APPENDIX A

Measurement in Science

Measurements are so much a part of your life that you likely take them for granted. Your clothing is sized, the mass of your food is determined by the gram, the liquids you drink are sold in litres, and many of the items you use every day are made according to detailed specifications. The money you use to pay for any of these items is itself a measurement. The measurements for clothing, amounts of food, and currency are not standard throughout the world, however. While this inconsistency does not make it impossible to buy clothing in Asia, use European tools, or pay in South American currency, the same inconsistency in science would make it almost impossible for scientists to share information, replicate findings, and collaborate on research. In order to avoid this problem, scientists have developed globally agreed-upon standards for measurement, and for recording and calculating data. These are the standards that you will use throughout this science program. This appendix reviews units of measurement, significant digits, and scientific notation so you can use these standard tools for designing and performing scientific experiments and communicating your findings.

Is the Measurement Accurate or Is It Precise?

Before you review the standard conventions used in this text, consider how scientists characterize the measurements they take. In everyday speech, it is acceptable to use the terms "accuracy" and "precision" to mean the same thing. In science, however, these terms have distinctly different meanings.

Scientific *accuracy* refers to how close a given quantity is to an accepted or expected value. For example, under standard (defined) conditions of temperature and pressure, 5 mL of water has a mass of 5 g. When you measure the mass of 5 mL of water under the same conditions, you should, if you are accurate, find the mass is 5 g. Accuracy in science, therefore, involves a comparison.

Scientific *precision* refers to the exactness of your measurements. The precision of your measurements is directly related to the instruments you use to make them. While faulty instruments (for example, a balance that is not working properly) will obviously affect the precision of your measurements, the calibration of the instruments you use is the most influential factor. For example, a ruler calibrated in millimetres will allow you to make more precise measurements than one that shows only centimetres.

Precision can also refer to the closeness of a series of data points. Data that are close to one another are said to be precise. There is no guarantee, however, that the data are accurate until a comparison with an accepted value is made.

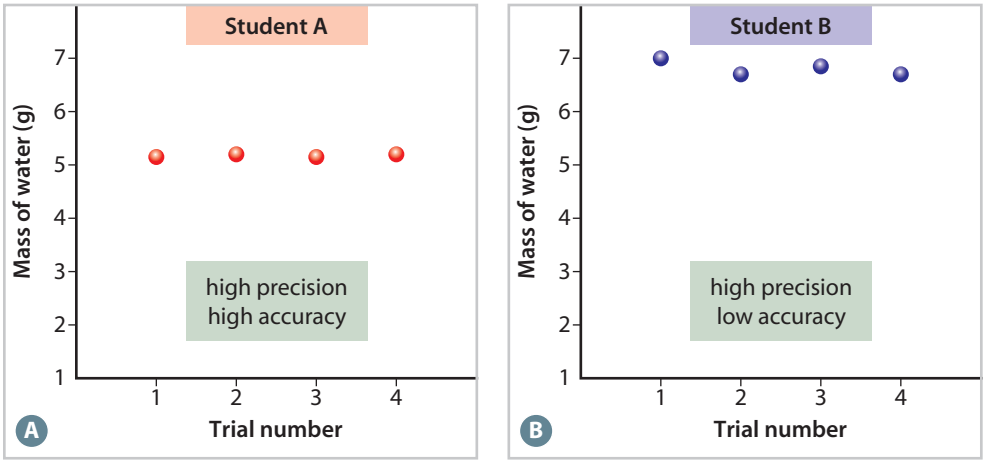
Units of Measurement

When you take measurements for scientific purposes, you use the International System of Measurement (commonly know as SI, from the French for *Système international d'unités*). SI includes the metric system and other standard units, symbols, and prefixes reviewed below.

In SI, the base units include the metre, the kilogram, and the second. The size of any particular unit can be determined by the prefix used with the base unit. Larger and smaller units of measurement can be obtained by either dividing or multiplying the base unit by a multiple of 10.

For example, the prefix *kilo-* means multiplied by 1000. So, one kilogram is equivalent to 1000 grams:

$$1\ \text{kg} = 1000\ \text{g}$$



The prefix *milli-* means divided by 1000. So, one milligram is equivalent to one thousandth of a gram:

$$1 \text{ mg} = \frac{1}{1000} \text{ g}$$

Table A.1 shows the most commonly used metric prefixes. Table A.2 shows some common metric quantities, units, and symbols.

Table A.1 Metric Prefixes

Prefix	Symbol	Relationship to the base unit
giga-	G	$10^9 = 1\,000\,000\,000$
mega-	M	$10^6 = 1\,000\,000$
kilo-	k	$10^3 = 1\,000$
hecto-	h	$10^2 = 100$
deca-	da	$10^1 = 10$
–	–	$10^0 = 1$
deci-	d	$10^{-1} = 0.1$
centi-	c	$10^{-2} = 0.01$
milli-	m	$10^{-3} = 0.001$
micro-	μ	$10^{-6} = 0.000\,001$
nano-	n	$10^{-9} = 0.000\,000\,001$

Significant Digits

In many of the biology experiments that you conduct, you will be making measurements. All measurements involve uncertainty. One source of this uncertainty is the measuring device itself. Another source is your ability to perceive and interpret a reading. You cannot, in fact, measure anything with complete certainty. The last (farthest-right) digit in any measurement is always an estimate.

The digits that you record when you measure something are significant digits. *Significant digits* include the digits that you are certain about and a final uncertain digit that you estimate. For example, 4.28 g has three significant digits. The first two digits, the 4 and the 2, are certain. The last digit, the 8, is an estimate. Therefore, it is uncertain. The value 1.2 has two significant digits. The 1 is certain, and the 2 is uncertain. Table A.3 lists some rules to help you identify the number of significant digits in any value.

Table A.2 Commonly Used Metric Quantities, Units, and Symbols

Quantity	Unit	Symbol
length	nanometre micrometre millimetre centimetre metre kilometre	nm μm mm cm m km
mass	gram kilogram tonne	g kg t
area	square metre square centimetre hectare	m^2 cm^2 ha (10 000 m^2)
volume	cubic centimetre cubic metre millilitre litre	cm^3 m^3 mL L
time	second	s
temperature	degree Celsius	°C
force	newton	N
energy	joule kilojoule*	J kJ
pressure	pascal kilopascal**	Pa kPa
electric current	ampere	A
quantity of electric charge	coulomb	C
frequency	hertz	Hz
power	watt	W

* Many dieticians in North America continue to measure nutritional energy in Calories, also known as kilocalories or dietetic Calories. In SI units, 1 Calorie = 4.186 kJ.

** In current North American medical practice, blood pressure is measured in millimetres of mercury, symbol mm Hg. In SI units, 1 mmHg = 0.133 kPa.

Table A.3 Rules for Determining Significant Digits

Rules	Examples
1. All non-zero numbers are significant.	7.886 has four significant digits. 19.4 has three significant digits. 527.226 992 has nine significant digits
2. All zeros that are located between two non-zero numbers are significant.	408 has three significant digits. 25 074 has five significant digits.
3. Zeros that are located to the left of a value are not significant.	0.0907 has three significant digits. They are the 9, the third zero to the right, and the 7. The function of the 0.0 at the beginning is only to locate the decimal. 0.000 000 06 has one significant digit.
4. Zeros that are located to the right of a value may or may not be significant.	22 700 may have three significant digits, or it may have five significant digits. See the box below for an explanation why.

Rule 4: Explaining Three Significant Digits

The Great Lakes contain 22 700 km^3 of water. Is there exactly this amount of water in the Great Lakes? No—22 700 km^3 is an approximate value. The actual volume could be anywhere from 22 659 km^3 to 22 749 km^3. You can use scientific notation to rewrite 22 700 as 2.270020×10^4 km^3. This notation shows that only three digits are significant. (See opposite for a review of scientific notation.)

Rule 4: Explaining Five Significant Digits

What if you were able to measure the volume of water in the Great Lakes? You could then verify the value of 22 700 km^3. Then all five digits (including the zeros) would be significant. Again, scientific notation enables you to show clearly the five significant digits: 2.2700×10^4 km^3.

Scientific Notation

Scientific notation is a method of expressing numbers that are very large or very small as exponents of the power 10. An exponent is the symbol or number denoting the power to which another number or symbol is to be raised. The exponent shows the number of repeated multiplications of the base. In 10^2, the exponent is 2 and the base is 10. Table A.4 shows the powers of 10 as numbers in standard form and in exponential form.

Table A.4 Powers of Ten in Standard and Exponential Form

	Standard form	Exponential form
ten thousands	10 000	10^4
thousands	1000	10^3
hundreds	100	10^2
tens	10	10^1
ones	1	10^0
tenths	0.1	$\frac{1}{10^1} = 10^{-1}$
hundredths	0.01	$\frac{1}{10^2} = 10^{-2}$
thousandths	0.001	$\frac{1}{10^3} = 10^{-3}$
ten thousandths	0.0001	$\frac{1}{10^4} = 10^{-4}$

Why use exponents? Consider a very large number, such as the distance between Mercury and the Sun (which is 58 000 000 km). If a zero were accidentally added to or left off this number, the distance would appear to be either 10 times larger or smaller than it really is. To avoid making these kinds of mistakes, scientists express numbers in scientific notation.

APPENDIX
B

A Quick Chemistry Reference for the Biology Student

Matter is anything that takes up space and has mass. Overwhelming evidence shows that the matter in living organisms is made up of atoms and that changes in the organic matter in living systems take place at the atomic level. An ordinary chemical or biochemical reaction cannot destroy, create, or split an atom. Current research also reveals a remarkable array of subatomic particles—particles smaller than an atom.

The Structure of Atoms

To understand and explain chemical reactions, you need to know about the subatomic particles called *protons*, *neutrons*, and *electrons*. Their properties are summarized in the following table.

Table B.1 Protons, neutrons, and electrons

Subatomic particle	Symbol	Charge	Amount of charge	Approximate relative mass (in atomic mass units)
proton	p^+	positive	+1	1
neutron	n^0	neutral	0	1
electron	e^-	negative	−1	$\frac{1}{2000}$

In atoms, these subatomic particles are arranged in a characteristic structure (Figure B.1). The protons and neutrons are clustered together in the nucleus, which contains over 99% of an atom's mass but makes up less than 1% of its volume. The electrons surround the nucleus in regions called shells. Electrons make up less than 1% of an atom's mass, although the shells they occupy make up over 99% of its volume.

Different elements, such as hydrogen and oxygen, are distinguished from one another by the number of protons their atoms contain. All atoms of the same element contain the same number of protons. The number of electrons in an atom always equals the number of protons it contains. This means that, overall, an atom has a neutral charge. The periodic table lists and provides information about all the known elements. For a given element, the number of neutrons may vary from one atom to another.

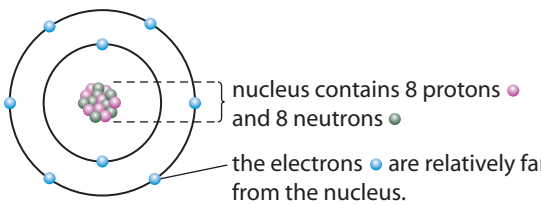


Figure B.1 This model of oxygen shows the arrangement of subatomic particles in the atom. Fixed numbers of electrons occupy regions called shells. The outermost shell is called the valence shell.

The Covalent Bond

Atoms group together, often forming very strong bonds. The following example will help you understand how and why one type of bond, the *covalent bond*, forms.

Figure B.2 illustrates the forces that come into play as two hydrogen atoms approach each other. Four interactions develop between the two atoms, as follows:

1. a force of repulsion between the two electrons;
2. a force of repulsion between the two protons;
3. a force of attraction between the electron of hydrogen atom A and the proton of hydrogen atom B; and
4. a force of attraction between the electron of hydrogen atom B and the proton of hydrogen atom A.

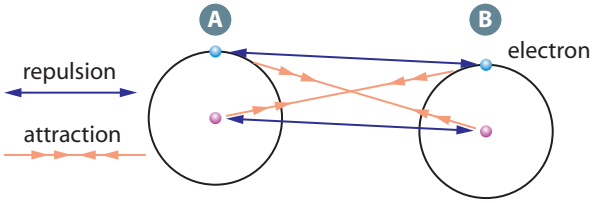


Figure B.2 The forces between two hydrogen atoms.

As the atoms continue to approach each other, the forces of both repulsion and attraction increase. The maximum force of attraction occurs when the nuclei of the two atoms are about 1.05×10^{-4} μm apart. At this point, the electron shells of the two atoms merge. Now each nucleus has access to both of the electrons. The two positive hydrogen nuclei share the same electron shell and are held together (bonded) by the shell's negative charge. The type of chemical bond that involves shared electrons is called a covalent bond.

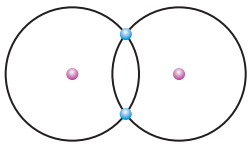


Figure B.3 Two hydrogen atoms that share a pair of electrons have formed a molecule (H_2) with a single covalent bond. The structural formula to show the single covalent bond between the hydrogen atoms is H — H.

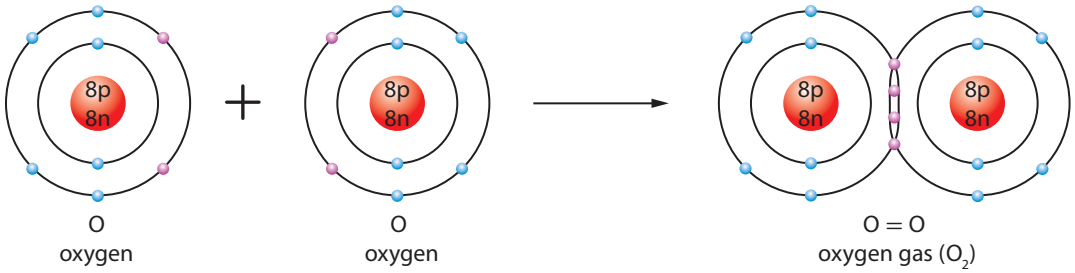


Figure B.4 Notice that by sharing two pairs of electrons (in a double bond), each of the oxygen atoms has access to eight electrons in its valence shell. This gives it the same stable valence-shell arrangement as the noble gas closest to it in the periodic table, neon.

Tendency Toward Stability

The noble gases (Group 18 on the periodic table) are known to be so chemically stable that they are unlikely to take part in chemical reactions. When atoms bond, they share, give up, or gain electrons to achieve the same arrangement of valence electrons as that of the noble gas to which they are closest in the periodic table.

You may recall from previous studies that the maximum number of electrons that can occupy the first valence shell outside a nucleus is two (the valence shell arrangement of the noble gas helium). By sharing a valence electron with another hydrogen atom, each of the hydrogen atoms in the new molecule achieves a stable valence shell arrangement. This is shown in Figure B.3.

Double and Triple Bonds

Atoms can also share two pairs of electrons or three pairs of electrons in a covalent bond. In a double covalent bond, two atoms share two pairs of electrons. This is illustrated using two oxygen atoms in Figure B.4.

The electron-dot diagram of carbon dioxide (Figure B.5) shows an example of a three-atom molecule held together by double covalent bonds. The maximum number of electrons that can occupy the valence shell of elements with atomic numbers 3 to 20 is eight. This is a stable electron shell configuration. Examine the CO_2 molecule in Figure B.5. Look for evidence that each atom in the molecule has access to a stable valence shell arrangement. In a triple covalent bond, two atoms share three pairs of electrons.

Figure B.5 An electron-dot diagram of carbon dioxide. Its structural formula is, thus, O = C = O.

The Polar Covalent Bond

Most of the biochemical reactions in a living cell take place in a water solution. The chemical bonds binding together the atoms in a water molecule have to be strong enough to keep the molecule intact even when heat added to the water makes it evaporate.

Figure B.6 An electron-dot model of a water molecule

The electron-dot diagram in Figure B.6 suggests that a water molecule is held together by ordinary covalent bonds. What this type of diagram cannot show is the relative importance of the protons in the nuclei of the three atoms. The O nucleus has eight positive protons; the hydrogen nuclei have only one proton each. The oxygen nuclei exert a greater attractive force on electrons than do hydrogen nuclei. As a result, the shared valence electrons spend more of their time around the O nucleus than they

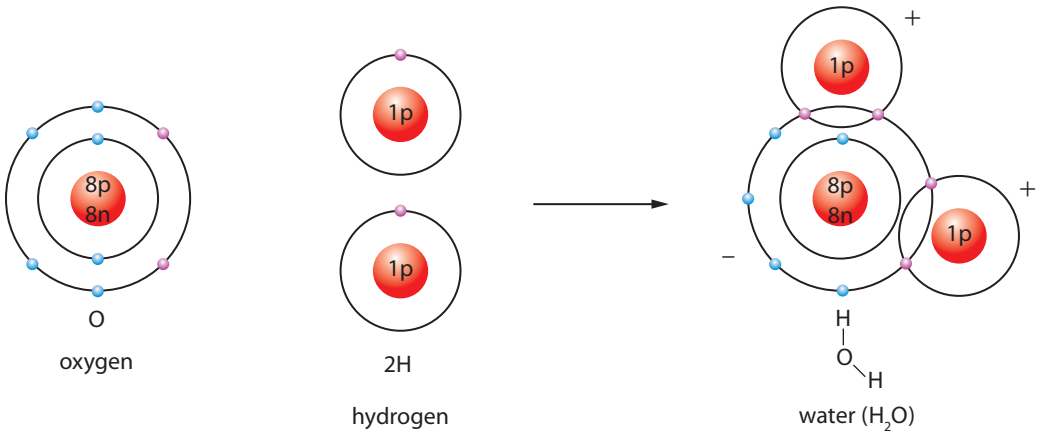


Figure B.7 Even though a water molecule is polar, it is electrically neutral overall.

do around the H nuclei. This gives the O end, or pole, of a water molecule a partially negative charge. The H ends, or poles, have partial positive charges. The model in Figure B.7 provides a useful representation of the polarity in a water molecule.

To reflect the unequal sharing of electrons within a water molecule, the special type of covalent bond holding it together is called a *polar covalent bond*. In a polar covalent bond, the valence electrons of the atoms are tightly bound, and no electrons are available to carry an electric current.

The Hydrogen Bond

When two water molecules collide, the polar nature of each molecule has an effect on what happens. If the two negative poles (O) meet "head to head," the molecules will repel each other because like charges repel. The two molecules will also repel each other if their positive poles (H) collide. However, in most collisions the negative pole of one molecule will be attracted by a positive pole of the other, and the two molecules will attract each other strongly enough to remain close together. Other water molecules in the vicinity will be attracted to each other in the same way. This type of electrostatic attraction between polar molecules containing a positive hydrogen pole is called a *hydrogen bond*. Figure B.8 shows the pattern of attractions that forms between liquid water molecules as a result of hydrogen bonding.

The Ionic Bond

Atoms can also form ionic bonds. From earlier studies, you may recall that when an atom or group of atoms gains or loses electrons, it acquires an electric charge and becomes an *ion*. The ions formed in this kind of electron transfer are chemically stable because each ion has a valence shell arrangement like that of a noble gas. When the number of electrons is less than the number of protons, the ion is positive (a cation). When the number of electrons exceeds the number of protons, the ion is negative (an anion). Ions can be composed of only one element, such as the hydrogen ion (H^+), or of several elements, such as the bicarbonate ion (HCO_3^-). The attraction between oppositely charged ions is called an *ionic bond*.

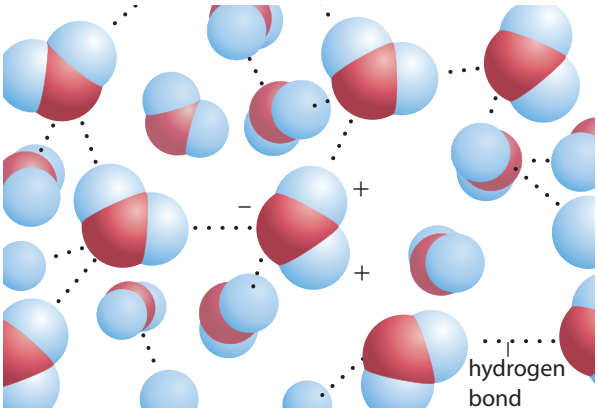


Figure B.8 The polarity of water molecules allows attractions called hydrogen bonds to form between the water molecules. A dotted line is used to represent a hydrogen bond; it indicates the hydrogen bond's weakness relative to covalent or ionic bonds.

Forming Ionic Compounds

If a large number of chlorine atoms are brought together, they pair up to form covalently bonded Cl_2 molecules. The shared electrons are strongly attracted by the two nuclei. In contrast, a sodium atom's single valence electron is only weakly attracted to its nucleus. If a large number of sodium atoms are brought together, a solid does form, but the valence electrons in the solid are so loosely attached to each nucleus that they can easily flow to conduct an electrical current.

However, if a piece of solid sodium is exposed to chlorine gas (Cl_2) there is an explosive reaction that releases both heat and light. In this reaction, electrons are actually transferred from the sodium atoms to the chlorine atoms. Thus, two ions are formed simultaneously: Na^+ and Cl^-. You can follow what happens in Figure B.9.

All that remains after the reaction are tiny cubic crystals of sodium chloride (table salt). The ions have aligned themselves in a pattern that reduces repulsion and maximizes attraction. For the ionic compound NaCl, the cubical ion arrangement shown in Figure B.10 is most stable. Ionic compounds bond into regular, repeating patterns that are determined by the size of the individual ions, the amount of charge they carry, and the kind of charge they carry.

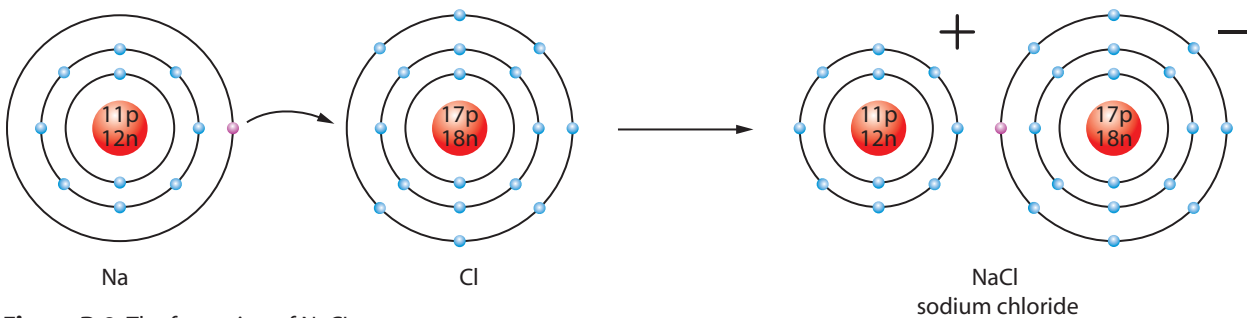


Figure B.9 The formation of NaCl

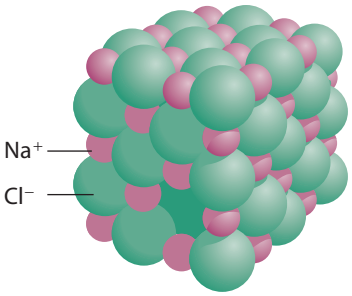


Figure B.10 An ionic compound such as NaCl (salt) has a characteristic crystalline shape. Like sodium chloride, most ionic compounds involve bonds between metal cations and non-metal anions.

Ionic Solids

The hundreds of different ionic compounds all have these two things in common:

1. They are solids at room temperature.
2. The total charge on the positive ions equals the total charge on the negative ions. Therefore, every ionic solid is electrically neutral even though it is composed of strongly charged particles.

The ionic bonds holding ionic solids (salts) together are extremely strong and stable. For example, sodium chloride melts only at a very high temperature (801 °C) and can safely be kept in a cupboard for years with no danger of decomposition.

Even though it contains millions of charged particles (ions), a crystal of sodium chloride cannot conduct an electrical current. Immobilized by their close-packed solid state, the ions cannot carry a current from one side of a crystal to the other.

Ionic Compounds in Solution

You know that table salt dissolves in water. Many other ionic compounds are also water soluble. What happens to the ions in sodium chloride when it dissolves in water? Attraction by the charged poles of the surrounding water molecules pulls the ions away from the crystal and into solution. Figure B.11 shows how the polar water molecules interact with and surround the sodium and chloride ions.

Figure B.11 Notice the orientation of the water molecules around the sodium ion and the chloride ion.

Once dissolved in water, the sodium and chloride ions are free to move about and collide with other particles. This makes the ions mobile enough to carry an electric current from one location to another. It also allows chemical reactions to occur. So, like many ionic compounds, sodium chloride is an electrolyte. An *electrolyte* is a substance that, when dissolved in water, enables the solution to carry an electric current.

The Biological Significance of Ions

Ions play a vital role in the chemistry of living cells and body systems. For example, modern athletes pay close attention to the level of electrolytes in their body. Intense physical activity causes the loss of NaCl (in sweat). If the lost sodium ions are not replaced, nerve cells cannot send signals to the muscles. Table B.2 identifies the significance of the important ions in your body.

Table B.2 Significant ions in the body

Name	Symbol	Special significance
sodium	Na^+	found in body fluids; important in muscle contraction and nerve conduction
chloride	Cl^-	found in body fluids
potassium	K^+	found primarily inside cells; important in muscle contraction and nerve conduction
phosphate	PO_4^{3-}	found in bones, teeth, and the high-energy molecule ATP
calcium	Ca^{2+}	found in bones and teeth; important in muscle contraction
bicarbonate	HCO_3^-	important in acid-base balance
hydrogen	H^+	important in acid-base balance
hydroxide	OH^-	important in acid-base balance

Understanding pH

Biological processes take place within specific limits of acidity and alkalinity. If an environment becomes too acidic or too alkaline for a process to continue at optimum levels, the organism that depends on that process may suffer and die. Fresh-water fish, for example, cannot survive in water that is too acid. Pitcher plants, sundews, and many other plants that grow in acidic soils cannot tolerate alkaline conditions.

Whether an environment is acidic or alkaline depends on the concentration of hydrogen ions ($H^+(aq)$) found in solution. Pure water at 25 °C ionizes very slightly to produce an equal number of hydrogen and hydroxide ions:

$$H_2O(\ell) \rightleftharpoons H^+(aq) + OH^-(aq)$$

Because the hydrogen and hydroxide ions are in balance (that is, equal in number), pure water is said to be neutral.

This neutral point is used as a reference in understanding how acidic or alkaline other solutions are. As solutions become increasingly acid from this point, the concentration of hydrogen ions in them increases. As they become increasingly alkaline, the concentration of hydrogen ions in them decreases. These relationships are summed up very neatly on the pH scale shown in Figure B.12. Each change in number up or down the scale represents a tenfold increase or decrease in the concentration of hydrogen ions.

Measuring pH

For a relative indication of the pH level, a sample can be tested with litmus paper. This simple test will determine whether a solution is either acidic or alkaline. It can also be tested by adding an acid-base indicator such as bromothymol blue. The resulting colour is then compared to a colour chart that indicates relative pH. More precise readings can be determined using a pH meter or probe, such as the one shown in Figure B.13. pH meters and probes use a pair of electrodes to measure the electrical potential of the solution being tested. When used to test a solution whose pH is unknown, the difference in potential between the two electrodes is measured and displayed as a pH value.

Figure B.13 Both pH paper and a pH meter can be used to determine the pH of a solution. The meter will give the more precise reading.

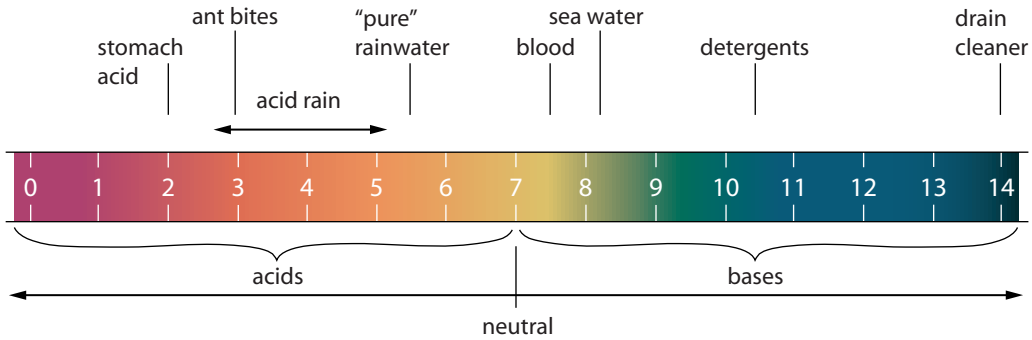


Figure B.12 The average pH values for various substances are indicated on this pH scale.

APPENDIX C

Microscopy Review

Part 1: Care of a Microscope

A *light microscope* is an optical instrument that greatly magnifies objects too small to be seen with the unaided eye. The figure on the next page shows a compound light microscope. This kind of microscope has a series of lenses (rather than only one, as in a hand lens) and requires a light source to view an object. Study the compound light microscope shown in Figure C.2 and review the major parts and their functions.

To keep your microscope in good operating condition, the following points should be observed.

1. To carry a microscope, always use one hand to hold the arm and your other hand to support the base.
2. Do not touch the lens surfaces with your fingers.
3. Use only lens tissue to clean the lens surfaces.
4. Do not adjust any of the focussing knobs until you are ready to use the microscope.
5. Always focus first using the coarse adjustment knob, with the low-power objective lens in position.
6. Do not use the coarse adjustment knob when either the medium-power or high-power objective lens is in position.
7. Cover the microscope when it is not in use.

Part 2: Using a Microscope

Here, you will use the microscope to view a prepared slide. You will determine the area that can be seen through the eyepiece, called the *field of view*, and calculate the magnification. Finally, you will make a scale drawing, and estimate the actual size of the object you are viewing.

CAUTION: Be sure your hands are dry when handling electrical equipment. Handle microscope slides carefully, since they can break easily and cause cuts.

Materials

- microscope
- prepared microscope slide
- mathematical compass
- clear plastic ruler
- blank sheet of paper
- pencil

Procedure

1. Place the microscope on a flat surface.
2. The microscope should always be stored with the low-power objective in position. If your microscope has not been stored that way, look from the side and rotate the revolving nosepiece until the low-power objective clicks into place.
3. Use the coarse-adjustment knob to lower the low-power objective until the lens is about 1 cm above the stage.
4. Look through the eyepiece and adjust the diaphragm until the view is as bright as possible.

Total Magnification and Field of View

5. To calculate the total magnification of an object, multiply the power of the eyepiece by the power of the objective. For example, if the eyepiece magnification is 10×, the low-power objective is 4×, and the high-power objective is 40×, then:
   a) The total magnification using the low-power objective is $10 \times 4 = 40\times$.
   b) The total magnification using the high-power objective is $10 \times 40 = 400\times$.
6. To determine the field of view, place the clear plastic ruler on the stage.
7. Using the coarse-adjustment knob, focus on the ruler. Position the ruler so that one of the millimetre markings is at the left edge of the field of view, as shown in Figure C.1.

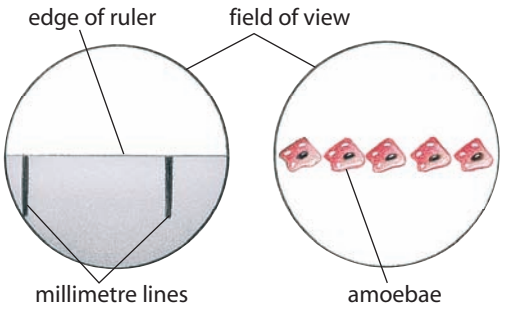


Figure C.1 The diameter of the field of view under low power illustrated here is about 1.5 mm.

8. Measure and record the diameter of the field of view in millimetres (mm) for the low-power objective.
9. Use the following formula to calculate the field of view for the medium-power objective:

$$\text{Medium-power field of view} = \text{Low-power field of view} \times \frac{\text{Magnification of low-power objective}}{\text{Magnification of medium-power objective}}$$

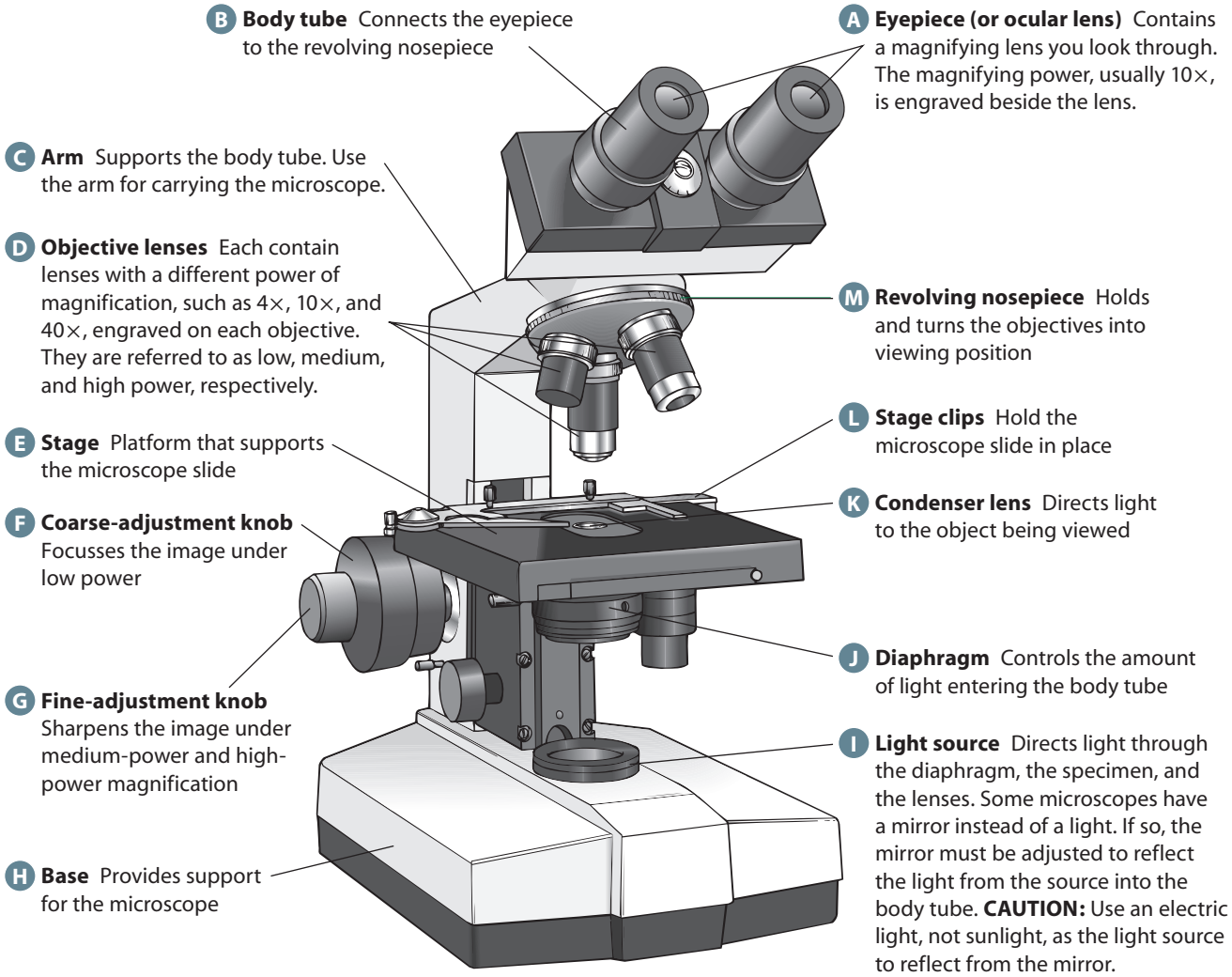


Figure C.2 Compound light microscope

For example, if the low-power objective is 4× with a field of view of 2 mm, and the medium-power objective is 10×, then:

$$\text{Medium-power field of view} = 2\text{ mm} \times \frac{4}{10}$$
$$= 2\text{ mm} \times 0.4$$
$$= 0.8\text{ mm}$$

Similarly, calculate the field of view for the high-power objective and record the value.

10. Objects in the field of view of a microscope are usually measured in micrometres (μm). One micrometre equals 0.001 mm; or 1000 μm equals one millimetre.

a) In the example in step 9, the field of view under the medium-power objective would be $0.8\text{ mm} \times 1000 = 800\ \mu\text{m}$.

b) Calculate the field of view in μm under the high-power objective.

11. You can determine the size of a specimen (such as an amoeba) by estimating how many could fit end to end across the field of view. See Figure C.1 on the previous page. To do this, divide the field of view by the number of specimens. If the field of view in the illustration is 1500 μm, what is the diameter of each amoeba?

Viewing a Prepared Slide

12. Place a prepared slide on the stage and secure it in place with the stage clips. The low-power objective should be in position. Make sure the object you intend to view is centred over the opening in the stage.

a) Look through the eyepiece. Slowly turn the coarse-adjustment knob until the object is in focus.

b) Use the fine-adjustment knob to sharpen the focus.

13. Once the object is in focus using low power, carefully rotate the revolving nosepiece to the medium-power objective. Look at the side of the objective as you rotate the nosepiece to be sure the objective lens does not strike the surface of the slide.

a) Adjust the focus using *only* the fine-adjustment knob.

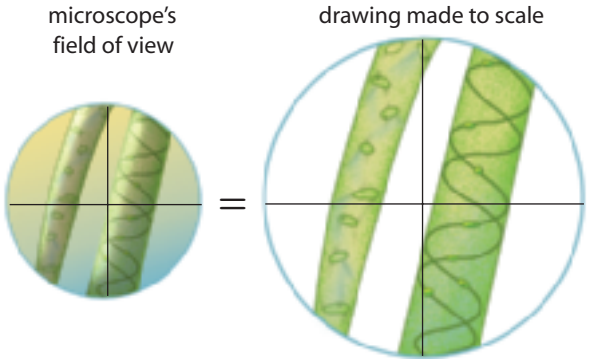
b) Next, view the object using the high-power objective. Carefully rotate the nosepiece until the high-power objective clicks into position. Again, be sure the objective does not strike the surface of the slide as you rotate the nosepiece. Adjust the focus using *only* the fine-adjustment knob.

14. Once you have finished viewing the slide, carefully rotate the nosepiece until the low-power objective is in position. If you do not proceed to step 15, making a scale drawing, remove the slide from the stage and return it to its proper container. Unplug the light source and return the microscope to its cabinet. **CAUTION:** Never tug on the electrical cord to unplug it.

Making a Scale Drawing

15. With a mathematical compass, draw a circle (the size does not matter) on blank paper. The circle represents the microscope's field of view.

16. Use the ruler and pencil to divide the circle into four equal sections, as shown in the illustration.



17. Using the low or medium-power objective, find an area of interest on the prepared slide. Imagine that the field of view is also divided into four equal sections.

18. Notice how much space each part of the object occupies in the field of view.

19. Draw the object to scale in the circle. Draw each part of the object so it is in the same part of the circle as it appears in the field of view. This means the object should occupy the same proportion of space in the circle as it does in the field of view. Label your drawing. Indicate the total magnification and calculate the actual size of the object.

Part 3: Preparing a Wet Mount

Now prepare and view slides of a variety of specimens.

CAUTION: Be careful when using sharp objects such as tweezers. Handle microscope slides and cover slips carefully, since they can break easily.

Materials

- microscope
- cover slips
- tweezers
- tap water
- microscope slides
- medicine dropper
- cotton fibres
- lens paper
- small piece of newspaper and other samples

Procedure

1. To prepare a wet mount, begin with a clean slide and cover slip. Hold the slide and cover slip by their edges to avoid getting your fingerprints on their surfaces.

2. Tear out a small piece of newspaper containing a single letter. Use an *e*, *f*, *g*, or *h*. Using the tweezers, position the letter in the centre of the slide.

3. Using the medicine dropper, place one drop of water on the sample. Hold a cover slip over the sample at a 45 ° angle. One edge of the cover slip should touch the surface of the slide near the newspaper letter sample.

4. Slowly lower the opposite edge of the cover slip over the sample. Be sure no bubbles form beneath the cover slip. This type of sample preparation is called a *wet mount*.

5. With the low-power objective of the microscope in position, place the slide on the stage and secure it with the stage clips. Centre the sample over the opening.

a) Look though the eyepiece. Reposition the slide, if necessary, until you can see the letter. Using the coarse-adjustment knob, focus on the letter. Then, adjust the focus with the fine-adjustment knob.

b) Examine the letter using medium power. Note that it is composed of many small dots.

6. To reveal the structure of small objects, the microscope must do more than magnify—it must also reveal detail. The capacity to distinguish detail is called *resolution*, and the measure of resolution is known as *resolving power*. The resolving power of a microscope is defined as the minimum distance that two objects can be apart and still be seen as separate objects. Prepare another wet mount using several fibres from a cotton ball. Using the low-power objective, locate a part of the slide where two fibres cross each other. Change to the high-power objective. Use the fine-adjustment knob to focus on the fibres. Can both strands of cotton be seen clearly at the same time under high power? How might you explain this result?

APPENDIX D

Review of Biological Drawings

A clear, concise drawing can often replace words in a scientific description. Drawings are especially important when you are trying to explain difficult concepts or describe complex structures. Follow these steps to make a good scientific drawing:

1. Use an unlined (blank) sheet of paper and a sharp lead pencil, ideally 2H, for the drawing, title, and all labels.
2. Make sure your drawing will be large enough to show all the necessary details; a drawing about half a page in size is usually sufficient. Also allow space for the labels, which identify parts of the object you are drawing. Place all labels to the right of your drawing.
3. Make your drawing as simple as is possible, using clean-cut pencil lines (do not sketch). Draw only what you observe. Do not draw parts of the object that are not visible from the angle of view you are observing. If you must show another part of the object, make a second drawing. Indicate the angle of view on each drawing.
4. Most animal and plant tissues are composed of many cells. If you are drawing a representative cell of such tissue, include the boundaries of the other cells surrounding it. This approach will provide context for your drawing.
5. Shading is not usually used in scientific drawings. To indicate darker areas in your drawing, use stippling (a series of dots) as shown in Figure AE.2. Also, use double lines to indicate thicker parts of an object, such as the wall of a plant cell.
6. Label your drawing carefully and completely. All labels should be horizontal, printed in lower-case, and placed in a column to the right of your drawing. Imagine for a moment that you know nothing about the object you are drawing. Think about what structures you would like identified if you were seeing the drawing for the first time.
7. Use a ruler to draw a horizontal line from each label to the structure you are identifying. Make sure that none of these label lines cross each other.
8. Give your drawing a title. The title should appear immediately above the drawing. The title should be printed and underlined. Indicate the magnification of the drawing in parentheses. **Note:** The drawing shown of onion skin cells is from a student's notebook. The student used stippling to show darker areas, horizontal labels and label lines for each structure observed, gave the drawing a title, and indicated the magnification—all elements of a complete scientific drawing. The student has also included the microscope's field of view to give definition to the drawing.

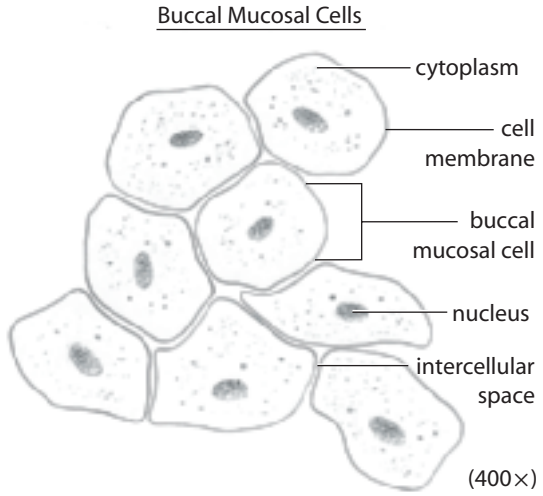


Figure AE.1 Buccal mucosal (cheek lining) cells

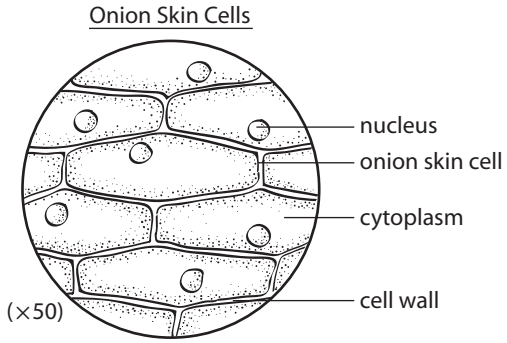


Figure AE.2 The stippling on this drawing of onion skin cells, as observed under a microscope, shows that some areas are darker in appearance than others.

APPENDIX
E

Tips for Writing Diploma Exam Written Response Questions

The Diploma Exam Preparation feature at *www.albertabiology.ca* shows examples of the different types of questions that require a written response, although the tips here will assist you in answering any type of question.

Your answers will be assessed on the basis of how well you communicate both your understanding of the information presented and your understanding of the applicable science. Evaluators will be looking for examples of your understanding of scientific principles and techniques. For more information about the Diploma Exams, visit the Alberta Education Diploma Exam web site at **http://www.education.gov.ab.ca/k%5F12/testing/diploma/**

Key Diploma Exam Skills

In order to successfully answer the questions, you must be able to:

1. Read critically and identify
   - key words, phrases, and data that deliver useful information
   - distractor information and data that can be ignored because it does not have any bearing on the answer to the question
   - if the question is an open-response style that requires a unified response, or if it is a closed-response style that requires a more analytical approach
   - precisely what the question is asking
     - pay close attention to the process words (see list below)
     - pay close attention to the directing words (see list opposite) to determine how you should answer the question. The directing words are always highlighted in boldface type.
   - the scientific concept(s) that you should include in your answer
   - any formula(s) that you will have to use
   - the information in your Data Booklet that you will need
2. Interpret and Analyze
   - process words and directing words
   - information including the key words, phrases, and data presented in the information box
   - information that is presented in charts, tables, and graphs
3. Communicate
   - conclusions by making a formal statement
   - results in the form of charts, graphs, or diagrams
   - ideas or answers to questions in the form of complete sentences, paragraphs, or short essays
4. If you are asked to perform an experiment, you must write the experimental design as follows:
   - state the problem or question to be answered
   - formulate a hypothesis or make a prediction
   - identify the manipulated and responding variable(s) if required
   - provide a method for controlling variables
   - identify the required materials clearly
   - describe any applicable safety procedures
   - list the steps in the experimental procedure
   - provide a sketch(es) of the apparatus to help make the set-up clear
   - provide a method for collecting and recording pertinent data—include the units for the data being collected

Guidelines

The Diploma Exam feature includes guidelines that direct you in the skills and knowledge you need to use to answer the questions successfully. This type of information will *not* appear on the exam.

Assess the type of question and the guidelines that are provided to help you answer it. Use the information provided here to develop your own technique for answering each type of question.

Alberta Science Process and Directing Words

The following "process" and "directing" words have specific meanings when they are used in the Diploma Exam questions. Study this list so you will understand exactly what you are being asked to do in the questions. The success of your answer depends not only on your interpretation of the information in the question but also on your understanding of the wording of the questions.

Process Words

Hypothesis: A single proposition intended as a possible explanation for an observed phenomenon; e.g., a possible cause for a specific effect

Conclusion: A proposition that summarizes the extent to which a hypothesis and/or a theory has been supported or contradicted by the evidence

Experiment: A set of manipulations and/or specific observations of nature that allow the testing of hypotheses and/or generalizations

Variables: Conditions that can change in an experiment. Variables in experiments are categorized as:

- *manipulated variables* (independent variables): conditions that were deliberately changed by the experimenter
- *controlled variables* (fixed or restrained variables): conditions that could have changed but did not, because of the intervention of the experimenter
- *responding variables* (dependent variables): conditions that changed in response to the change in the manipulated variables

Directing Words

Discuss The word "discuss" **will not** be used as a directing word on math and science diploma examinations because it is not used consistently to mean a single activity.

The following words are specific in meaning.

Algebraically Using mathematical procedures that involve letters or symbols to represent numbers

Analyze To make a mathematical, chemical, or methodical examination of parts to determine the nature, proportion, function, interrelationship, etc. of the whole

Compare Examine the character or qualities of two things by providing characteristics of both that point out their *similarities* and *differences*

Conclude State a logical end based on reasoning and/or evidence

Contrast/Distinguish Point out the *differences* between two things that have similar or comparable natures

Criticize Point out the *demerits* of an item or issue

Define Provide the essential qualities or meaning of a word or concept; make distinct and clear by marking out the limits

Describe Give a written account or represent the characteristics of something by a figure, model, or picture

Design/Plan Construct a plan; i.e, a detailed sequence of actions for a specific purpose

Determine Find a solution, to a specified degree of accuracy, to a problem by showing appropriate formulas, procedures, and calculations

Enumerate Specify one by one or list in concise form and according to some order

Evaluate Give the significance or worth of something by identifying the good and bad points or the advantages and disadvantages

Explain Make clear what is not immediately obvious or entirely known; give the cause of or reason for; make known in detail

Graphically Using a drawing that is produced electronically or by hand and that shows a relation between certain sets of numbers

How Show in what manner or way, with what meaning

Hypothesize Form a tentative proposition intended as a possible explanation for an observed phenomenon; i.e., a possible cause for a specific effect. The proposition should be testable logically and/or empirically

Identify Recognize and select as having the characteristics of something

Illustrate Make clear by giving an example. The form of the example must be specified in the question; i.e., word description, sketch, or diagram

Infer Form a generalization from sample data; arrive at a conclusion by reasoning from evidence

Interpret Tell the meaning of something; present information in a new form that adds meaning to the original data

Justify/Show How Show reasons for or give facts that support a position

Model Find a model (in mathematics, a model of a situation is a pattern that is supposed to represent or set a standard for a real situation) that does a good job of representing a situation

Outline Give, in an organized fashion, the essential parts of something. The form of the outline must be specified in the question; eg., list, flow chart, concept map

Predict Tell in advance on the basis of empirical evidence and/or logic

Prove Establish the truth of validity of a statement for the general case by giving factual evidence or logical argument

Relate Show logical or causal connection between things

Sketch Provide a drawing that represents the key features of an object or graph

Solve Give a solution for a problem; i.e., explanation in words and/or numbers

Summarize Give a brief account of the main points

Trace Give a step-by-step description of the development

Verify Establish, by substitution for a particular case or by geometric comparison, the truth of a statement

Why Show the cause, reason, or purpose

APPENDIX F

The Dissection of a Fetal Pig

Target Skills

Observing and **identifying** principal structures of mammalian digestive, respiratory, and circulatory systems

Recording accurate biological drawings

Working cooperatively to ensure safety

Note: Illustrations used in this dissection are also available electronically. If you do not dissect a fetal pig or other organism in your course, many virtual dissections are available to enhance your learning.

Pigs are members of the class mammalia. Before birth, the young are nourished by the placenta in the mother's womb. For this reason, pigs (like humans) are known as placental mammals. The structure and organization of the internal organs of the pig are representative of those of all placental mammals. Although the fetal pig is not yet born, its internal systems are complete. In this investigation you will dissect a fetal pig to study its internal organs. This dissection will give you a sense of how internal systems are arranged within your own body.

Dissection involves the careful and systematic examination of the internal structures of an organism. A good dissection will reveal not only the location and structure of individual organs, but also how different organs relate to one another in the various systems of the body. To carry out a successful dissection, you should be familiar with the terms listed in Table A10.1. These are the terms used to describe the location of the various features of the animal and to direct incisions.

This dissection is divided into four parts. In the first part, you will investigate the external anatomy of your specimen and identify its age and sex. In the second part, you will examine the organs of the digestive system. In the third part, you will examine the organs of the circulatory system. Finally, in the fourth part, you will examine the organs of the respiratory system. In between each investigation you will store your specimen. Remember to wrap and store your specimen properly, and to label it so you can identify it again.

Table A10.1 The anatomical terms used to locate organs or incisions during this dissection.

Term	Meaning
Dorsal	Upper or back surface
Ventral	Under or belly surface
Lateral	Side
Anterior	Toward the front (head) end
Posterior	Toward the back end
Superficial	Near the surface
Proximal	Close to
Distal	Far from

Safety Precautions

Extreme care must be taken when using dissecting instruments, particularly scalpels. To the extent possible, make cuts away from your body. The pigs are preserved in a chemical solution. Wear plastic gloves, goggles and an apron at all times, and work in a well-ventilated area. If some of the chemical comes into contact with your skin, wash it off. At the end of each lesson, wash your hands thoroughly. Dispose of all materials as instructed by your teacher, and clean your work area.

Materials

- preserved fetal pig
- dissecting instruments
- plastic bag and tie (to store your specimen)
- disposable plastic gloves
- large tongs
- dissecting tray
- string or strong thread
- water-proof tags (to identify your specimen)
- apron
- T pins
- newspapers and/or paper towelling

Procedure

Part 1 External Anatomy

1. Rinse your specimen and place it on its side in the dissecting tray.
2. Measure your specimen from the snout to the base of the tail. Use Figure A10.1 to estimate the gestational age of your specimen.

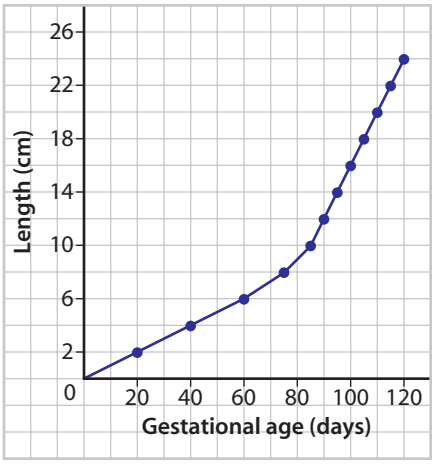


Figure A10.1 The gestation period of the pig is about 115 days. About how old is your specimen?

3. Identify the external features of your specimen using Figure A10.2. Make your own drawing of the lateral view of your specimen, labelling the features. Record the age of your specimen with this drawing.

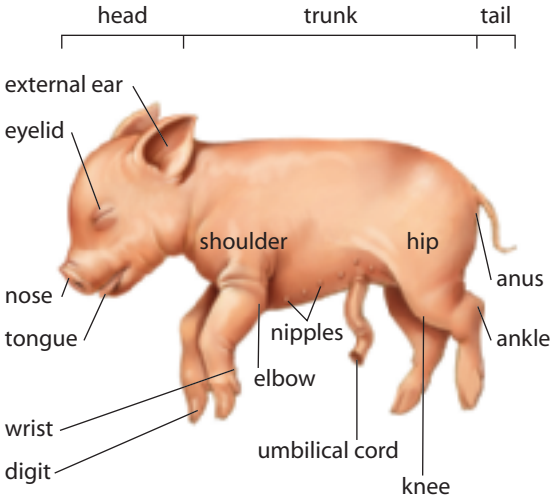


Figure A10.2 A lateral view of a fetal pig.

4. Turn your specimen onto its back. Using Figures A10.3 and A10.4, determine the sex of your specimen. Examine a specimen of each sex.

5. Make your own drawing of the external reproductive organs of specimens of both sexes. Label the structures.

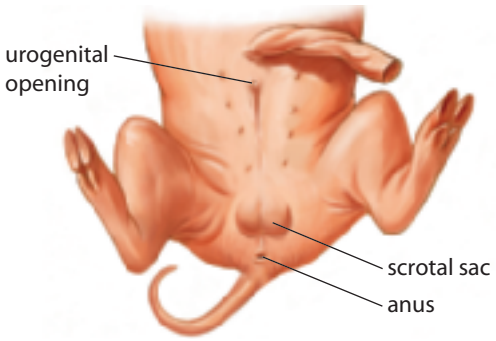


Figure A10.3 The external reproductive organs of a male fetal pig.

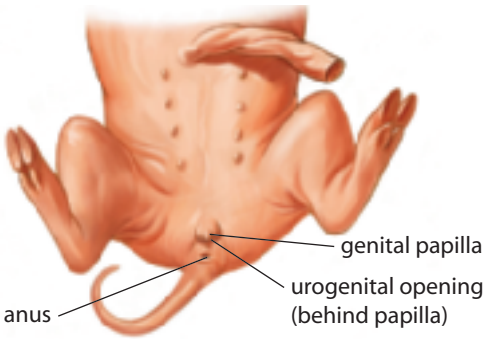


Figure A10.4 The external reproductive organs of a female fetal pig.

Part 2 The Digestive System

A. The mouth

1. Using a strong pair of dissecting scissors, make a cut in the corner of the mouth, cutting toward the posterior of the specimen. Repeat on the other side.

2. Pry the mouth open. Using Figure A10.5, locate and identify the features of the oral cavity.

3. Make your own drawing of the mouth of your specimen, labelling the features.

Analysis

1. Explain how the appearance of the following structures relates to their function as part of the digestive system. Give as much detail as possible, including size, texture, external structure, and internal structure.
   - **a)** the teeth
   - **b)** the tongue
   - **c)** the epiglottis

2. What differences can you see between the pig's mouth structures and your own? Suggest a reason for these differences.

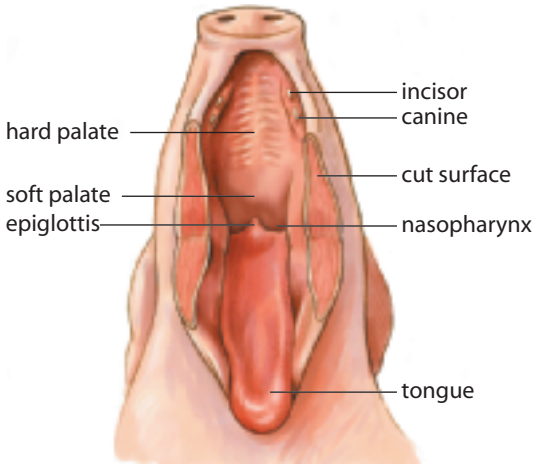


Figure A10.5 The oral cavity of the fetal pig.

B. Exposing the abdominal organs

1. Place the pig in the dissecting tray with its ventral surface uppermost. Spread out the limbs. Tie a piece of string to one of the forelimbs near the ankle. Pass the string under the tray and securely tie the other forelimb. Repeat the process with the hind limbs.

2. Select a point just anterior to the umbilical cord on the specimen's ventral surface. Using forceps, pinch the skin of the abdomen along the midventral line and pull it slightly away from the animal. With your scissors, make an incision in the skin. The incision should be just large enough to pass the point of your scissors through. Now make a midventral cut ending

just posterior to the midline of the animal (shown as #1 in Figure A10.6). To avoid damaging the organs as you cut, keep the tips of the scissors pointing up. Be careful not to damage the umbilical cord.

3. From the same starting point, make a second incision around the base of the umbilical cord extending back to just anterior to the anus (shown as #2 on Figure A10.6). You may wish to turn your specimen around so you can cut away from you. Repeat on the other side.

4. Locate the base of the sternum (breast bone), situated in the centre of the chest. The ribs are attached to the sternum. Select a point slightly posterior to the sternum and cut across the ventral surface (shown as #3 in Figure A10.6). The incision should be posterior to the diaphragm, which you will be able to see as a dome-shaped layer of muscle separating the abdominal and thoracic cavities.

5. Make two final incisions, one on each side of the cuts bordering the umbilical cord and just anterior to the hind limbs (shown as #4 in Figure A10.6). Use T pins to pin back the skins to expose the internal organs of the abdominal cavity. The T pins should point away from the specimen so they will not interfere with your work.

6. The organs of the abdomen are covered and protected by a membrane called the peritoneum. The double-layered sheets of peritoneum are called mesenteries. Using forceps or a dissecting probe, gently move the mesenteries aside to reveal the underlying organs.

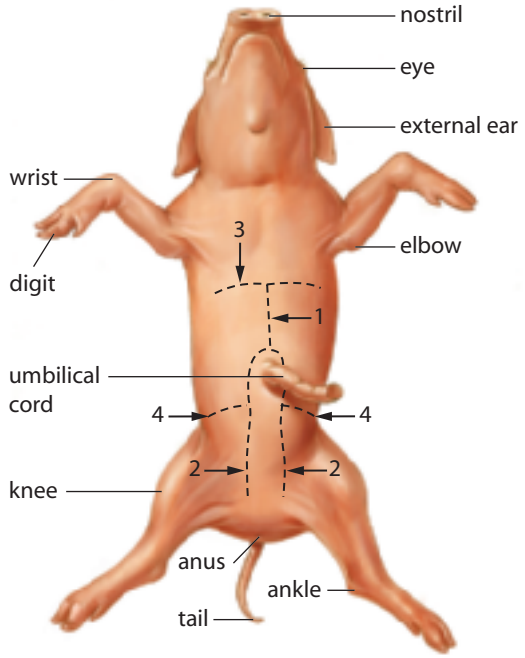


Figure A10.6 A ventral view of a fetal pig showing the pattern of incisions that expose the organs of the abdominal cavity.

7. Using Figure A10.7 below and Figure A10.8, locate and identify the organs of the abdominal cavity. Make a drawing of your specimen showing the location of the internal organs and labelling them.

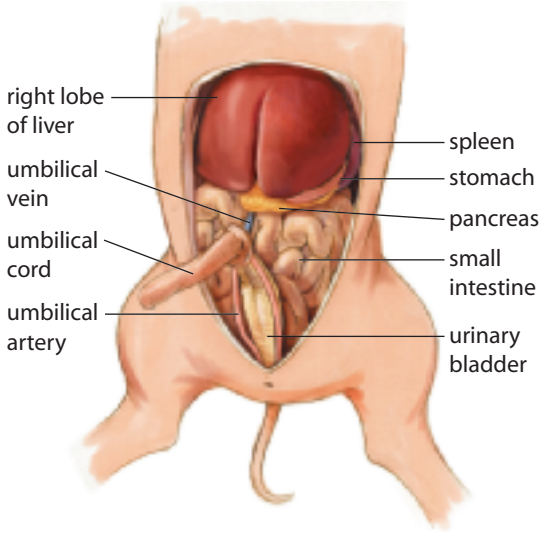


Figure A10.7 The major organs found in the abdominal cavity of the fetal pig.

C. Examining the abdominal organs

1. Locate the liver, the largest organ of the abdominal cavity. Describe its appearance in your own words. Note its different lobes.

2. Locate and describe the esophagus. Note how it passes through the diaphragm just before it enters the stomach.

3. Locate and describe the stomach. Carefully cut open the stomach and describe the inner surface.

4. Locate and describe the pancreas, situated below the stomach and between the stomach and the small intestine. It is usually lighter in colour than the surrounding organs.

5. Locate and describe the small intestine. See if you can identify the separate portions of the duodenum, ileum, and jejunum.

6. Using forceps or a probe, gently lift the connective tissue that links the liver and the duodenum. Locate the bile duct in this mesentery and trace it back to its source at the gall bladder. The gall bladder is embedded on the surface of the liver.

7. Move to the distal end of the small intestine and locate the point on the left side of the abdominal cavity where the large intestine begins.

8. The main part of the large intestine is called the colon. Identify the path the colon takes in the abdomen.

9. Toward the end of the large intestine is the rectum. Note where the tract terminates at the anus.

10. Cut the esophagus as close to the top of the abdominal cavity as you can. Make a second cut as close as you can to the end of the digestive tract near the anus. Carefully remove the entire digestive tract, in one piece, from the specimen.

11. Carefully cut away the connective tissue around the digestive tract. Unravel the tract and make a drawing of it, identifying the different sections of the digestive tract. Measure each section of the digestive tract.

12. Make a drawing of the unravelled digestive tract and describe the appearance of this tissue in your own words.

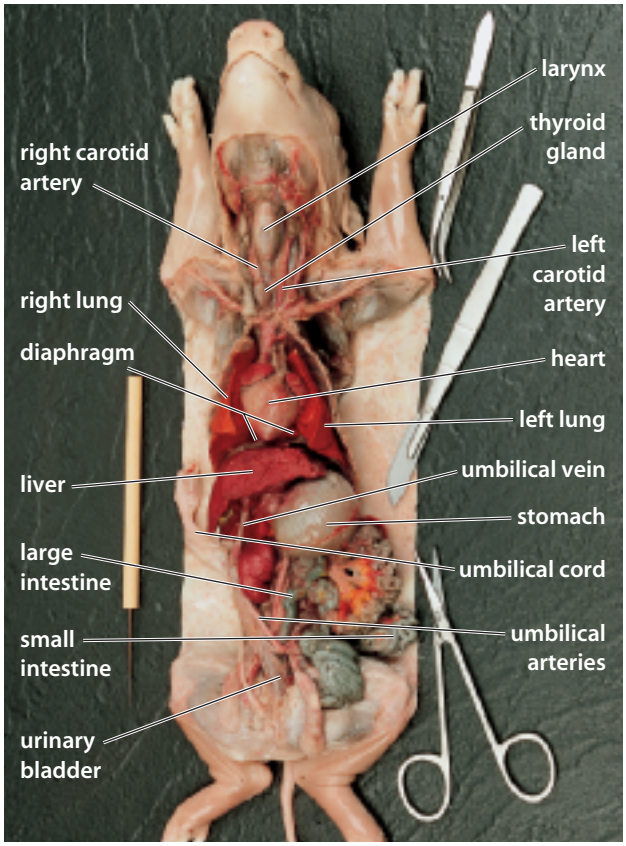


Figure A10.8 The internal abdominal and thoracic organs. (Note: the pancreas is not visible in this photograph.)

Analysis

1. Explain how the appearance of the following structures relates to their function as part of the digestive system. Give as much detail as possible, including size, texture, external structure, and internal structure.
   - **a)** liver
   - **b)** pancreas
   - **c)** esophagus
   - **d)** stomach
   - **e)** small intestine
   - **f)** large intestine
   - **g)** gall bladder

2. Using your own drawings of the abdominal organs, trace the path of food from the mouth to the rectum. Identify the major steps in the digestive process that take place along the way.

Part 3 The Circulatory System

A. Exposing the organs of the thoracic cavity

1. Locate the base of the sternum (breast bone), situated in the centre of the chest. The ribs are attached to the sternum. Use this as the starting point for your incision. With forceps, pinch the skin of the abdomen along the midventral line and draw it slightly away from the animal. With your scissors, make an incision in the skin. The incision should be just large enough to pass the point of your scissors through. Now make a midventral cut (shown as #1 in Figure A10.9). This cut should extend as far forward as the hairs near the base of the throat. Be careful not to damage the underlying body wall as you cut. Remember to keep the tips of your scissors pointing up, not down, to avoid damaging the internal organs.

2. Next, make two cuts (shown as cuts #2 and #3 in Figure A10.9) from the midventral line in the region of the thoracic cavity. Carefully lift the skin and pin it to the sides of the specimen using T pins. The T pins should point away from the specimen so they will not interfere with your work.

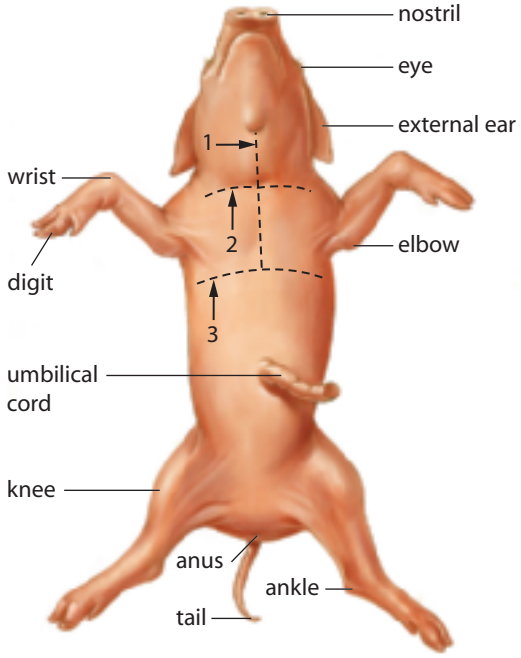


Figure A10.9 A ventral view of a fetal pig showing the pattern of incisions that will expose the organs of the thoracic cavity.

3. Using a sturdy pair of dissecting scissors, cut the ribs along the sternum, and pry them apart to reveal the organs of the thoracic cavity.

4. Using forceps or a dissecting probe, remove the connective tissues and membranes that surround the lungs and heart.

5. Using Figure A10.8 and Figure A10.9, identify the internal organs of the thoracic cavity. Make a drawing of your specimen.

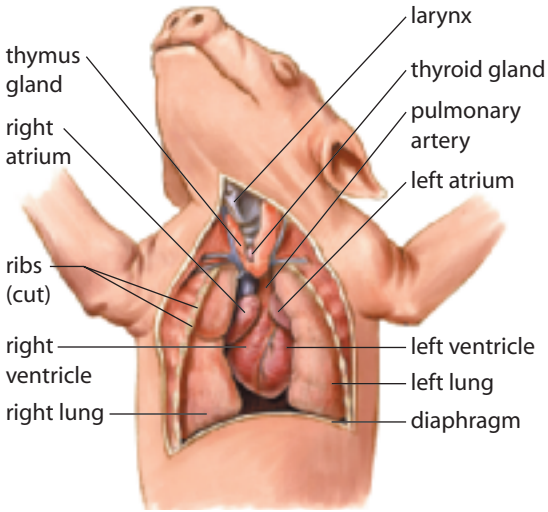


Figure A10.10 The organs of the thoracic cavity.

B. Examining the organs of the circulatory system

1. Using Figure A10.10 and A10.12 for reference, identify and compare the sizes of the following major blood vessels.
   - **a)** the aorta, including the aortic arch;
   - **b)** the superior vena cava;
   - **c)** the pulmonary artery;
   - **d)** the pulmonary vein;
   - **e)** the inferior vena cava;
2. Your specimen may have a small blood vessel connecting the pulmonary artery to the aorta. This vessel is called the ductus arteriosis. Try to locate this vessel on your own specimen. If you cannot find it, examine another specimen in which this vessel is visible.
3. Locate and describe the heart.
4. Make a drawing of your specimen showing the location of the circulatory organs.
5. Carefully cut through the blood vessels a short distance from the heart. Remove the heart. Make an incision in the ventral surface of the heart as shown in Figure A10.11. Your incision should expose all four chambers of the heart.
6. Using Figure A10.12 for reference, identify the internal features of the heart. Try to locate and identify the heart valves at the opening to the blood vessels.
7. Compare the structure of the different chambers of the heart. Make a labelled drawing and describe the structures in your own words.

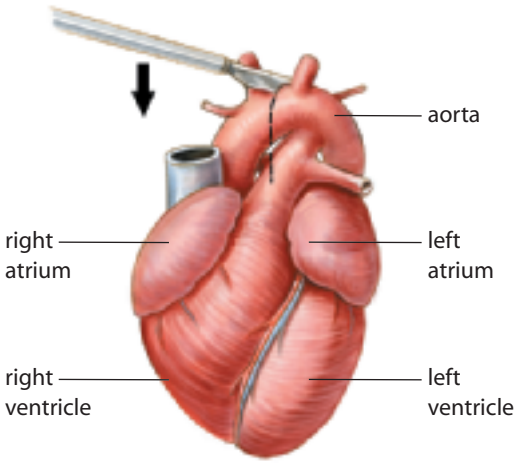


Figure A10.11 With the heart on its dorsal surface, make your incision beginning at the aortic arch and continuing straight to the base of the ventricles.

Analysis

1. Explain how the appearance of the following structures relates to their function as part of the circulatory system. Give as much detail as possible, including size, texture, external structure, and internal structure.
   - **a)** right atrium
   - **b)** left atrium
   - **c)** right ventricle
   - **d)** left ventricle
   - **e)** arteries
   - **f)** veins
   - **g)** ductus arteriosis
   - **h)** heart valves
2. Using your own drawings, trace the passage of blood from the body through the heart and back to the body.

Part 4 The Respiratory System

Examining the respiratory organs

1. Using Figure A10.10 for reference, identify the major organs of the respiratory system.
2. Note the difference in structure between the right and left lung. In your own words, describe the structure and texture of the lungs.
3. Locate and describe the pleural membranes encasing each lung.
4. Using a probe, move aside the layers of muscle to work deeper into the neck. If necessary, carefully cut the muscle tissue. Locate the larynx, trachea, and esophagus. Describe the difference in structure between the trachea and esophagus.

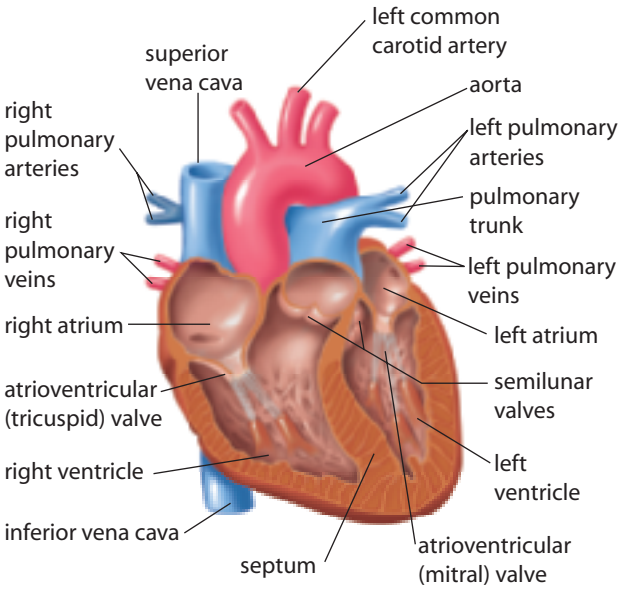


Figure A10.12 A ventral cross section of the heart.

5. Examine the rib cage and try to identify the external and internal intercostal muscles.
6. Open the mouth and describe the relationship between the glottis, esophagus, and pharynx.
7. Trace the passage of the trachea through the throat. Try to identify the two branches of the bronchi.
8. Make a drawing of your specimen showing the location of the organs of the respiratory system.
9. Using a small syringe or dropper, push a small amount of air into the trachea. Note the inflation of the lungs.

Analysis

1. Explain how the appearance of the following structures relates to their function as part of the circulatory system. Give as much detail as possible, including size, texture, external structure, and internal structure.
   - **a)** trachea
   - **b)** right lung
   - **c)** left lung
   - **d)** pleural membrane
   - **e)** larynx
   - **f)** glottis
   - **g)** diaphragm
   - **h)** rib cage
2. Using your own drawings, trace the path of air from the mouth to the lungs.