises, peaks and then falls
   Interpretation: Variable Y initially increases with increase in variable X, peaks and then declines with further increase in variable X
   (f) **Slope**: Exponentially increasing slope
   Interpretation: As variable X increases, variable Y increases exponentially

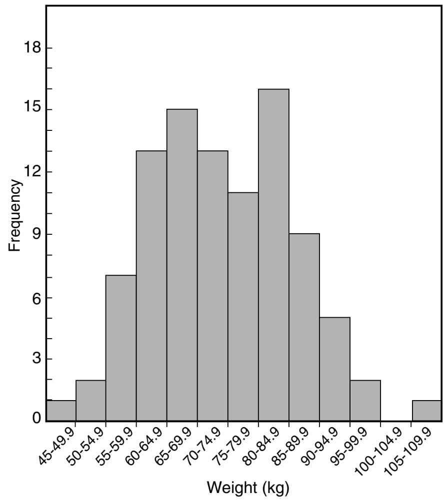
Drawing bar graphs:

Average abundance of eight mollusc species at two sites along a rocky shore



Drawing histograms:

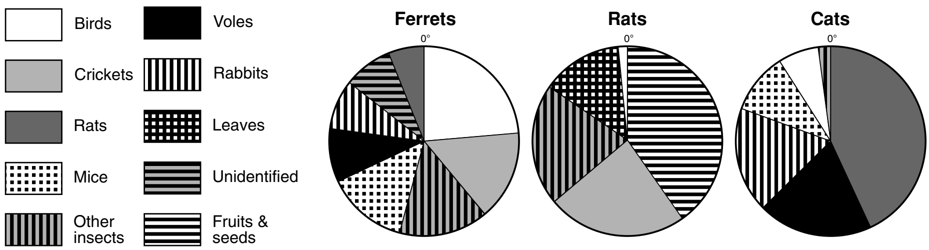
Frequency histogram of weights of 95 individuals (males and females)



Drawing pie graphs:

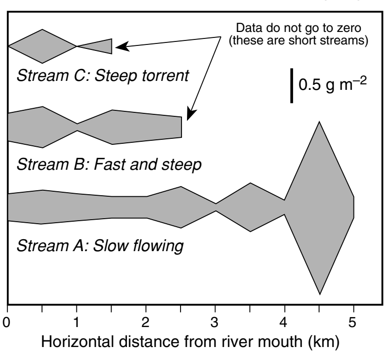
Key to food items in the diet

Percentage occurrence of different food items in the diets of ferrets, rats, and cats

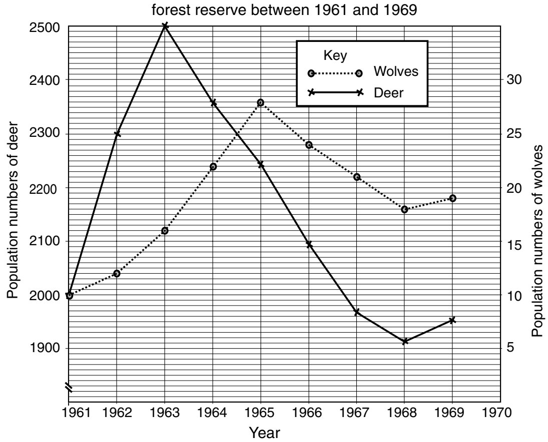


Drawing kite graphs:

Distribution of invertebrates along 3 different streams as indicated by biomass measured as wet weight (g m−2)



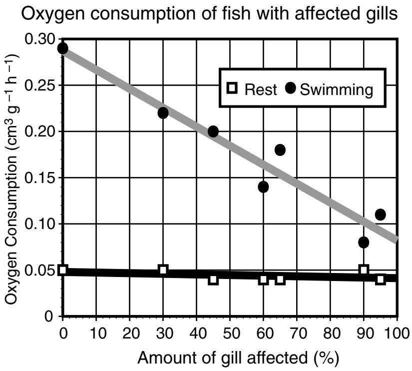
Numbers of deer and wolves on an island forest reserve between 1961 and 1969



2. The data suggest that the deer population is being controlled by the wolves. Deer numbers increase to a peak when wolf numbers are at their lowest; the deer population then declines (and continues declining) when wolf numbers increase and then peak.
   Note: A scenario of apparent control of the deer population by the wolves is suggested, but not confirmed, by the data. In natural systems, this suggestion (of prey control by a large predator) *may* be specious; most large predators do not control their prey (except perhaps at low population densities in certain systems), but are themselves controlled by the numbers of available prey, which are regulated by other factors such as food availability. In this case, the wolves were introduced for the purpose of controlling deer and were probably doing so. However, an equally valid interpretation of the data could be that the wolves are responding to changes in deer numbers (with the usual lag inherent in population responses), and the deer were already peaking in response to factors about which we have no information.

Drawing Scatter Plots (page 37)

1. Scatter plot and fitted curve:



2. (a) At rest: No clear relationship; the line on the graph appears to have no significant slope (although this could be tested). (**Note**: there is a slight tendency for oxygen consumption to fall as more of the gill becomes affected, but the scatter of points precludes making any conclusions about this).
   (b) Swimming: A negative linear relationship; the greater the proportion of affected gill, the lower the oxygen consumption.

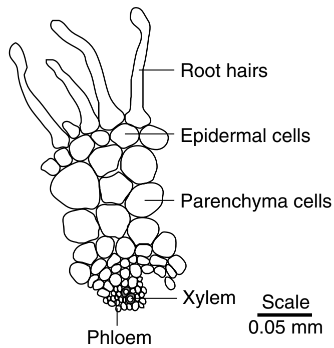
3. The gill disease appears to have little or no effect on the oxygen uptake in resting fish.

Biological Drawings (page 38)

Eight features in any order:

1. (a) Lines cross over each other and are angled.
   (b) Cells are inaccurately drawn: they are not closed shapes, they do not even nearly represent what is actually there, there are overlaps.
   (c) There is no magnification given.
   (d) The drawing is cramped at the top corner.
   (e) Labels are drawn on an angle.
   (f) There is no indication of whether the section is a cross section or longitudinal section.
   (g) There is a line to a cell type that has no label
   (h) Shading is inappropriate and does not indicate anything. It is apparently random and is unnecessary.
   (i) The material being drawn has not been identified accurately in the title by species.

2. Student's response required here. Some desirable features are shown in the figure below, but page position and size cannot be shown:



Root tranverse section from Ranunculus

3. A **biological drawing** is designed to convey useful information about the structure of an organism. From such diagrams another person should be able to clearly identify similar organisms and structures. By contrast, **artistic drawings** exhibit 'artistic license' where the image is a single person's impression of what they saw. It may not be a reliable source of visual information about the structure of the organism.

Descriptive Statistics (page 40)

1. The modal value and associated ranked entries indicate that the variable being measured (spores per frond) has a bimodal distribution i.e. the data are not normally distributed. (Therefore) the mean and median are not accurate indicators of central tendency. Note also that the median differs from the mean; also an indication of a skewed (non-normal) distribution.

2. See results below:

Beetle mass (g)	Tally	Total
2.1	|	1
2.2	||	2
2.3		0
2.4	||	2
2.5	////	4
2.6	///	3
2.7	|	1
2.8	||	2

Median = 8th value when in rank order
= 2.5

Mode = 2.5

Mean = 2.49
= 2.5

The Student's *t* Test (page 42)

1. (a) The calculated t value is less than the critical value of $t = 2.57$. The null hypothesis cannot be rejected. (There is no difference between the control and the experimental treatments).
   (b) The new t value supports the alternative hypothesis at $P = 0.05$ (reject the null hypothesis and conclude that there is a difference between the control and experimental treatments). Note the critical value of t in this case is 2.23 at 10 d.f. $P = 0.05$.

2. Outliers can skew the data set, leading to mean values between data sets that are very different (even though the bulk of the data may not be very different). This could result in the rejection of H_0 when it is true.

3. Statistical significance refers to the probability that an observed difference (or trend) will occur by chance. It is an arbitrary criterion used as the basis for accepting or rejecting the null hypothesis in an investigation. **Note**: in science the term 'significantly different' has a specific meaning and should not be used in a casual manner when no statistical test has been performed.

The Structure of a Report (page 44)

1. (a) **Hypothesis**: The soil from immediately around the rhododendrons differs from the soil outside the area of rhododendron growth with respect to its suitability for the growth of soft leaved species A.
   Conclusion: The soil type from the two regions has no effect on the growth of soft leaved species A.
   (b) **Hypothesis**: The water content of the soil influences the growth of soft leaved species A.

Writing the Methods Section (page 45)

1. (a) - (h) Any of the following in any order:
   - Number of worms used not stated.
   - No description of the pond (size, water depth etc.).
   - Value of "room" temperature not stated.
   - Date somewhat irrelevant (time of year could be).
   - Source of seawater not stated.
   - Conditions of the worms before experiment not stated.
   - Volume of 100% seawater used not stated.
   - Dilution of seawater not stated.
   - Volume of diluted seawater used not stated.
   - Weighing equipment used not stated.
   - Time interval for reweighing not stated.

Citing and Listing References (page 46)

1. Reference list as follows:

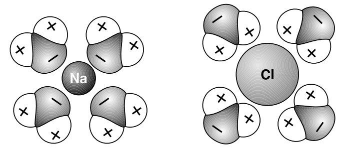
Ball, P. 1996: Living factories. New Scientist 2015: 28-31.
Campbell, N. 1993: Biology. Benjamin/Cummings. Ca. pp. 18-23.
Cooper, G. 1997: The cell: a molecular approach. ASM Press, Washington DC. pp. 75-85
Moore, P. 1996: Fuelled for life. New Scientist 2012: 1-4.
O'Hare, L. and O'Hare, K. 1996: Food biotechnology. Biological Sciences Review 8(3): 25.
Roberts, I. and Taylor, S. 1996: Development of a procedure for purification of a recombinant therapeutic protein. Australasian Biotechnology 6(2): 93-99.

Report Checklist (page 47)

To be competed by the student.

Biological Molecules (page 50)

1. See diagram below:



Water surrounding a positive ion (Na^+)   Water surrounding a negative ion (Cl^-)

2. The dipole nature of water means that it is a good solvent for many substances, e.g. ionic solids and other polar molecules such as sugars and amino acids. It is therefore readily involved in biochemical reactions.

3. Carbon, hydrogen, and oxygen.

4. Sulfur and nitrogen.

5. Four covalent bonds (valency of 4).

6. It is an aldehyde

7. (a) **Clarity**: *Property*: Water is colorless and light penetrates through it. *Biological importance*: This property allows photosynthesis to continue to considerable depth. The photosynthetic region (the euphotic zone) supports life on Earth.
   (b) **Xylem transport**: *Property*: Cohesive properties and high tensile strength. *Biological importance*: These properties allow water molecules to stick together and move cohesively through vessels to considerable heights (important in water and mineral uptake from the soil).
   (c) **Glucose transport**: *Property*: Water is the universal solvent. *Biological importance*: Solvent properties of water enable materials such as glucose to be transported around the body.
   (d) **Thermal stability**: *Property*: High specific heat capacity; water absorbs large amounts of energy for a small rise in temperature. *Biological importance*: The thermal stability of aquatic environments allows organisms (without thermoregulatory abilities) to maintain stable internal temperatures despite fluctuations in seasonal air temperatures.
   (e) **Cooling effect of evaporation**: *Property*: High latent heat of vaporization; water absorbs large amounts of energy before evaporating. *Biological importance*: Organisms in fluctuating environments can use sweating and transpiration effectively in temperature control.

Carbohydrates (page 52)

1. (a) Cellulose: Major constituent of plant cell walls - provides strength and support for the plant.
   (b) Starch: Storage form of carbohydrate for plants.
   (c) Glycogen: Storage form of carbohydrate in animals.
   (d) Deoxyribose: A ribose sugar that is a component of deoxyribonucleic acid (DNA), the genetic material

that makes up chromosomes and has a central role in determining the characteristics of an organism.
(e) Sucrose: a simple sugar that is the major component of plant cell sap (especially in sugar cane and sugar beet). It is the primary form in which sugar is translocated around the plant to regions for storage or use.

2. (a) Structural isomers have the same molecular formula but their atoms are linked in different sequences.
(b) Optical isomers are identical in every way except that they are mirror images of each other.

3. Isomers will have different bonding properties and will form different disaccharides and macromolecules depending on the isomer involved e.g. glucose and fructose are structural isomers; glucose + glucose forms maltose, glucose + fructose from sucrose. A polysaccharide of the alpha isomer of glucose forms starch whereas the beta isomer forms cellulose.

4. The hydroxyl group on the no. 1 C atom is projecting below the ring in the alpha isomer and above the ring in the other (beta) isomer. They are structural isomers.

5. Condensation reactions involve the joining of two carbohydrate molecules by a glycosidic bond with the release of a water molecule.

6. Hydrolysis reactions involve splitting a carbohydrate molecule into two, where a water molecule is used to provide a hydrogen atom and a hydroxyl group.

Lipids (page 54)

1. (a) Hydrophilic: “Water loving”: attracted to water.
(b) Hydrophobic: “Water hating”: repelled by water.

2. (a) Solid fats: Saturated fatty acids.
(b) Oils: Unsaturated fatty acids.

3. (a) Saturated fatty acids contain the maximum number of hydrogen atoms, whereas unsaturated fatty acids contain some double-bonded carbon atoms.
(b) Saturated fatty acids tend to produce lipids that are solid at room temperature, whereas lipids that contain a high proportion of unsaturated fatty acids tend to be liquid at room temperature.

4. A neutral fat comprise a glycerol attached to one, two, or three fatty acids. In waxes, the glycerol is replaced by a complex alcohol.

5. In phospholipids, one of the fatty acids is replaced with a phosphate; the molecule is ionized and the phosphate end is water soluble. Triglycerides are non-polar and not soluble in water.

6. (a) and (b) any of the following:
   - Male and female sex hormones (testosterone, progesterone, estrogen): regulate reproductive physiology and sexual development.
   - Cortisol: glucocorticoid required for normal carbohydrate metabolism and response to stress.
   - Aldosterone: acts on the kidney to regulate salt (sodium and potassium) balance.
   - Cholesterol is a sterol lipid and, while not a steroid itself, it is a precursor to several steroid hormones and a component of membranes.

7. The amphipathic nature of phospholipids (with a polar, hydrophilic end and a hydrophobic, fatty acid end) causes then to orientate in aqueous solutions so that the hydrophobic ‘tails’ point in together. Hence the bilayer nature of phospholipid membranes.

8. (a) Energy: Fats provide a compact, easily stored source of energy. Energy yield per gram on oxidation is twice that of carbohydrate.
(b) Water: Metabolism of lipids releases water (**Note**: oxidation of triglycerides releases twice as much water as carbohydrate).
(c) Insulation: Heat does not dissipate easily through fat therefore thick fat insulates against heat loss.

Amino Acids (page 56)

1. Comprise the building blocks for constructing proteins (which have diverse structural and metabolic functions). Amino acids are also the precursors of many important molecules (e.g. neurotransmitters and hormones).

2. The side chains (R groups) differ in their chemical structure (and therefore their chemical effect).

3. Peptide bond.

4. Translation of the genetic code. Genetic instructions from the chromosomes (genes on the DNA) determine the order in which amino acids are joined together.

5. Essential amino acids cannot be manufactured by the human body, they must be included in the food we eat.

6. Condensation reactions involve the joining of two amino acids (or an amino acid to a dipeptide or polypeptide) by a peptide bond with the release of a water molecule.

7. Hydrolysis involves the splitting of a dipeptide (or the splitting of an amino acid from a polypeptide) where the peptide bond is broken and a water molecule is used to provide a hydrogen atom and a hydroxyl group.

8. The L-form.

Proteins (page 58)

1. (a) **Structural**: Proteins form an important component of connective tissues and epidermal structures: collagen, keratin (hair, horn etc.). Proteins are also found scattered on, in, and through cell membranes, but tend to have a regulatory role in this instance. Proteins are also important in maintaining a tightly coiled structure in a condensed chromosome.
(b) **Regulatory**: **Hormones** such as insulin, adrenaline (modified amino acid), glucagon (peptide) are chemical messengers released from glands to trigger a response in a target tissue. They help maintain homeostasis. **Enzymes** regulate metabolic processes in cells.
(c) **Contractile**: Actin and myosin are structural components of muscle fibers. Using a ratchet system, these two proteins move past each other when energy is supplied.
(d) **Immunological**: Gamma globulins are blood proteins that act as antibodies, targeting antigens (foreign substances and microbes) for immobilization and destruction.

(e) **Transport**: Hemoglobin and myoglobin are proteins that act as carrier molecules for transporting oxygen in the bloodstream of vertebrates. Invertebrates usually have some other type of oxygen carrying molecule in the blood.
(f) **Catalytic**: Enzymes, e.g. amylase, lipase, lactase, trypsin, are involved in the chemical digestion of food. A vast variety of other enzymes are involved in just about every metabolic process in organisms.

2. Denaturation destroys protein function because it involves an irreversible change in the precise tertiary or quaternary structure that confers biological activity. For example, a denatured enzyme protein may not have its reactive sites properly aligned, and will be prevented from attracting the substrate molecule.

3. Any of the following:
   - Globular proteins have a tertiary structure that produces a globular or spherical shape. Fibrous proteins have a tertiary structure that produces long chains or sheets, often with many cross-linkages.
   - The structure of fibrous proteins makes them insoluble in water. The spherical nature of globular proteins makes them water soluble.

4. (a) 21 amino acids (b) 29 amino acids

Modification of Proteins (page 60)

1. (a) Glycoproteins are proteins with attached carbohydrates (often relatively small polymers of sugar units).
   (b) In any order, three roles of glycoproteins:
   - **Intercellular recognition**: Present on cell surfaces for recognition between cells (when cells interact to form tissues and for immune function).
   - **Transport**: Embedded in cell membranes to transport molecules through the membrane (the sugars help to maintain the position of the glycoprotein in the membrane).
   - **Regulation**: Secretory proteins from glands with a role in regulation, e.g. many pituitary hormones.

2. (a) **Lipoproteins** are proteins with attached fatty acid molecules.
   (b) Lipoproteins transport lipid molecules in the plasma between different organs in the body.

3. Proteins made on free ribosomes are released directly into the cytoplasm; there is no facility for attachment of carbohydrate as this generally requires a packaging region (the Golgi).

4. Protein orientation in the membrane is important because it is usually critical to the functional role of the protein, e.g. in intercellular recognition or transport.

Biochemical Tests (page 61)

1. Rf = 15 mm ÷ 33 mm = **0.45**

2. Rf must always be less than one because the substance cannot move further than the solvent front.

3. Chromatography would be an appropriate technique if the sample was very small or when the substance of interest contains a mixture of several different compounds and neither is predominant.

4. Immersion would just wash out the substance into solution instead of separating the components out behind a solvent front.

5. Leucine, arginine, alanine, glycine (most soluble to least soluble).

6. Lipids are insoluble in water. They will not form an emulsion in water unless they have first been dissolved in ethanol (a non-polar solvent).

Enzymes (page 62)

1. They allow reactions to proceed that would not otherwise take place (i.e. they reduce the activation energy). They speed up the rate of a reaction.

2. The substrate is the chemical(s) or compound that an enzyme acts on.

3. Active sites create points of attraction that draw the substrate onto the surface of the enzyme.

4. Metabolism is the collection of chemical reactions that sustain life within an organism.

5. (a) **Catabolism** involves metabolic reactions that break large molecules into smaller ones (releases energy therefore **exergonic**).
   Examples: Digestion and cellular respiration.
   Nature of digestion: breaks large food molecules down into simple building blocks (e.g. fats to glycerol and fatty acids; starch to glucose; proteins to free amino acids). Cellular respiration: breaks glucose down to carbon dioxide and water in a controlled series of reactions.
   (b) **Anabolism** involves metabolic reactions that build larger molecules from smaller ones (requires input of energy therefore **endergonic**).
   Example: Protein synthesis and photosynthesis.
   Nature of protein synthesis: Amino acids are joined together to form proteins (under the control of genes). Photosynthesis: In a series of reactions, CO_2 and water are used to make glucose.

6. The lock and key model proposed that the substrate was simply drawn into a closely matching cleft (active site) on the enzyme. In this model, the enzyme's active site was a somewhat passive recipient of the substrate.

7. The induced fit model is a modified version of lock and key, where the substrate fits into the active site, and this initiates a change in the shape of the enzyme's active site so that the reaction can proceed.

8. A mutation could result in a different amino acid being positioned in the polypeptide chain. The final protein may be folded incorrectly (incorrect tertiary and quaternary structure) and lose its biological function. **Note**: if the mutation is silent or in a non-critical region of the enzyme, biological function may not be affected.

Enzyme Reaction Rates (page 64)

1. (a) Increases reaction rate
   (b) By manufacturing more or less (increasing or decreasing the rate of protein synthesis).

2. (a) An increase in substrate concentration increases reaction rate to a point. Reaction rate does not continue increasing but levels off as the amount of substrate continues to increase.
   (b) The reaction rate changes because after a certain substrate level the enzymes are fully saturated by substrate and the rate cannot increase any more.

3. (a) An optimum temperature for an enzyme is the temperature at which enzyme activity is maximum.
   (b) Most enzymes perform poorly at low temperatures because chemical reactions occur slowly or not all at low temperatures (enzyme activity will reappear when the temperature increases; usually enzymes are not damaged by moderately low temperatures).

4. (a) Optimum pH: pepsin: 1-2, trypsin: approx 7.5-8.2, urease: approx. 6.5-7.0.
   (b) The stomach is an acidic environment which is the ideal pH for pepsin.

Enzyme Cofactors and Inhibitors (page 65)

1. Cofactors are non-protein molecules or ions that are required for proper functioning of an enzyme either by altering the shape of the enzyme to complete the active site or by making the active site more reactive (improving the substrate-enzyme fit).

2. (a) Arsenic, lead, mercury, cadmium.
   (b) Heavy metals are toxic because they bind to the active sites of enzymes and permanently inactivate them. While the active site is occupied by the heavy metal the enzyme is non-functional. Because they are lost exceedingly slowly from the body, anything other than a low level of these metals is toxic.

3. (a) Examples: nerve gases, cyanide, DDT, parathion, pyrethrins (insecticides).
   (b) **Nerve gases** deactivate the enzyme acetyl-cholinesterase which is important in the functioning of nerves and muscles (it normally deactivates acetylcholine in synapses and prevents continued over-response of nerve and muscle cells).
   Cyanide poisons the enzyme cytochrome oxidase, one of the enzymes in the electron transport system. It therefore stops cellular respiration.
   DDT and other organochlorines: inhibitors of key enzymes in the nervous system.
   Pyrethrins: Insecticides which inactivate enzymes at the synapses of invertebrates. This has a similar over-excitation effect as nerve gases in mammals.

4. In competitive inhibition, the inhibitor competes with the substrate for the enzyme's active site and, once in place, prevents substrate binding. A noncompetitive inhibitor does not occupy the active site but binds to some other part of the enzyme, making it less able to perform its function as an effective biological catalyst.

5. Whilst noncompetitive inhibitors reduce the activity of the enzyme and slow down the reaction rate, allosteric inhibitors block the active site altogether and prevent its functioning completely.

Industrial Production of Enzymes (page 66)

1. (a) In the production of intracellular enzymes, the microbial cells must first be separated from the culture medium and then disrupted. The production of extracellular enzymes does not require this cellular disruption.
   (b) Cellular disruption is required to release intracellular enzymes from within the cells. Extracellular enzymes are present in the medium after being secreted by the cells.

2. A crude extract is cheaper to produce in cases where a highly purified product is not required.

Putting Enzymes to Use (page 67)

1. (a) Cell free enzyme extracts generally show a high level of activity. This makes them an efficient option for industrial processes, especially those with a limited number of steps.
   (b) A cell free extract might not be used if (one of):
      – the processes involved in production of the end product were complex (involving several intracellular enzymes).
      – the enzyme involved was unstable or inactive outside the cell.

2. (a) Benefits of immobilized enzymes. Any two of:
      – Easy recovery of enzyme for reuse.
      – Easy harvesting of enzyme-free end-product.
      – Greater stability (protection of a solid matrix).
      – Continuous fermentation is possible
      – Keeps proteolytic enzymes apart so that they do not digest each other.
      – Lower cost (because enzymes can be reused).
   (b) Disadvantage of immobilized enzymes. Any of:
      – Immobilization may be difficult to achieve.
      – Immobilization may lower enzyme activity and reaction rates.
      – Immobilization technique may not be stable; enzymes may eventually wash away.
   (c) Factors affecting the rate of end-product harvest: supply of substrate, temperature, pH, method of immobilization (if any).

3. Enzymes are proteins, therefore proteases could break each other down. Immobilization holds proteolytic enzyme molecules apart from each other on an inert material so that they do not interact. In this way, the active life of the enzymes is prolonged.

4. Any of: Encapsulation may make it difficult for enzyme and substrate to interact. Covalent bonding may damage the enzyme or subtly interfere with the active site. Entrapment may affect charges on the enzyme and affect interaction with the substrate. The enzyme may also leak away. Reaction rates may be slowed if rates of diffusion of substrate and end-product into and out of a matrix are reduced. Adsorbed enzymes are not firmly attached and may wash away.

Applications of Enzymes (page 68)

Erratum: Code should be RA3

1. (a) Biosensors use biological material, e.g. an enzyme, to detect the presence or concentration of a particular substance. **Note**: The biological material is immobilized within a semi-conductor. Its activity (in response to the substrate), causes an ion change which is detected by a transducer, amplified, and displayed as a read-out.
   (b) An enzyme that uses alcohol as its substrate (e.g. alcohol dehydrogenase) could be immobilized in the biological recognition layer. The product of its activity (on alcohol) would produce a detectable change, which would be amplified and displayed as a read-out.

2. (a) The reaction would not proceed or would require high temperatures or pressures to make it proceed.
   (b) The reaction would proceed only slowly.
   Both consequences add expense to a process.

3. Brief answers only (one enzyme example given, there are often others. Students might provide more detail.
   (a) **Chymosin** from GE yeast or bacteria (including *E. coli* (Chy-max in the US) and *Kluyveromyces lactis*).
   (b) Used to coagulate the milk protein, casein.

   (a) **Amyloglucosidases** from GE bacteria.
   (b) Used to speed up the conversion of starch to sugars to get a low-calorie beer. **Note**: **proteases**, from GE microbes are used to modify the proteins from the malt and prevent cloudiness in the finishing stage. (These are in addition to the proteases arising naturally from the grain in germination, which solubilize the proteins in the grains and make the amino acids available to the yeast).

   (a) **Pectinases** from the soft-rot bacterium *Erwinnia* or from GE *Aspergillus niger*.
   (b) Breaks down the soluble pectin chains remaining in pressed juice and reduces cloudiness.

   Note: In the example of citric acid production, the connection to how enzymes are involved was not made clear. This has been clarified here and will be explained in coming editions.
   (a) **Citrate synthase** is produced by a mutant strain of the fungus *Aspergillus niger*.
   (b) Citrate synthase (also isocitrate dehydrogenase), catalyses the fermentation of sucrose (under nitrogen limitation) to citric acid, a widely used preservative and pH regulator in the food industry.

   (a) **Proteases** from *Bacillus subtilis*.
   (b) Break the peptide bonds in protein-based stains.

   (a) **Invertase** (sucrase) from *Saccharomyces* spp.
   (b) Converts sucrose to glucose and fructose (invert syrup) to produce a soft center in sweets.

   (a) **Glucose oxidase** from the fungus *Aspergillus niger*.
   (b) Used in medical biosensors for the detection of blood glucose level. Glucose oxidase catalyses the conversion of the glucose to gluconic acid.

   (a) **Proteases** from *Bacillus subtilis*.
   (b) Break the peptide bonds in proteins, and digesting the hair and tissue from animal hides.

   (a) **Lactase** from the bacterium *Kluyveromyces lactis*.
   (b) Converts lactose to glucose and galactose in low lactose dairy products.

   (a) **Ligninases** from white rot fungal species.
   (b) Breaks down the lignin in wood pulp and wood waste. Lignin is a complex molecule and several enzymes, including laccase, lignin peroxidase, and manganese peroxidase are involved.

The Cell Theory (page 71)

1. Microscopes enabled cells to be seen and examined in detail. Microscopy opened up an entire new field: the study of cells and microorganisms.

2. Spontaneous generation referred to the arising of living matter from non-living (inanimate) material (e.g. blowflies arising from meat). It was discredited because closer examination of cells and their processes revealed how cells really arise, grow, and divide.

Characteristics of Life (page 72)

1. Cytoplasm (nutrient "soup"), plasma membrane, metabolism (the cell's own cellular machinery).

2. (a) **Size**: viruses are very small: generally 50-500 times smaller than a typical prokaryotic cell and up to 5000 times smaller than a eukaryote cell.
   (b) **Metabolism**: Cells have metabolic activity; there are chemical reactions taking place much of the time. A virus has no cytoplasm and no metabolism of its own. It relies on the metabolism of its host cell.
   (c) **Organelles**: Viruses have no organelles unlike cells, most of which have organelles which carry out specific roles in the cell.
   (d) **Genetic material**: Viruses have a single or double stranded chromosome which can be RNA or DNA. Cells have only double stranded DNA chromosomes. In eukaryotes the chromosomes are contained within a nuclear membrane.
   (e) **Life cycle**: Outside a living cell viruses exist as inert particles, adopting a "living" program only when they invade a host cell and can take over the cellular machinery of the cell. At times, they may integrate into the host cell's chromosome and remain latent. Cells are generally either "alive" (when there is metabolic activity) or dead (no metabolic activity). **Note**: There are exceptions to this generalization, e.g. bacterial endospores which are special resting stages with no metabolic activity.

3. Virion (inert but fully assembled and ready to infect).

4 They are considered non-living because they are non-cellular (cells being the unit structure of life) and they do not show all the eight characteristics of living things.

Types of Living Things (page 73)

1. (a) **Autotrophic**: Obtain their energy from an inorganic source (from the physical environment); either light or chemical energy.
   (b) **Heterotrophic**: Obtain their energy from living or dead remains of other organisms.

2. (a) and (b) any two of:
   - Prokaryotes lack a distinct nucleus.
   - Prokaryotes have no membrane-bound organelles.
   - Prokaryote cell wall usually contains peptidoglycan.
   - DNA is present as a single, naked chromosome.

3. (a) Lack chlorophyll
   (b) Cell walls contain chitin (not cellulose)
   (c) Heterotrophic (not autotrophic)

4. Protistans often exhibit both animal-like and plant-like features and the group is very diverse in terms of nutrition, reproduction, and structure.
   Note: From a phylogenetic point of view, the protists are not monophyletic and should be classified accordingly.

Cell Sizes (page 74)

1.

(a) *Amoeba*:	300 µm	0.3 mm
(b) Foraminiferan:	400 µm	0.4 mm
(c) *Leptospira*:	7-8 µm	0.007-0.008 mm
(d) Epidermis:	120 µm	0.12 mm
(e) *Daphnia*:	2,500 µm	2.5 mm
(f) *Papillomavirus*:	0.13 µm	0.00013 mm

2. *Papillomavirus*; *Leptospira*; Epidermis; *Amoeba*; Foraminiferan; *Daphnia*

3. Epidermis (possibly), *Amoeba*, Foraminiferan, *Daphnia*

4. (a) 0.00025 mm (b) 0.45 mm (c) 0.0002 mm

Unicellular Eukaryotes (page 75)

1. Summary for each organism under the given headings:
   Amoeba:
   Nutrition: Heterotrophic, food (e.g. bacteria) ingested by phagocytosis. Food digested in food vacuoles.
   Movement: By pseudopodia (cytoplasmic projections).
   Osmoregulation: Contractile vacuole.
   Eyespot: Absent
   Cell wall: Absent

   Paramecium:
   Nutrition: Heterotrophic (feeds on bacteria and small protists). Food digested in food vacuoles.
   Movement: By beating of cilia.
   Osmoregulation: Contractile vacuoles.
   Eyespot: Absent
   Cell wall: Absent

   Euglena:
   Nutrition: Autotrophic (photosynthetic), but can be heterotrophic when light deprived.
   Movement: By flagella (one larger, which is labeled, and one very small, beside the gullet).
   Osmoregulation: Contractile vacuole.
   Eyespot: Present.
   Cell wall: Absent, although there is a wall-like pellicle, which lies inside the plasma membrane and is flexible.

   Chlamydomonas:
   Nutrition: Autotrophic (photosynthetic).
   Movement: By flagella.
   Osmoregulation: Contractile vacuole.
   Eyespot: Present.
   Cell wall: Present.

2. *Amoeba*, *Paramecium*, *Euglena*, *Chlamydomonas.*

3. An eye spot enables an autotroph to detect light so that it can move into well lit regions where it can photosynthesize.

Optical Microscopes (page 76)

1. Compound microscope (a)-(h) and dissecting microscope (i)-(m) as follows:
   (a) Eyepiece lens
   (b) Arm
   (c) Coarse focus knob
   (d) Fine focus knob
   (e) Objective lens
   (f) Mechanical stage
   (g) Condenser
   (h) In-built light source
   (i) Eyepiece lens
   (j) Eyepiece focus
   (k) Focus knob
   (l) Objective lens
   (m) Stage

2. Phase contrast: used where the specimen is transparent (to increase contrast between transparent structures). **Note**: it is superior to dark field because a better image of the interior of specimens is obtained.

3. (a) Plant cell – any two of: cell wall, nucleus (may see chromatin if stained appropriately), vacuole, cell membrane (high magnification), Golgi apparatus, mitochondria (high magnification), chloroplast, cytoplasm (if stained), nuclear envelope (maybe).
   (b) Animal cell – any two of: nucleus (may see chromatin if stained appropriately), centriole, cell membrane (high magnification), Golgi apparatus, mitochondria (high magnification), cytoplasm (if stained), nuclear envelope (maybe).

4. Ribosomes, microtubules, endoplasmic reticulum, Golgi vesicles (free), nuclear envelope as two layers, lysosomes (animal cells). Also detail of organelles such as mitochondria and chloroplasts.

5. (a) Leishman's stain
   (b) Schultz's solution
   (c) Feulgen's stain
   (d) Aniline blue
   (e) Hemotoxylin/methylene blue
   (f) Schultz's solution

6. (a) 600X magnification (b) 600X magnification

7. Bright field microscopes produces a flat (2-dimensional) image, which looks through a thin, transparent sample. Dissecting microscopes produces a 3-dimensional image, which looks at the surface details.

8. Magnification is the number of times larger an image is than the specimen. Resolution is the degree of detail which can be achieved. The limit of resolution is the minimum distance by which two points in a specimen can be separated and still be distinguished as separate points. **Note**: By adding stronger, or more, lenses, a light microscope can magnify an image many thousands of times but its resolution is limited. Electron microscopes have a greater resolving power than light microscopes because of the very short wavelength of the electrons used.

Electron Microscopes (page 78)

1. The limit of resolution (see point 8 above) is related to wavelength (about 0.45X the wavelength). The shortest visible light has a wavelength of about 450 nm giving a resolution of 0.45 x 450 nm; close to 200 nm. Points less than 200 nm apart will be perceived as one point or a blur. Electron beams have a much shorter wavelength than light so the resolution is much greater (points that are 0.5 nm apart can be distinguished as

separate points; a resolving power that is 400X that of a light microscope).

2. (a) TEM: Used to (any of): show cell ultrastructure i.e organelles; to investigate changes in the number, size, shape, or condition of cells and organelles i.e. demonstrate cellular processes or activities; to detect the presence of viruses in cells.
   (b) SEM: Used to (any of): show the surface features of cells e.g. guard cell surrounding a stoma; to show the surface features of entire organisms for identification purposes (often used for invertebrates and viruses); for general identification by surface feature e.g. for pollen grains used in paleoclimate research.
   (c) Bright field (compound): Used for (any of): examining prepared sections of tissue for cellular detail; for examining living tissue for large scale movements e.g. blood flow in capillaries or cytoplasmic streaming.
   (d) Dissecting: Used for (any of): examining living specimens for surface detail and structures; sorting material from samples (e.g. leaf litter or stream invertebrates; dissecting a small organism where greater resolution than the naked eye is required.

3. A TEM — E SEM
   B Bright field LM — F Bright field LM
   C TEM — G Dissecting LM
   D Bright field LM — H SEM

Bacterial Cells (page 80)

1. (a) The nuclear material (DNA) is not contained within a clearly defined nucleus with a nuclear membrane.
   (b) Membrane-bound cellular organelles (e.g. mitochondria, endoplasmic reticulum) are missing.
   (c) Single, circular chromosome sometimes with accessory chromosomes called plasmids.

2. (a) Locomotion: flagella enable bacterial movement out of unsuitable conditions to preferred conditions.
   (b) Fimbriae are shorter, straighter, and thinner than flagella. They are used for attachment rather than locomotion.

3. The gram stain is based on the retention of the stain by the cell wall. This is dependent on the amount of peptidoglycan in the wall. **Note**: Gram positive bacteria have a thick layer of peptidoglycan which retains the stain so that the bacteria appear dark violet. Gram negative bacteria have only a thin layer of peptidoglycan that does not retain the stain during the decolorization phase and the cells appear clear, although they can be counterstained with safranin.

4. (a) The glycocalyx is a viscous, gelatinous layer outside the cell wall in some bacteria. It usually comprises polysaccharide and/or polypeptide and may take the form of a capsule (firmly attached to the wall) or a slime layer (loosely attached to the wall).
   (b) Capsules contribute to bacterial virulence, allowing the bacterium to evade the host's immune system. Capsules may also facilitate attachment to surfaces.

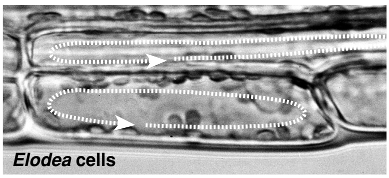
5. (a) Conjugation enables the exchange of DNA from a donor cell to a recipient cell. In this way, beneficial mutations, such as those conferring antibiotic resistance, can be transferred between bacteria.
   (b) Conjugation allows bacteria that have acquired new genes (e.g. for antibiotic resistance) to pass on those genes to other (compatible) bacteria. This allows for rapid genetic change since mutations are not lost but on to other bacteria. NOTE: the genes for antibiotic resistance are often carried on extra-chromosomal (plasmid) DNA, so that chances of gene transfer through conjugation are increased.

6. Plasmids are used extensively in recombinant DNA technology. Being accessory to the main chromosome, the plasmid DNA can be manipulated easily. Using restriction enzymes, foreign genes (e.g. gene for producing insulin) can be spliced into a plasmid, which then carries out the instructions of the foreign gene.

Plant Cells (page 82)

1. A: Nucleus — C: Nucleus
   B: Cell wall — D: Chloroplasts

2. (a) Cytoplasmic streaming is the rapid movement of cytoplasm within eukaryotic cells, seen most clearly in plant and algal cells.
   (b)

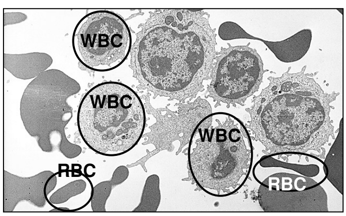


3. Any three of:
   - Starch (branched carbohydrate) granules stored in amyloplasts (energy store)
   - Chloroplasts, discrete plastids containing the pigment chlorophyll, involved in photosynthesis.
   - Large vacuole, often central (vacuoles are present in animal cells, but are only small).
   - Cell wall of cellulose forming the rigid, supporting structure outside the plasma membrane.

Animal Cells (page 83)

1. A: Nucleus B: Plasma membrane C: Nucleus

2. (a)



White blood cells (WBC) & red blood cells (RBC)

   (b) Any of the following reasons: The RBCs have no nucleus and they are smaller than the white blood cells. The white blood cells have extensions of the plasma membrane (associated with being mobile and phagocytic), are larger than the RBCs, and have a nucleus.

3. Centrioles (although these are present in lower plants, they are absent from higher plants). They are microtubular structures responsible for forming the poles and the spindles during cell division.

Cell Structures and Organelles (page 84)

(b) **Name**: Ribosome
Location: Free in cytoplasm or bound to rough ER
Function: Synthesize polypeptides (=proteins)
Present in plant cells: Yes
Present in animal cells: Yes
Visible under LM: No

(c) **Name**: Mitochondrion
Location: In cytoplasm as discrete organelles
Function: Site of cellular respiration (ATP formation)
Present in plant cells: Yes
Present in animal cells: Yes
Visible under LM: Not with most standard school LM, but can be seen using high quality, high power LM.

(d) **Name**: Golgi apparatus
Location: In cytoplasm associated with the smooth endoplasmic reticulum, often close to the nucleus.
Function: Final modification of proteins and lipids. Sorting and storage for use in the cell or packaging molecules for export.
Present in plant cells: Yes
Present in animal cells: Yes
Visible under LM: Not with most standard school LM, but may be visible using high quality, high power LM.

(e) **Name**: Endoplasmic reticulum (in this case, rough ER)
Location: Penetrates the whole cytoplasm
Function: Involved in the transport of materials (e.g. proteins) within the cell and between the cell and its surroundings.
Present in plant cells: Yes
Present in animal cells: Yes
Visible under LM: No

(f) **Name**: Chloroplast
Location: Within the cytoplasm
Function: The site of photosynthesis
Present in plant cells: Yes
Present in animal cells: No
Visible under LM: Yes

(g) **Name**: Centrioles
Location: In cytoplasm,usually next to the nucleus.
Function: Involved in cell division (probably in the organization of the spindle fibers).
Present in plant cells: Variably (absent in higher plants)
Present in animal cells: Yes
Visible under LM: No

(h) **Name**: Cilia and flagella
Location: Anchored in the cell membrane and extending outside the cell.
Function: Motility.
Present in plant cells: No
Present in animal cells: Yes
Visible under LM: Variably (depends on magnification and preparation/fixation of material).

(i) **Name**: Cellulose cell wall
Location: Surrounds the cell and lies outside the plasma membrane.
Function: Provides rigidity and strength, and supports the cell against changes in turgor.
Present in plant cells: Yes
Present in animal cells: No
Visible under LM: Yes

(j) **Name**: Lysosome
Location: Free in cytoplasm.
Function: Ingests and destroys foreign material. Able to digest the cell itself under some circumstances.
Present in plant cells: Yes but variably (vacuoles may have a lysosomal function in some plant cells).
Present in animal cells: Yes
Visible under LM: No

(k) **Name**: Vacuole (a food vacuole in an animal cell is shown, so students may answer with respect to this).
Location: In cytoplasm.
Function: In plant cells, the vacuole (often only one) is a large fluid filled structure involved in storage and support (turgor). In animal cells, vacuoles are smaller and more numerous, and are involved in storage (of water, wastes, and soluble pigments).
Present in plant cells: Yes, as (a) large structure(s).
Present in animal cells: Yes, smaller, more numerous
Visible under LM: Yes in plant cells, no in animal cells.

(l) **Name**: Nucleus
Location: Discrete organelle, position is variable.
Function: The control center of the cell; the site of the nuclear material (DNA).
Present in plant cells: Yes
Present in animal cells: Yes
Visible under LM: Yes.

Differential Centrifugation (page 86)

1. Cell organelles have different densities and spin down at different rates. Smaller organelles take longer to spin down and require a higher centrifugation speed to separate out.

2. (a) Supernatant: the fluid remaining above a pellet that has spun down.
(b) Homogenized: broken up (of cells).

3. (a) Isotonic solution is needed so that there are no volume changes in the organelles.
(b) Cool solution prevent self digestion of the organelles by enzymes released during homogenization.
(c) Buffered solution prevents pH changes that might denature enzymes and other proteins.

4. (a) Ribosomes and endoplasmic reticulum
(b) Lysosomes and mitochondria
(c) Nuclei

Identifying Cell Structures (page 87)

1. (a) Cytoplasm
(b) Vacuole
(c) Starch granule
(d) Chloroplast
(e) Mitochondria
(f) Cell wall
(g) Chromosome
(h) Nuclear membrane
(i) Endoplasmic reticulum
(j) Plasma membrane

2. 9 cells (1 complete cell, plus the edges of 8 others)

3. Plant cell; it has chloroplasts and a cell wall. It also has a highly geometric cell shape.

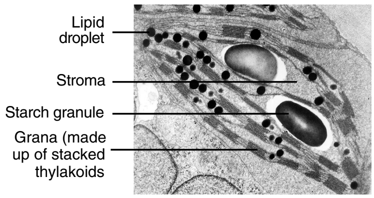
4. (a) Cytoplasm located between the plasma membrane and nuclear membrane (extranuclear).
(b) Composition of cytoplasm: A watery soup of

dissolved substances. In eukaryotic cells, organelles are found in the cytoplasm. Cytoplasm = cytosol (including cytoskeleton) + organelles.

5. (a) and (b), any of:
    - Phagocytosis: lysosomes fuse with food vacuoles (which may also contain engulfed bacteria) releasing digestive enzymes to break them down
    - Breakdown of worn out organelles; these are enveloped in a membrane. Lysosomes fuse and supply digestive enzymes to break them down.
    - Responsible for self destruction of the cell (autolysis) under certain circumstances (e.g. at the programmed end of its life).

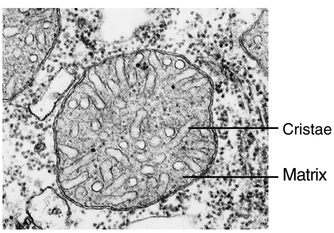
Identifying TEM Photographs (page 88)

1. (a) Chloroplast
   (b) Plant cells, particularly in leaf and green stems.
   (c) Site of photosynthesis. Captures solar energy to build glucose from carbon dioxide and water.
   (d)



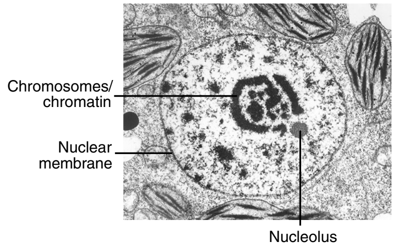
2. (a) Golgi apparatus
   (b) Plant and animal cells
   (c) Function: Packages substances to be secreted by the cell. Forms a membrane vesicle containing the chemicals for export from the cell (e.g. nerve cells export neurotransmitters; endocrine glands export hormones; digestive gland cells export enzymes).

3. (a) Mitochondrion
   (b) Plant and animal cells (most common in cells that have high energy demands, such as muscle).
   (c) Site of most of the process of cellular respiration, which releases energy from food (glucose) to fuel most cellular reactions (i.e. metabolism).
   (d)

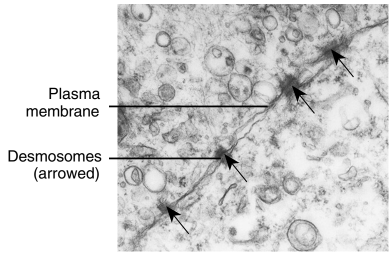


4. (a) Endoplasmic reticulum
   (b) Plant and animal cells (eukaryotes)
   (c) Function of endoplasmic reticulum: Site of protein synthesis (translation stage). Transport network that moves substances through its system of tubes. Many complex reactions need to take place on the surface of the membranes.
   (d) Endoplasmic reticulum structure: ribosomes

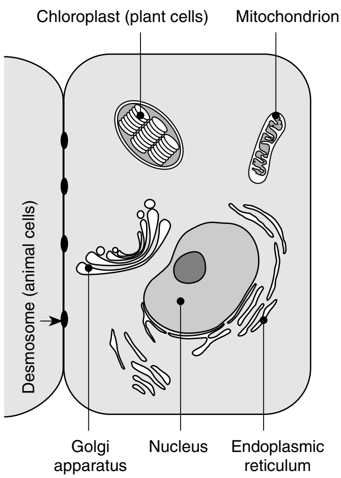
5. (a) Nucleus
   (b) Plant and animal cells (eukaryotes)
   (c) Function of nucleus: Controls cell metabolism (all the life-giving chemical reactions), and functioning of the whole organism. These instructions are inherited from one generation to the next.
   (d)



6. (a) Function of plasma membrane: Controls the entry and exit of substances into and out of the cell. Maintains a constant internal environment.
   (b)



7. Generalized cell.



Cell Division (page 90)

1. (a) Mitosis: Cell division for growth and repair produces cells with 2N chromosome number.
   (b) Meiosis: Cell division for producing gametes (sperm, pollen, eggs) with 1N chromosome number.

2. Zygote: A fertilized egg resulting from the fusing together of the sperm and the egg cells.

3. In spermatogenesis, the nucleus of the germ cell divides twice to produce four similar sized gametes (sperm cells). In oogenesis, the the two divisions are not equal and only one of the four nuclei (and most of the cytoplasm) produce the egg cell.

Mitosis and the Cell Cycle (page 91)

1 (a) Anaphase
  (b) Prophase
  (c) Early anaphase
  (d) Late anaphase
  (e) Late telophase or beginning of interphase

2. Replicate the DNA to form a second chromatid. Coil up into visible chromosomes to avoid tangling.

3. A. Interphase: The stage between cell divisions (mitoses). Just before mitosis, the DNA is replicated to form an extra copy of each chromosome - still part of the same chromosome as an extra chromatid.
   B. Late prophase: Chromosomes condense (coil and fold up) into visible form. Centrioles move to opposite ends of the cell.
   C. Metaphase: Spindle fibers form between the centrioles. Chromosomes attach to the spindle fibers at the cell 'equator'.
   D. Late anaphase: Chromatids from each chromosome are pulled apart and move in opposite directions, towards the centrioles
   E. Telophase: Chromosomes begin to unwind again. Two new nuclei form. The cell plate forms across the midline where the new cell wall will form.
   F. Cytokinesis: Cell cytoplasm divides to create two distinct 'daughter cells' from the original cell. It is in this form for most of its existence, and carries out its designated role (normal function).

Cancer: Cells out of Control (page 92)

1. They have lost control of the genetic mechanisms that regulate the cell cycle so that the cells become 'immortal'. Cancer cells also lose their specialized functions and are unable to perform their roles.

2. **Oncogene**: A mutated form of a gene regulating cell division; it results in uncontrolled cell division so that a normal cell is transformed into a malignant state.

3. Tumor-suppressor gene: Switches off cell division when it detects damage to DNA.

4. A faulty oncogene that is constantly active causes the cell to start cell division continuously.

5. A damaged tumor-suppressor gene cannot stop the cell division cycle.

Root Cell Development (page 93)

1. (a) Cells specialize to take on specific functions.
   (b) Cells are becoming longer and/or larger.
   (c) Cells are dividing by mitosis.

2. (a) Late anaphase; chromatids are being pulled apart and are at opposite poles.
   (b) Telophase; there are two new nuclei formed and the cell plate is visible.
   (c) 25 of 250 cells were in mitosis, therefore mitosis occupies 25/250 or one tenth of the cell cycle.

3. The **cambium layer** of cells (lying under the bark between the outer phloem layer of cells and the inner xylem layer of cells). **Note**: Cells dividing from each side of this layer specialize to form new phloem on the outside and new xylem on the inside.

Differentiation of Human Cells (page 94)

1. 230 different cell types
2. 50 cell divisions
3. 100 billion cells
4. Skin cells, intestinal epithelial cells, blood (stem) cells
5. Nerve cells, bone cells, kidney cells.
6. (a) Germ line is the series of cell divisions destined to produce gamete cells.
   (b) Germ cells will produce gametes (eggs and sperm) and must be essentially unspecialized cells. This is necessary so that none of the genes that are needed to produce the 230 specialized cells in new offspring are turned off before they are needed.
7. (a) A copy of a cell (or complete organism) with a genetic makeup that is identical to the single parent cell it was created from.
   (b) As for 6(b): none of the genes required to produce specialized cells have been turned off.
8. Cancerous cells are cells that have lost control of the regulatory processes that govern the cell's function. Instead they become generalized cells that lose their tissue identity, pulling away from cells around them and undergoing cell division at a rapid rate.
9. At certain stages in the sequence of cell divisions as the embryo grows, some genes get switched on while others get switched off permanently, causing the cells to take on specialized functions.

Human Cell Specialization (page 96)

1. (b) **Erythrocyte**:
   <u>Features</u>: Biconcave cell, lacking mitochondria, nucleus, and most internal membranes. Contains the oxygen-transporting pigment, hemoglobin.
   <u>Role</u>: Uptake, transport, and release of oxygen to the tissues. Some transport of CO_2. Lack of organelles creates more space for oxygen transport. Lack of mitochondria prevents oxygen use.
   (c) **Retinal cell**:
   <u>Features</u>: Long, narrow cell with light-sensitive pigment (rhodopsin) embedded in the membranes.
   <u>Role</u>: Detection of light: light causes a structural change in the membranes and leads to a nerve impulse (result is visual perception).

(d) **Skeletal muscle cell(s)**:
Features: Cylindrical shape with banded myofibrils. Capable of contraction (shortening).
Role: Move voluntary muscles acting on skeleton.
(e) **Intestinal epithelial cell**:
Features: Columnar cell with a high surface area as a result of fingerlike projections (microvilli).
Role: Absorption of digested food.
(f) **Motor neuron cell**:
Features: Cell body with a long extension (the axon) ending in synaptic bodies. Axon is insulated with a sheath of fatty material (myelin).
Role: Rapid conduction of motor nerve impulses from the spinal cord to effectors (e.g. muscle).
(g) **Spermatocyte**:
Features: Motile, flagellated cell with mitochondria. Nucleus forms a large proportion of the cell.
Role: Male gamete for sexual reproduction. Mitochondria provide the energy for motility.
(h) **Osteocyte**:
Features: Cell with calcium matrix around it. Fingerlike extensions enable the cell to be supplied with nutrients and wastes to be removed.
Role: In early stages, secretes the matrix that will be the structural component of bone. Provides strength.

Plant Cell Specialization (page 97)

1. (b) **Pollen grain**:
Features: Small, lightweight, often with spikes.
Role: houses male gamete for sexual reproduction.
(c) **Palisade parenchyma cell**:
Features: Column-shaped cell with chloroplasts.
Role: Primary photosynthetic cells of the leaf.
(d) **Epidermal cell**:
Features: Waxy surface on a flat-shaped cell.
Role: Provides a barrier to water loss on leaf.
(e) **Vessel element**:
Features: Rigid remains of a dead cell. No cytoplasm. End walls perforated. Walls are strengthened with lignin fibers.
Role: Rapid conduction of water through the stem. Provides support for stem/trunk.
(f) **Stone cell**:
Features: Very thick lignified cell wall inside the primary cell wall. The cytoplasm is restricted to a small central region of the cell.
Role: Protection of the seed inside the fruit.
(g) **Sieve tube member**:
Features: Long, tube-shaped cell without a nucleus. Cytoplasm continuous with other sieve cells above and below it. Cytoplasmic streaming is evident.
Role: Responsible for translocation of sugars etc.
(h) **Root hair cell:**
Features: Thin cuticle with no waxy layer. High surface area relative to volume.
Role: Facilitates the uptake of water and ions.

Levels of Organization (page 98)

1. **Animals**
(a) **Organ system**: Nervous system, reproductive system
(b) **Organs**: Brain, heart, spleen
(c) **Tissues**: Blood, bone, cardiac muscle, cartilage, squamous epithelium
(d) **Cells**: Leukocyte, mast cell, neuron, Schwann cell
(e) **Organelles**: Lysosome, ribosomes
(f) **Molecular**: Adrenaline, collagen, DNA, phospholipid

2. **Plants**
(a) **Organs**: Flowers, leaf, roots
(b) **Tissues**: Collenchyma*, mesophyll, parenchyma*, phloem, sclerenchyma
(c) **Cells**: Companion cells, epidermal cell, fibers, tracheid
(d) **Organelles**: Chloroplasts, ribosomes
(e) **Molecular**: Pectin, cellulose, DNA, phospholipid
* **Note** that parenchyma and collenchyma are simple tissues comprising only one type of cell (parenchyma and collenchyma cells respectively). It would not be incorrect to place these two entries under the cellular level (except that simple plant tissues are usually identified by cell name only).

3. Organization allows a grouping together of particular specialized cells and tissues to perform particular functions. This improves efficiency of function because different tasks can be shared amongst specialized cells. Energy is saved in not maintaining non-essential organelles in cells that do not require them.

4. Example only: **Organ system**: circulatory systems (cardiovascular and lymphatic systems)
Organs: Heart, lymphoid organs (spleen, tonsils etc)
Tissues: Lymph, blood, lymphatic and blood vessels, lymphoid tissues, cardiac muscle, connective tissues
Specialized cells: red blood cells, leukocyte (white blood cells of various types e.g. lymphocytes, phagocytes), platelets, cardiac muscle cells.

5. (a) **Epithelial tissues**: Single or multiple layers of simple cells forming the lining of internal and external body surfaces. Cells rest on a basement membrane of fibers and collagen and may be specialized. **Note**: epithelial cells may be variously shaped: squamous (flat), cuboidal, columnar etc.
(b) **Connective tissues**: Supporting tissue of the body, comprising cells widely dispersed in a semi-fluid matrix (or fluid in the case of blood and lymph).
(c) **Muscle tissue**: Dense tissue comprising highly specialized contractile cells called fibers held together by connective tissues.
(d) **Nervous tissue**: Tissue comprising densely packed nerve cells specialized for transmitting electro-chemical impulses. Nerve cells may be associated with supportive cells (e.g. Schwann cells), connective tissue, and blood vessels.

Cell Processes (page 101)

1. (a) Golgi apparatus
(b) Cytoplasm, mitochondria
(c) Plasma membrane, vacuoles
(d) Plasma membrane, vacuoles
(e) Endoplasmic reticulum, ribosomes, nucleus
(f) Chloroplasts
(g) Centrioles, nucleus
(h) Lysosomes
(i) Plasma membrane, Golgi apparatus

2. Anabolic processes require an input of energy to form bonds and construct molecules (e.g. photosynthesis, protein synthesis); catabolic processes involve the breaking of bonds in molecules with the consequent release of energy (e.g. cellular respiration, digestion).

The Structure of Membranes (page 102)

1. Membranes are composed of a phospholipid bilayer in which are embedded proteins, glycoproteins, and glycolipids.

2. Any two of: • Forms outer limit of the cell; keeps the cytoplasm separate from the extracellular spaces. • Controls entry and exit of materials. • Contains proteins that enable cell recognition (identifies the cell as belonging to self). • Provides a surface for enzyme attachment for metabolic reactions. • Provides compartments within cells for localization of metabolic (enzymatic) reactions.

3. (a) Any of: Golgi apparatus (bodies), endoplasmic reticulum, mitochondria, vacuoles, nucleus, chloroplasts, lysosomes.
   (b) Depends on choice: Generally the membrane's purpose is to compartmentalize the location of enzymatic reactions, to control the entry and exit of substances that the organelle operates on, and/or to provide a surface for enzyme attachment.

4. Any three of the following not already chosen: Golgi apparatus, mitochondria, vacuoles, endoplasmic reticulum, chloroplasts, lysosomes.

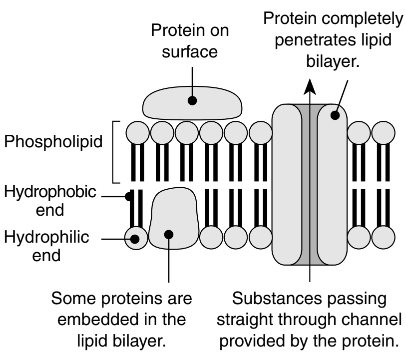
5. (a) Cholesterol lies between the phospholipids and prevents close packing. It thus functions to keep membranes more fluid. The greater the amount of cholesterol in the membrane the greater its fluidity.
   (b) At temperatures close to freezing, high proportions of membrane cholesterol is important in keeping membranes fluid and functioning.

6. The Davson-Danielli model described membranes as a lipid bilayer with a coating of protein. This model was modified when freeze-fracture techniques showed that the proteins were embedded in the membrane rather than coating the outside. Some proteins spanned the entire width of the membrane, some were either on the outside or the inside.

7. In any order: oxygen, food (sugars, carbohydrates), minerals and trace elements, water.

8. Carbon dioxide, nitrogenous wastes

9. Plasma membrane:



The Role of Membranes in Cells (page 104)

1. (a) Compartments within cells allow specific metabolic pathways in the cell to be localized. This achieves greater efficiency of cell function and keeps potentially harmful reactions and substances (e.g. hydrogen peroxide) contained.
   (b) Greater membrane surface area provides a greater area over which membrane-bound reactions can occur. This increases the speed and efficiency with which metabolic reactions can take place.

2. (a) Glycoproteins and glycolipids act as cell identity markers so that self and non-self cells can be recognized. Glycolipids also help cells to aggregate in the formation of tissues.
   (b) Channel protein and carrier proteins facilitate selective transport of substances through the membrane. (They can help to speed up the transport of substances into and out of the cell, especially for enzymatic reactions requiring a steady supply of substrate and constant removal of end-product e.g. ADP supply to the mitochondrion during cellular respiration).

3. Cholesterol can regulate the entry or exit of substances by acting as a selective plug, allowing some substances but not others to enter or leave the cell.

4. (a) Lipid soluble molecules pass easily through the phospholipid bilayer by dissolving in it. Lipid insoluble substances cannot pass directly into the bilayer (they must move through channels).
   (b) Lipid soluble substances pass very rapidly into cells (many drugs are lipid soluble). Lipid insoluble molecules must pass through protein channels (either by facilitated diffusion or active transport).

Diffusion and Osmosis (page 106)

1. Movement of molecules along a concentration gradient from regions of high concentration to regions of low concentration. Accelerated by a rise in temperature.

2. (a) Large surface area (b) Thin membrane

3. Constant use or transport away of a substance on one side of a membrane (e.g. use of ADP in mitochondria). Production of a substance on one side of a membrane (e.g. production of CO_2 by respiring cells).

4. Ionophores allow the preferential passage of some molecules but not others.

5. (a) and (b) any two of:
   - Gas exchange (O_2 and CO_2 into and out of fluids).
   - Reabsorption of water in the kidney.
   - Pheromone (chemical) attraction where chemical molecules diffuse through the medium.
   - Reabsorption of water in the gut.
   - Movement of materials within cells.

6. Cell wall pressure generated within plant cells provides the turgor to keep unlignified plant tissues supported.

7. Animal cells are less robust than plant cells against changes in net water content: Excess influx will cause bursting and excess loss causes crenulation.

8. (a) Water will move into the cell and it will burst (lyse).
   (b) The cell would lose water and the plasma membrane would crinkle up (crenulate).

9. (a) Hypotonic
   (b) Fluid replacements must induce the movement of water into the cells and tissues (which are dehydrated and have a higher solute concentration than the drink). Many sports drinks are isotonic. Depending on the level of dehydration involved, these drinks are more effective when diluted.

Online Alternative Activity: Diffusion (page 1)

1. (a) Large surface area (b) Thin membrane

2. Constant use or transport away of a substance on one side of a membrane (e.g. use of ADP in mitochondria). Production of a substance on one side of a membrane (e.g. production of CO_2 by respiring cells).

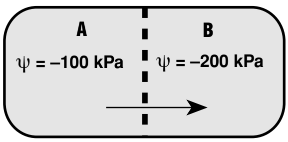
3. Ionophores allow the preferential passage of some molecules but not others.

Online Alternative Activity: Osmosis and Water Potential (page 2)

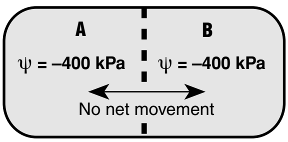
1. Zero

2. and 3. (a)- (c) as below.

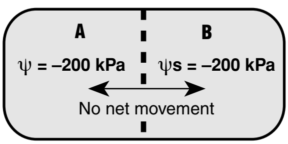
(a)



(b)



(c)



4. (a) Hypotonic
   (b) Fluid replacements must induce the movement of water into the cells and tissues (which are dehydrated and therefore have a more negative water potential than the drink). **Note**: Many sports drinks are isotonic. Depending on the level of dehydration involved, these drinks are more effective when diluted.

5. *Paramecium* is hypertonic to the surrounding freshwater environment and water constantly flows into the cell. This must be continually pumped out (by contractile vacuoles).

6. (a) Pressure potential generated within plant cells provides the turgor necessary for keeping unlignified plant tissues supported.
   (b) Without cell turgor, soft plant tissues (soft stems and flower parts for example) would lose support and wilt. **Note** that some tissues are supported by structural components such as lignin.

7. Animal cells are less robust than plant cells against changes in net water content: Excess influx will cause bursting and excess loss causes crenulation.

8. (a) Water will move into the cell and it will burst (lyse).
   (b) The cell would lose water and the plasma membrane would crinkle up (crenulate).
   (c) Water will move into the cell and it will burst (lyse).

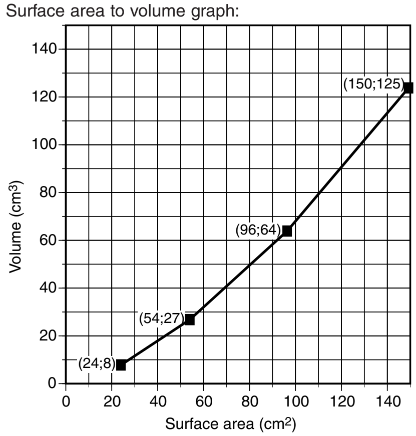
9. Malarial parasite: isotonic to blood.

Surface Area and Volume (page 108)

1.

Cube	Surface area	Volume	Ratio
3cm:	3 x 3 x 6 = 54	3 x 3 x 3 = 27	2.0 to 1
4cm:	4 x 4 x 6 = 96	4 x 4 x 4 = 64	1.5 to 1
5cm:	5 x 5 x 6 = 150	5 x 5 x 5 = 125	1.2 to 1

2. Surface area to volume graph:



3. Volume

4. Increasing size leads to less surface area for a given volume. The surface area to volume ratio decreases.

5. Less surface area at the cell surface. This is the gas exchange surface - so large cells will have difficulty moving enough materials in and out of the cell to meet demands. This is what limits a cell's maximum size. **Note**: Eukaryote cells are typically about 0.01-0.1 mm in size, but some can be bigger than 1 mm. The largest cell is the female sex cell (ovum) of the ostrich, which averages 15-20 cm in length. Technically a single cell, it is atypical in size because almost the entire mass of the egg is food reserve in the form of yolk, which is not part of the functioning structure of the cell itself.

Ion Pumps (page 110)

1. If an animal cell (not protected by a rigid cell wall), contains excessive quantities of ions, it may take up so

much water by osmosis that it would swell up and burst.

2. An ion exchange pump creates an unequal balance of ions across the membrane. The transport of other molecules (e.g sucrose) can be coupled to the passive diffusion of an ion (e.g. H^+) as it diffuses down its concentration gradient.

3. ATP is required to move ions **against** their concentration gradient (an energy requiring process). (When a phosphate is transferred from the ATP to the carrier protein, a shape change in the protein brings about the transfer of the bound molecule (e.g. an ion) from one side of the membrane to the other).

4. Coupled pumps operate in:
   - Loading of sucrose into the phloem sieve tube cells (coupled to a proton pump).
   - Transport of glucose across the epithelium of the gut into the blood (coupled to a sodium pump).

Exocytosis and Endocytosis (page 111)

1. Phagocytosis is the engulfment of solid material by endocytosis whereas pinocytosis is the uptake of liquids or fine suspensions by endocytosis.

2. Phagocytosis examples (any of):
   • Feeding in *Amoeba* by engulfment of material using cytoplasmic extensions called pseudopodia. • Ingestion of old red blood cells by Küpffer cells in the liver. • Ingestion of bacteria and cell debris by neutrophils and macrophages (phagocytic white blood cells).

3. Exocytosis examples (any of):
   • Secretion of substances from specialized secretory cells in multicellular organisms e.g. hormones from endocrine cells, digestive secretions from exocrine cells. • Expulsion of wastes from unicellular organisms e.g. *Paramecium* and *Amoeba* expelling residues from food vacuoles.

4. Any type of cytosis (unlike diffusion) is an active process involving the use of ATP. Low oxygen inhibits oxidative metabolism and lowers the energy yield from the respiration of substrates (ATP availability drops).

5. (a) **Oxygen**: diffusion.
   (b) **Cellular debris**: phagocytosis.
   (c) **Water**: osmosis.
   (d) **Glucose**: facilitated diffusion.

Active and Passive Transport (page 112)

1. **Passive transport**: Requires no energy input from the cell; materials follow a concentration gradient.
   Active transport: Requires considerable amounts of energy (ATP) to make materials go in a direction they would not normally go (at least at the rate required).

2. Gases moving by diffusion: oxygen, carbon dioxide.

3. Cells in the digestive (exocrine) glands of the stomach, pancreas, upper small intestine (duodenum); endocrine glands (e.g. adrenal glands); salivary glands.

4. (a) Protozoan: *Amoeba*, *Paramecium*
   (b) In *Paramecium*, a food vacuole develops at the end of the oral groove and is pinched off to circulate within the cell. In *Amoeba*, the pseudopodia engulf a food particle and a vacuole is formed where the membrane pinches off after the particle is engulfed.
   (c) Human cell: Phagocyte (white blood cell).

Energy in Cells (page 115)

1. (a) **Heterotrophs** (strictly a chemoheterotroph): Derive energy for biosynthesis from an organic energy source (other living organisms, their dead remains, or their excreted products).
   (b) **Photosynthetic autotrophs** (photoautotroph): Derive energy for biosynthesis from light energy (e.g. sunlight) which is the inorganic energy source.
   (c) **Chemosynthetic autotrophs (chemoautotroph):** Derive energy for biosynthesis from an inorganic chemical energy source (e.g. hydrogen sulfide gas from volcanic vents).

2. (a) At this depth there is no sunlight (it is filtered out after several hundred meters). Photosynthetic organisms require a source of sunlight.
   (b) Hydrogen sulfide
   (c) They would die due to inability to respire.
   (d) Chemosynthetic autotrophs (chemoautotrophs)

The Role of ATP in Cells (page 116)

1. In the presence of the enzyme ATPase, ATP is hydrolyzed to produce ADP plus a free phosphate, releasing energy in the process.

2. Glucose

3. Cellular respiration; strictly oxidative phosphorylation

4. Solar energy

5. Food (gaining nutrient from plants and other animals)

6. Like a rechargeable battery, the ADP/ATP system toggles between a high energy state and a low energy. The addition of a phosphate to ADP recharges the molecule so that it can be used for cellular work.

7. **PHOTOSYNTHESIS**
   Starting materials: carbon dioxide, water (as a source of hydrogens), in the presence of light and chlorophyll.
   Waste products: oxygen, water.
   Role of hydrogen carriers: NADP: carries hydrogen between light dependent and light independent phases (where the hydrogen is incorporated into sugars).
   Role of ATP: Produced in the light dependent phase and used in the light independent phase to make sugars from carbon dioxide and hydrogen.
   Overall biological role: uses light energy to fix carbon into organic molecules which become part of the energy available in food chains.
   CELLULAR RESPIRATION
   Starting materials: organic molecules (ultimately glucose), oxygen.
   Waste products: carbon dioxide, water.
   Role of hydrogen carriers: NAD: carries hydrogens to the electron transport system where their transfer between carriers is coupled to ATP production.
   Role of ATP: A small amount of ATP is used initially to

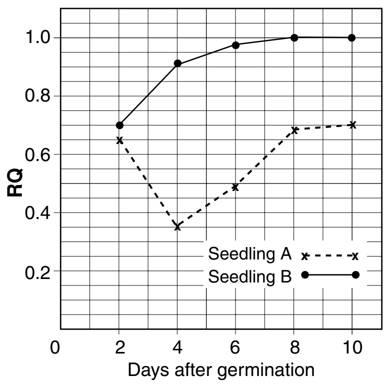
produce pyruvate from glucose. Produced in glycolysis, Krebs cycle, and the ETS.
Overall biological role: The process by which organisms break down energy rich molecules to release energy in a usable form (ATP).

Measuring Respiration (page 117)

1. RQ at 20°C/48 h = 1.97 ÷ 2.82 = **0.7** (0.698)

2. RQ at 20°C/1 h = 2.82 ÷ 2.82 = 1. After 2 days without feeding the cricket was metabolizing fats for energy. Shortly (1 hour) after feeding it was metabolizing only carbohydrate (RQ = 1).

3. (a) RQ of two seedlings during early germination:



(b) Both seedlings began their germination metabolizing primarily fats for energy. However, while seedling A continued to metabolize mainly fats (with some synthesis of carbohydrate and organic acids), throughout the 10 day period, seedling B rapidly moved to metabolizing carbohydrate alone. **Note**: The value of 0.91 (seedling B) may have been the result of protein metabolism alone or (more likely) respiration of a mix of fat and glucose.

Cellular Respiration (page 118)

1. (a) Glycolysis: cytoplasm
   (b) Krebs cycle: matrix of mitochondria
   (c) Transition reaction: matrix of mitochondria
   (d) Electron transport chain: cristae (inner membrane surface) of mitochondria.

2. (a) 6 carbon atoms
   (b) 3 carbon atoms (glucose split into two)
   (c) 2 carbon atoms (1 carbon lost as CO_2)
   (d) 6 carbon atoms (2-carbon acetyl added to 4 carbon)
   (e) 5 carbon atoms (1 carbon lost as CO_2)
   (f) 4 carbon atoms (1 carbon lost as CO_2)

3. (a) Glycolysis: 2 ATPs
   (b) Krebs cycle: 2 ATPs
   (c) Electron transport chain: 34 ATPs
   (d) Total produced: 38 ATPs

4. Released as carbon dioxide gas and breathed out through gas exchange surfaces.

5. (a) Supply energy in the form of high energy electrons. **Note**: These are passed along the respiratory chain, losing energy as they go. The energy released is used to generate ATP.
   (b) Oxygen is the final electron acceptor at the end of the respiratory chain.

6. (a) ATP is generated is **chemiosmosis**.
   (b) **In brief**: The synthesis of ATP is coupled to electron transport and movement of hydrogen ions.
   In more detail: Energy from the passage of electrons along the chain of electron carriers is used to pump protons (H^+), against their concentration gradient, into the intermembrane space, creating a high concentration of protons there. The protons return across the membrane down a concentration gradient via the enzyme complex, ATP synthetase (also called ATP synthase or ATPase), which synthesizes the ATP.

Anaerobic Pathways (page 120)

1. Aerobic respiration requires the presence of oxygen and produces a lot of useable energy (ATP). Fermentation does not require oxygen and uses an alternative H^+ acceptor. There is little useable energy produced (the only ATP generated is via glycolysis).

2. (a) 2 ÷ 38 x 100 = 5.3% efficiency
   (b) Only a small amount of the energy of a glucose molecule is released in anaerobic respiration. The remainder stays locked up in the molecule.

3. The build up of toxic products (ethanol or lactate) inhibits further metabolic activity.

Pigments and Light Absorption (page 121)

1. The absorption spectrum of a pigment is that wavelength of the light spectrum absorbed by a pigment e.g. chlorophyll absorbs red and blue light and appears green. Represented graphically, the absorption spectrum shows the relative amounts of light absorbed at different wavelengths.

2. Accessory pigments absorb light wavelengths that chlorophyll a cannot absorb, and they pass their energy on to chlorophyll a. This broadens the action spectrum over which chlorophyll a can fuel photosynthesis.

Photosynthesis (page 122)

1. Importance of photosynthesis (in any order):
   (a) Transforms light energy into chemical energy available to food chains.
   (b) Creates organic molecules used as building blocks for creating more complex molecules.
   (c) Releases free oxygen into the atmosphere; oxygen is required by other advanced life forms.

2. (a) Water + carbon dioxide → glucose + oxygen + water
   (b) $12H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$

3. **NADP**: Carries H_2 from the light dependent phase to the light independent reactions.

4. **Chlorophyll**: Traps light energy, producing high energy electrons. These are used to make ATP and NADPH. It also splits water molecules, releasing H^+ for use in the light independent reactions, and liberates free O_2.

5. (a) 5C (c) 3C
(b) 3C (X2 molecules) (d) 5C

6. Solar energy → ATP → glucose

7. (a) **Light dependent phase**: Requires light energy to proceed- creates ATP and obtains hydrogen from water (used to make NADPH).
(b) **Light independent phase**: Does not require light energy. Uses ATP and hydrogens, plus carbon and oxygen from carbon dioxide to make glucose.

8. Carbon and oxygen from carbon dioxide gas (via stomata). Hydrogen from water (via the roots and vascular system) obtained from the soil. (**Note**: it has been shown through oxygen isotope studies that the free oxygen produced as a result of photosynthesis comes from water and the oxygen in the carbohydrate comes from carbon dioxide).

9. The ATP synthesis is coupled to electron transport. When the light strikes the chlorophyll molecules, high energy electrons are released by the chlorophyll molecules. The energy lost when the electrons are passed through a series of electron carriers is used to bond a phosphate to ADP to make ATP.

Note: ATP is generated (in photosynthesis and cellular respiration) by **chemiosmosis**. As the electron carriers pick up the electrons, protons (H^+) pass into the space inside the thylakoid, creating a high concentration of protons there. The protons return across the thylakoid membrane down a concentration gradient via the enzyme complex, ATP synthetase that synthesizes the ATP (also called ATP synthase or ATPase).

Photosynthetic Rate (page 124)

1. (a) Photosynthetic rate increases rapidly then levels off.
(b) Up to a certain light intensity more light is available to the chlorophyll so the rate increases. When all the chlorophyll molecules are activated (saturated) by the light, more light has no further effect.

2. (a) Increased temperature increases the photosynthetic rate, but this effect is not marked at low CO_2.
(b) At higher temperature biochemical reactions occur more rapidly. At low CO_2 levels, rate is determined more by the CO_2 (raw material) available - rates are low regardless of temperature.

3. The photosynthetic rate is determined by the rate at which CO_2 enters the leaf. When this declines because of low atmospheric levels, so does photosynthetic rate.

4. (a) By changing only one factor at a time (either temperature or CO_2 level) it is possible to assess the effects of each one separately.
(b) CO_2 has the greatest effect of these two variables.
(c) At low levels of CO_2, increase in temperature has little effect (the rate of CO_2 entry into the leaf is the greatest determinant of photosynthetic rate).

Events in Biochemistry (page 125)

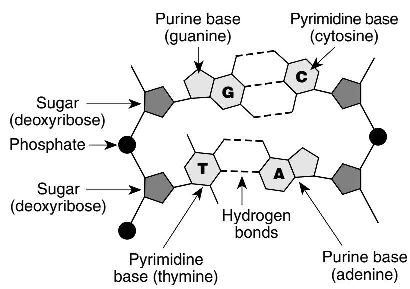
1. Only missing scientists in timeline are listed below:
(a) Johann van Helmont (1662)
(c) Joseph Priestly (1774)
(g) Julius von Mayer (1842/1845)
(k) Mikhail Tsvett (1906)
(o) Robert Hill (1939)
(p) Martin Kamen (1940s)
(r) Melvin Calvin (1946)

2.&3. Student's own research

Note : In the next activities, including that on transcription, the **accepted convention** amongst molecular geneticists has been used, i.e. the **coding** (sense or non-transcribed) strand contains the **same base sequence as the mRNA** that is transcribed from the **template** (antisense) **strand**. This terminology arises from the fact of where the gene (to be transcribed) is located (the "coding" strand). This may oppose what appears in some texts, where there is much confusion in the use of these terms. In fact, with the exception of template strand, the modern view (and the view in the more authoritative, current texts) is to avoid the use of these terms, as they imply that one strand alone always carries the genes.

Nucleic Acids (page 128)

1. Labels see below (only half of the section of DNA illustrated in the manual is shown here):



2. The following bases always pair in a normal double strand of DNA: guanine with cytosine, cytosine with guanine, thymine with adenine, adenine with thymine.

Student's *may* have to look elsewhere in the manual for the information to answer all parts of question 3.

3. (a) **Nucleotides**: building blocks of DNA. Their precise sequence provides the blueprint for the organism.
(b) **ATP**: Supplies energy (in the form of a high energy bond) for most endergonic reactions.
(c) **NAD/NADP**: Important coenzymes that are hydrogen and electron carriers in respiration and photosynthesis respectively.
(d) **Coenzyme A**: Important coenzyme responsible for the transfer of acetyl units from glycolysis to the Krebs cycle in cellular respiration.

4.

	DNA	RNA
Sugar present	Deoxyribose	Ribose
Bases present	Adenine Guanine Cytosine Thymine	Adenine Guanine Cytosine Uracil
Number of strands	Two (double)	One (single)
Relative length	Long	Short

DNA Molecules (page 130)

1. (a) 95 times more base pairs
   (b) 630 times more base pairs
2. 10% encodes proteins or structural DNA
3. Any order (a) to (c) any three of: gene expression; DNA replication; chromosome division; chromatin organization
4. 99 cm (about 1 m)

The Genetic Code (page 131)

1. This exercise demonstrates the need for a 3-nucleotide sequence for each codon and the resulting 'degeneracy' in the genetic code.

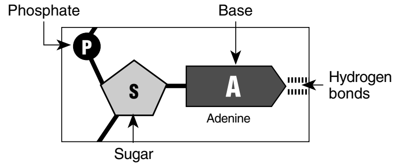
Amino acid	Codons	No
Alanine	GCU GCC GCA GCG	4
Arginine	CGU CGC CGA CGG AGA AGG	6
Asparagine	AAU AAC	2
Aspartic Acid	GAU GAC	2
Cysteine	UGU UGC	2
Glutamine	CAA CAG	2
Glutamic Acid	GAA GAG	2
Glycine	GGU GGC GGA GGG	4
Histidine	CAU CAC	2
Isoleucine	AUU AUC AUA	3
Leucine	UAA UUG CUU CUC CUA CUG	6
Lysine	AAA AAG	2
Methionine	AUG	1
Phenylalanine	UUU UUC	2
Proline	CCU CCC CCA CCG	4
Serine	UCU UCC UCA UCG AGU AGC	6
Threonine	ACU ACC ACA ACG	4
Tryptophan	UGG	1
Tyrosine	UAU UAC	2
Valine	GUU GUC GUA GUG	4

2. (a) 16 amino acids
   (b) Two-base codons (e.g. AT, GG, CG, TC, CA) do not give enough combinations with the 4-base alphabet (A, T, G and C) to code for the 20 amino acids.

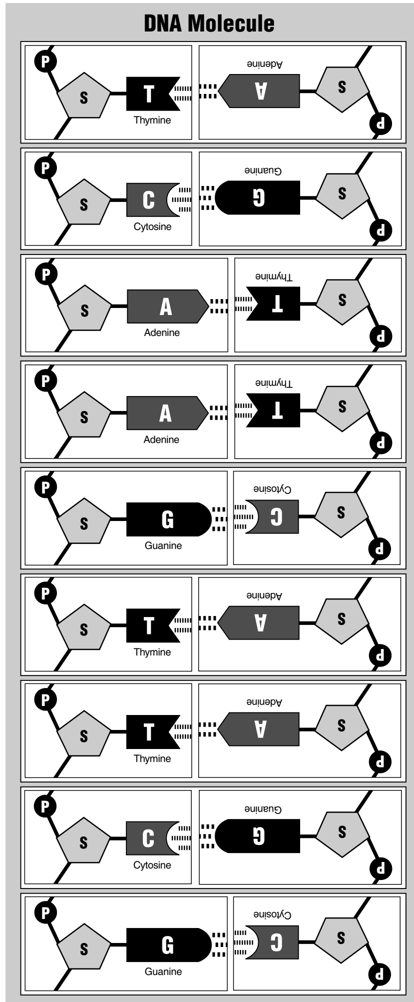
3. Many of the codons for a single amino acid vary in the last base only. This would reduce the effect of point mutations; only some changes would create new and potentially harmful amino acid sequences. **Note**: Only 61 codons are displayed above. The remaining 3 are **terminato**r codons (labeled 'STOP' codons in the tale in the manual). These are considered the 'punctuation' or controlling codons that mark the end of a gene sequence. The amino acid **methionine** (AUG) is regarded as the 'start' (initiator) codon.

Creating a DNA Model (page 132)

3. Labels as follows:



4 & 5.



6. Factors preventing a mismatch of nucleotides:
   – The number of hydrogen bond attraction points
   – The size (length) of the base (thymine and cytosine are short, adenine and guanine are long)

Examples: • Cytosine will not match cytosine because the bases are too far apart. • Guanine will not match guanine because they are too long to fit side-by-side. • Thymine will not match guanine because there is a mis-match in the number and orientation of hydrogen bonds.

DNA Replication (page 136)

1. (a) Step 1: Enzymes unwind DNA molecule to expose the two original strands.
   (b) Step 2: DNA polymerase enzyme uses the 2 original strands as templates to make complementary strands.
   (c) Step 3: The two resulting double-helix molecules coil up to form two chromatids in the chromosome.

2. (a) **Helicase**: Unwinds the 'parental' strands.
   (b) **DNA polymerase I**: Hydrolyzes the RNA primer and replaces it with DNA.
   (c) **DNA polymerase III**: Elongates the leading strand. It synthesizes the new Okazaki fragment until it encounters the primer on the previous fragment.
   (d) **Ligase**: Joins Okazaki fragments into a continuous length of DNA.

3. DNA replication prepares a chromosome for cell division by producing two chromatids which are (or should be) identical copies of the genetic information for the chromosome.

4. 16 minutes
   4 million nucleotides replicated at the rate of 4000 per second: 4 000 000 ÷ 4000 = 1000 s
   Convert to minutes = 1000 ÷ 60 = 16.67 minutes
   (Note that, under ideal conditions, most of a bacteria's cell cycle is spent in cell division).

Genes Code for Proteins (page 138)

1. This exercise is designed to demonstrate the way in which the DNA codes for the protein. Note that nucleotide has no direct protein equivalent.
   (a) Nucleotide codes for: Nothing by itself
   (b) Triplet codes for: Amino acid.
   (c) Gene codes for: Polypeptide chain (may be a protein).
   (d) Transcription unit codes for: Functional protein.

2. (a) **Nucleotide** is made up of: phosphate, sugar and one of 4 bases: guanine, adenine, cytosine, or thymine (uracil in mRNA).
   (b) **Triplet** is made up of three consecutive nucleotide bases that are read together as a code.
   (c) **Gene** comprises a sequence of triplets, starting with a start code and ending with a termination code.
   (d) **Transcription unit** is made up of two or more genes that together code for a **functional** protein.

Gene Expression (page 139)

1. Genes in the DNA are transcribed into mRNA. This is in turn decoded (translated) to control the assembly of proteins. Proteins cannot directly control the formation of mRNA or DNA although they may affect their activity. There are some viruses (such as retroviruses, e.g. HIV) that can insert their mRNA and cause reverse transcription. This causes some DNA to be inserted into the host's chromosome.

2. (a) **Intron**: Lengths of non-coding DNA in eukaryote DNA that are edited out during protein synthesis.
   (b) **Exon**: Coding segments of the DNA that end up forming the gene when converted to mRNA.

Transcription (page 140)

1. mRNA carries a copy of the genetic instructions from the DNA in the nucleus to ribosomes in the cytoplasm. The rate of protein synthesis can be increased by making many copies of identical mRNA from the same piece of DNA.

2. (a) AUG (b) UAA, UAG, UGA

3. (a) AUG AUC GGC GCU AAA
   (b) AUG UUC GGA UAU UUU

Translation (page 141)

1. AUG AUC GGC GCU AAA

2. (a) 61
   (b) There are 64 possible codons for mRNA, but three are terminator codons. 61 codons for mRNA require 61 tRNAs each with a complementary codon.

Protein Synthesis Summary (page 142)

1. (a) Process 1: Unwinding the DNA molecule.
   (b) Process 2: mRNA synthesis: nucleotides added to the growing strand of messenger RNA molecule.
   (c) Process 3: DNA rewinds into double helix structure.
   (d) Process 4: mRNA moves through nuclear pore in nuclear membrane to the cytoplasm.
   (e) Process 5: tRNA molecule brings in the correct amino acid to the ribosome.
   (f) Process 6: Anti-codon on the tRNA matches with the correct codon on the mRNA and drops off the amino acid.
   (g) Process 7: tRNA leaves the ribosome.
   (h) Process 8: tRNA molecule is 'recharged' with another amino acid of the same type, ready to take part in protein synthesis.

2. (a) A=DNA
   (b) B=Free nucleotides
   (c) C=RNA polymerase
   (d) D=mRNA
   (e) E=Nuclear membrane
   (f) F=Nuclear pore
   (g) G=tRNA
   (h) H=Amino acids
   (i) I=Ribosome
   (j) J=Polypeptide chain

3. The process by which the cell (and therefore the organism) makes proteins for use as building materials, enzymes, or other regulatory chemicals.

Analyzing a DNA Sample (page 143)

1. Use the *mRNA* table on the page: **The Genetic Code** in the manual to determine the amino acid sequence.

Synthesized DNA	CGT AAG TAC TTG ATC AGA GCT CTT CGA AAA TCG
DNA sample:	GCA TTC ATG AAC TAG TCT CGA GAA GCT TTT AGC
mRNA:	CGU AAG UAC UUG AUC AGA GCU CUU CGA AAA UCG

Amino acids: Arg Lys Tyr Leu Iso Arg
Ala Leu Arg Lys Ser

2. (a) ATG ATC GGC GCT AAA TGT TAA
   (b) ATG CGG AAT TTC CCG GCT TAG
   (c) DNA replication

3. (a) mRNA: AUG AUC GGC GCU AAA UGU UAA
   Amino acids: Met Iso Gly Ala Lys Cys STOP
   (b) mRNA: AUG CGG AAU UUC CCG GCU UAG
   Amino acids: Met Arg Asn Phe Pro Ala STOP
   (c) Protein synthesis

Metabolic Pathways (page 144)

1. A series of related chemical reactions that converts one compound to another in a sequence of steps.

2. Enzymes control each step in the metabolic pathway. A failure of any one enzyme will result in the pathway stopping at that point.

3. Any of: thyroxine, melanin, carbon dioxide, water

4. (a) Tyrosinase
   (b) Phenylalanine hydroxylase
   (c) A series of enzymes
   (d) Hydroxyphenylpyruvic acid oxidase
   (e) Homogentisic acid oxidase

5. They have low levels of tyrosine, the raw material for making melanin. Tyrosine is normally created from phenylalanine by an enzyme (in this case, faulty).

6. Thyroxine is an important growth hormone. It stimulates the development of body organs during the crucial early years. The lack of this growth hormone has led to: small body size generally (dwarfism), poor brain development (mental retardation), undeveloped sexual organs.

7. (a) Lack of melanin
   (b) Excess phenylpyruvic acid
   (c) Lack of thyroxine
   (d) Excess hydroxyphenylpyruvic acid
   (e) Excess homogentisic acid

8. Take a blood sample and test for excessive amounts of phenylpyruvic acid.

9. (a) Chemicals present in excess: Precursor
   (b) Chemicals absent: Intermediate, End product

Control of Metabolic Pathways (page 146)

1. (a) **Operon**: Consists of at least one structural gene coding for the primary enzyme structure, two regulatory elements: the operator and the promoter.
   (b) **Regulator gene**: (Sometimes called the repressor gene) produces a repressor substance that binds to the operator, preventing transcription of the structural genes.
   (c) **Operator**: This is a non-coding sequence of DNA that is the binding site for the repressor molecule.
   (d) **Promoter**: Site of RNA polymerase binding to start the transcription process.
   (e) **Structural genes**: Genes responsible for producing enzymes that control the metabolic pathway.

2. (a) In an inducible enzyme system, the enzymes required for the metabolism of a particular substrate are produced only when the substrate is present. This saves the cell valuable energy in not producing enzymes that have no immediate use.
   (b) Inducible enzyme systems are not adaptive when the substrate is present all (or most) of the time.

3. Each cell has the same genetic content, yet cells are specialized for very different functions. Controlling gene expression allows specialized cells to express only the genes required to regulate their own metabolism.

Eukaryote Chromosome Structure (page 150)

1. (a) **DNA**: A long, complex nucleic acid molecule found in the chromosomes of nearly all organisms (some viruses have RNA instead). Provides the genetic instructions (genes) for the production of proteins.
   (b) **Chromatin**: Chromosomal material consisting of DNA and histone and non-histone proteins.
   (c) **Histone**: Simple proteins that bind to DNA helping it to coil up during cell division. They may also regulate DNA function in some way.
   (d) **Centromere**: A bump or constriction along the length of a chromosome to which spindle fibers attach during cell division. Binds chromatids together (when there are two).
   (e) **Chromatid**: One of a pair of duplicated chromosomes produced prior to cell division, joined at the centromere.

2. The chromatin (DNA and proteins) combine to coil up the DNA into a super coiled arrangement. Three levels of coiling, together with histone proteins that hold the DNA in tight configurations, enable this huge amount of DNA to be packed into a small space in an orderly way.

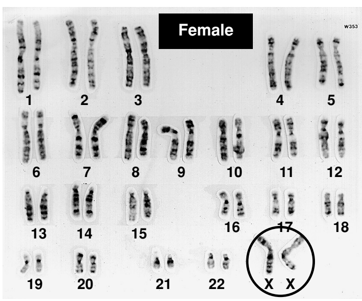
Karyotypes (page 152)

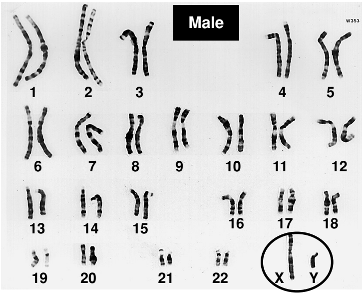
1. The chromosome complement of a cell or organism, characterized by the number, size, shape, and centromere position of the chromosomes.

2. (a) **Autosome**: One of the non-sex chromosomes (not involved in determining the sex of the organism).
   (b) **Sex chromosome**: Also called heterosome. One of a pair of chromosomes that is different in the two sexes and is involved in sex determination.

3. Number the chromosomes: (*see below*).

4. Circle the sex chromosomes: (*see below*).





5. (a) Female autosomes: 44, sex chromosomes: XX
   (b) Male autosomes: 44, sex chromosomes: XY

6. (a) Chromosomes in human somatic cell: 46
   (b) Chromosomes in human sperm or egg cell: 23

Human Karyotype Exercise (page 154)

This procedure is similar to that actually carried out in the cytogenetics lab of hospitals (they use photographs instead of drawings). By studying the distinguishing features of the chromosomes, you can arrange them in their correct sequence on the karyotype record sheet.

1. Should have the same appearance as the male karyotype shown above, but will have one extra chromosome (#21) making it a Down syndrome male.

2. (a) Sex: Male
   (b) Abnormal
   (c) Chromosome arrangement:
   45 + XY (trisomy 21 or Down syndrome)

Genomes (page 157)

1. Genome: The complete complement of genetic material carried by a cell or organism.

2. (a) 5375 bases (b) 5.375 kb (c) 0.005375 Mb

3. It is a comparatively small genome, others having 10 - 40 times as much genetic material (e.g. 48.6 - 190 kb).

4. 1542 bases

Genome Projects (page 158)

1. (a) Yeast: 461.5 (c) Fruit fly: 93.3
   (b) *E. coli*: 957.2 (d) Mouse: 12

2. Different species have different amounts of DNA in regions that do not apparently code for anything. therefore, the amount of coding DNA (genes) per Mb of DNA varies tremendously.

3. Determining the genomes of major crop plants (wheat, rice, maize) will improve the feasibility of making appropriate, high value, and safe genetic modifications to the plants. **Note**: These modifications may be for characteristics such as improved pest resistance, higher yield, lower water demand, nitrogen fixation etc. Other reasons include a better understanding of crop diseases, growth potential, and genetic resilience in the face of selective (in)breeding.

4. (a) First animal genome sequenced: the nematode worm *Caenorhabditis elegans*
   Date: December 1998 (source Wellcome Trust)
   (b) First plant genome sequenced: Thale cress, *Arabidopsis thaliana*, a weed related to mustard
   Date: December 2000 (source, Nature)

Genetic Counseling (page 159)

1. **Psoriasis**: The man has at least one of the dominant alleles for the gene that causes psoriasis. If he is heterozygous, then there is a 50% probability that any given child will have it. If he is homozygous, then there is a 100% probability. It would be possible to tell if the man was homozygous or not by investigating his family pedigree chart for this characteristic.

2. **Tay-Sachs disease**: Both partners intending to have another child are heterozygous for this recessive disorder. There is a 1 in 4 probability (25%) that their next child will be afflicted with Tay-Sachs disease.

3. There is no ‘correct’ answer to this is question; subjective arguments can be used to support either position. Issues of ‘informed choice’ over decisions to have children should be raised, together with the ‘costs to society’ of affected individuals (and the costs due to lost opportunity of not having them).

Sources of Genetic Variation (page 160)

1. (a) By providing an assortment of different gametes as a result of independent assortment.
   (b) Crossing over: exchanges tips of chromosomes causing genes to be swapped on chromosome pairs
   (c) Mate selection will bring together the genes of two different individuals.

2. The environment can alter the phenotype by altering the basic expression of a trait. Examples include: trees that are grown at high altitude are stunted in growth, trees exposed to a strong prevailing wind appear distorted in shape (windswept), poor nutrition in infancy can retard brain and bone development.

3. (a) Getting a suntan to look brown-skinned.
   (b) Dieting to lose weight.
   (c) Exercising to increase fitness or build muscle mass.

4. Although they share many identical genes from their parents with their brothers and sisters, there are enough differences (due to random sorting of chromosomes into each gamete) to make them appear different. **Note**: An adult male has the ability to produce over 8 million different sperm, each with different combinations of maternal and paternal chromosomes.

5. Mutations create new genetic variations upon which evolutionary processes act. Gene mutations are the only source of new alleles for a gene.

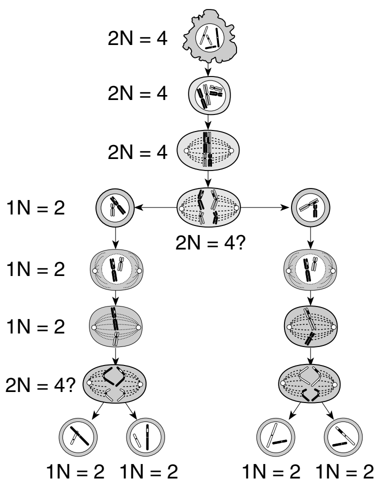
6. (a) A neutral mutation is one that has no harmful or beneficial effect under the prevailing conditions.
   (b) While a neutral mutation may not have an effect initially, in the future it may disadvantage or benefit the individual that possesses it. Such a change may confer a selective disadvantage or advantage (with respect to survival or reproduction) to that individual in the prevailing environment.

Gene-Environment Interactions (page 162)

1. Some species of dinosaur may have become extinct because a global cooling of the climate would have resulted in all females being produced from eggs. (This theory is unsubstantiated as there is no physiological evidence that dinosaur sex was determined in this way).
2. Physical factors: Wind speed, temperature, air density, water availability.
3. The acidity (pH) of the soil. Acid soil produces pink flowers, while alkaline soil produces blue flowers.
4. Water availability (water regularly), nutrient supply (fertilizer application), sunlight (keep out of shade), temperature (keep warm).
5. These are the cooler parts of the body. Body heat is lost from these areas which make it cool enough for the enzyme responsible for color-pointing to remain active.
6. (a) **Plant species A**: The observed phenotype (low growing appearance) of this species is not due to genetic factors, but to the effect of the weather conditions on growth patterns. In the absence of these harsh environmental factors, the plant reverts to its normal growing habit.
   (b) **Plant species B**: The low growing phenotype is controlled by genes (not environmental factors).
7. (a) **Genotype**: The genetic makeup of an organism, which acting together with environmental factors, determines the phenotype.
   (b) **Phenotype**: The physical and biochemical characteristics of an organism, resulting from the influence of the environment on the genetic potential of an organism.

Meiosis (page 164)

1. Chromosome numbers (see below): The uncertainty of chromosome status at the point of chromatid separation, is indicated by the question marks.



2. (a) First division: reduces the number of chromosomes in the intermediate cells, so that only one chromosome from each homologous pair is present.
   (b) Second division: is more or less a 'mitotic' division which involves the separation of chromatids to double the production of gametes.

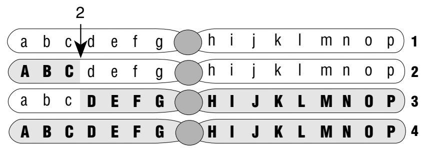
Crossing Over (page 165)

1. Unexpected combinations of alleles for genes will occur that would not normally be present in gametes.
2. This provides a source of genetic variation amongst individuals in a population; important for providing the raw material on which natural selection acts.

Crossing Over Problems (page 166)

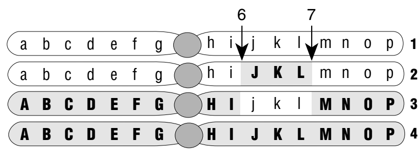
Note that each of the problems is independent of the other problems (i.e. they are not a sequence).

1. (a) Gene sequences after crossing over at point 2:



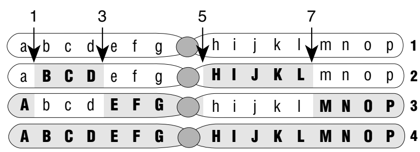
   (b) A, B and C

2. (a) Gene sequences after crossing over at points 6 & 7.



   (b) J, K and L

3. (a) Gene sequences after crossing over at points 1,3,5, and 7. (Note that results for chromatids 2 & 3 are interchangeable)



   (b) B, C, D and H, I, J, K, L

4. Increases the amount of mixing of genes to produce new combinations in offspring - increases variation in the gene pool. Counteracts the effect of gene linkage.

Linkage (page 167)

1. **Gene linkage**: Genes that are located on the same chromosome and, as a result, tend to be inherited together as a unit.
2. (a) AaBb, Aabb, aaBb, aabb
   (b) F1 genotype : all CucuEbeb (heterozygotes)
   F1 phenotype: all wild type (straight wing, gray body)

3. Gene linkage reduces the amount of variation because the linked genes are inherited together and fewer genetic combinations of their alleles are possible.

Recombination (page 168)

1. **Recombination**: The exchange of alleles between homologous chromosomes as a result of crossing over. It produces new associations of alleles in the offspring.

2. Recombination increases the amount of genetic variation because parental linkage groups separate and new associations of alleles are formed in the offspring. The offspring show new combinations of characters that are unlike the parental type. An answer "Linkage **does not** increase variation in the offspring" is acceptable.

3. A greater than 50% recombination frequency indicates that there is independent assortment (the genes must be on separate chromosomes).

Mutagens (page 169)

1. (a) **Mutagen**: A substance or form of energy that causes a mutation to occur or increases the chances that a mutation will occur.
   (b) **Carcinogen**: An agent capable of causing cancer.

2. A high fat diet slows the passage of food through the gut and provides a longer time for harmful agents in the food to be in contact with the gut wall or to be converted to carcinogens (e.g. meat preservatives such as nitrites and nitrates are converted in the gut to nitrosamines, which are carcinogenic).

The Effect of Mutations (page 170)

1. **Mutation**: Alteration in the base sequence of DNA resulting in the production of a new protein or failure in the production of a protein.

2. Somatic mutations occur in the body (non-gametic or somatic) cells and are not inherited. They may affect an individual within its lifetime. Gametic mutations may be inherited and can therefore affect descendants.

3. The mutation does not extend to the seeds (the gametic portion which will be inherited).

4. Organisms such as these have short generation times, so the cumulative effects of mutations over several generations can be feasibly studied. In addition (especially in bacteria) mutation rates are high and mutations can be induced easily.

5. (a) A neutral mutation has no effect on the survival and reproduction (fitness) of the individual, whereas a beneficial mutation confers a selective advantage in terms of fitness and a harmful mutation has a deleterious effect on fitness. Effects apply in the prevailing environment.
   (b) Harmful mutations are the most common, because changes in the normal genetic make-up of an individual are more likely to have a deleterious effect (and cause errors) than be fortuitously beneficial or neutral.

6. People with the mutation are able to eat food high in cholesterol without suffering from atherosclerosis.

Antibiotic Resistance (page 172)

1. (a) Enzyme inactivation of the antibiotic.
   (b) Alteration of the antibiotic's target, e.g. cell wall (so that it is no longer vulnerable to the antibiotic).
   (c) Mechanisms to exclude the antibiotic from the cell.
   (d) Mechanisms to pump the antibiotic out of the cell.

2. When we interfere with microbial survival by using antibiotics, we inadvertently select for antibiotic resistant mutants. Patients assist this process when they fail to complete a course of antibiotics and do not kill all the targeted microorganisms in their system. When the antibiotic level (in their body) decreases, some resistant bacteria survive (and go on to reproduce). Patients may also request and take antibiotics when they are not needed (e.g. for viral infections), exposing bacteria in their system to the antibiotic and giving opportunity for resistance to develop.

Gene Mutations (page 173)

1. (a) **Substitution**: The least damaging of single gene mutations because it affects only one amino acid. If it is the third base in a triplet, it may not even cause a change to the amino acid coded for.
   (b) **Deletion**: Causes large scale alteration of the coding sequence from the point of deletion onwards, due to a reading 'frame shift'.
   (c) **Insertion**: Causes large scale alteration of the coding sequence due to a 'frame shift'.

2. (a) Reading frame shifts and nonsense substitutions
   (b) They may cause large scale disruption of the coded instructions for making a protein. Either a wrong amino acid sequence for part of the protein or a protein that is only partly completed (missing some amino acids due to a displaced terminator codon).

3. Biological activity of a protein refers to its ability to carry out its designated role (e.g. structural, catalytic, transport, messenger).

4. Diseases include cystic fibrosis, sickle cell disease, Huntington disease, thalassemias.

Examples of Gene Mutations (page 174)

1. Mutations would have arisen in a an individual and spread out gradually from that origin. Thus certain genetic disorders tend to have a higher occurrence in certain regions, especially where the population tends to have stayed relatively isolated geographically.

2. (b) *Gene name*: HBB *Chromosome*: 11
   Mutation type: autosomal recessive. *May be caused be base deletion, base insertion, or gene deletion (severity depends on the mutation).
   (c) *Gene name*: CFTR *Chromosome*: 7
   Mutation type: autosomal recessive. Great range: deletion, missense, nonsense, misplaced terminator codon. Most common is a deletion of 3 nucleotides.
   (d) *Gene name*: IT15 *Chromosome*: 4
   Mutation type: autosomal dominant. Duplication (CAG repeats of varying length).

3. Few or no β chains causes severe anemia. Frequent blood transfusions are required and this can cause iron accumulation in the tissues and organs.

The Cystic Fibrosis Mutation (page 175)

1. (a) Bases: 33 (b) Triplets: 11
   (c) Amino acids coded for: 11
2. **mRNA**: GGC ACC AUU AAA GAA AAU AUC AUC UUU GGU GGU
3. **Amino acids**: Gly Thr Iso Lys Glu Asn Iso Iso Phe Gly Gly
4. (a) **Mutant DNA strand**: CCG TGG TAA TTT CTT TTA TAG TAG | CCA CCA
   (b) **Type of mutation**: Deletion (of three nucleotides)
5. **Mutant mRNA**: GGC ACC AUU AAA GAA AAU AUC AUC | GGU GGU
6. **Amino acids coded by mutant DNA**: Gly Thr Iso Lys Glu Asn Iso Iso | Gly Gly
7. Amino acid missing: Phenylalanine (Phe)

Sickle Cell Mutation (page 176)

1. (a) Bases: 21
   (b) Triplets: 7
   (c) Amino acids coded for: 7
2. **mRNA**: GUG CAC CUG ACU CCU GAG GAG
3. **Amino acids**: Val His Leu Thr Pro Glu Glu
4. **Mutant DNA**: CAC GTG GAC TGA GGA CAC CTC
   Type of mutation: Substitution
5. **Mutant mRNA**: GUG CAC CUG ACU CCU GUG GAG
6. **Amino acids coded by mutant DNA**:
   Val His Leu Thr Pro Val Glu
7. A base substitution causes a change in one amino acid in the hemoglobin molecule. The mutated hemoglobin, being less soluble, causes a distortion of the red blood cells and results in various severe circulatory problems.

Chromosome Mutations (page 177)

1. (b) **Original**: ABCDEFGHMNOPQRST
   Mutated: AB**FED**CGHMNOPQRST
   (c) **Original**: ABCDEFGHMNOPQRST
   1234567890
   Mutated: **ABCDEF**1234567890
   GHMNOPQRST
   (d) **Original**: ABCDEFMNOPQ
   ABCDEFMNOPQ
   Mutated: ABCDE**ABCDE**FMNOPQ
   FMNOPQ
2. Inversion, since there is no immediate potential loss of genes from the chromosome. (However, at a later time, inverted genes may be lost from a chromosome during crossing over, due to unequal exchange of segments).

Aneuploidy in Humans (page 178)

Erratum: In the explanatory box for Barr bodies (page 179), the chromosomes next to the one Barr body examples should read 46, XX and 47, X**XY** (not 47, X). The XY was inadvertently lost during production. Download a replacement from:
www.thebiozone.com/errata.html

1. Embryos from left to right: XXY, XO, XXY, XO.
2. (a) Trisomic female (metafemale) (or superfemale)
   (b) Klinefelter syndrome
   (c) Turner syndrome
3. The YO configuration has no X chromosome (the X contains essential genes not found on the Y).
4. (a) For karyotype A: circle X chromosome
   Chromosome configuration: 45, X (44 + X)
   Sex: female
   Syndrome: Turner
   (b) For karyotype B: (circle XXY chromosomes)
   Chromosome configuration: 47, XXY (44 + XXY),
   Sex: male
   Syndrome: Klinefelter
5. Number of Barr bodies:
   (a) Jacob syndrome: 0
   (b) Klinefelter syndrome: one Barr body
   (c) Turner syndrome: 0
6. Phenotypic traits resulting from underdeveloped testes: infertility, sparse body hair, breast development, underdeveloped penis.
7. (a) **Nullisomy**: 0, both of a pair of homologous chromosomes are missing.
   (b) **Monosomy**: 1, one chromosome appears instead of the normal two.
   (c) **Trisomy**: 3, three chromosomes appear instead of two, the result of faulty meiosis.
   (d) **Polysomy**: 3+, the condition in which one or more chromosomes are represented more than twice in the cell (includes trisomy).

Down Syndrome (page 180)

1. **Trisomy**: A form of polysomy where one chromosome pair is represented by three chromosomes.
2. (a) Having an extra chromosome may allow for the overproduction of some proteins. Having an extra copy of the gene on the third chromosome may result in more mRNA being produced for that gene.
   (b) **Syndrome**: a suite of symptoms that typically occur together that result from a particular genetic condition. In Down, the syndrome is characterized by a collective suite of abnormalities affecting the face, limbs, internal organs, and musculature.
3. (a) Non-disjunction, which is the failure of chromosome 21 in one of the parents to separate during gamete formation (meiosis). Proportion: 92%.
   (b) Down syndrome phenotype: Mental retardation, retarded growth and short stature, upward slanting eyes, stubby fingers, and folds in the inner corners of the eyes. They also tend to suffer from congenital heart disease.

4. Either:
   – Translocation: One parent (a carrier) has chromosome 21 fused to another chromosome (usually number 14). Proportion: less than 5%.
   – Mosaic: Failure of chromosomes 21 to separate in only some cell lines during mitosis (very early in embryonic development). Proportion: less than 3%.

5. 47

The Fate of Conceptions (page 181)

1. Older women have a greater probability of producing eggs with abnormal chromosome complements.

2. Amniocentesis is a process by which a sample of the amniotic fluid is extracted from the uterus by syringe. It is used to obtain a sample of the baby's chromosomes that are floating in the fluid (some cellular material is always present in small amounts in the amniotic fluid). This enables detection of many chromosome abnormalities.

3. Routine tests are now carried out to detect Down syndrome conditions in the fetuses in older mothers. Termination of such pregnancies is increasingly common in some countries, reducing the incidence in this age group (and, as a consequence, skewing the incidence data toward younger mothers).

Alleles (page 184)

1. Alleles are different versions of the same gene that code for the same trait. There are often two alleles for a gene, with one dominant and one recessive. Sometimes alleles for a gene can be more or less equally dominant. There are instances where 3 or more alleles for a gene exist; the gene is then said to have multiple alleles.

2. (a) Heterozygous: Each of the homologous chromosomes contains a different allele for the gene (one dominant and one recessive).
   (b) Homozygous dominant: Each of the homologous chromosomes contains an identical dominant allele.
   (c) Homozygous recessive: Each of the homologous chromosomes contains an identical recessive allele.

3. (a) **Aa** (b) **AA** (c) **aa**

4. Each chromosome of a homologous pair comes from a different parent; one of maternal and one of paternal origin (they originated from the sperm and the egg that fused to form the zygote). They contain the same sequence of genes for the same traits, but the alleles on each chromosome may be different.

Mendel's Pea Plant Experiments (page 185)

1. and 2. (see table below):

	Dominant	Recessive	Ratio
Seed shape	Round	Wrinkled	2.96 : 1
Seed color	Yellow	Green	3.01 : 1
Pod color	Green	Yellow	2.82 : 1
Flower position	Axial	Terminal	3.14 : 1
Pod shape	Constricted	Inflated	2.95 : 1
Stem length	Tall	Dwarf	2.84 : 1

3. (a) Seed shape (2.96:1), seed color (3.01:1), and pod shape (2.95:1).
   (b) Considering all the traits, larger sample sizes generally produced ratios closer to the predicted theoretical ratio. Smaller samples are more likely to produce results that deviate from the theoretical ideal, because they are affected more by the randomness of meiosis and fertilization.

Mendel's Laws of Inheritance (page 186)

1. Inherited characteristics are transmitted by discrete entities (genes) which themselves remain unchanged from generation to generation. **Further explanation**: *Flower color is controlled by two alleles: a dominant (purple) one and a recessive (white) one. Offspring receive one of each of the alleles, but only the dominant one is expressed. In subsequent offspring, it is possible for recessive alleles to be provided by each of the two gametes to produce white flowers.*

2. During meiosis, the two alleles for a gene will separate into different gametes, and subsequently into different offspring. Normally both alleles cannot end up in the same offspring. Occasionally, faulty meiosis can occur, resulting in aneuploidy or polyploidy.
   (a) Aa
   (b) A, A, a, a
   (c) Two kinds of gamete: A and a

3. During meiosis, all combinations of alleles are distributed to gametes with equal probability. The pair of alleles for each gene are sorted independently of those for all other genes. Genes that are 'linked' on the same chromosome tend to be inherited together.
   (a) AB and ab
   (b) Four kinds of gamete: AB, Ab, aB, ab

Basic Genetic Crosses (page 187)

1.

	YR	Yr	yR	yr
YR	YYRR	YYRr	YyRR	YyRr
Yr	YYRr	YYrr	YyRr	Yyrr
yR	YyRR	YyRr	yyRR	yyRr
yr	YyRr	Yyrr	yyRr	yyrr

2. Yellow-round: 9/16 Yellow-wrinkled: 3/16
   Green-round: 3/16 Green-wrinkled: 1/16

3. Ratio: 9 : 3: 3 : 1

Monohybrid Cross (page 188)

	Genotype	Phenotype
Cross 1	100% Bb	100% black
Cross 2	50% BB 50% Bb	100% black
Cross 3	25% BB 50% B b 25% bb	75% black 25% white
Cross 4	100% BB	100% black
Cross 5	50% Bb 50% bb	50% black 50% white
Cross 6	100% bb	100% white

Inheritance Patterns (page 189)

1. **Autosomal recessive:**
   (a) Punnett square:
   Male parent phenotype: Normal, carrier
   Female parent phenotype: Normal, carrier

	P	p
P	PP	Pp
p	Pp	pp

   (b) Phenotype ratio:
   Normal 3
   Albino 1

2. **Autosomal dominant:**
   (a) Punnett square:
   Male parent phenotype: woolly hair
   Female parent phenotype: woolly hair

	w	W
w	ww	wW
W	wW	WW

   (b) Phenotype ratio:
   Normal 1
   Woolly 3

3. **Sex linked recessive:**
   (a) Punnett square:
   Male parent phenotype: Normal
   Female parent phenotype: Normal - carrier

	X_o	X_h
X_o	X_oX_o	X_oX_h
Y	X_oY	X_hY

   (b) Phenotype ratio:
   Females:
   Males:
   Normal 2 Normal 1
   Hemophiliac 0 Hemophiliac 1

4. **Sex linked dominant:**
   (a) Punnett square:
   Male parent phenotype: Affected (with rickets)
   Female parent phenotype: Affected (with rickets)

	X_R	X_o
X_R	X_RX_R	X_oX_R
Y	X_RY	X_oY

   (b) Phenotype ratio:
   Females:
   Males:
   Normal 0 Normal 1
   Hemophiliac 2 Hemophiliac 1

Dominance of Alleles (page 190)

1. (a) Incomplete dominance: neither allele is dominant (neither can mask the other).
   (b) Codominance: Two or more alleles are dominant over any recessive alleles; both are fully expressed.

2. (a) Incomplete dominance: heterozygote's phenotype is intermediate between homozygous parents.
   (b) Codominance: heterozygotes have a phenotype that is unique from either homozygous parent.

3. Ratio: **1 : 2 : 1** (1 red : 2 roan : 1 white).

Gametes from male (columns); Gametes from female (rows)

	C^R	C^W
C^W	C^RC^W	C^WC^W
C^R	C^RC^R	C^RC^W

4. Parents: white and pink. Will produce 50% pink and 50% white offspring.

Gametes from male (columns); Gametes from female (rows)

	r	r
R	Rr	Rr
r	rr	rr

5. (a) Diagram labels:

	White bull	**Roan cow**
Parent genotype:	C_WC_W	C_RC_W
Gametes:	C_W, C_W	C_R, C_W
Calf genotypes:	C_RC_W, C_WC_W	C_RC_W, C_WC_W
Phenotypes:	Roan, white	Roan, white

   (b) Phenotype ratio: 50% roan, 50% white (1:1)
   (c) By choosing only the roan calves (male and female) to breed from. Initial offspring from roan parents should include all phenotypes: white, roan and red. By selecting just the red offspring from this generation it would be possible to breed a pure herd of red cattle. The unwanted phenotypes must be prevented from breeding (e.g. by castration).

6. (a) Diagram labels:

	Unknown bull	**Roan cow**
Parent Genotype:	C_RC_R	C_RC_W
Gametes:	C_R, C_R	C_R, C_W
Calf Genotypes:	C_RC_R, C_RC_W	C_RC_R, C_RC_W
Phenotypes:	Red, Roan	Red, Roan

   (b) Unknown bull: **red bull**

7. (a) Diagram labels:

	Pink	**Red**
Parent Genotype:	Rr	RR
Gametes:	R, r	R, R
Offspring:	RR,RR	Rr, Rr
Phenotypes:	Red, Red	Pink, Pink

   (b) Phenotype ratio: **50% red, 50% pink**

Multiple Alleles in Blood Groups (page 192)

Note: In this activity, any reference to the I alleles has been removed on the advice of researchers involved in the latest work in this area. References to the I gene are now considered to be incorrect and misleading.

1. Blood group table:

Blood group **B**	BB, BO
Blood group **AB**	AB

2.

Cross 2	**Group O**	**Group O**
Gametes:	O, O	O, O
Children's genotypes:	OO, OO	OO, OO
Blood groups:	O, O	O, O

Cross 3	**Group AB**	**Group A**
Gametes:	A, B	A, O
Children's genotypes:	AA, AO	BA, BO
Blood groups:	A, A	AB, B

Cross 4	**Group A**	**Group B**
Gametes:	A, A	B, O
Children's genotypes:	AB, AO	AB, AO

Blood groups:	AB, A	AB, A
Cross 5	**Group A**	**Group O**
Gametes:	A, O	O, O
Children's genotypes:	AO, AO	OO, OO
Blood groups:	A, A	O, O
Cross 6	**Group B**	**Group O**
Gametes:	B, O	O, O
Children's genotypes:	BO, BO	OO, OO
Blood groups:	B, B	O, O

Note: Depending on which gamete circle each symbol of a gene is placed, it is possible to have the answers arranged differently. There are of course many more crossover combinations possible.

3. (a) Parent genotypes:

Parent genotype:	AO	OO
Gametes:	A, O	O, O
Children's genotypes:	AO, AO	OO, OO
Blood groups:	A, A	O, O

(b) 50% (c) 50% (d) 0%

4. (a) Possible parent genotypes: Mother assumed to be heterozygous to get maximum variation in gametes (homozygous would also work).

Phenotypes	**Group A**	**Group O**
Genotypes:	AO	OO
Gametes:	A, O	O, O

Child's genotype would have to be AO or OO

(b) Therefore the only possible offspring from this couple would have been children with group **A** or group **O**. The man making the claim could not have been the father of the child.

5. (a) **A** or **B** (b) **AB, A, B** or **O**

Dihybrid Cross (page 194)

Cross no. 1: Q1-3 integrated

Genotypes: and ratios	BbLL	2	bbLl	4
	BbLl	4	Bbll	2
	bbLL	2	bbll	2
Phenotypes: and ratios	6 black/short		6 white/short	
	2 black/long		2 white/long	

Cross no. 2: Q1-4 integrated

Gametes:	White parent: all bl			
	Black parent: Bl, Bl, bl, bl			
Genotypes and ratios:	BbLl	8	bbLl	8
Phenotypes and ratios:	8 black/short		8 white/short	
	1:1 ratio			

Sex Determination (page 196)

1. Presence of the Y chromosome (XX female, XY male).

2. The males have differing sex chromosomes (X and Y).

Breeding Pet Varieties (page 197)

1. **Note**: Persian and Siamese parents are pedigrees (truebreeding) and homozygous for the genes involved.
   (a) Persian: UUss, Siamese: uuSS, Himalayan: uuss
   (b) F1: Genotype: all heterozygotes UuSs. Phenotype; all uniform color, short haired.
   (c) F2 generation: UuSs **X** UuSs

	US	**Us**	**uS**	**us**
US	UUSS	UUSs	UuSS	UuSs
Us	UUSs	UUss	UuSs	Uuss
uS	UuSS	UuSs	uuSS	uuSs
us	UuSs	Uuss	uuSs	uuss

   (d) 1/16 uuss: Himalayan
   (e) Yes (only one type of allele combination is possible)
   (f) 3/16 (2 uuSs, 1 uuSS)
   (g) All of the following have different genotypes but produce a uniform color-short hair cat:
   UUSS, UuSS, UuSs, UUSs, because they all have at least one dominant allele for each gene. Similarly uuSs and uuSS both produce a color pointed short hair cat, and UUss and Uuss both produce a uniform colored, long hair cat.
   (h) Test cross with a Himalayan (i.e. double homozygous recessive: uuss). If any heterozygous cats are presented for mating then some of their offspring could be expected to be long-haired.

2. (a) **bbSS** (brown/spotted) X **BBss** (solid/black) (which parent was male and which female is unknown. Parents must be homozygous since all the offspring are of one type: BbSs: black spotted)
   (b)

Spotted/black	9/16
Spotted/brown	3/16
Solid/black	3/16
Solid/brown	1/16

   (c) Dihybrid cross (no linkage)

3.

(a) **F1 generation**	Rough/black	All (100%)
(b) **F2 generation**	Rough/black	9/16
	Rough/white	3/16
	Smooth/black	3/16
	Smooth/white	1/16

   (c) RRBB X RrBb. F1 all RrBb. Note that this is a back cross rather than a test cross because the parent is homozygous dominant (RRBB). Offspring all rough/black, 4/16 RrBb, 4/16 RRBB, 4/16 will be RRBb, and 4/16 RrBB.
   (d) Note that this is also a back cross, since the cross is back to the parental phenotype.

Rough/black	4/16 (RrBb)
Smooth/black	4/16 (rrBb)
Rough/white	4/16 (Rrbb)
Smooth/white	4/16 (rrbb)

4. (a) Mm and mm (MM is lethal; see below).
   (b) The homozygous dominant condition (MM) is linked to a **lethal** factor (related to spine length). Embryos with this genotype are resorbed and never appear.

Dihybrid Crosses with Linkage (page 198)

1. Crossover value for the offspring of the test cross:
   For crossover value: use the formula:
   No. of recombinants ÷ total no. of offspring X 100
   (21 + 27) ÷ (123 + 129 + 21 + 27) X 100
   = (48 ÷ 300) X 100
   = **16%**

Using Chi-Square in Genetics (page 199)

1. (a) H_0: "If both parents are heterozygous and there is independent assortment of alleles (no linkage) then we would expect to see a 9:3:3:1 ratio of phenotypes in the offspring ".
   (b) H_A: "If both parents are heterozygous and the genes are linked (i.e. on the same chromosome), then we would expect the ratios of phenotypes in the offspring to deviate from the 9:3:3:1".

2. (a) Completed table below:
   Expected frequencies calculated as follows:
   Purple stem, jagged leaf = 9/16 x 29 = 16.3
   Purple stem, smooth leaf = 3/16 x 29 = 5.4
   Green stem, jagged leaf = 3/16 x 29 = 5.4
   Green stem, smooth leaf = 1/16 x 29 = 1.8
   Note: Whole numbers could be used in preference to rounding to one decimal place.

Category	O	E	O – E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Purple stem, jagged leaf	12	16.3	–4.3	18.5	1.1
Purple stem, smooth leaf	9	5.4	3.6	13	2.4
Green stem, jagged leaf	8	5.4	2.6	6.8	1.3
Green stem, smooth leaf	0	1.8	–1.8	3.2	1.8
	∑ 29				∑ 6.6

   (b) $\chi^2 = 6.6$
   (c) Degrees of freedom = 3 (4-1)
   (d) The critical value of χ^2 at $P = 0.05$ and at d.f.= 3 is 7.82. The calculated χ^2 value is less than the critical value (6.6 < 7.82).
   (e) Accept H_0: There was no significant difference between the observed results and the expected phenotype ratio of 9:3:3:1. We must conclude that the genes controlling stem color and leaf shape in tomatoes are on separate chromosomes (unlinked).

3. (a) H_0 and H_A as for question 1.
   (b) Completed table below:

Category	O	E	O – E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Round-yellow seed	441	450	–9	81	0.18
Round-green seed	159	150	9	81	0.54
Wrinkled-yellow seed	143	150	–7	49	0.33
Wrinkled-green seed	57	50	7	49	0.98
	∑ 800				∑ 2.03

   Expected frequencies were calculated as follows:
   Round-yellow seed = 9/16 x 800 = 450
   Round-green seed = 3/16 x 800 = 150
   Wrinkled-yellow seed = 3/16 x 800 = 150
   Wrinkled-green seed = 1/16 x 800 = 50

   $\chi^2 = 2.03$

   (c) Degrees of freedom = 3 (4-1)
   (d) The critical value of χ^2 at $P = 0.05$ and at d.f.= 3 is 7.82. The calculated χ^2 is less than the critical value (2.03 < 7.82).
   (e) Accept H_0: There was no significant difference between the observed results and the expected phenotype ratio of 9:3:3:1. We must conclude that the genes controlling seed shape and color are on separate chromosomes (unlinked).

4. We accept H_0 in both cases but in the first case, the χ^2 value is much higher. In the case of the tomatoes, the genes for stem color and leaf shape **are** on separate chromosomes, but given the relatively large χ^2 value, repeating the experiment using more plants, or replicate setups, would serve as a check.

Types of Human Variation (page 200)

1. (a) **Discontinuous variation**: Also known as qualitative inheritance. Differences in phenotypes of individuals in a population in which differences are marked and do not grade into each other (such phenotypes are usually controlled by a few different alleles at a few genes). **Examples**: Ear lobe shape, tongue roll.
   (b) **Continuous variation**: Differences in phenotypes of individuals in a population in which differences are slight and grade into each other (such phenotypes are usually determined by a large number of genes and/or environmental influence). Characteristics with continuous variation show a normal distribution curve when sampled. **Examples**: height, weight, hand span, foot size.

2. Varies depending on data. Data should show a **3 to 1 ratio** (dominant to recessive) if sample is large enough.

3. Students own plot. Dependent on data collected. Should show a **normal distribution** if sample is large enough.

4. (a) Continuous distribution (and statistically normal distribution) if the sample is large enough.
   (b) Polygenic inheritance: several (two or more) genes are involved in determining the phenotypic trait.
   (c) The mean and standard deviation: students own calculation: see formulae below.

CALCULATING THE MEAN, $\bar{x}$

$$\bar{x} = \frac{\sum x}{n}$$

where,
$\sum x$ = sum of all measurements
n = sample size

CALCULATING STANDARD DEVIATION, s

$$s = \sqrt{\frac{\sum x^2 - ((\sum x)^2 / n)}{n}}$$

where,
$(\sum x)$ = sum of value x
$\sum x^2$ = sum of value x^2
n = sample size

Note: when only a small sample of the population can be measured, the formula for calculating *s* is modified, so that the divisor *n* is changed to (*n*-1).

(d) A large enough sample size (20-30+) provides sufficient data to indicate the distribution. The larger the sample size, the more closely one would expect the data plot to approximate the normal curve.

Sex-Linked Genes (page 202)

1.

Parent genotype:	X_BX_B	X_OY
Gametes:	X_B, X_B	X_O, Y
Kitten genotypes:	X_BX_O, X_BY	X_BX_O, X_BY
Phenotypes:	Tortoise, black	Tortoise, black

	Genotypes	**Phenotypes**
Male kittens:	X_BY	Black
Female kittens:	X_BX_O	Tortoiseshell

2.

Parent genotype:	X_BX_O	X_OY
Gametes:	X_B, X_O	X_O, Y
Kitten genotypes:	X_OX_O, X_BX_O	X_BY, X_OY
Phenotypes:	Orange female, Tortoise female,	Black male, Orange male

(a) Father's genotype: XOY
(b) Father's phenotype: Orange

3.

Parent genotype:	X_BX_B	X_OY
Gametes:	X_B, X_B	X_O, Y
Kitten genotypes:	X_BX_O, X_BY	X_BX_O, X_BY
Phenotypes:	Tortoise female, Black male,	Tortoise female, Black male

(a) Father's genotype: X_OY
(b) Father's phenotype: Orange
(c) Yes, the same cat could have fathered both litters.

4.

Parent:	Normal wife	Affected husband
Parent genotype:	XX	X_RY
Gametes:	X, X	X_R, Y
Children's genotypes:	X_RX, XY	X_RX, XY
Phenotypes:	Affected girl, Normal boy	Affected girl, Normal boy

(a) Probability of having affected children = 50% or 0.5
(b) Probability of having an affected girl = 50% or 0.5
However, all girls born will be affected = 100%
(c) Probability of having an affected boy = 0% or none

5.

Parent:	Affected wife	Normal husband
Parent genotype:	X_RX	XY
Gametes:	X_R, X	X, Y
Children's genotype:	X_RX, X_RY	XX, XY
Phenotypes:	Affected girl, Affected boy	Normal girl, Normal boy

Note: Because the wife had a normal father, she must be heterozygous since her father was able to donate only an X-chromosome with the normal condition.
(a) Probability of having affected children = 50% or 0.5
(b) Probability of having an affected girl = 25% or 0.25
However, half of all girls born may be affected
(c) Probability of having an affected boy = 25% or 0.25
However, half of all boys born may be affected

6. The location of genes on one or other of the sex chromosomes (usually the X, but a few are carried on the Y). Such genes produce inheritance patterns that are different from those shown by autosomes:
   - Reciprocal crosses produce different results (unlike autosomal genes that produce the same results).
   - Males carry only one allele of each gene.
   - Dominance operates in females only.
   - A 'cross-cross' inheritance pattern is produced: father to daughter to grandson, etc.

7. Over a hundred X-linked genes are known, including those that control:
   - Blood clotting: A recessive allele for this gene causes hemophilia affecting about 0.01% of males and almost unheard of in females.
   - Normal color vision: A recessive allele causes red-green color blindness affecting 8% of males but only 0.7% of females.
   - Antidiuretic hormone production: A version of this gene causes some forms of diabetes insipidus.
   - Muscle development: a rare recessive allele causes Duchene muscular dystrophy.

Interactions Between Genes (page 204)

1. **Polygeny** is the situation where a single character (trait) is determined by two or more genes. **Pleiotropy** is the situation where the same gene affects several traits.

2. **Epistasis** describes the situation where one gene masks or overrides the expression of other genes.

3. (a) Point mutation to the gene coding for the production of the β chain of the hemoglobin molecule.
(b) Hb^SHb^S
(c) Primarily deformed red blood cells resulting in anemia and clumping of the red blood cells. The clumping causes circulatory problems and organ damage and, eventually, death.
(d) Although this mutation results primarily in a faulty hemoglobin molecule, this also affects the shape of the red blood cells and leads to the suite of other abnormalities associated with the disease.

Epistasis (page 205)

1. No. of possible phenotypes: 3

2. Black: B_C_ (a dominant allele for each gene)
Brown: A dominant allele for gene C only (e.g. Ccbb)
White: No dominant allele for gene C (e.g. ccBB, ccbb)

3.

Eggs \ Sperm	BC	bC	Bc	bc
BC	**BBCC** Black	**BbCC** Black	**BBCc** Black	**BbCc** Black
bC	**BbCC** Black	**bbCC** Brown	**BbCc** Black	**bbCc** Brown
Bc	**BBCc** Black	**BbCc** Black	**BBcc** White	**Bbcc** White
bc	**BbCc** Black	**bbCc** Brown	**Bbcc** White	**bbcc** White

Ratio: 9 Black: 3 brown: 4 white

4. Homozygous white (bbcc) x homozygous black (BBCC): Offspring genotype: 100% BbCc, phenotype: All black

5. Homozygous brown (bbCC) x homozygous black (BBCC): Offspring genotype: 100% BbCC, phenotype: all black

Polygenes (page 206)

1. No. of possible phenotypes: 5

2. Black: AABB (all four dominant)
   Medium: Any two dominant alleles (e.g. aaBB, AaBb)
   White: aabb (all four recessive)

3. Punnett square: see below:

Eggs \ Sperm	AB	Ab	aB	ab
AB	**AABB** Black	**AABb** Dark	**AaBB** Dark	**AaBb** Medium
Ab	**AABb** Dark	**AAbb** Medium	**AaBb** Medium	**Aabb** Light
aB	**AaBB** Dark	**AaBb** Medium	**aaBB** Medium	**aaBb** Light
ab	**AaBb** Medium	**Aabb** Light	**aaBb** Light	**aabb** White

Ratios: White: light: medium: dark: black
1: 4: 6: 4: 1

4. All medium (AaBb)

5. Black, dark, medium, light, white

6. Seven phenotypes (number of dominant alleles present in the genotype can range from none (aabbcc) to six (AABBCC). A Punnett square would involve a grid of 8 x 8 = 64 squares.

What Genotype Has That Cat? (page 209)

Model answers cannot be provided for this exercise as there are so many different possible cat phenotypes. After the *Phenotype Record Sheet* has been completed, the extension exercise, where the genotype of each cat is identified should be completed on a separate sheet.

See the web sites linked from the Biozone web site ***www.thebiozone.com*** Under Bio Links: Genetics: Inheritance: • Coat color and pattern genetics of the domestic cat • Cat color genetics.

Pedigree Analysis (page 210)

1. **Pedigree chart of your family**: Each chart will be unique to each student. The chart should be drawn up carefully with a ruler, using the symbols illustrated at the top of the page called 'Pedigree Analysis' in your manual. Students who do not know their biological family tree (e.g. they are adopted) can do it for their adoptive family or that of another student.

2. (a) Dominant; each individual has an affected parent.
   (b) Not sex-linked: Some of the daughters of the affected parent (I-3) are not affected. They would be if the gene were located on the X chromosome.

3. (a) Explanatory background: I1 is a normal male, while the mother (I-2) must be a carrier (heterozygous) because she gave birth to both a normal and hemophiliac son. There is a 50% probability that II-2 is heterozygous (she could have received either of her mother's X chromosomes). If a carrier woman has children by a normal man then 25% of their children can be expected to be a hemophiliac. Because there is uncertainty as to whether the woman is a carrier or not, the total probability of II-2 producing hemophiliac children is:
   Probability of being a carrier X probability of producing hemophiliac children if she is a carrier =?
   ie. 1/2 x 1/4 = 1/8 (12.5%).
   (b) 1/4 (25%). Because her first child was a hemophiliac, she must be a carrier.
   (c) 3/4 (75%). II-4 has a 50% chance of being a carrier. If she was a carrier and has children with a hemophiliac man, 1/2 of their children (boys and girls) are expected to be hemophiliac. The combined chance of II-4 being a carrier and producing a hemophiliac child is 1/2 X 1/2 = 1/4. Therefore the probability that the child will be normal is the complementary fraction (3/4).
   (d) It is impossible to determine the phenotype of the father of I1 from the information given, because the father could be either normal or a hemophiliac and still produce a daughter (I-1) that is a carrier (heterozygous normal).

4. (a) 1/2 (b) 0 (c) 0
   (d) 3/4 (e) 1/2

Restriction Enzymes (page 214)

1. (a) **Restriction enzyme**: Enzymes that cut DNA at very precise base sequences (they are able to create sticky end or blunt end junctions).
   (b) **Recognition site**: The base sequence that a restriction enzyme recognizes and cuts.
   (c) **Sticky end**: The exposed ends of DNA after a restriction enzyme has cut, leaving a partially unmatched base sequence.
   (d) **Blunt end**: The exposed ends of DNA after a restriction enzyme has cut, leaving two blunt ends with no exposed nucleotide bases.

2. (a) EcoRI
   (b) Escherichia coli RY13
   (c) GAATTC

3. (a) GGATCC
   (b) Recognition sites: *Diagram the top of the next page.*
   (c) 5 fragments

4. 400 restriction enzymes that recognize 100 sites.

5. There is a need to have a tool kit of enzymes that allows scientists to cut DNA at any point they wish. The action of such enzymes allows DNA to be manipulated for other recombinant DNA technologies.


```
|AATGGGTACG|CACAGTGGAT|CCACGTAGTA|TGCGATGCGT|AGTGTTTATG|GAGAGAAGAA|
|AACGCGTCGC|CTTTTATCGA|TGCTGTACGG|ATGCGGAAGT|GGCGATGAGG|ATCCATGCAA|
|TCGCGGCCGA|TCGXGTAATA|TATCGTGGCT|GCGTTTATTA|TCGTGACTAG|TAGCAGTATG|
|CGATGTGACT|GATGCTATGC|TGACTATGCT|ATGTTTTTAT|GCTGGATCCA|GCGTAAGCAT|
|TTCGCTGCGT|GGATCCCATA|TCCTTATATG|CATATATTCT|TATACGGATC|GCGCACGTTT|
```

Ligation (page 216)

1. (a) **Annealing**: The two single-stranded DNA molecules are recombined into a double-stranded form. Achieved by simple attraction of complementary bases (hydrogen bonds).
   (b) **DNA ligase**: This enzyme joins together the two adjacent pieces of DNA by linking nucleotides in the sticky ends.

2. DNA ligase performs the task of linking together the Okazaki fragments during DNA replication.

3. It joins together DNA molecules, whereas restriction enzymes cut them up.

Gel Electrophoresis (page 217)

1. Purpose: to separate mixtures of molecules (proteins, nucleic acids) on the basis of size, electric charge and other physical properties.

2. The frictional (retarding) force of each fragment's size (larger fragments travel more slowly than smaller ones). The strength of the electric field (movement is more rapid in a stronger field). **Note**: temperature and ionic strength of the buffer can be varied to optimize separation of the fragments.

3. The gel is full of pores (holes) through which the fragments must pass. Smaller fragments pass through these pores more easily than larger ones.

Polymerase Chain Reaction (page 218)

1. To produce large quantities of 'cloned' DNA from very small samples. Large quantities are needed for effective analysis. Minute quantities are often unusable.

2. A double stranded DNA is heated to 98°C for 5 min, causing the two strands to separate. Primer starting DNA polymerase are added to the sample. This is then incubated at 60°C for a few minutes during which time, complementary strands are created using each strand of the DNA sample as a template. The process is repeated about 25 times, each time the number of templates doubles over the previous cycle.

3. (a) Forensic samples taken at the scene of a crime (e.g. hair, blood, semen).
   (b) Archaeological samples from early human remains.
   (c) Samples taken from the remains of prehistoric organisms preserved in ice, mummified, preserved in amber, tar pits etc.

4. This exercise can be done on a calculator by pressing the 1 button (for the original sample) and then multiplying by 2 repeatedly (to simulate each cycle). Most calculators will not display more than about 8 digits. Alternatively, use a computer spreadsheet.
   (a) 1024 (b) 33 554 432 (33.5 x 106)

5. (a) It would be amplified along with the intended DNA sample, thereby contaminating the sample and rendering it unusable.
   (b) Sources of contamination:
      – Dirty equipment (equipment that has DNA molecules left on it from previous treatments)
      – DNA from the technician (dandruff from the head is a major source of contamination!)
      – Spores, viruses, and bacteria in the air or aerosols floating in the air.
   (c) Ways to avoid contamination:
      – Using disposable equipment (pipette tips, gloves)
      – Wearing a head cover (disposable cap)
      – Use of sterile procedures
      – Use of plastic disposable tubes with caps that seal the contents from air contamination

6. (a) and (b) any of the following procedures require a certain minimum quantity of DNA in order to be useful: DNA sequencing; gene cloning; DNA profiling; transformation; making artificial genes. Descriptions of these procedures are provided in the manual.

Manual DNA Sequencing (page 220)

1. (a) **Forensic**: Samples of blood, semen, hair left at the scene of a crime can be used to identify the perpetrator of a crime.
   (b) **Legal disputes**: Arguments over paternity of humans (and lately, the pedigree of racehorses).
   (c) **Medical**: Identification of genetic disorders in humans to provide opportunity for genetic counseling.
   (d) **Evolution/taxonomy**: Determining the genetic relatedness of groups of organisms to reassess the traditional classification schemes (which should reflect evolutionary relationships or phylogeny).
   (e) **Archaeology/anthropology**: Studies of the genetic makeup of modern human races to determine the geographic origin of modern humans and the timing of this event.
   (f) **Conserving endangered species**: Studies of populations of threatened species to determine the degree of genetic diversity. This is important for endangered species that have small populations with low genetic diversity due to in-breeding. The degree to which populations are genetically isolated from each other can also be determined.
   (g) **Livestock breeding programs**: Assist with the tracking of offspring from matings between livestock parents. Will also assist in the identification of

transgenic offspring from mated transgenic parents.

2. The Human Genome Project required an **automated process** that could cope with the sequencing of the 3 billion bases making up the human genome. It has to be automated, rapid, and cost-effective (cheap to run).

DNA Profiling using Probes (page 224)

1. (a) Suspect 1
   (b) If it had to be one of the 3 suspects then there is 100% certainty as there is a perfect match in DNA samples. If there may have been someone else involved, then there is a one in a million chance that the suspect is not the killer (since his DNA pattern is found in one in a million people).
   (c) The evidence (semen sample) would be contaminated with the victim's DNA. It must be shown that the victim's DNA pattern is not the same as that of the semen sample. If it was, it would invalidate the test.
   (d) **Forensic**: (broadly) relating to or used in a court of law. Specifically here, relating to, or denoting, the application of scientific methods and techniques to the investigation of crime.

2. Blood types are not precise enough. Given that ABO blood groups are shared by many people (eg. 49% of people of European origin are blood group **O**, while 40% are blood group **A**). Even minor blood group types (e.g. Rh, Kell, MN) are not that helpful.

3. The reliability of the purity or non-contamination of the suspect's tissue sample being analyzed in the lab has been raised. There are also fierce arguments over the frequency of DNA markers in the population at large that are tested for in the forensic analysis.

4. (a) and (b) any of the following: screening for genetic diseases; identifying the sex of animals that are difficult to sex visually (e.g. some parrots, ostriches reared commercially); checking the pedigree of dogs, racehorses, stud cattle; checking for genetic diversity in trees in commercial forests.

DNA Profiling using PCR (page 226)

1. (a) DNA profiling: Obtaining a pattern on an electrophoresis gel that represents an organism's unique complement of DNA for a highly variable region of their DNA.
   (b) STRs: Non-coding nucleotide sequences (2-6 base pairs long) that repeat themselves many time over.
   (c) Microsatellites: another name for STRs (above)

2. (a) Gel electrophoresis: Used to separate the DNA fragments (STRs) according to size to create the 'fingerprint'.
   (b) PCR: Used to make many copies of the STRs. Only the STR sites are amplified by PCR as the primers that are used to initiate the PCR are very specific.

3. (a) Extract the DNA from sample. Treat the tissue with chemicals and enzymes to extract the DNA, which is then separated and purified.
   (b) Amplify the microsatellite using PCR. Primers are used to make large quantities of the STR.
   (c) Run the fragments through a gel to separate them. The resulting pattern represents the STR sizes for that individual (which will vary from that of many other individuals).

4. To ensure that the number of STR sites, when compared, will produce a 'unique' profile for an individual (different from just about everybody else in the population). It provides high degree of statistical confidence when a match occurs.

Gene Cloning (page 228)

1. The process of making large quantities of a specific piece of DNA (a gene).

2. Once a gene has been isolated and inserted into a host organism for replication, the host organism can be made into a biological factory to manufacture unlimited quantities of the protein product (e.g. human insulin).

3. Restriction enzymes are used to prepare the DNA fragment (e.g. a human gene) that is to be cloned by isolating it from other DNA and providing it with sticky ends. The same enzymes are used to open up the plasmid or viral DNA into which the DNA fragment is to be inserted.

4. **Recombinant DNA**: Genetic material from two different sources is combined into a single DNA molecule, using genetic engineering techniques. The two different sources may or may not be from different species.

5. One can identify recombinant colonies by their ability to grow on agar with ampicillin but not tetracycline.
   – Grow the bacteria on agar containing ampicillin. All resulting colonies must contain the plasmid.
   – Press a sterile filter paper firmly onto the surface of the agar, taking care to mark the paper's position relative to the agar plate. Press the paper onto another agar plate containing tetracycline and mark the position of the paper relative to the plate. Any colonies that do not grow on this agar must contain the recombinant DNA (the tetracycline killed them).
   – Match the position of colonies between the first and second agar plates. Those on the 1st plate that are missing from the 2nd plate are isolated & cultured.

Nature of Genetic Modification (page 230)

1. (a) Through the addition of a foreign gene
   (b) Through alteration of an existing gene
   (c) Through deletion or inactivation of an existing gene

2. Student's own account based on information provided in the student manual or in other texts.

Genetically Modified Plants (page 231)

1. *A. tumefaciens* has a large, tumor inducing plasmid that can infect plant cells and become incorporated into the plant's own genome. **Note**: The plasmid can be successfully modified and transferred to plant cells, where the genetic modification is taken up and expressed by the plant.

2. (a) Improvement for oil storage capacity as oleic acid oxidizes less rapidly than linolenic acid (therefore stored products will not go rancid).

Note: This also benefits human nutrition because stabilization of the oil by extensive hydrogenation is not required (hydrogenation is a process that produces trans-fatty acids. These fatty acids have been found to be deleterious to human health).
(b) Enables crops to be sprayed for weeds without themselves being damaged.

Transgenic Organisms (page 232)

1. (a) **Transformation**: The acquisition of genetic material by the uptake of naked DNA by the recipient (so that the recipient takes on the characteristics encoded by the foreign DNA). **Note**: Most often used with respect to bacteria (in which transformation occurs naturally), but increasingly applied to other organisms. Outside the field of GE, transformation is used to refer to changes occurring in cultured cells after infection with tumor viruses.
   (b) **Foreign DNA**: DNA that is not part of the natural genome of a species.

2. The DNA of one organism is introduced (by way of a vector, direct injection, or protoplast fusion) into the genome of another (recipient) organism. The foreign DNA, when expressed, confers new properties on the recipient organism.

3. Examples include:
   – A gene that provides resistance to bacterial disease in rice plants.
   – A gene that provides resistance to a crop against herbicide sprays (so that weed control with herbicides will not affect the crop).

4. (a) to (c) any of the following: A need to:
   – Treat genetic diseases in humans.
   – Improve production in livestock (milk, cheese, beef, mutton, wool, leather).
   – Increase pest resistance in crops and livestock.
   – Provide existing crops and livestock with new novel traits that may be useful (e.g. timber with reduced lignin, cows milk with altered constituents).
   – Provide crops with an ability to synthesize their own fertilizer (to reduce dependence on application of agricultural fertilizers).

5. **Advantages**: • Viruses are good vectors because they are adapted to gain entry into a host's cells • Viruses are very host specific with respect to infection • Viruses can integrate their DNA into that of the host. **Disadvantage** (any of): • The host can develop a strong immune response to the viral vector (infection). In patients immune suppressed by their disorder, this could severely undermine their health • Retroviruses can only infect dividing cells (uptake may be sporadic or poor). • The inserted genes may only function sporadically because they are not inserted into the chromosome.

6. The purpose of this experiment was simply to show that the technology was viable and that a transgenic animal could be produced.

Using Recombinant Bacteria (page 234)

1. Chymosin (an enzyme) is used to coagulate milk into curds in the production of cheese.

2. Traditional source of chymosin was from the stomachs of young (suckling) calves.

3. (a) **Restriction enzymes** are used to cut the *E. coli* plasmid and isolate the gene for chymosin production (from the calf).
   (b) **DNA ligase** is then used to incorporate the chymosin gene into the plasmid DNA at the point where the restriction enzyme cut.

4. Advantages of using chymosin from GE bacteria:
   (a) The chymosin produced is identical to chymosin from its natural source.
   (b) The chymosin can be produced without the unnecessary slaughter of calves (a welfare issue for many people).
   (c) The chymosin can be produced on demand, in the quantities required. This makes it cost effective.

Note: Chymosin is also made from other species of GE bacteria, e.g. *Kluyveromyces lactis*.

Gene Therapy (page 235)

1. The purpose of gene therapy is to correct a genetic disorder of metabolism arising from the expression of a defective gene. **Note**: Some techniques involve culturing corrected cells ex-vivo. Injection of corrected cells into the patient relieves the symptoms of the disorder but does cure it.

2. Three general categories of disease targeted by gene therapy: Inherited genetic disorders of metabolism, cancers and other non-infectious acquired diseases, and treatment of infectious diseases.

Gene Delivery Systems (page 236)

1. (a) Viruses are good vectors because they are adapted to gain entry into a host's cells and integrate their DNA into that of the host.
   (b) Problems with viral vectors include (any one of):
      – The host can develop a strong immune response to the viral infection. In patients immune suppressed by their disorder, this could severely undermine their health.
      – Retroviruses can only infect only dividing cells.
      – The genes may only function sporadically if they do not integrate into the chromosome.
      – Useful genes may be disrupted by integration of the viral DNA.
   Liposomes might offer an advantage by (one of):
      – There are no viral genes, so no risk of disease.
      – Liposomes can be recognized and taken up by cells without integration into the chromosome and its consequent problems.

2. (a) **CF symptoms**: Disruption of gland function including the pancreas, intestinal glands, biliary tree, sweat glands, and bronchial glands. Infertility occurs in males and females. Disruption of lung function produces the most obvious symptom of accumulation of thick, sticky mucus in the lungs and

associated breathing difficulty.
(b) CF is eagerly targeted because the majority of cases are the result of a gene defect involving the loss of only one triplet (three nucleotides). In theory, correction of this one gene should not be difficult.
(c) Vectors: Adenoviruses, piped directly into the lungs. Liposomes, delivered via inhalation of a spray formulation (in aerosol of nebulizer).
(d) Correction rate has been low (25%), and the effects of correction have been short lived and the benefits quickly reversed. In one patient, treatment was fatal.

Production of Human Proteins (page 238)

1. (a) High cost (extraction from tissue is expensive).
   (b) Non-human insulin (from pigs or cattle) is different enough from human insulin to cause side effects.
   (c) The extraction methods did not produce pure insulin so the insulin was often contaminated.

2. The insulin is synthesized as two (A and B) nucleotide sequences (corresponding to the two polypeptide chains) because a single sequence is too large to be inserted into the bacterial plasmid. Two shorter sequences are small enough to be inserted (separately) into bacterial plasmids.

3. The β-galactosidase gene in *E.coli* controls the transcription of genes, so the synthetic "genes" must be tied to that gene in order to be transcribed.

4. (a) Insertion of the gene: The yeast plasmid is larger and could accommodate the entire synthetic nucleotide sequence for the A and B chains as one uninterrupted sequence.
   (b) Secretion and purification: Yeast, being eukaryotic, has secretory pathways that are more similar to humans than those of a prokaryote. Secretion from the cell of the precursor insulin molecules is thus less problematic. Purification would be simplified because removal of β-galactosidase is not required.

5. Mass production of human proteins using GMOs facilitates a low cost, reliable supply for consumer use. The protein (e.g. insulin) is free of contaminants and, because it is a human protein, the side effects of its use are minimized.

6. In the future, gene therapy, where a faulty gene is corrected in the patient, could treat many inherited disorders of metabolism. The use of stem cells, which can differentiate and proliferate in the patient's tissue, may prove the best way to correct genetic disorders.

The Human Genome Project (page 240)

1. – To map the entire base sequence of every chromosome in the human cell (our genome).
   – To identify all genes in the sequence and determine what they express (protein produced).
   – To determine the position of every gene at precise locations on the chromosomes.

2. (a) Medical: any of the following:
   – Will identify the location and sequence for up to 4000 known genetic diseases, opening up opportunities for drug therapy.
   – Will provide the information to enable the production of human proteins to correct metabolic deficiencies.
   – Will open up the possibility of gene therapy for many genetic diseases.
   – Will enable the development of new therapeutic drugs to block metabolic pathways.
   – With greater knowledge, emphasis will shift from treatment of disease to better diagnosis and prevention of disease.
   – Screening for genetic predisposition to disease.
   – The ability to sequence quickly and directly will revolutionize mutation research (direct study of the link between mutagens and their effects).
   (b) Non-medical (any of the following):
   – What we learn about human genetics will enable improvement of livestock management.
   – Provides a knowledge base that is a key to understanding the structure, function, and organization of DNA in chromosomes.
   – Provides the basis for comparative studies with other organisms.
   – Provides a greater understanding of human evolution and anthropology
   – Facilitates developments in forensics.

3. (a) and (b) any two of:
   – The difficulty in deciding who has the rights to control our genetic information.
   – Ethical problems of restricting access to information necessary for the development of new therapies.
   – It may not be possible to prevent onset of a disease. Some people may rather not know about their inevitable demise.
   – A person's genetic profile could be used in a discriminatory way by employers, insurance companies, and governments.

4. Proteomics is the study (including identification) of the protein products of identified genes. It relies on the knowledge gained by the HGP but will ultimately provide the most useful information.

5. (a) The HGDP aims to map the differences in genomes between different racial and ethnic groups.
   (b) Genomic differences on the basis of race could be misused for discriminatory purposes.

The Ethics of GMO Technology (page 242)

1. Plants produce pollen which has the potential to be spread in a broadcast fashion (broadcast pollination). This increases the risk that genes (e.g. for herbicide resistance) will be transferred from a GM plant to a weed or other plant. **Note**: Such gene transference has already been demonstrated between plant species. Transfer of sex cells (and therefore genes) between animals in this way does not occur; breeding in animals is generally a more precise and difficult process.

2. (a) **Advantage**: Crop growers could spray a field with herbicide to kill weeds without harming the crop.
   (b) **Problem**: Herbicide resistance may be spread to weed plants by viral or bacterial vectors that infect plants. Encourages overuse of herbicide chemicals.

3. (a) **Advantage**: Ability to grow tropical food crops in regions that could not previously do so.
   (b) **Problem**: Such plants in a new environment may become pest species. Undeveloped economies that rely on tropical cash crops may suffer as a result of competition from economically strong countries.

4. (a) **Advantage**: Will allow regions that are poor in agricultural production to produce crops.
   (b) **Problem**: Such plants in a new environment may become pest species. Disturbs natural wetland habitats, probably resulting in the loss of wetland and marsh native species.

5. (a) Enhancing wool production in sheep (yield and/or wool quality).
   (b) Use of livestock animals as biofactories by producing useful proteins in their milk (especially cattle, but also sheep and goats).

6. The widespread use of antibiotic marker genes in food crops for human consumption or stock food may give rise to antibiotic resistant strains of pathogenic bacteria which affect humans and stock animals. Restrained use of antibiotics is now considered essential in preventing large scale development of antibiotic resistance.

7. (a) Introduces nitrogen fixing ability in non-legumes thereby reducing the need for nitrogen fertilizers.
   (b) The bacterium would prevent attack on the seeds by pathogenic bacteria and fungi.

8. (a) Some points for discussion are:
   - That the GM product and/or the GMO could have some unwanted harmful effect on humans or other organisms.
   - That the genetic modification would spread uncontrollably into other organisms (breeding populations of the same or different species).
   - Consumer choice is denied unless adequate labeling protocols are in place. If everything contains GM products then there is no choice.
   - General fear of what is not understood (fear of real or imagined consequences).
   - Objections on the grounds that it is ethically and morally wrong to tamper with the genetic make-up of an organism.
   - Generation of monopolies where large companies control the rights to seed supplies and breeding stock.

   (b) Those that pose a real biological threat are:
   - Amongst plant GMOs, the indiscriminate spread of foreign genes.
   - Unusual physiological reactions e.g. allergies, to novel proteins.
   - Some animal rights issues may be justified if genetic modification causes impaired health.

   Note: This question was not intended to imply that ethical or moral concerns are less valid than biological ones. It was merely an exercise in identifying the nature of the biological concerns.

Cloning by Nuclear Transfer (page 244)

1. **Adult cloning** (using nuclear transfer): Producing genetically identical individuals from non-embryonic (somatic) tissue from a known phenotype.

2. **Embryo splitting** is a simpler technique involving the splitting of a normally produced embryo at a very early stage in development. The embryos continue to develop normally (as in the case of natural identical twins).

3. (a) Switching off genes in the donor cell: Induced by low nutrient medium (starvation of the egg).
   (b) Fusion of donor and enucleated egg: Induced by a short electric pulse.
   (c) Activation of the cloned cell (reconstructed egg cell): Induced by a second gentle electric pulse or by chemical means. A time delay of about 6 hours improves the success of the egg activation process, probably through the prolonged contact of the chromatin with (unknown) cytoplasmic factors.

4. – Production of clones from a proven phenotype that can quickly be disseminated into commercial herds.
   – Rapid production of transgenic animals that produce a particular product (e.g. a pharmaceutical secreted in the milk), in order to respond to market demand.
   – Conservation of rare livestock breeds. It is hoped that cloning will eventually be integrated into zoo management programs. By retaining the tissues of individuals before they die, some of the genetic diversity of rare species can be retained. It may even be possible, in the future, to restore species that are on the verge of extinction using cloning.

Cloning by Embryo Splitting (page 246)

1. Making an exact copy of a cell or organism by replicating it from a single parent. This is achieved either by splitting embryos at an early stage of embryonic development (embryo splitting), or by nuclear transfer techniques.

2. (a) Stem cells are undifferentiated; this allows them to be used to make any type of tissue in the recipient (a similar outcome for the production of blood cells is already achieved with bone marrow transplants).
   (b) Cloning high milk yielding cows will enable high yielding herds to be produced quickly (without waiting to see the phenotypic outcome of usual selective breeding processes). Ultimately, this will improve supply at low cost and may also free up land for other uses (since, theoretically, smaller herds would be required).

3. Continued use of embryo splitting will reduce the total pool of genetic diversity from which to select new breeds/strains/varieties.

The Human Cloning Debate (page 247)

1. Questions (a) - (f) taken from CNN/TIME Magazine survey, 8th Nov. 1993, p53 (taken in the USA). Their results for those questions are:

	Approve	**Disapprove**
(a)	45%	46%
(b)	40%	52%
(c)	24%	70%
(d)	17%	78%
(e)	16%	80%
(f)	6%	89%

Biomes (page 250)

1. Northern extent of boreal forest limited by low temperatures and short daylight hours for half of the year (=short growing season), and the presence of a permanently frozen ground layer which prevents deep root hold in the soil (required by larger trees).

2. Less biomass is tied up in woody tissues (there are few trees) and turnover times for grasses are high (i.e. the plant tissue is replaced entirely with a high frequency).

3. These are rainshadow areas: dry areas in the leeward side of mountains in the path of rain-bearing winds. Much of the precipitation is dropped at high altitude in the mountain ranges as snow and ice, leaving a paucity of precipitation in lowland areas adjacent to mountains.

4. Most of the natural extent of temperate forest is mid-latitude with a reasonably equable climate and moderately high, evenly distributed rainfall. These factors make the forest area ideal for settlement and agriculture. Consequently, much of the original forest has now been cleared.

Components of an Ecosystem (page 252)

1. A community is a naturally occurring group of organisms living together as an ecological entity. The community is the biological part of the ecosystem. The ecosystem includes all of the organisms (the community) and their physical environment.

2. The physical environment refers to the physical surroundings of any organism, including the medium, substrate, and climatic conditions, light and other physical properties.

3. The biotic factors are the influences that are the result of the activities of living organisms in the community whereas the abiotic (physical) factors are the influences of the non-living part of the community e.g. climate.

4. (a) Population (c) The community
   (b) Ecosystem (d) Physical factor

Habitats (page 253)

2. **Herring gull**: Habitat: Widespread in coastal and inland regions; lakes, rivers, coasts, and garbage dumps.
   (a) Biotic factors: Suitable food (almost anything but a preference for shellfish), vegetation suitable for nesting material.
   (b) Abiotic factors: Tolerant of wide climate range. Suitable nesting sites (usually dunes behind the high tide line).

3. **Coyote**: Habitat: Prairies, open forests, brush. Widespread in a variety of habitats.
   (a) Biotic factors: Suitable food (rodents, rabbits, and other small mammals, but also opportunistic scavengers), some vegetation cover, does better in the absence of competition from larger wolves.
   (b) Abiotic factors: Drinking water. Soil type suitable for digging a burrow for pups, typically prefers temperate to north temperate climates but can be pushed in more marginal habitat (mountain ranges and deserts).

4. **White-tailed deer**: Habitat: Forests, swamps, and adjacent bushy areas. Advantaged by forest clearance for agriculture.
   (a) Biotic factors: Suitable browse (forbs, agricultural crops especially corn and alfalfa, twigs, buds, young shoots, and leaves of deciduous trees and shrubs, grasses to a limited extent). Forested cover. Sustainable level of predation from timber wolf, coyote, mountain lion, and bobcat. Populations expand rapidly when numbers of competitors (mule deer, elk, bison, moose) are reduced.
   (b) Abiotic factors: Drinking water. Temperate to cool climate (food availability depends on growing season adequate to support the vegetation on which they rely).

5. **Barn owl**: Habitat: Forests near open country, farmland, towns (with available green space).
   (a) Biotic factors: Suitable prey (primarily voles, shrews, rats, and mice). In some cases, vegetation (hollow trees) to provide nesting sites. Sustainable level of predation/attacks from crows, ravens, hawks, and great horned owls.
   (b) Abiotic factors: Water for drinking and bathing. Suitable, non-biotic nesting sites help survival and protect against attack from predators. Tolerant of cold, but temperature will determine abundance of suitable prey.

6. **Oak tree** (this example is live oak but a local oak species example could be used): Habitat (southeastern USA distribution from SE Virginia to Florida): coastal sand plains and dunes, to inland sand flats. Common dominant in maritime forests. Also succeeds when planted elsewhere.
   (a) Biotic factors: Intermediate in shade tolerance; once established withstands competition. Success largely depends on the impact of various insect pests and diseases, and competition from other plants when establishing as seedlings.
   (b) Abiotic factors: Grows best on lighter (sandy) soils, although tolerant of a wide range of soil water content. Salt tolerant. Tends to a shrubby growth habit near the coast (site dependent). Withstands flooding but not constant saturation.

Dingo Habitats (page 254)

1. Densities per 100 km^2 as follows:
   Pack B: 12.8 Pack C: 3.5 Pack D: 9.5

2. (a) Hills (d) Floodplain
   (b) Floodplain and hills (e) Hills and floodplain
   (c) Floodplain

3. Dingoes prefer riverine habitat. This is indicated by the fact that they spend a disproportionate amount of time in riverine compared to the total habitat available (even when riverine habitat is scarce, the packs spend time there). Stony areas are avoided.

4. (a) Dingoes are caught and fitted with radiotransmitters. At set intervals, the signals from individual animals can be recorded and mapped giving a composite picture of movements over a period of time.
   (b) 4194
   (c) 4 years
   (d) A large number of records provides more accurate information about the size and boundaries of the area over which the packs range. Too few records would not clearly indicate the ranges covered.

5. It probably plays some part since the areas with very low kangaroo abundance also have low dingo densities. However other limiting factors in the environment

(particularly the availability of suitable riverine habitat) are important. **Note**: High kangaroo abundance will not necessarily equate with high dingo densities if other factors are limiting; there is a trade-off between food availability and other factors (such as suitable habitat).

6. (a) Home ranges are larger in areas where water (and vegetation) are limited (arid regions with no riverine areas). Moist, forested areas (high water availability and vegetation cover) have the smallest ranges.
   (b) Areas with poor water supply offer little in the way of vegetation diversity. Habitats end to be rather homogeneous in arid areas.

Physical Factors and Gradients (page 256)

1. **Microclimate**: Climatic variation on a small scale; this can vary depending on shelter and aspect, as well as the influence of objects in the environment. The immediate climate in which an organism lives.

2. High humidity underground, in cracks, under rocks.

3. In a crack or crevice, in a burrow underground, in spaces under rocks.

4. An animal unable to find suitable shelter would undergo heat stress, dehydration and eventually die.

5. High humidity enables land animals to reduce their water loss due to evaporation.

6. At night, temperature drops and humidity increases (to the point where condensation may occur; this is a source of valuable water for some invertebrates).

7. Environmental gradients:
   (a) Salinity: increases from LWM to HWM.
   (b) Temperature: increases from LWM to HWM.
   (c) Dissolved oxygen: decreases from LWM to HWM.
   (d) Exposure: increases from LWM to HWM.

8. (a) Rock pools may have very low salinity if there has been rain falling into them directly or through runoff.
   (b) Rock pools may have very high salinity due to evaporation after exposure without rainfall.

9. (a) **Mechanical force of wave action**: Point B will receive the full force of waves moving inshore, point A will receive only milder backwash, point C will experience surge but no direct wave impacts.
   (b) **Surface temperature**: Points A and B will experience greater variations in rock temperature depending upon whether the tide is in or out, day or night, water temperature, wind chill factors. Point C is more protected from some of these factors and will not experience the heating effect of direct sun.

10. Environmental gradients from canopy to leaf litter:
    (a) Light intensity: decreases.
    (b) Wind speed: decreases.
    (c) Humidity: increases.

11. Reasons why factors change:
    (a) Light intensity: Foliage above will shade plants below, with a cumulative effect. The forest floor receives light that has been reflected off leaf surfaces several times, or passed through leaves.
    (b) Wind speed: Canopy trees act as a wind-break, reducing wind velocity. Subcanopy trees will reduce the velocity even further, until near the ground the wind may be almost non-existent. An opening in the forest canopy (a clearing) can expose the interior of the forest to higher wind velocities.
    (c) Humidity: The sources of humidity (water vapor) are the soil moisture, leaf litter, and the transpiration from plants. Near the canopy, the wind will carry away moisture-laden air. Near the forest floor, there is little wind, and humidity levels are high.

12. The color of the light will change nearer the forest floor. White light (all wavelengths) falling on the canopy will be absorbed by the leaves. Reflected light in the green wavelength bounces off the leaves and passes downward to lower foliage and the forest floor.

13. (a) **Advantages**: Reduced wind speed reduces water loss due to transpiration; water balance (drying out) is not a problem. Increased humidity is an advantage for plants that are sensitive to water loss
    (b) **Disadvantages**: There is a marked reduction in the quantity and quality of light available for photosynthesis. Plants on the forest floor are typically slow-growing and may have special leaf modifications to enhance light capture (e.g. large size and arrangement to avoid shadow effect).

14. Environmental gradients from water surface to bottom:
    (a) Water temperature: Decreases gradually until below the zone of mixing when there is a sharp drop.
    (b) Dissolved O_2: Oxygen at a uniform concentration until below the zone of mixing when there is a sharp drop, with little oxygen (or anoxia) at the bottom.
    (c) Light penetration: Decreases at an exponential rate (most light is absorbed near the surface).

15. (a) Prevents mixing of the oxygen-rich surface water with the deeper oxygen-deficient water (represents a thermal barrier.)
    (b) Organisms (particularly bacteria) living below the thermocline use up much of the available oxygen. Decomposition also uses up oxygen.

16. (a) Heavy rainfall or inflow of floodwater from nearby river channels may cause a decline in conductivity.
    (b) Evaporation from the lake concentrates salts and the conductivity will increase.

Shoreline Zonation Patterns (page 260)

1. (a) Exposure time determines what species can extend higher up the shore where the time without submergence is longer. Some species are intolerant of long exposure times, others are very tolerant.
   (b) Intensity of wave action, salinity (in pools), temperature (in pools), oxygen level (in pools).
   (c) Presence or absence of competing species, presence or absence of predators.

2. Broad bands approximately parallel to the water's edge, formed by distinct assemblages of species.

Ecological Niche (page 261)

1. The (fundamental) niche describes the total collection of adaptations that allows an organism to exploit the resources of its habitat according to the lifestyle to which it is fitted. The physical conditions will determine the organism's preferred habitat within a range (according to the law of tolerances).

2. Competition with other species may prevent the organism from exploiting all resources it is adapted to use. Competition forces species to occupy a **realized niche** that is narrower than their fundamental niche.

3. Organisms occupying the same habitat and general feeding niche can minimize competition by exploiting:
   - Different times of the day or night (e.g. feeding at dawn or dusk vs feeding during the daylight)
   - Slightly different foods, e.g. specializing to feed on particular types of insect rather than feeding on all insects generally.
   - Living in slightly different regions within the same area e.g. high in the canopy vs near the forest floor. Similar foods may be available in both places.

   Students may give specific local examples if they wish.

Ecological Niches (page 262)

2. **Sea star**:
   (a) Nutrition: A predator of worms, molluscs, and other echinoderms.
   (b) Activity: Very low metabolic rate. "Active" at a low rate most of the time.
   (c) Habitat: Coastal water and sandy shores, often burrowing from the extreme lower shore downward.
   (d) Adaptations: Slow moving but well protected from predators by a tough skin containing calcareous plates. Tube feet are adapted for digging (unlike other starfish). Smothers prey and protrudes its stomach. Produces large numbers of planktonic larvae, most of which are food for plankton feeders.

3. **Bluebottle blowfly**:
   (a) Nutrition: Larvae feed immediately after hatching on flesh. Adults have spongy mouthparts for mopping up fluid nutriment.
   (b) Activity: Primarily, but not exclusively, diurnal. Active most of the year. Adults may hibernate in houses.
   (c) Habitat: Global, in almost every type of habitat where there are other organisms.
   (d) Adaptations: Short life cycle (completed in as few as 7 days). Eggs laid in very large numbers on dead animals, wounds, and necrotic or soiled tissue (e.g. sheep dags). Adult may overwinter. Highly adaptable and widespread.

4. **Red fox**: General habitat: Highly adaptable and widely distributed in many habitats from salt marshes and sand dunes, to mountains, to urban environments.
   (a) Nutrition: Opportunistic; suitable food includes live prey (small mammals and birds) and carrion, as well as insects and fruits.
   (b) Activity: Active most of the year; most daily activity in early morning and late afternoon-evening.
   (c) Habitat: Farmlands, forest with open areas.
   (b) Adaptations: Opportunistic; learns quickly and highly adaptable. Good sight and hearing, swift, and will go underground (into a den) when threatened.

5. **Pheasant**:
   (a) Nutrition: Seeds, fruits, and vegetation.
   (b) Activity: Diurnal.
   (c) Habitat: In fields and rough scrubland offering cover (especially in winter), also in woods and marshes.
   (d) Adaptations: Plumage coloration acts as camouflage in their habitat. Behavior is to crouch low in vegetation when threatened. Cocks are polygamous and mate with many hens. Chicks precocial (active soon after hatching) which makes them less prone to predators plundering the nests.

6. **Gray squirrel**:
   (a) Nutrition: Main diet is nuts (particularly acorns), and a wide range of roots and bulbs. Also eats insects, eggs, and small birds, and will strip bark from trees.
   (b) Activity: Diurnal. Active throughout year and does not hibernate.
   (c) Habitat: Widespread in deciduous woodland in the British Isles. Also common in parks and gardens. Less common in coniferous woodland.
   (d) Adaptations: Limbs well adapted for tree climbing and grasping. Acute vision, hearing, and sense of smell. Teeth grow continuously and are worn down by hard foods in the diet. Agile and swift (predator escape). Voracious feeder and said to be more adaptable and aggressive than the competing species, the red squirrel. Females adept at laying down fat before winter, which improves their breeding success the following spring.

Competition and Niche Size (page 263)

1. (a) Interspecific competition is competition for resources between members of different species.
   (b) Intraspecific competition is competition for resources between members of the same species.

2. (a) One species (the more 'able' competitor) would do better at the expense of the other (the less able competitor). The less able species would then be pushed into a less favorable area.
   (b) At different times of the year different foods/mating and nesting sites might be taken by different species, either intensifying or lessening resource overlap (therefore resource competition).
   (c) If the zone of resource use overlap was increased the breadth of the realized niche of each species would increase because of niche expansion into less favored areas.

3. Niche breadth can become broader where a species is an "ecological generalist" and can exploit a wide variety of habitats, food types, nesting/breeding sites etc. Many pest species are such generalists.

Adaptations to Niche (page 264)

For each of the following the list is not exhaustive, but uses examples given on the diagrams. Note that most adaptations have components of structure, physiology, and behavior (e.g. threat behaviors involve use of structural features. Thermoregulatory physiology involves some behavior etc.). Categories may not be mutually exclusive.

1. Common mole adaptations:
   (a) **Structural**: Generally these are adaptations to aid efficient digging and tunneling, assisting survival

though protection and effective food gathering. Clawed hindfeet push soil out of the way when digging (improves efficiency). External ear openings are covered by fur to protect them when digging. Short, powerful limbs with efficient lever arrangement of muscles and joints aids rotation-thrust movement in digging. Forefeet powerfully clawed as digging tools. Velvety fur reduces friction when moving through the soil. Fur can lie in either direction so backward movement in tunnel is not hampered. Tubular body shape aids movement underground. Heavily buttressed head and neck makes tunneling easier and more energy efficient.
   (b) **Physiological**: Well developed chemical sense aids location of food. Good sense of hearing.
   (c) **Behavioral**: Solitary and territorial behavior (except when breeding) helps to maintain a viable food supply and reduce aggressive encounters. Sleep and feed underground offering effective protection from predators.

2. Snow bunting adaptations:
   (a) **Structural**: large amount of white plumage reduces heat loss, white feathers are hollow and air filled (acting as good insulators).
   (b) **Physiological**: Lay one or two more eggs than (ecologically) equivalent species further south producing larger broods (improving breeding success), rapid molt to winter plumage is suited to the rapid seasonal changes of the Arctic.
   (c) **Behavioral**: feeding activity continues almost uninterrupted during prolonged daylight hours (allowing large broods to be raised and improving survival and breeding success), migration to overwintering regions during Arctic winter (escapes harsh Arctic winter), will burrow into snow drifts for shelter (withstand short periods of very bad weather), males assist in brood rearing (improved breeding success).

3. (a) **Structural adaptations** - any of:
   – Long, mobile ears provide acute detection of sounds from many angles (for predator detection).
   – Long, strong hind legs are adapted for rapid running (for escape from predators).
   – Cryptic/camouflage coloring of fur assists in avoiding being detected by predators.
   – Limb structure facilitates burrowing behavior.

   (b) **Physiological adaptations** - any of:
   – High metabolic rate and activity allows rapid response to dangers.
   – Keen sense of smell - allows detection of potential threats from predators and from rabbits from other warrens (they are highly territorial).
   – Digestive system suited for coping with microbial digestion of cellulose in the hindgut.

   (c) **Behavioral Adaptations** - any of:
   – European rabbit is active during any time of the day or night, but modifies its behavior around humans to be active around dusk and dawn (crepuscular).
   – Lives in groups of highly organized social structure (cooperative defense) and reduced competition between rabbits of the same warren.
   – Burrows into ground to provide nesting sites, and shelter from physical conditions and predators.
   – Thumps the ground with hind legs to warn others in the warren of impending danger.

4. Extra detail is provided:
   (a) Structural (larger, stouter body conserves heat).
   (b) Physiological (concentrated urine conserves water).
   (c) Behavioral (move to favorable sites).
   (d) Physiological (higher photosynthetic rates and water conservation).
   (e) Structural (reduction in water loss).
   (f) Behavioral and physiological (hibernation involves both a reduction in metabolic rate and the behavior necessary to acquire more food before hibernation and to seek out an appropriate site).

Ecosystem Stability (page 266)

1. **Ecosystem stability**: the apparently unchanging nature of an ecosystem over time. Includes the ecosystem inertia (ability to resist disturbance) and resilience (ability to recover from disturbance).

2. High diversity systems have a greater number of biotic interactions operating to buffer them against change (the loss or decline of one component (species) is less likely to affect the entire ecosystem). With a large number of species involved, ecosystem processes, such as nutrient recycling, are more efficient and less inclined to disruption.

3. Species diversity index used in (any of):
   – Comparisons of similar ecosystems which have been subjected to (beneficial or detrimental) human influence (e.g. restoration or pollution).
   – Assessment of the same ecosystem before and after some event (fire, flood, pollution, environmental restoration).
   – Assessment of the same ecosystem along some environmental gradient (e.g. distance from a point source of pollution).
   – Assessment of the biodiversity value of an area for the purposes of management or preservation (tends to be a political lobbying point).

4. (a) DI = $37 \times 36 \div ((7 \times 6) + (10 \times 9) + (11 \times 10) + (2 \times 1) + (4 \times 3) + (3 \times 2)) = 1332 \div 262 = 5.08$
   (b) Without any frame of reference (e.g. for a known high or low diversity system), no reasonable comment can be made about the diversity of this ecosystem. Herein lies the problem with an index that has no theoretical upper boundary.

5. Keystone species are pivotal to some important ecosystem function such as production of biomass or nutrient recycling. Because their role is disproportionately large, their removal has a similarly disproportionate effect on ecosystem function.

Ecological Succession (page 268)

1. (a) **Primary succession**: Colonization of a completely barren area (e.g. rocky slope, exposed slip, new volcanic island) by colonizing (pioneer) species, then by successive seral stages, until a climax community is reached.
   (b) **Secondary succession** follows the interruption of an established climax community (e.g. logging, pasture reverting to bush). The land is cleared, but there is no loss of soil and the succession proceeds more rapidly than primary succession.

2. (a) A deflected succession refers to a succession that is deflected from its natural course by human intervention. A climax community (a plagioclimax) develops that is different from the one that would have developed if the intervention had not occurred.
   (b) Many human-modified landscapes (e.g. agricultural lands, grasslands, woodlands) are managed (by burning, grazing, mowing) with the express purpose of preventing the establishment of a natural climax community. These communities are quite distinct from those that would naturally develop if the land were left alone.

3. (a) *Sphagnum* lowers the pH of the surrounding soil and hampers the establishment of the acid intolerant species typical of swamps and fens. Acid tolerant (bog) species can then become established.
   (b) Low evaporation rates and high rainfall (conditions found at high latitudes).

Energy in Ecosystems (page 272)

1. (a) **Photosynthesis**: carbon dioxide + water → (in the presence of light and chlorophyll) carbohydrate (glucose) + oxygen (**Note**: some water is produced as a waste product of photosynthesis, but more is used than is produced so there is a net water use).
   (b) **Respiration**: organic molecules (glucose) + oxygen → energy (ATP) + carbon dioxide

2. Energy, unlike matter, cannot be recycled (its is degraded and lost from the system). Therefore ecosystems must receive a constant input of new energy from an external source.

3. The waste products of photosynthesis are the raw materials for cellular respiration, and vice versa.

Food Chains (page 273)

1 (a) Sunlight.
  (b) - (d) *Refer to diagram below.*

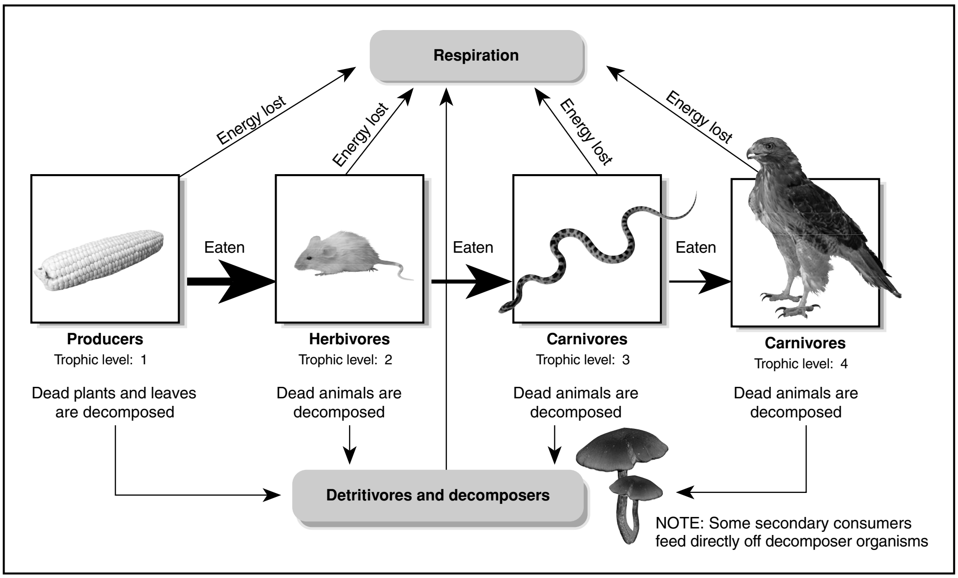
2. (a) Each successive trophic level has less energy.
   (b) Energy is lost by respiration as it is passed from one trophic level to the next.

3. (a) Food chain: A sequence of organisms, each of which is a source of food for the next.
   (b) Trophic level: Any of the feeding levels that energy passes through as it moves through a food chain.
   (c) 1st order consumer: (primary consumers) eat plants or other producers (i.e herbivores). First consumer in a food chain is also correct.
   (d) 2nd order consumer: (secondary consumer) eats herbivores (i.e. carnivores). The second consumer in a food chain is also an appropriate answer.

4. The eagle occupies different trophic levels at different times (depending on the prey of choice).

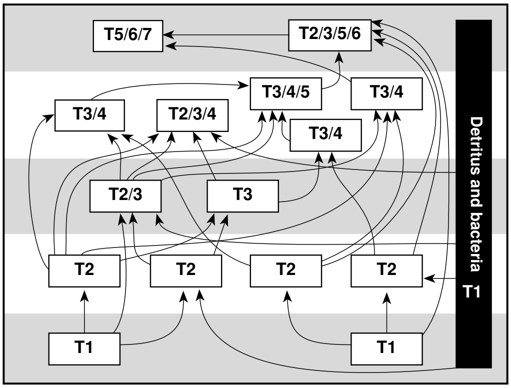
Constructing a Food Web (page 274)

3. Food chain examples as below (others are possible):
   - Algae → zooplankton → great diving beetle
   - Algae → zooplankton → stickleback → pike
   - Macrophyte → great pond snail → herbivorous water beetle → stickleback → pike
   - Algae → mosquito larva → *Hydra* → dragonfly larva → carp → pike
   - Macrophyte → carp → pike
   - Macrophyte → herbivorous water beetle → carp → pike
   - Algae → zooplankton → *Asplanchna* → leech → dragonfly larva → carp → pike



Constructing a lake foodweb:

For reasons of space, the names have been omitted from this solution but the relative positions of each organism is as presented in the manual. Trophic levels are indicated by the letter T and the number(s) of the level(s) occupied. Note: the trophic level a species occupies will depend on the trophic position of its food items. For example, the carp occupies several different trophic levels, since it feeds on macrophytes, and on both primary and tertiary consumers. The tertiary consumers that the carp eats will also be feeding at a number of different levels, hence the complexity of food webs and the difficulty in accurately representing them in diagrams.



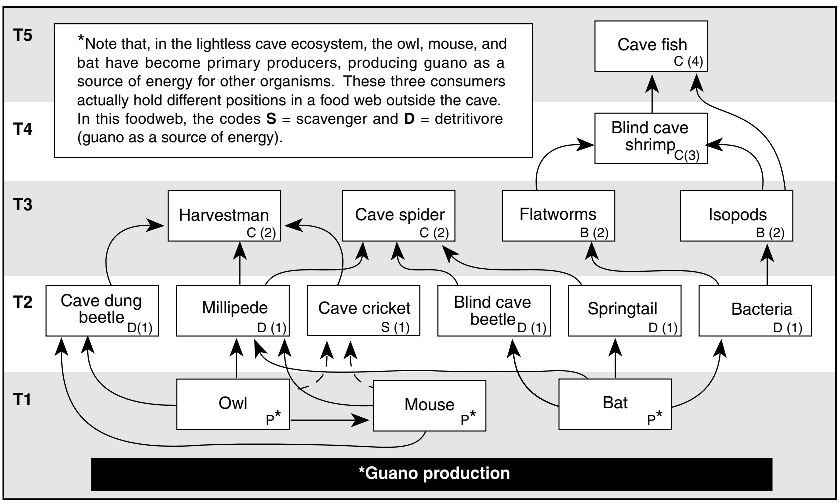
4. Food web: *See diagram above.*

Cave Food Webs (page 276)

1. Cave food web: *See diagram below.*
2. The major level missing from the cave food web is the producer level.
3. Energy is imported into the cave ecosystem in the form of guano (droppings) from organisms that enter the cave (either briefly or to roost). Rotting vegetation etc. may also enter by being washed in from outside.
4. Energy may be removed by organisms leaving the cave and/or dying outside it or by material being carried out of the system by the stream.
5. The amount of guano in the cave would decline. If sufficient decline in guano production occurred there would not be enough energy to support all the organisms of the cave food web. Some or all would die and the food web or parts of it would collapse.

Energy Inputs and Outputs (page 278)

1. (a) **Autotroph**: Organisms that use inorganic sources of carbon (CO_2), nitrogen etc. as starting materials for the synthesis of organic compounds. Autotrophs may use either sunlight (photoautotrophs) or chemical (chemoautotrophs) energy sources.
   (b) **Heterotroph**: Organisms dependent on external organic compounds as a means of obtaining energy and/or nutrients. Includes all animals, fungi, and a few flowering plants.
   (c) **Saprotroph**: Organism obtaining organic matter in solution from dead and decaying organisms (extracellular digestion). Includes bacteria, and fungi involved in decay.
2. The activity of decomposing bacteria produces heat from respiration.
3. By breaking down dead matter, decomposers make nutrients available to other trophic levels (especially to producers). They have an important role in recycling nutrients within ecosystems and some consumers also rely on them directly for food.



4. (a) Decomposers generally refers to those organisms that obtain their nutrients from the extracellular breakdown of dead material whereas detritivores is a term usually reserved for organisms that obtain nutrients from ingesting dead material (typically, but not exclusively, of plant origin).
   (b) Detritivores, by directly feeding on dead material, break it into smaller fragments. This increases the surface area available for decomposers to work on and thus speeds up the decomposition process.

5. (a) Excreted products still rich in energy (urea, uric acid, ammonia, alcohol). Some egested material leaves the organism in an undigested state, e.g. cellulose in plant material.
   (b) Cellular respiration is not completely efficient. Some energy from the break down of glucose is lost as heat energy to the environment.

Energy Flow in an Ecosystem (page 280)

1. (a) 14 000 (b) 180
   (c) 35 (d) 100

2. Solar energy

3. A. Photosynthesis
   B. Eating
   C. Respiration
   D. Export - lost from the ecosystem to another
   E. Decomposers feeding on other decomposers
   F. Radiation of heat to the atmosphere
   G. Excretion/egestion/death

4. 1 700 000 ÷ 7 000 000 x 100 = 24.28%

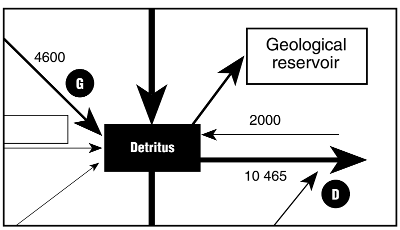
5. Reflected. Plants appear green because those wavelengths are not absorbed. Reflected light falls on other objects as well as back into space.

6. 87 400 ÷ 1,700,000 x 100 = 5.14%

7. (a) 78 835 kJ (b) 78 835 ÷ 1 700 000 x 100 = 4.64%

8. (a) Decomposers and detritivores
   (b) Transport by wind or water to other ecosystems (e.g. carried in air/stream/river/ocean currents).

9. (a) Energy remains locked up in the detrital material and is not released.
   (b) Geological reservoir:



   (c) Oil (petroleum), natural gas, peat, coal

10. (a) 87 400 → 14 000: 14 000 ÷ 87 400 x 100 = 16%
    (b) 14000 → 1600: 1600 ÷14 000 x 100 = 11.4%
    (c) 1600 → 90: 90 ÷ 1600 x 100 = 5.6%

Ecological Pyramids (page 282)

1. (a) Number pyramid: Numbers of individual organisms at each trophic level.
   (b) Biomass pyramid: Weight (usually dry weight) of all organisms at each trophic level.
   (c) Energy content of all organisms at each trophic level.

2. Biomass or energy pyramids usually more accurately reflect the energy available to the next trophic level than pyramids of numbers. Pyramids of numbers can be misleading because a small number of producers may represent a large amount of biomass or energy.

3. Producers include the large trees. These have a large biomass and energy content per individual.

4. (a) 8690 → 142 = 8548 kJ = 1.6%
   (b) 142 → 12 = 130 kJ = 8.5%
   (c) Energy passed on from producers to primary consumers is less than the expected 10% because a lot of energy is diverted to the decomposers.
   (d) Decomposers
   (e) In a plankton community, turnover times (generation times of organisms) are very short and there is a lot of dead material both in the water and on the bottom. This provides a rich energy source to support a large biomass of decomposers.

5. The algae are reproducing at a high rate, but are being heavily cropped by the larger biomass of zooplankton.

The Carbon Cycle (page 284)

1. Arrows can be added for the points (a)-(d) as follows:
   (a) Dissolving of limestone by acid rain: arrow from the limestone layer to atmospheric CO_2.
   (b) Release of carbon from the marine food chain: arrows (labeled **respiration**) from marine organisms (shark, algae, small fish) to atmospheric CO_2.
   (c) Mining and burning of coal: arrow from the coal seam to atmospheric CO_2.
   (d) Burning of plant material: arrow (**combustion**) from the trees and/or grassland to atmospheric CO_2.

2. (a) Coal: Plant material trapped under sediment in swampy conditions millions of years ago.
   (b) Oil: Marine plankton rapidly buried in fine sediment millions of years ago.
   (c) Limestone (also chalk = fine limestone): Shells of molluscs, skeletons of coral and other marine organisms with skeletons of calcium carbonate piled upon seabeds and compressed.

3. Respiration (stepwise oxidation of glucose) and combustion (rapid oxidation of organic substances accompanied by heat). Both involve the release of CO_2.

4. (a) - (d) in any order: atmosphere; coal; limestone; oil and natural gas.

5. Carbon would eventually be locked up in the bodies (remains) of dead organisms. Dead matter would not rot. Possible gradual loss of CO_2 from the atmosphere.

6. (a) Photosynthesis (b) Respiration

7. (a) Dung beetles: Bury the cow manure and the larvae feed on it. Burying the dung makes it available to

decomposers in the soil. The beetle larvae reprocess the dung, using it as a food source. It therefore re-enters the trophic system.
(b) Termites: Digest the cellulose in plant material, breaking it down and freeing up the carbon back into the ecosystem.
(c) Fungi: Break down dead material, utilizing it as food and converting it into the fungal body. This makes it available to reenter the food chain.

8. (a) Humans deplete these fossil fuel reserves through mining (fossil fuels provide readily available energy).
(b) The burning of fossil fuels increases the amount of carbon dioxide in the atmosphere, contributing to the rise in global temperatures. Burning also increases levels of air pollution.
(c) Minimizing fossil fuels use through the use of alternative, environmentally clean sources of energy (solar energy, wind energy). Making sure that when fossil fuels are burnt, that combustion is as clean (complete) as possible, to minimize pollution.

The Nitrogen Cycle (page 286)

1. (a) Decomposing/decaying bacteria (rotting)
(b) Nitrifying bacteria $NH_4^+ \rightarrow NO_2^-$ (*Nitrosomonas*)
(c) Nitrifying bacteria $NO_2^- \rightarrow NO_3^-$ (*Nitrobacter*)
(d) Denitrifying bacteria $NO_3^- \rightarrow N_{2(g)}$ (*Pseudomonas*)
(e) Nitrogen fixing bacteria $N_{2(g)} \rightarrow NO_3^-$ (*Azotobacter*, *Rhizobium*)

2. (a) Lightning oxidizes nitrogen in atmosphere
(b) Nitrogen fixing bacteria
(c) Manufacturing nitrogen fertilizer.

3. Atmosphere.

4. Nitrate.

5. Humans can intervene in the nitrogen cycle by:
   - Adding nitrogen fertilizers to the land.
   - Industrial physical-chemical fixation of nitrogen (Haber process).
   - Genetic modification of crop plants so that they can fix nitrogen, also preferential planting of legumes and other nitrogen fixers.
   - Large-scale, assisted composting.

The Phosphorus Cycle (page 287)

1. Arrows from guano deposits and/or rock phosphate (labeled **mining**/**removal**) to the box: *Dissolved phosphates available to plants (PO_4^{3-}).*

2. (a) Decomposers release organic molecules (ATP, DNA, etc.) that can be further broken down.
(b) Phosphatizing bacteria release soluble phosphate.

3. (a) and (b) any two of: DNA, ATP, phospholipids (in cellular membranes).

4. (a) Rock phosphate: much phosphate is washed into the ocean where it builds up in phosphate-rich rocks made from marine sediments.
(b) Bone deposits: remains of dead marine vertebrates washed down rivers into lakes and into the sea.
(c) Guano deposits: the droppings of birds (especially fish-eating birds) accumulated at nesting colonies. Cave dwelling bats also produce guano deposits.

5. Geological uplift and weathering (erosion).

6. Any one of: Phosphorus, unlike carbon, has **no** (significant) **atmospheric component**. **Cycling** of phosphorus **is slow** and tends to be local.

The Water Cycle (page 288)

1. (a) Surface runoff (b) Ground-water flow

2. (a) - (c) any of the following, in any order:
   – Humans withdraw water from ground-water storage, rivers, and lakes. It may be used to supply domestic or personal use, or for irrigation. Consequently it may become depleted in specific areas or its normal destination altered.
   – Humans divert water and alter natural flows through damming and controlled flows. This alters the normal balance of seasonal water movements.
   – Humans may use water courses or water bodies for disposal of waste, polluting it and making it unsuitable for other organisms.
   – Humans clear vegetation, reducing the amount of water re-entering the atmosphere and being returned to the land via precipitation.

3. The oceans

4. In descending order of magnitude: snow and ice (in ice sheets and glaciers), ground-water, lakes, soil, atmosphere, rivers.

5. Plants lose a vast amount of water through transpiration. This is returned to the atmosphere where it condenses and then precipitates back to the land.

Features of Populations (page 290)

1. (a) **One** of the following:
Population growth rate: if this increases (or decreases) from one time interval to the next, it indicates that the population is probably also increasing (or decreasing). **Note**: The **intrinsic** rate of population increase (r_{max}) should be distinguished from population growth rates that account for the increasing number of individuals in the population (rN). The intrinsic population growth rate is a characteristic value for each species but rN can increase rapidly as more and more individuals add to the population increase (giving an exponential curve). Population growth rates account for birth and death rates but do not usually account for losses and gains through migration, which are usually assumed to be equal.
Total abundance: if this increases (or decreases) from one time interval to the next, it indicates that the population is also increasing (or decreasing).
Mortality rate: if this is increasing from one time interval to the next, it indicates that the population may be decreasing (you must also account for other sources of population change).
Birth rate & population fertility: If these increase from one time interval to the next, they indicate that the population may be increasing (you must also account for other sources of population change).
Age structure: a population dominated by young individuals is usually increasing. A population

dominated by old (especially post-reproductive) individuals is usually decreasing.

(b) One of the following:
Distribution: a very clumped distribution may indicate that only some parts of the environment are suitable for supporting individuals.
Population growth and birth rates: if these are low or declining it may indicate an inability of the environment to support the population density.
Mortality rates: if these are very high or increasing it *may* indicate an inability of the environment to support the present population density.

2. (a) **Measurable attributes**: Density, distribution, total abundance, sex ratios, migration (sometimes difficult). In some cases, depending on the organism, also age structure and population fertility.
(b) **Calculated attributes**: population growth rate, natality (birth rate) and mortality (death rate).

3. (a) Population sampling of an endangered species allows us to determine (any of): how fast a population is growing (if at all); the age and sex structure of the population (i.e. is it dominated by young or very old, non-reproductive, individuals); population abundance, density and distribution in different areas (indicating habitat preference and suitability); sources of mortality (predation, disease, starvation etc.); population fertility (reproductive state). This type of information allows more informed decisions to be made about the current status of the population and how best to manage it (through habitat restoration or captive breeding for example).
(b) Population sampling of a managed fish species allows us to determine the population growth rate. This is critical to establishing the level of fishing that can be supported by the population (the sustainable harvest) without irreversible population decline. The growth rate is calculated taking into account population abundance, and birth and death rates. Sustainable harvest can be built into the equation as one of the (controllable) sources of mortality.

Density and Distribution (page 291)

1. (a) Resources such as food and shelter are not usually spread through the environment in an even manner. Organisms will clump around these resources.
(b) Some organisms group together for protection from the physical environment or from predators. They may also group together for mating and reproduction. Clumped distributions may also result from the method of dispersal (e.g. in plants, vegetative spread (as opposed to dispersal by seeds) leads to clumping around the parent plant).

2. Territorial behavior.

3. Resources in the environment are limited but are distributed uniformly.

4. (a) **Clumped**: Many marine gastropods, colonial birds (seasonally), many mammals that exhibit grouping/herd behavior, schooling fish, colonial insects, many other invertebrates such as coral, some plants with limited dispersal.
(b) **Random**: Weed plants with effective dispersal method, shellfish on sand or mud substrate.
(c) **Uniform**: Territorial organisms, monoculture plantings (e.g. crops, timber plantations)

Population Regulation (page 292)

1. (a) Factors that have an increasing effect on population growth as the density of the population increases.
(b) Factors that have a controlling effect on population size and growth, regardless of population density.

2. When population density is low, individuals are well spaced apart. This can reduce stress between individuals (improving the resistance to diseases) as well as making the transmission of the pathogen more difficult. Crowded populations are more susceptible to epidemics of infectious disease.

3. (a) Density dependent factor: predation (e.g. by ladybird beetles), competition with other aphids for position on the best part of the plant to feed.
(b) Temperature (drop in temperature in autumn months in cooler climates causes the population to crash).

Population Growth (page 293)

1. (a) Mortality: Number of individuals dying per unit time.
(b) Natality: Number of individuals born per unit time.
(c) Immigration: Individuals moving into the population.
(d) Emigration: Individuals moving out of the population.
(e) Net migration rate: Net change in population size per unit time due to immigration and emigration.

2. (b) A declining population: $B + I < D + E$
(c) An increasing population: $B + I > D + E$

3. Rate of change for USA: + 1.0
Rate of change for Mexico: + 3.3

4. (a) Birth rate = 14 births ÷ 100 total number of individuals x 100 % = 14% per year
(b) Net migration rate = 2% per year
(c) Death rate = 20% per year
(d) Rate of population change: birth rate – death rate + net migration rate = 14 – 20 + 2 = –4% per year
(e) The population is **declining**.

Life Tables and Survivorship (page 294)

1. In some undeveloped countries, with high reproductive rates but poor infant survival (high infant mortality), the curve may resemble a modified Type III curve. Even though there is parental care, this does not offset the losses of young to starvation and disease.

2. They produce vast quantities of eggs/offspring.

3. Parental care is highly developed and for a longer time than for most Type II and all Type III species.

4. The majority of deaths occur in the first year.

Population Growth Curves (page 295)

1. As population numbers increase, the resistance of the environment (to further population increase) increases. This constrains the population to keep to a size that the environment can support at any one time.

2. Environmental resistance refers to all the limiting factors that together act to prevent further population increase (achievement of intrinsic rate of population increase, r_{max}).

3. (a) The maximum population size (of a species) that can be supported by the environment.
   (b) Carrying capacity limits population growth because as the population size increases, population growth slows (when N = K population growth stops). **Note**: For those interested in extension in this area, the effect of K on population growth is defined by the mathematical expression of logistic growth. This is covered in many, more advanced, biology texts.

4. (a) A new introduction increases exponentially (or nearly so) in a new area because its niche in that environment is unexploited up to that point. Resources (food, space, shelter etc.) are plentiful and readily available. The population rapidly increases, then slows as the population encounters environmental resistance.
   (b) Population numbers would fluctuate around some relatively stable population size that equates to what the environment can support (the carrying capacity).

5. Introduced grazing species can lower the carrying capacity of environments by reducing the ability of the environment to recover from the impacts of grazing. **Note**: High population numbers and high stocking levels (e.g. sheep in Australia, cattle in sub-Saharan Africa) lead to overgrazing and trampling of the soil. Soil is lost through erosion and desirable plant species are then replaced by (weed) species that can survive the heavy grazing pressure. Native consumers tend not to overexploit the environment in this way because they have different patterns of resource use and population growth.

Growth in a Bacterial Population (page 296)

1. Tabulated figures below.

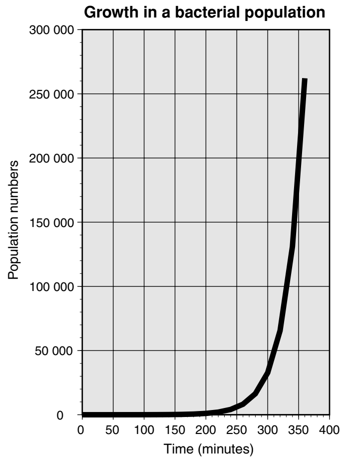
Min	No.	Min	No.	Min	No.
0	1	140	128	280	16 384
20	2	160	256	300	32 768
40	4	180	512	320	65 536
60	8	200	1024	340	131 072
80	16	220	2048	360	262 144
100	32	240	4096		
120	64	260	8192		

2. Graph: Growth in a bacterial population: see the top of the next column

3. 1 hour: 8 3 hours: 512 6 hours: 262 144

4. Exponential curve (logarithmic growth).

5. Some essential resource (e.g. food) becomes limiting.



Population Age Structure (page 297)

1. (a) Mortality
   (b) Higher proportion of smaller/younger fish.

2. (a) 3 years (b) 5 years (c) 8 years

3. (a) Gray face: It has palms of all sizes and therefore all ages are represented.
   (b) Golf course: No small (young) plants are represented.

4. The population will age, with the established palms growing taller, and no new palms becoming established. Eventually these older palms will die with no replacement (unless there is a planting program).

5. Not all organisms (e.g. plants, fish) grow at the same rate. Size may depend on the quality and quantity of food supply. Some seasons may produce more growth than others.

6. If the age structure in the short-medium term shows a trend to smaller/younger age classes, then harvesting pressure is too severe. If this continues, there will be few individuals of reproductive age and, consequently, a decline in the harvestable stock (population size).

Species Interactions (page 298)

Q 1. - 5. refer to interactions *with humans*.

1. **Mutualism**: Domesticated animals and plants not eaten for consumption (e.g. dogs and cats in western culture, work horses).

2. **Commensalism**: Seagulls, rats, algae in lakes that are eutrophic from human activity.

3. **Amensalism**: Trampling of plants around any area of activity. Any (remote) pollution event that kills or adversely affects other organisms unintentionally, but does not directly affect the perpetrator (although it could be argued there might be a detrimental effect on humans, if only distantly and in the future).

4. **Exploitation**: Using plants and animals for food source, skins/pelts for clothing, timber and other plant products for shelter and building materials.

5. **Competition**: Invertebrate pests and some fungi feeding on our crops (eg. insects such as aphids, locusts, caterpillars; slugs, snails, mildew, rusts).

6. (a) Mutualism
   (b) Clown fish benefit by gaining protection from predators. Anemone benefits by making use of the food scraps discarded by the fish.

7. (a) Commensalism
   (b) Shrimp benefits by gaining protection from predators. Anemone is unaffected.

8. (a) Exploitation (herbivory)
   (b) Insect benefits by having a source of food. Plants may be harmed if cropping is severe. In many cases they are unharmed to any great extent and recover the lost material quickly. In some cases, plants require cropping to stimulate new growth and remove older material (e.g. takahe grazing tussock, large herbivores grazing savanna grasslands).

9. (a) Mutualism
   (b) Large herbivore benefits in two ways: parasites are removed, and warning of approaching predators is provided. The bird benefits by food being supplied.

10. (a) Exploitation (parasitism)
    (b) The ticks benefit from gaining a food source and a protected place to live. The host animal is harmed by the loss of blood and by infections that can develop in the wounds left by the ticks (the extent of harm depends on the level of infestation).

11. (a) Competition
    (b) Both species are harmed by the competition for resources. Neither gains as much access to the resources as they would have done alone.

Niche Differentiation (page 300)

1. (a) Different species may exploit different microhabitats within the ecosystem (e.g. tree trunks, leaf litter, lower or upper canopy).
   (b) Different species may exploit the same resources but at different times of the day or year.

2. Reduce competition by: occupying different positions on the reef, having different activity patterns, occupying different microhabitats (e.g. different coral types), specializing in food type in a restricted area vs generalized feeding over a wider area.

Interspecific Competition (page 301)

1. The two species have similar niche requirements (similar habitats and foods). Red squirrels once occupied a much larger range than currently. This range has contracted steadily since the introduction of the grays. The circumstantial evidence points to the reds being displaced by the grays.

2. The grays have not completely displaced the reds. In areas of suitable coniferous habitat, the reds have maintained their numbers. In some places the two species coexist. **Note**: It has been suggested that the reds are primarily coniferous dwellers and extended their range into deciduous woodland habitat in the absence of competition.

3. Habitat management allows more effective long term population management *in-situ* (preferable because the genetic diversity of species is generally maintained better in the wild). Reds clearly can hold their own in competition with grays, provided they have sufficient resources. **Enhancing the habitat** preferred by the reds (through preservation and tree planting), assists their success as a competing species. Providing **extra suitable food plants food** also enables the reds to increase their breeding success and maintain their weight through winter (thus entering the breeding season in better condition).

Intraspecific Competition (page 302)

1. Competition for resources between individuals of the same species i.e. within a species.

2. (a) Intraspecific competition reduces population growth rate (competition intensifies with increasing population size and at carrying capacity the rate of population increase slows to zero).
   (b) Intraspecific competition will limit population size to a level that can be supported by the carrying capacity of the environment. In some territorial species, this will be determined by the number of suitable territories that can be supported.

3. (a) Carrying capacity might decline as a result of unfavorable climatic events (drought, flood etc.) or loss of a major primary producer (plant species).
   (b) Final population size would be smaller (relative to what it was when carrying capacity was higher).

4. Final population size is determined by the number of suitable sites available in which to set up and maintain (breeding) territories.

5. (a) They reduce their individual growth rate (and take longer to reach the size for metamorphosis).
   (b) Density dependent.
   (c) The results of this tank experiment are unlikely to represent a real situation in that the tank tadpoles are not subject to normal sources of mortality and there is no indication of long term survivability (of the growth retarded tadpoles). **Note**: Many tadpoles at high densities would fail to reproduce and this would naturally limit population growth (and size) in the longer term.

Predator-Prey Strategies (page 303)

1. (a) **Any of**: Good vision for detecting movement in the environment. Antennae are held as a barrier in the direction of any potential threat. Limbs can self-amputate if the animal is caught (another limb grows back later). Backward tail flip propels the crayfish quickly out of the way of predators. Hard exoskeleton and sharp, forward pointed spines protect the body. Crayfish are nocturnal and hide in inaccessible places (e.g. crevices and under rocks) during daylight hours when they are vulnerable. Grouping behavior aids to detect predators.

(b) **Any of**: Group defense of the nest provides constant vigilance against intruders. Aggressive behavior when threatened and sharp sting, with an ability to sting repeatedly. Coloration warns would-be predators that they are dangerous.
(c) **Any of**: Black and white coloration advertises the fact that they can defend themselves if provoked! When confronted, tend to raise tail, arch the back, stamp the front feet, and shuffle backwards. If provocation continues, a skunk will spray acrid, foul-smelling, blinding fluid from its anal glands into the eyes of the attacker (an effective deterrent).

2. By advertising the fact that they are unpalatable, predators quickly learn to associate the coloration with distastefulness. When seen, they are not mistaken for a palatable species and they are left alone.

3. Deceptive markings such as fake eyes can momentarily deceive predators into thinking that they are faced with a larger animal than they really are. This may give time for the prey to escape or may result in the predator attacking a non-vital part of the prey.

4. Batesian mimicry benefits the mimic because predators universally avoid attacking animals with the same warning coloration - poisonous or not.

5. **Freezing**, i.e. lying low to the ground and remaining very still, can enable a prey species (e.g. rabbit, hare, deer, various ground-dwelling birds) to avoid detection.

Predator-Prey Interactions (page 304)

1. (a) Usually between about 3 and 7 years (especially for pronounced peaks), although sometimes as great as a full 10 year cycle. Note that peaks often appear to be superimposed or the lynx peaks appear to be ahead of hare peaks. Remember that the lynx are responding to the earlier peaks in hare abundance.
(b) Lynx are top predators, with longer reproductive times and generation times than hares. When the hare populations increase there is a considerable time delay before this increase in available food is translated into higher population growth rates in lynx (birth rates must increase, usually mortality rates must also fall). Likewise, a fall in hare numbers takes some time to be registered by a decline in lynx population growth rate.

2. Hares are the principal food item for lynx in this system; there is little opportunity for prey switching (few alternative prey). The lynx cycles follow those of the hares closely with a similar periodicity.

3. (a) When the supply of palatable food declines, birth rates decline (adults are less well nourished and litters are smaller) and the mortality rate increases (more deaths due to starvation and disease). **Note**: Population growth rates depend on both birth and death rates: ($r = b–d$). When birth rates decline and mortality increases, r becomes negative and the population goes into decline.
(b) High mortality (losses from the population) can be sustained by species such as rodents and lagomorphs as long as they can maintain their intrinsically high birth rates. Declines in palatable food adversely affects their ability to do this.

Designing your Field Study (page 306)

1. Recognizing assumptions is critical to asking the appropriate questions in a study. For even the simplest of studies, some background information is important. Making some intelligent assumptions based on present knowledge allows you to focus on the questions that you really want to answer. At the same time, identifying assumptions allows you to recognize possible reasons for findings that do not support your predictions.

2. To test quadrat size it would be necessary to sample using a series of quadrats of increasing size. The cumulative number of species recorded after each successive increase in quadrat size could be plotted on a simple graph (i.e. number of species vs quadrat size). The optimum quadrat size occurs when the number of species recorded stops increasing. (**Note**: a smaller size may be accepted if you are prepared to record only dominant species. However, this always carries a risk that differences between areas may be missed).

3. Litter was weighed in order to quantify the weight of litter per quadrat. It is possible that the same sized quadrat contained different amounts of litter at different sites. By weighing, this is accounted for (numbers can be expressed per unit weight of litter).

4. It is possible that the presence or absence of other invertebrates may be useful in later explaining the trends observed in the millipede abundance at different sites (e.g. millipede numbers could be low where the numbers of predatory centipedes are high).

   Checklist to be completed by the student.

Monitoring Physical Factors (page 308)

1. Relevant physical factors are listed after each ecosystem:
   Polluted stream: Temperature, light intensity, pH, dissolved O_2, specific ions.
   Ocean waters: Temperature, light intensity, pH, dissolved O_2, specific ions.
   Estuarine mudflat: Temperature, wind velocity, pH, dissolved O_2 (if tidal), specific ions (if tidal).
   Woodland leaf litter: Temperature, light intensity, humidity.
   Open field: Temperature, wind velocity, humidity
   Diurnal changes in a small pond: Temperature, light intensity, pH, dissolved O_2, specific ions.
   Soil: Temperature, pH.
   Peat bog: Temperature, pH, dissolved O_2, specific ions.

2. **Severity of wave action**:
   Exposed coastline: severe wave action (high impact).
   Estuarine mudflat: very little wave action (tidal only).
   Light intensity and quality:
   Exposed coastline: high light intensity, full spectral range except for organisms either submerged or beneath dense seaweed (lower light intensity and less long wavelength light).
   Estuarine mudflat: for the mudflat surface: full intensity and spectral quality.
   Salinity/conductivity:
   Exposed coastline: near full salinity (3.3-3.7% dissolved salts) low on the shore. May be lower higher on shore

(further from the sea).
Estuarine mudflat: less saline than rocky shore because of the influence of freshwater input. (Also tends to vary depending on sampling position in the estuary and tidal input, fluctuating from nearly freshwater to almost full strength seawater).

Diurnal temperature change:
Exposed coastline: very little diurnal fluctuation of water temperature near the sea. Greater fluctuation in the pools of the upper shore.
Estuarine mudflat: wider fluctuations in water temperature depending on tidal input and water depth.

Substrate/sediment type:
Exposed coastline: hard substrate (high exposure) with no fine particulates.
Estuarine mudflat: soft substrate, fine particulates.

Oxygen concentration:
Exposed coastline: high, relatively uniform, oxygen concentrations near the sea. Lower and more variable in the pools of the upper shore.
Estuarine mudflat: wider fluctuations in oxygen concentration depending on the water temperature, and tidal and riverine inputs.

Exposure time to air (tide out):
Exposed coastline: from very little exposure near the sea to longer periods of exposure higher on the shore.
Estuarine mudflat: Long periods of exposure.

Sampling Populations (page 310)

1. We sample populations in order to gain information about their abundance and composition. Sampling is necessary because, in most cases, populations are too large to examine in total.

2. (a) Plant percentage cover: Random or systematic quadrat sampling.
   (b) Plankton density/age structure: Random or systematic point sampling (using a vertical haul net or plankton trap).
   (c) Altitudinal change in community composition. **Note**: If time for sampling and analysis is constrained, a line transect with point sampling from low to high altitude. If time for sampling and analysis is less constrained, a belt transect using quadrats at regular intervals provides the most information.

Quadrat Sampling (page 311)

1. Mean number of centipedes captured per quadrat:
   Total number centipedes ÷ total number quadrats
   = 30 individuals ÷ 37 quadrats
   = 0.811 centipedes per quadrat

2. Number per quadrat ÷ area of each quadrat
   0.811 ÷ 0.08 = 10.1 centipedes per m^2

3. Clumped or random distribution

4. Presence of suitable microhabitats for cover (e.g. logs, stones, leaf litter) may be scattered.

Sampling a Leaf Litter Population (page 312)

The actual results for this practical are not particularly important. What is valuable is learning the limitations of this method **before** being are asked to carry it out in a field situation. The results will vary, depending upon the group's agreed criteria for including organisms in a quadrat.

Note: Some leaves are almost completely obscured by invertebrates or have other leaves on top of them.

6. Typical results for samples used are:

	Direct count	A	B	C	D
Woodlouse:	89	9.5	5	13	14.5
Centipede:	3	0	0	1	1
False scorpion:	3	1	0	1	0
Springtail:	6	0	3	0	0
Leaf:	168	29	20.5	24.5	26.5

Class results will vary depending on counting criteria

7. Typical results for calculated density are:

	Direct count	A	B	C	D
Woodlouse :	2747	1759	926	2407	2685
Centipede:	93	0	0	185	185
False scorpion:	93	185	0	185	0
Springtail:	185	0	556	0	0
Leaf:	5185	5370	3796	4537	4907

Note:
Area of 6 quadrats = (0.03 x 0.03) x 6 = 0.0054 m^2
Area of total sample area = 0.18 x 0.18 = 0.0324 m^2

8. (a) **Problems** with sampling moving organisms: Once the quadrats have been laid, the animals moving from one quadrat to another risk being counted twice. **Solutions**: The quadrat could involve the placement of physical barriers between each quadrat (what about the invertebrates directly underneath!). Possibility of exposing the entire area and photographing it for later analysis.
   (b) Exemplar data given in the tables above. Students should be aware of the significance of extrapolating data from a small sample. The inclusion or exclusion of single individuals may have a large effect on the calculated density, particularly where species occur in low numbers.

Extension activity:
Groups could try combining their data to see if they get a more representative sample (i.e. closer to the direct count).

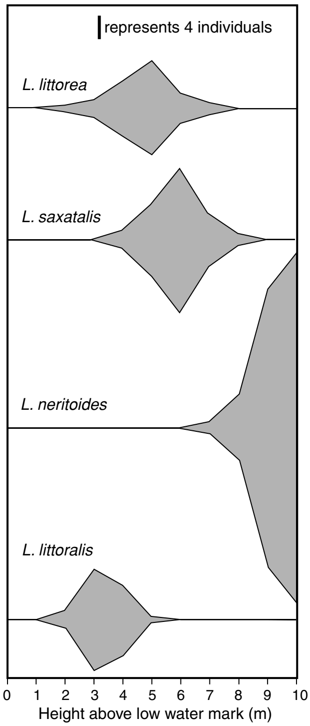
Transect Sampling (page 314)

1. (a) With transects of any length (10 m or more), sampling (and sample analysis) using this method is very time consuming and labor intensive.
   (b) Line transects, although quicker than belt transects, may not be representative of the community. There may be many species which are present but which do not touch the line and are not recorded.
   (c) Belt transects use a wider strip along the study area and there is much less chance that a species will not be recorded.
   (d) It is not appropriate to use transects in situations involving highly mobile organisms.

2. To test whether or not the transect sampling interval was sufficient to accurately sample the community, the sampling interval could be decreased (e.g. from a sampling interval of every 1.5 m to an interval of every

0.25 m). If no more species are detected and the trends along the transect remain the same, then the sampling interval was adequate.

3. Distribution of *Littorina* species along a rocky shore:



Mark and Recapture Sampling (page 316)

1. Results will vary from group to group for this practical. The actual results are not important, but it should serve as a useful vehicle for discussion of such things as sample size, variation in results between groups, and whether the method is a reliable way to estimate the size of a larger unknown group. Discussion could center around what factors could be altered to make it a more reliable method (e.g. larger sample size, degree of mixing, increasing number of samples taken).

2. **Trout in Norwegian lake**:

Size of 1st sample:	109
Size of 2nd sample:	177
No. marked in 2nd sample:	57
Estimated total population:	109 x 177 / 57 = 338.5

3. (a) Some marked animals may die.
   (b) Not enough time for thorough mixing of marked and unmarked animals.

4. (a) and (b) in any order (any two of):
   – Marking does not affect their survival.
   – Marked & unmarked animals are captured randomly.
   – Marks are not lost.
   – The animals are not territorial (must mix back into the population after release).

5. (a) Any animal that cannot move or is highly territorial (e.g. barnacle, tube worm, many mammals).
   (b) Unable to mix with unmarked portion of the population. Recapture at the same location would simply sample the same animals again.

6. (a) - (c) in any order:
   – Banding: leg bands of different color on birds.
   – Tags: crayfish shell, fish skin, mammal ears.
   – Paint/dye used to paint markings in shell/fur.

7. The scientists hope to monitor fish growth to establish the relationship between age and growth. This will help manage the population to prevent overfishing. Tracking also helps to map breeding grounds and migrations so that fish can be protected at critical times in their life histories. In addition to these data, researchers will find out more about the general biology of the tuna (e.g. data on feeding), which will help in future long term management of the species.

Sampling Animal Populations (page 318)

1. (b) **Beating tray**: provides a qualitative sample of the organisms in a certain height of vegetation.
   (c) **Pooter or aspirator**: provides a means of capturing small invertebrates from leaf litter (quantitative if animals are removed from a known area of litter).

2. Pitfall traps rely on being placed in an area where the organisms are active. The traps take no account of clumped distributions or microhabitat preferences, overestimating densities in some areas and underestimating them in others.

3. (a) A **large mesh size may fail to capture** some smaller plankton species or life stages (e.g. rotifers and copepod nauplii, which would pass through a large mesh). A very **fine mesh is apt to clog**, especially in eutrophic waters. Clogging reduces filtering efficiency so that much of the sampled volume is pushed out of the net instead of passing through it.
   (b) Mesh size should be fine enough to capture most or all of the species in which you are interested and it should be coarse enough to filter efficiently.

Using Chi-Square in Ecology (page 319)

1. (a) H_0: "There is no difference between the numbers of periwinkles associated with different seaweed species".
   (b) H_A: "There is a real difference between the numbers of periwinkles associated with different seaweed species. Periwinkles show preference for the seaweed species with which they associate".

2. (a) Completed table below:

Category	O	E	O – E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Spiral wrack	9	30	–21	441	14.70
Bladder wrack	28	30	–2	4	0.13
Toothed wrack	19	30	–11	121	4.03
Knotted wrack	64	30	34	1156	38.53
	∑ 120				∑ 57.4

(b) χ^2 = 57.39 (57.4)

(c) Degrees of freedom = 3 (4-1)

(d) The critical value of χ^2 at P = 0.05 and at d.f.= 3 is 7.82. The calculated χ^2 is (much) greater than the critical value (57.4 >> 7.82). *This means that **by chance alone**, a χ^2 value of 57.4 could be expected less than 0.1% of the time.*

(e) Reject H_0: The data are strongly in favor of H_A. Periwinkles show significant preference for one seaweed species (toothed wrack) over the others.

3. (a) H_0: "There is no difference between the number of woodlice in each habitat - woodlice show no preference for either habitat".
H_A: "There is a real difference between the numbers of woodlice found in dry and humid conditions".

(b) Calculation of χ^2:
- Total number of woodlice observed in dry = 15.
- Total number of woodlice observed in humid = 35.

Completed table below:

Category	O	E	O – E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Dry atmosphere	15	25	–10	100	4
Humid atmosphere	35	25	10	100	4
	∑ 50				∑ 8

χ^2 = 8

(c) Degrees of freedom = 1 (2-1)
The critical value of χ^2 at P = 0.05 and at d.f.= 1 is 3.84. $\chi^2_{calc.}$ > the critical value (8 > 3.84).

(d) Reject H_0: The data are strongly in favor of H_A. Woodlice show significant preference for humid conditions over dry habitat conditions.

Note: When dealing with only two categories (i.e. degrees of freedom = 1) the **Yate's correction** formula should be used:

$$\chi^2 = \sum ((O-E) - 0.5)^2 /E$$

Using on this formula, χ^2 = 7.22. This is still greater than the critical value so H_0 is still rejected.

Student's *t* Test Exercise (page 320)

1. (a) Completed table:

x (counts)		$x - \bar{x}$		$(x - \bar{x})^2$	
Popn A	**Popn B**	**Popn A**	**Popn B**	**Popn A**	**Popn B**
465	310	9.3	-10.6	86.5	112.4
475	310	19.3	-10.6	372.5	112.4
415	290	-40.7	-30.6	1656.49	936.36
480	355	24.3	34.4	590.49	1183.36
436	350	-19.7	29.4	388.09	864.36
435	335	-20.7	14.4	428.49	207.36
445	295	-10.7	-25.6	114.49	655.36
460	315	4.3	-5.6	18.49	31.36
471	316	15.3	-4.6	234.09	21.16
475	330	19.3	9.4	372.49	88.36
n_A = 10	n_B = 10			$\sum(x-\bar{x})^2$ 4262.1	$\sum(x-\bar{x})^2$ 4212.4

The number of samples in each data set

(b) Variance of population A: 473.57
Variance of population B: 468.04

(c) Difference between population means: 135.1

(d) *t* value = 13.92

(e) Degrees of freedom: 18

(f) P = 0.05 *t* (critical value) = 2.101

(g) Decision: We can reject the null hypothesis of no difference. The difference between the population means is significantly different at P = 0.05.
Note at P = 0.001, the critical *t* value is 3.922, so we can also reject the null hypothesis at P = 0.001.

2. (a) Completed spreadsheet: *see below*.
(b) New *t* value: 0.76
DECISION: Accept the null hypothesis (P= 0.05). There is no difference between population means.

	XA	XB	Deviation of XA from mean A	Deviation of XB from mean B		(Deviation of XA from mean A)^2	(Deviation of XB from mean B)^2
	465	310	9.3	-10.6		86.49	112.36
	475	310	19.3	-10.6		372.49	112.36
	415	290	-40.7	-30.6		1656.49	936.36
	480	355	24.3	34.4		590.49	1183.36
	436	350	-19.7	29.4		388.09	864.36
	435	335	-20.7	14.4		428.49	207.36
	445	295	-10.7	-25.6		114.49	655.36
	460	315	4.3	-5.6		18.49	31.36
	471	316	15.3	-4.6		234.09	21.16
	475	330	19.3	9.4		372.49	88.36
Totals	4557	3206			**Sum x^2**	4262.1	4212.4
Count	10	10			**s^2**	473.5666667	468.04444
Mean	455.7	320.6					
Difference between means			135.1				
t value	13.92257486						

The New Tree of Life (page 323)

1. The argument for the new classification as three domains is based on the fact that the genetic differences between the Bacteria and the Archaea are at least as great as between the Eukarya and the Bacteria. In other words, the traditional scheme does not accurately reflect the true evolutionary (genetic) relationship between the three groupings.
2. (a) The eukaryote groups are given much less prominence, reflecting the true diversity of the prokaryote groups.
   (b) The Archaea have been separated out as distinct from other bacteria in order to reflect their uniqueness and indicate their true relationship to eukaryotes and to other prokaryotes.

The Species Concept (page 324)

1. Behavioral (they show no interest in each other).
2. Physical barrier; the sea separating Australia from South East Asia.
3. The red wolf is rare and may have difficulty finding another member of its species to mate with.
4. The populations on the two land masses, which have identical appearance and habitat requirements, were connected relatively recently by a land bridge during the last ice age (about 18 000 years ago). This would have permitted breeding between the populations. Individuals from current populations have been brought together and are able to interbreed to produce fertile offspring.
5. Species definition should include the following:
   – The lowest taxonomic grouping of organisms.
   – A group of freely interbreeding, or potentially interbreeding, organisms. Reproductively isolated gene pool, unable to breed freely with other species.
   – Usually recognized by morphological characters. **Note**: sibling species may be morphologically identical with reproductive isolation being achieved through differences in behavior.
6. (a) Supporting single species: Continuous gene flow between neighboring subspecies comprising a single gene pool.
   (b) Where the two ends of a species population overlap there is no gene flow (mating) between them. Regions of the species population are unable to interbreed freely.
7. Ring species are species which overlap in range and behave as true species, but are connected by a series (the ring) of interbreeding sub-species so that no true specific separation can be made. Usually this occurs around a looped or circular geographical distribution.

Features of the Five Kingdoms (page 331)

1. **Prokaryotae**: lack nuclei and the organized chromosomes typical of eukaryotes. Some genetic material carried on plasmids. Small (70S) ribosomes but lack membrane-bound organelles. Most have a cell wall containing peptidoglycan (unique to bacteria). Divide by binary fission. Cell wall may be associated with a glycocalyx (capsule or slime layer). As a taxon, show a diversity of nutritional modes and lifestyles.
2. **Protista**: Unicellular or simple multicellular eukaryotes. A diverse group of organisms, many of which are not related phylogenetically. Includes animal-like organisms such as protozoans and plant-like photosynthetic algae.
3. **Fungi**: Eukaryotic unicellular or multicellular organisms. Heterotrophic and lack chlorophyll. Saprophytes, parasites, or symbionts. Rigid cell walls of chitin. Nutrition always absorptive. Typical organizational unit in filamentous forms is the hypha. Sexual/asexual reproduction involving spores.
4. **Plantae**: multicellular eukaryotes, the large majority being photosynthetic autotrophs with chlorophyll. Clearly defined cellulose cell walls. Food stored as starch (and lipid). Primarily sexual reproduction with cycles of alternating haploid and diploid generations.
5. **Animalia**: heterotrophic, multicellular eukaryotes. Lack a cell wall and have a blastula stage during development. Further characterization of animal taxa is based on body symmetry, type of body cavity (coelom), and internal and external morphology.

Classification System (page 332)

1.

(a)	(b)
1. Kingdom	1. Animal
2. Phylum	2. Chordata
3. Class	3. Mammalia
4. Order	4. Primates
5. Family	5. Hominidae
6. Genus	6. *Homo*
7. Species	7. *sapiens*

2. A two part naming system where the first word (capitalized and italicized) denotes the genus and the second word (lower case and italicized) denotes the species. Sometimes a third word (also lower case and italicized) denotes a subspecies.
3. (a) and (b) in any order:
   Avoid confusion over the use of common names for organisms, provide a unique name for each type of organism, attempt to determine/define the evolutionary relationship of organisms (phylogeny).
4. Any of the following:
   DNA profiling/sequencing: where the unique genetic makeup of an individual is revealed and used for comparisons with related organisms.
   DNA hybridization: where the percentage DNA similarity between organisms is compared.
   Amino acid sequencing: where the number of amino acid differences between organisms are compared.
   Immunological distance: indirectly estimate the degree of similarity of proteins in different species.
5. (a) **Monotreme**: Egg laying with little internal development before laying, most development takes place in egg.
   (b) **Marsupial**: Birth takes place after limited internal development, when foetus moves to pouch and attaches to nipple, most development at this stage.
   (c) **Placental**: Long period of internal development, sustained by placenta. Birth takes place at highly developed stage.

Classification Keys (page 334)

1. The case (presence or absence and case features)

2. | | Insect Order | Common name |
|---|---|---|
| (a) | Odonata | Dragonflies and damselflies |
| (b) | Hemiptera | Bugs |
| (c) | Coleoptera | Beetles |
| (d) | Plecoptera | Stoneflies |
| (e) | Lepidoptera | Moths and butterflies |
| (f) | Emphemoptera | Mayflies |
| (g) | Megaloptera | Dobsonflies |
| (h) | Trichoptera | Caddisflies |
| (i) | Diptera | True flies |

Note: This activity will be revised in the next edition of the manual to include more detail of the features important in keying out the orders.

Human Impact on Resources (page 338)

1. (a) 7.7 billion (b) 9.37 billion (c) 11.2 billion

2. (a) Africa
   (b) Poor education on family planning. Entrenched cultural practices (large families are desirable).

3. Any of: Pollution, resource depletion, famine, loss of biodiversity.

4. North-east of North America, Europe, China.

5. China 1959-1961. 20-30 million.

6. Availability of fresh water.

7. 45-85 tonnes.

8. 100-1000 times.

9. As population levels increase, there is greater pressure on resources, more pollution, and a greater loss of biodiversity.

Water Pollution (page 340)

1. Accelerated eutrophication is caused by the runoff and leaching of excess nitrate and phosphate fertilizers from agricultural land.

2. (a) Domestic use: shower/bath, washbasin, food preparation, toilet flush, watering garden, cleaning car, drinking water, cleaning house inside and out.
   (b) Industrial use: cooling system for plant machinery, cleaning, solvent for various processes.
   (c) Agricultural use: irrigation, water for stock, cleaning milking sheds, frost control (fine mist spray).

3. (a) BOD is a measure of the polluting capacity of the effluent where pollution is caused by the use of dissolved oxygen by microorganisms that decompose the organic material in the effluent.
   (b) By discharging sewage rich in organic matter into the water. Agricultural fertilizers run off the land and contribute to excessive algal/aquatic weed growth. Some of this vegetation sinks and rots, thereby depleting oxygen in the water and increasing BOD.
   (c) In the short term, causes death to the existing biota. In the long term, results in a change (reduction) in the community diversity in favor of a small number of species tolerant of low oxygen tensions.
   (d) If the sample were exposed to light then any living algae or plant organisms in the water sample will produce oxygen as a result of photosynthesis, thereby altering the dissolved oxygen levels.

4. (a) Liquid sewage is a valuable source of nutrients and can be utilized to promote the growth of crops.
   (b) Spraying effluent can lead to the contamination of land and food crops with fecal bacteria and viruses. Some may be pathogens that present a risk to livestock and consumers.
   (c) Full treatment of the sewage to remove pathogens and organic material. Water can then be used safely for a variety of purposes.
   Anaerobic decomposition of sewage sludge to produce biogas (methane).

5. Pollution of an aquatic system may be indicated by a change from a species assemblage typical of clean waters (high numbers and diversity of clean water species) to an assemblage typical of lower quality water bodies (low diversity, although some species may occur in high numbers). Polluted waters typically lack the key species that are indicators of high water quality (e.g. mayflies, stoneflies, caddises).

Monitoring Water Quality (page 342)

1. Each of these water quality measurements must be made in the flowing water as these physical factors may immediately change if a sample is removed for later analysis (e.g. water sample will change temperature in the container, oxygen may be gained or lost, suspended matter may settle to the bottom thereby changing clarity).

2. Earthworks (e.g. mining, new roading) or deforestation leading to runoff of soil into streams and rivers.

3. Many land-based activities result in intentional or accidental discharges into waterways. Surface runoff during rain washes chemicals, silt, and organic matter into the natural drainage systems to rivers and lakes.

Sewage Treatment (page 343)

1. | | | |
|---|---|---|
| A = mechanical | D = biological | G = chemical |
| B = mechanical | E = mechanical | |
| C = biological | F = biological | |

2. Student's own summary and report. Summary responses will be very specific to the region. Problems of waste water management will center around cost (a major consideration as sewage treatment is paid for by landowners), availability of sites and public opposition to sitings, availability of suitable discharge points and public opposition to these, volume of waste water and capacity of current treatment facilities.

Atmospheric Pollution (page 344)

1. Automobile exhaust (usually) or, if the city is a large industrial one, industrial emissions could be important.

2. (a) Coal: Home heating, energy for power stations

(b) Diesel: Fuel for (usually) large vehicles.
(c) Natural gas: Home heating, car fuel, energy for power stations, industrial applications
(d) Petrol: Car fuel

3. (a) Biological indicator: an organism that is sensitive to various forms of pollution. Its presence in an ecosystem indicates that pollution levels are low.
   (b) Some species of lichen are more sensitive to atmospheric pollution than others. Which species are found at a particular location can give an indication of the level of atmospheric pollution.

4. **Types of air pollutant**: Missing answers only are provided. In some cases, extra detail is provided.

   CARBON MONOXIDE
   Sources: Motor vehicle exhaust (forms when hydrocarbons are burnt with a limited supply of oxygen)
   Harmful effects: Poisonous to animals using hemoglobin to transport oxygen. Binds preferentially and strongly to hemoglobin, preventing it from transporting oxygen. Causes dizziness, headaches, impairs mental processes. Can cause death if exposed to high concentrations over short period of time. Cigarette smoke contains small amounts of carbon monoxide (CO) that chronically impairs the smoker.

   HYDROGEN SULFIDES
   Harmful effects: Very poisonous gas, unpleasant odor (will oxidize to become sulfur dioxide).
   Prevention/control: Use low sulfur or sulfur-free fuel.

   SULFUR OXIDES
   Sources: Coal-burning industries (including coal-burning power stations and metal smelters). Some coals have naturally low sulfur levels.
   Harmful effects: Irritate the nose and respiratory tract. Dissolve to form acids when in contact with moisture. Can cause severe leaf injury.

   NITROGEN OXIDES
   Sources: The exhaust from motor vehicle engines and high temperature furnaces.
   Prevention/control: Catalytic converters can be fitted to motor vehicle exhausts to reduce nitrogen and CO_2.

   SMOKE
   Sources: Carbon, soot and ash from motor vehicle exhausts, jet engines, fuel-burning power stations and industries, domestic fires, metal smelters.
   Harmful effects: Creates a smoky haze. Aggravates respiratory problems, reduces sunlight penetration and coats leaf surfaces (both reduce photosynthesis).
   Prevention/control: Remove smoke/dust particles from chimneys with electrostatic precipitators. Use alternative, non-burning energy sources.

   LEAD
   Sources: Emitted as lead oxide in the exhaust of cars using leaded petrol (in a few countries, tetraethyl lead is still added to petrol to increase octane rating and act as an antiknock agent. This practice has been discontinued in most westernized countries).
   Prevention/control: Use unleaded petrol with a catalytic converter fitted to the exhaust.

   OZONE
   Sources: A secondary air pollutant formed by reaction between nitrogen oxides and volatile hydrocarbons (part of the process of forming photochemical smog).
   Harmful effects: The most harmful component of photochemical smog, this tropospheric ozone reduces visibility and causes health problems. It irritates and disturbs function of eyes, nose and lungs. It also stresses plants and may contribute to forest decline.
   Note: Do not confuse this lower atmospheric ozone with that of the upper atmosphere where it forms a protective barrier to UV radiation. Tropospheric ozone does not replenish the ozone that has been depleted in the stratosphere because it is converted back to oxygen in a few days.

   HYDROCARBONS
   Harmful effects: React with other pollutant gases to form photochemical smog. Retard plant growth, causing abnormal bud and leaf development. Carcinogenic.
   Prevention/control: Ensure car engines are well tuned for complete combustion. Control vehicle exhaust emissions through the use of catalytic converters.

5. (a) Sick building syndrome occurs when a large office building is polluted by gases from equipment and microbes in the air-conditioning system.
   (b) Using low gas emission materials; treat the air conditioning system for microbe contamination
   (c) Up to 400 people are sitting in very close proximity to each other for up to 12 hours at a time. Anybody with a contagious disease is likely to spread it to other passengers nearby, as well as through the cabin's air circulatory system.

Global Warming (page 346)

1. (a) Carbon dioxide: 28.5% increase
   (b) Methane: 110.5% increase
   (c) Nitrous oxide: 10.9% increase

2. (a) Sea level: Will rise
   (b) Regional climates: Will vary considerably. Some will become much wetter, while others will become drier. **Note**: According to one computer model, most of Africa (including the Sahara), Australia, southern Asia and Europe may become wetter. North America, Brazil, Argentina, New Zealand, and almost all of Russia (including Siberia) will be drier.
   (c) The characteristics and distribution of some habitats will change; some vegetation types will retreat from their current range, while others may spread.
   (d) Some species will become extinct as their habitat disappears or the physical environment changes. Other species may find that the available habitat or physical environment changes so that they are able to expand their range.

Stratospheric Ozone Depletion (page 348)

1. Ultraviolet radiation is a powerful carcinogen causing an increase in the mutation of genes and generally interfering with genetic processes. Notable are increased rates of all types of skin cancers.

2. UV light causes the release of free chlorine from CFCs and this chlorine destroys the ozone. The ozone layer absorbs most of the incoming UV and prevents it from reaching Earth. With fewer ozone molecules to absorb the UV, its penetration through the stratosphere is much greater and more reaches the Earth's surface.

3. Development and implementation of new technologies required to reduce ozone depleting chemicals is costly. Furthermore, the technology is controlled by the affluent Western economies. Poorer developing countries will find it difficult to spend large amounts of money on converting to alternative technologies. Recent studies have suggested that some of the proposed replacement chemicals may themselves cause damage to ozone.

4. (a) Greatest geographical extent: September to early October (Southern hemisphere early spring).
   (b) Most depleted: Mid-October (1992)
   (c) Trend of ozone depletion: generally a steady decline over the last two decades with the exception of 1989 when there was a brief increase to 1983 levels.
   (d) In September 1997 the concentration of ozone between altitudes 10 and 20 km increased. By October 1997, ozone levels had declined markedly (to approx. 0 mpa pp at 15-20 km) between these altitudes. (The ozone was severely depleted at these altitudes in October but not in September).

Acid Rain (page 350)

1. Increases the acidity (lowers pH) of the water/soil that it falls into. This will affect the kinds of organisms that can live in the community as some will not be acid-tolerant.

2. (a) Mussel (tolerates pH 6.0)
   (b) Water boatman (tolerates pH 3.5)
   (c) Determine which of these species is present in a lake (using a diversity index). The lower the diversity and number of species, the more adversely affected the lake.

3. Use sulfur free fuels (low sulfur coal, natural gas) in industry, catalytic converters on car exhausts.

4. There are substantial costs involved in changing to a new fuel source or installing catalytic converters. Installation of costly equipment would need to be required by law (i.e. legislation is required).

Energy Resources (page 351)

1. (a) **Biogas**: A mixture of methane (50-80%), carbon dioxide (15-45%), and water (5%) produced by the anaerobic decomposition (fermentation) of organic waste (e.g. sewage sludge or crop residues)
   (b) **Gasohol**: A blend of petrol and fuel alcohol (usually ethanol but sometimes methanol). ethanol but sometimes methanol). The ethanol is produced by the fermentation of crop residues or other low cost sources of carbohydrate.

2. Any of: sugar cane, corn starch, cellulose waste (e.g. from timber and straw), cassava roots.

3. Any two of: Motors run on ethanol tend to overheat because ethanol runs hotter than petrol. Fuel consumption is higher. Fuel tanks and pipes need to be coated to prevent corrosion.

4. A small biogas fermenter could be employed to process organic wastes and provide fuel to power farm machinery, fuel boilers, and heat glasshouses. Organic wastes suitable for feeding into the digester include animal manure and crop residues.

Waste Management (page 352)

1. (a) Glass waste: Kerbside pick-up and community bottle banks for recycling. Glass is melted down and made into other glass products. It may also be dumped in landfill (this is undesirable).
   (b) Paper: Kerbside/commercial collection. Paper is recycled into cardboard/toilet paper. It may also be dumped in landfill of burned in low grade incinerators (these are undesirable options).
   (c) Aluminum: Community recycling initiatives for aluminum are strong in most countries. Cans can be recycled into new cans in 6-8 weeks. Aluminum may also be dumped in landfill (this is undesirable).
   (d) Steel: Kerbside collection for recycling into new steel products. Some is dumped in landfills. The metals in vehicles are recycled (in part) into new vehicles.
   (e) Organic waste: Household or commercial composting. Landfill disposal (an undesirable option).
   (f) Hazardous waste: Collected for incineration in high temperature furnaces. Some chemicals and radioactive materials must be sealed in containers and buried at secure landfill sites.

2. **Waste disposal in landfills**
   (a) Problems: Leakage of groundwater into and out of the landfill (leading to groundwater contamination). lack of suitable sites (this depends largely on land usage and geology). Gas emissions are flammable. Landfills give off offensive smells and siting is often a cause of public opposition.
   (b) Advantages: Centralized containment rather than scattered small dumps. Modern landfill sites can be properly designed and managed for minimal environmental impact.
   (c) Basic design and operation: Layers of compact clay and high density plastic. Perforated drains collect the leachates (liquid run-off). Pipes sunk into the fill collect the methane gas.
   (d) Suitability for all waste types: All waste can be dumped, but much can be recycled or composted. Hazardous waste is often not identified and therefore can't always be properly managed.
   (e) Viability in the long term: It is increasingly difficult to find (geologically) suitable sites. It is far better to recycle and reuse materials than to dump indiscriminately. Landfills are better as part of a wider, integrated waste management scheme.

   Incineration of waste
   (a) Problems: Requires very high temperatures for some wastes. Incineration releases carbon dioxide (the government has an initiative not to do this). It also produces toxic gas discharges and releases dioxins, creating local air pollution. It is not practical for all wastes.
   (b) Advantages: It may provide a source of power. It leaves little solid residue and what remains may be suitable for another purpose (e.g. for roading).
   (c) Basic design and operation: A furnace with a conveyor for ash collection. Scrubbers clean the smoke and remove particulates and some toxic discharges. Fly ash is usually removed to hazardous waste landfills.
   (d) Suitability for all waste types: Combustible waste only, although if temperatures are high enough (as in some modern incineration facilities in other countries), this includes almost everything.
   (e) Viability in the long term: An option for the future if

the problems of carbon dioxide emissions and airborne pollutants can be addressed. Many of the problems associated with incineration are resolved if the incineration temperature is high enough. There should still be an initiative to re-use and recycle.

Endangered Species (page 354)

1. (a) **Vulnerable**: A species that being reduced in numbers or its range to an extent that it is likely to become endangered in the near future.
   (b) **Endangered**: A species that is reduced to so few in number that it is likely to become extinct unless immediate action is taken to prevent it.
   (c) **Extinct**: There are no living individuals of the species; every last one on the planet has died.

2. (a) and (b) any two of the the following:
   - Each species has a functional role in its ecosystem. The loss of a species may upset the dynamics, stability, and long term viability of an ecosystem.
   - Some endangered organisms may be valuable to humans as food sources, medicines, or sources of chemicals for which uses have yet to be identified.
   - From a humanitarian point of view, humans have no right to exterminate another species and should prevent extinction if they have the power to do so.

   Note: Some people argue that extinction is a natural process anyway and that it is a waste of money trying to save species that are doomed to become extinct. Other people say that we have a moral responsibility to act as custodians of life on the planet, as human activities have such a profound effect on them.

3. (a) CITES: Aims to ensure that international trade in species of wild plants and animals does not threaten their survival. Species are placed into CITES categories based on their ability to sustain trade (take). The categories range from a complete ban on trade to varying degrees of regulated take.
   (b) Gene banks: Provide a store of genetic diversity from wild stocks so that the genetic diversity is preserved in the advent of species decline. Using modern reproductive technologies, gene banks can be used to boost the genetic diversity of inbred populations of endangered species.
   (c) Habitat restoration: Aims to restore habitat to the state where it can support and maintain its previous flora and fauna. Suitably restored habitat may be used to enable expansion of populations threatened by loss of suitable habitat in specific areas.
   (d) Habitat protection: Aims to protect existing areas of high conservation value habitat. Habitat protection is an important part of endangered species programs: it enables endangered species to be managed *in situ* and without disturbance and supports captive breeding programs (captive bred species cannot be successfully returned to the wild if their natural habitat is degraded).
   (e) Captive breeding and release programs: Aims to restore numbers of endangered species to levels where they can be released into areas of suitable habitat and (hopefully) survive and breed there. For very rare species (e.g. where there are fewer than 100 individuals left) captive breeding may offer the only chance to prevent rapid extinction.

4. Students should give an answer appropriate to their own country or local region. Link into CITES and WWF from Biozone's website (Bio links) for information.
   Typical reasons for decline include: human pressure and habitat loss, pressure from introduced predators or competitors, hunting/trade, introduction and spread of diseases as a result of contact with alien species.
   Typical management strategies include: legislative protection on hunting and trade in the species, habitat protection or restoration, captive breeding and release.

   Examples to illustrate these ideas are described below.
   Plant: Marsh gentian (UK), *Gentiana pneumonanthe*
   (a) **Reason for decline**: Habitat loss. Habitat of this plant is wet lowland heathland, which is now a rare and threatened habitat in Britain (over half has been lost since 1940).
   (b) **Management**: The importance of the habitat has been recognized under the Habitat and Species Directive. Careful management practices encourage marsh gentian: a combination of light grazing (to reduce competition from vigorous plants) and small scale turf cutting or controlled winter burning (to remove surface vegetation around the plants and provide new sites for germination).

   Animal 1: Gharyal, *Gavialis gangeticus* (crocodilian)
   (a) **Reason for decline**: As a result of human population pressure, usable habitat (broad-banked rivers of Pakistan, Bangladesh, Burma, India, and Nepal) has declined. Habitat also brings them into contact with humans and they have been heavily hunted and fished with gill nets. Natural populations teeter on the brink of extinction.
   (b) **Management**: Listed in CITES 1 and as endangered by ICUN. Currently being restocked from heat-started farm-reared eggs, and more reintroductions are in progress.

   Animal 2: Orang-utan, *Pongo pygmaeus*
   (a) **Reason for decline**: Habitat destruction, as a result of commercial logging and land clearance for agriculture, is the major cause of decline; huge tracts of forest have been cleared throughout the orang-utan's range in Indonesia. Trade in the species is another major threat; although recorded international trade has declined there is an increasing illegal pet trade. It is estimated that 5-6 orangs die for every one that is traded.
   (b) **Management**: Listed in CITES, Appendix 1, and as critically endangered by ICUN. All trade is banned. In 1999, WWF published an orang-utan action plan, calling for measures to prevent competition between humans and orangs, preserve old growth forests, create corridors to link isolated populations, and halt degradation of protected areas. Captive breeding programs are in place worldwide.

   Animal 3: American alligator (previously endangered), *Alligator mississippiensis*
   (a) **Reason for decline**: Has previously been heavily hunted and exploited for skin and meat.
   (b) **Management**: Was protected by CITES bans on trade but has now been removed from CITES and listed by the ICUN as out of danger. Populations in some areas are experiencing considerable growth and controlled hunting is now allowed in some US states. Extensive ranching, farming, and restocking efforts have been successful in increasing numbers.

Conservation of African Elephants (page 356)

1. In 1989, the African elephant was placed in Appendix 1 of CITES, which imposed a ban on trade in living or dead material from elephants.

2. (a) A limited legal trade in ivory has resulted from a policy of management and quota operation. Removal of the ban on ivory has allowed the rural communities of these countries to earn money from the controlled exploitation of their wildlife. (Advocates of this claim that it has dramatically increased the amount of land given over to wildlife, as the returns from wildlife exploitation have exceeded those from cattle).
   (b) Any two of:
   – Quota systems can be abused (and have been in the past, with illegal hunting continuing).
   – As returns from ivory increase there will also be pressure to extend the quota above what individual elephant populations can sustain.
   – As ivory is traded, there will be pressure to illegally bring in ivory (for trade) poached from vulnerable populations outside quota countries.

Tropical Deforestation (page 357)

1. (a) They enhance removal of carbon dioxide from the atmosphere (anti-greenhouse).
   (b) They maintain species diversity.
   (c) They have, as-yet-undiscovered, potentially useful species for medicines etc.

2. Logging, fires, road-building/agriculture.

3. Brazil, Zaire, Indonesia.

Ecological Impacts of Fishing (page 358)

1. Overexploitation refers to harvesting a commercial fish species such that the population falls below its optimal size. Overexploited populations show a progressive decline in growth rate and thus in population size.

2. By-catch: The proportion of the catch that is discarded for economic, legal, or personal reasons.

3. (a) MSY: The largest amount of a naturally renewable resource (e.g. fish) that can be regularly harvested without causing a decline in the stock.
   (b) The anchovy population has collapsed. Once the anchovy numbers declined to low numbers, other fish species, notably sardines, increased in numbers (although their niches are not exactly the same). In the presence of high sardine populations, the anchovy populations cannot recover.

4. (a) At about 5 or 6 years, being the point where stock numbers are still moderately high, total fish biomass is high, and individuals are of an intermediate size (relative to maximum achievable size). If the few, older (larger) individuals are taken, the population quickly becomes skewed towards younger fish with lower reproductive capacity.
   (b) 0-6 years
   (c) Longevity, age at which reproduction begins, mortality at different life stages.

5. – Placing a size/age limit on take.
   – Enforcing and regularly reviewing maximum sustainable yield so that fish stocks can replenish themselves and the catch never exceeds what can be supported by the population.
   – Limiting the number of licenses (to fish) issued.
   – Regulation of the fishing equipment used.
   – Limits on allowable by catch so that fishing vessels cannot keep fishing to remove only the large individuals while discarding smaller individuals of the same species.
   – For some species, supplementing the natural stocks with captive-bred fry.

6. (a) – Can be used to enhance natural fish stocks.
   – Can be used to take the fishing pressure off natural stocks.
   – Undesirable bycatch could be usefully used to produce fish meal.
   (b) – Producing fish meal to feed farmed fish uses more fish than is produced.
   – Fish farming can destroy natural fish habitat.
   – large effluent run-offs from fish farms can pollute.

Fisheries Management (page 360)

1. Total landings and spawning stock biomass (a measure of the number of adults breeding) have been steadily declining since the early 1980s, and were indicating a decline (although not consistently) prior to that. As a consequence of declining spawning biomass, recruitment at age 1 also declined steadily during this period (with the exception of better years in 1984 and 1986). These data indicated unsustainable catches and decline of the stock below safe biological limits.

2. Summary responses only given:
   (a) North Sea
   (b) Risk of stock collapse is high. Stock is outside safe biological limits; spawning stock supported by only a few age groups and is less than half the level considered safe. TAC now half of the TAC in 2000.
   (c) Important features of biology: size (age) at harvest, breeding rate, age at first reproduction, growth rate, spawning behavior, effect of fishery on habitat.
   (d) Methods to assess sustainability include: surveys to estimate biomass (trawl and acoustic surveys, tagging), otolith examination to assess population age structure, assessment of stock recruitment (spawning assessment and survivorship).
   (e) Management options: size limits, deterring directed fishing, reducing by-catch of cod in other fisheries, restricted and closed seasons, reduced quota, closed areas (e.g. in breeding grounds), updating biological information on species spawning.