Paramedic Resource Manual

FLUIDS & ELECTROLYTES

SECTION FIVE

2014 Update by
Ontario Base Hospital Group Education Subcommittee

OBJECTIVES: FLUIDS & ELECTROLYTES

The objectives indicate what you should know, understand and be prepared to explain upon completion of this module. The self-assessment questions and answers will enable you to judge your understanding of the material.

Upon completion of this module, the student should be able to:

1. Name and describe the body fluid compartments.

2. Describe the distribution of body fluid in the intracellular and extracellular compartments.

3. Define and state the role of the following in fluid and electrolyte movement.

   a) Diffusion
   b) Active Transport
   c) Osmosis
   d) Osmotic Pressure
   e) Oncotic Pressure (colloidal osmotic pressure)

4. State the approximate volume of body water in the normal adult.

5. State the distribution (as % of body weight) of fluid volumes in the normal adult and the pediatric patient.

6. Identify significant fluid loss (as % of body weight) in the adult and the pediatric patient.

7. Briefly explain the use of normal saline and 5% D/W in management of fluid depletion.

8. Describe briefly the role of the kidney (including the hormones involved) in the maintenance of fluid and electrolyte balance.

9. Define:

   a) Dehydration
   b) Edema
   c) Volume depletion.

10. State the physiological roles of Na^+, K^+, Cl^-, Ca^{++} and HCO_3^-.

If you have studied this subject previously, you may test your ability using the self-assessment questions at the end of each section. If you are able to obtain 90% or greater, you may choose not to do the unit and merely review the section, or parts of sections, where weakness may exist. If you obtain less than 90%, it is recommended that the module be done in its entirety, stressing areas where more review is needed.

GLOSSARY

ACTIVE TRANSPORT	The passage of molecules or ions across a semi-permeable membrane against the concentration gradient, i.e. from an area of lower to higher concentration of that substance; requires expenditure of energy.
ANION	An ion with a negative (-) charge
ANOXIA	Absence of oxygen in the body tissues
CATION	An ion with a positive (+) charge.
COLLOID	Molecules which are invisible to the naked eye but are too large to dissolve and are therefore suspended in solution. In the blood, this refers to large protein molecules.
CONCENTRATION GRADIENT	The tendency for substances to move from an area of higher to lower concentration with two solutions of different concentrations are separated by a semi-permeable membrane.
DEHYDRATION	A condition in which there is a net loss of water from the fluid compartments of the body.
DIFFUSION	The movement of molecules of ions from an area of higher to lower concentration of that substance, i.e. with the concentration gradient; a passive transport system.
EDEMA	A condition in which the interstitial (tissue) spaces contain an excessive amount of extracellular fluid; characterized by swelling and puffiness of the tissues.
ELECTROLYTE	A substance capable of dissociating into ions and which in solution will conduct an electrical current.
HOMEOSTASIS	The maintenance of a steady state in the body, and a relatively constant concentration of ions, pH, and osmotic pressure in the various body fluids.
EXTRACELLULARY FLUID (ECF)	A solution, primarily saline (NaCl), which occupies the areas outside the cells. (“extra” = outside; “cellular” = the cells)
INTRACELLULAR FLUID (ICF)	A solution of water, electrolytes, and proteins which circulates within the cells (“intra” = inside; “cellular” = the cells)

GLOSSARY

INTERSTITIAL FLUID (ISF)	Extracellular fluid composed of water and electrolytes which circulates between and around the cells. ("inter" = between; "stitial" – spaces)
INTRAVASCULAR FLUID (IVF)	Extracellular fluid composed of water, electrolytes and proteins which is contained within the blood vessels. ("intra" = inside; "vascular" = blood vessels)
METABOLIC ACIDOSIS	A disturbance of the acid-base balance in which the body pH decreases (becomes more acidic) due to decreased blood levels of bicarbonate ions.
METABOLIC ALKALOSIS	A disturbance of the acid-base balance in which the body pH increases (becomes more alkaline) due to increased blood levels of bicarbonate ions.
ONCOTIC PRESSURE	Osmotic pressure due to the presence of plasma colloids.
OSMOSIS	The passage of water (solvent) across a semi-permeable membrane from a more dilute solution (lower solute concentration, higher water concentrations) to a more concentrated solution (higher solute concentration, lower water concentration), i.e. with the concentration gradient; a passive transport system.
OSMOTIC PRESSURE	The amount of pressure that would be required to prevent the movement of water (osmosis) across semi-permeable membrane when two solutions of different concentrations are separated by that membrane.
PASSIVE TRANSPORT	The movement of ions or molecules in the direction of the concentration gradient, thereby requiring no energy expenditure.
SEMI-PERMEABLE MEMBRANE	A membrane that only permits the passage of certain molecules and not others.
SKIN TURGOR	The degree of tension of the skin.
SOLUTE	The substance/compound that is dissolved in a solution.
SOLVENT	The liquid in which another substance (the solute) is dissolved to form a solution.

FLUID AND ELECTROLYTE BALANCE

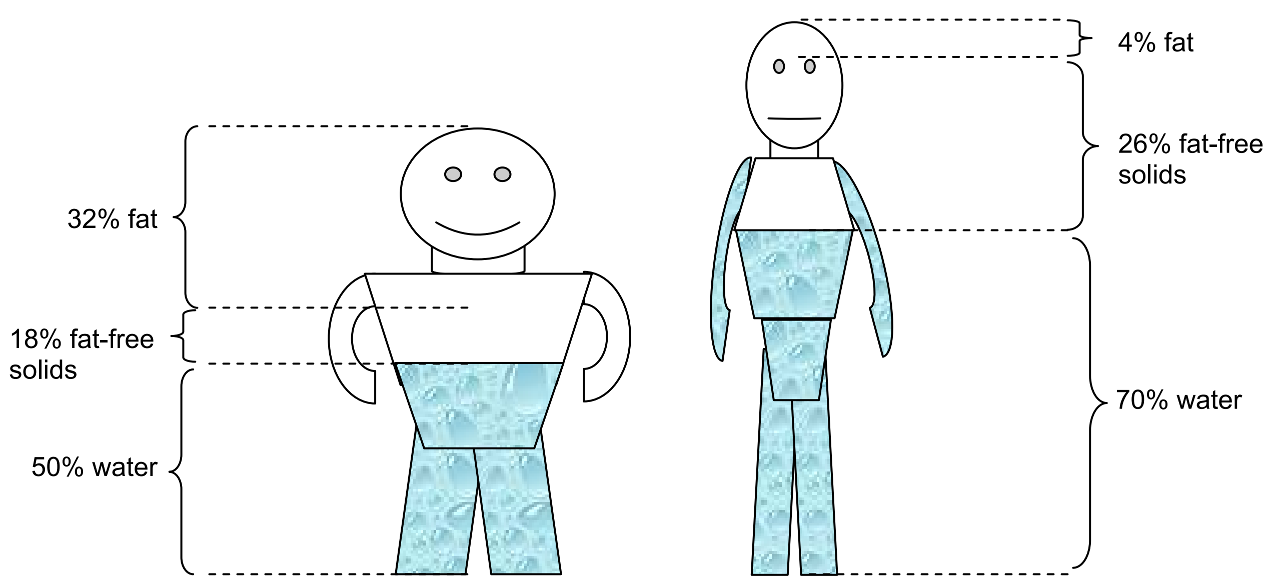
Body cells must have fluids and electrolytes available to them in order to function normally. All of the body's processes (respiration, metabolism, digestion, excretion, etc.) are affected by the volume of body fluid present as well as its specific composition, i.e. the concentrations of the various electrolytes and other solutes.
Disturbances in the fluid or the electrolyte balance may lead to cellular dysfunction and can seriously jeopardize a patient's life. These imbalances occur during many illnesses, usually due to the loss of fluids and/or electrolytes, e.g. by vomiting, diarrhea, fistulas, excessive urination, etc. Although the fluid or electrolyte imbalance itself is rarely a direct cause of death, it certainly contributes to the seriousness of an illness. It is therefore important to understand how water and electrolytes are distributed in the body, as well as the mechanisms involved in maintaining the body's normal water and electrolyte balance.

DISTRIBUTION OF BODY FLUID

Body fluid (mainly water) accounts for about 60% of the total body weight of an adult, but this varies with fat content and with age. A fat person has proportionally less body water than a thin person (Figure 1). In infants, body fluid comprises about 80% of total body weight, while in the elderly, there is a decrease in total body water (Figure 2).

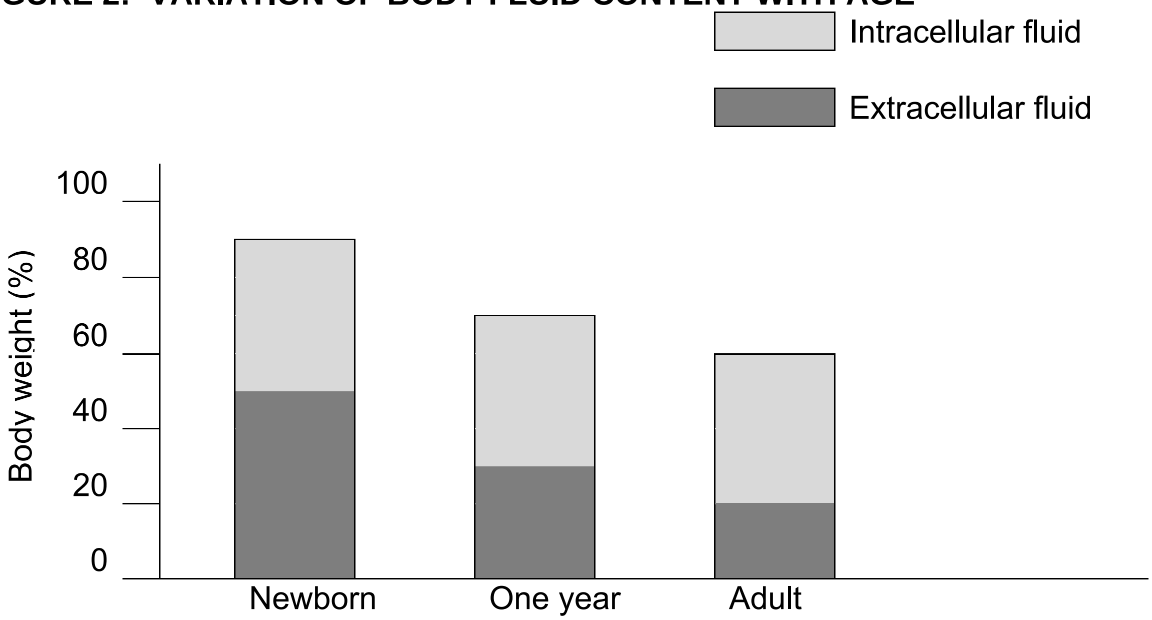
The amount of body fluid in an adult varies from 45%-75% depending on the fat content of the body. Fat tissue is essentially water-free. An obese person has the same volume of body water as a leaner person, therefore it represents a lower percentage of his total body weight. Thus, there is an inverse relationship between body water (as % of body weight) and fat content.

FIGURE 1: VARIATION OF BODY FLUID CONTENT WITH FAT CONTENT



The thin man pictured in Figure 1 contains less fat and therefore more water in proportion to his total body weight. The fat man contains proportionally less water as a percentage of his body weight because of the large amount of adipose (fat) tissue present.

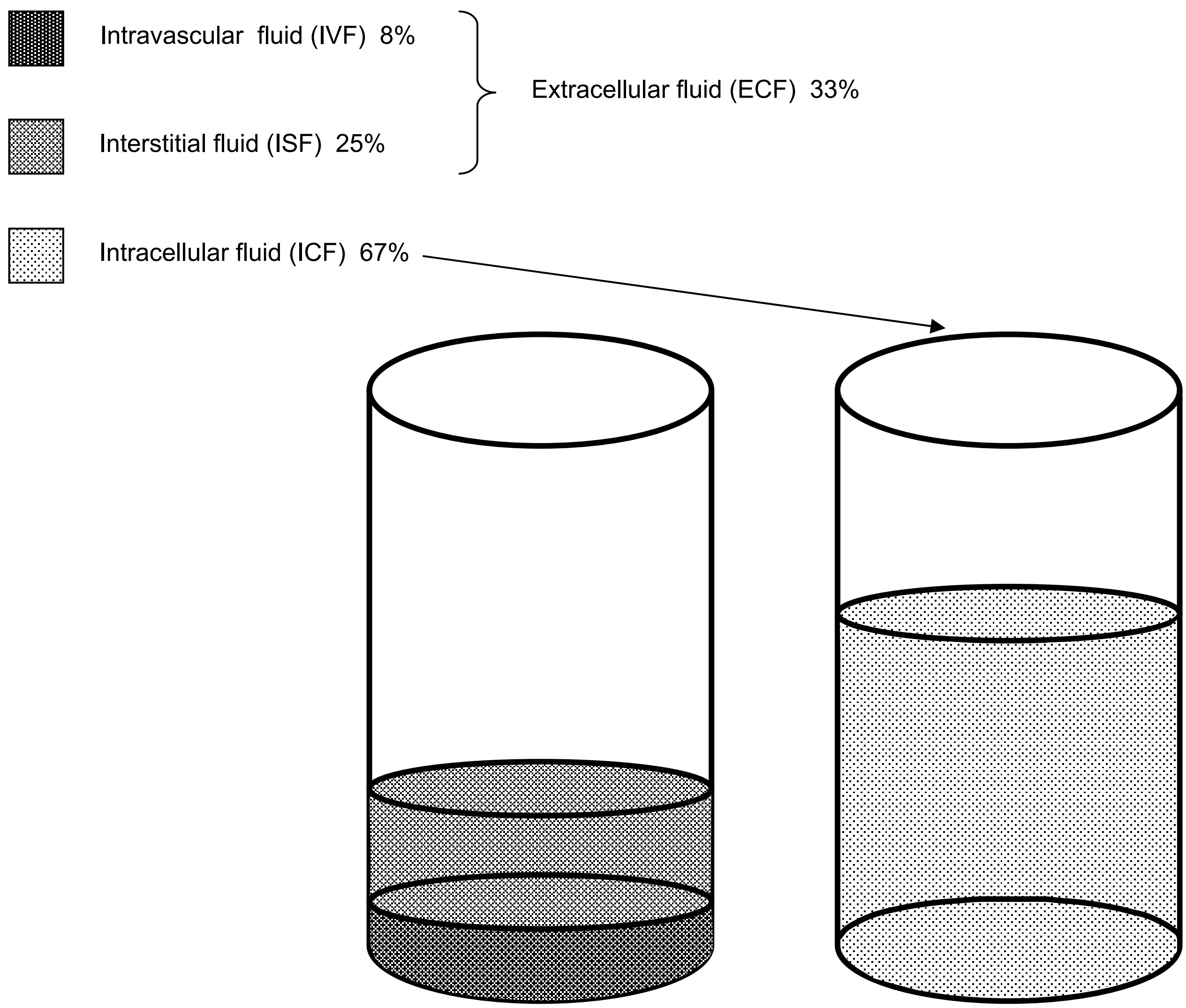
FIGURE 2: VARIATION OF BODY FLUID CONTENT WITH AGE



In the newborn, body fluid comprises about 80% of the total body weight, with more than one half of this as extracellular fluid. As the child grows, proportions and total volume gradually approximate the adult fluid distribution.

Water is found both inside and outside the cells, and is usually considered to be divided into two main "compartments"* or spaces. Of the total body water, approximately 2/3 of the water is contained inside the cells themselves. This water is collectively referred to as the **INTRACELLULAR FLUID (ICF)**, and is said to be found in the intracellular compartment.
The remaining 1/3 of total body water is distributed throughout the body as the **EXTRACELLULAR FLUID (ECF)**. This refers to all the fluid found outside the cells and is said to be located in the extracellular compartment. The extracellular fluid is further divided into two main categories. The **INTRAVASCULAR FLUID (IVF**) is that part of the extracellular fluid located within the blood vessels as blood plasma. The remainder of the extracellular fluid, referred to as the **INTERSTITIAL FLUID (ISF)**, is found between the cells and the blood vessels and in tissue spaces.

FIGURE 3: BODY FLUID COMPARTMENTS



* It is important to understand that the term "compartment" does not refer to one specific contained space, like an organ, but rather it is a convenient abstraction used to describe where fluid is found throughout the body.

The relative distribution of body fluid is summarized as follows:

- The average adult has approximately 42 liters of body water, which represents about 60% of his/her total body weight.
- Of this 60%, 40% (28 L) is present as intracellular fluid (ICF) and 20% (14 L) is present as extracellular fluid(ECF).
- The extracellular fluid can be further divided as intravascular fluid or plasma 5%, (3.5 L) and interstitial fluid, 15% (10.5 L).

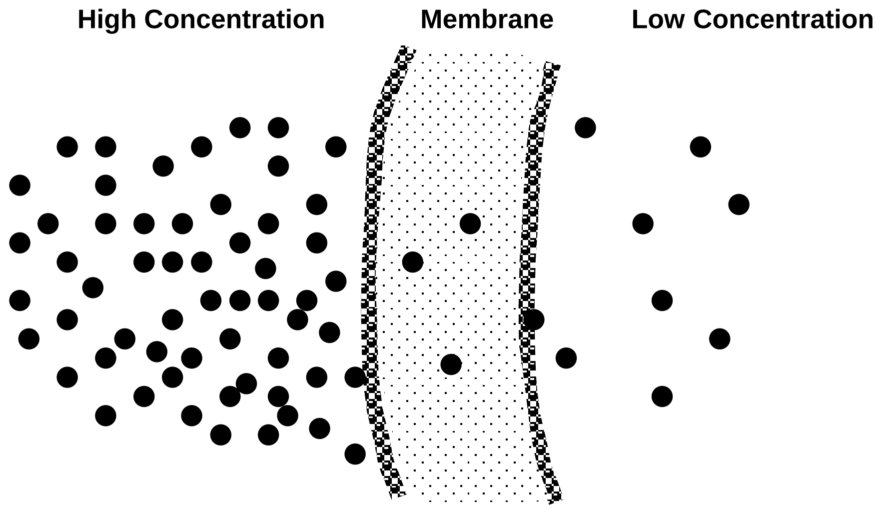
MOVEMENT OF FLUIDS AND ELECTROLYTES

The various fluid "compartments" of the body are separated by semi-permeable (or selectively-permeable) membranes. These membranes allow some molecules to pass through freely, while restricting or preventing the passage of other molecules. In health, the total volume and composition of the fluid in each compartment remains remarkably stable in spite of the fact that the water and solute molecules are in constant motion, moving from one compartment to another. There are several mechanisms by which this movement may occur.

DIFFUSION

Many solute molecules move between fluid compartments by means of simple diffusion. This term refers to the natural tendency of all substances to move about in a solution in an effort to distribute themselves evenly throughout the solution. If a membrane is permeable to a certain substance, i.e. if it allows free passage of that substance across it, then those molecules will move through the membrane in an effort to equalize their concentration on either side of the membrane.

FIGURE 4: DIFFUSION



The direction of movement in diffusion is said to be "with the concentration gradient". This means that molecules follow the natural tendency to equalize concentration by moving from an area of higher concentration to an area of lower concentration of that substance. Because it follows the "natural" direction of flow, no energy is required for simple diffusion to take place. Therefore, diffusion is referred to as a **passive transport system**.

Diffusion, then, is a general term referring to the **passive movement of any substance** from an area of higher to lower concentration of that substance. When discussing biological systems, the term diffusion is usually used loosely in reference to the movement of solute molecules. Of course, solvent molecules diffuse as well. In fact, in the human body, the majority of molecules diffusing across semi-permeable membranes are solvent molecules, e.g. water. Because the diffusion of water molecules is such an important process, it is given the special name of osmosis.

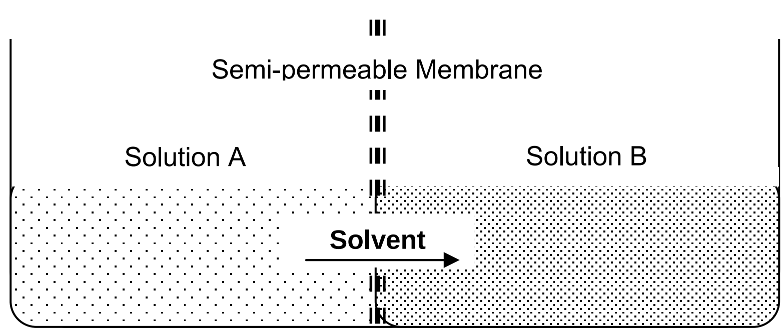
OSMOSIS

In osmosis, water moves across a semi-permeable membrane from the more dilute solution (lower solute concentration) to the more concentrated solution (higher solute concentration). It may appear at first glance that this is a contradiction of the earlier statement that diffusion is movement from an area of higher to lower concentration, i.e. with the concentration gradient. However, remember that the definition refers to the concentration of the substance that is doing the diffusing.

The process of osmosis does occur in the direction of the concentration gradient since water is moving from an area of higher concentration of water (more dilute solution; lower solute concentration) to an area of lower concentration of water (more concentrated solution; higher solute concentration). Because movement is with the concentration gradient, osmosis is also a passive transport system, i.e. no energy required. Therefore, osmosis refers specifically to the movement of water (solvent) molecules across a semi-permeable membrane from an area of higher to lower concentration of water (lower to higher concentration of solute). Osmosis is illustrated in Figures 5 and 6.

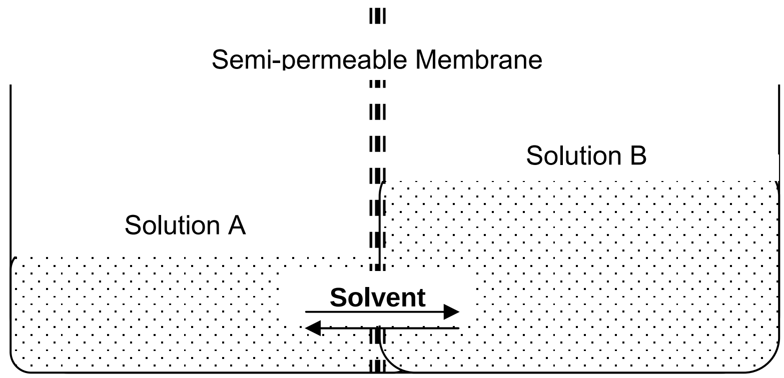
In Figure 5, solution "A" has fewer solute particles per unit volume than solution "B". Therefore, solvent molecules move from solution A to solution B. Osmosis occurs until the number of solute particles per unit volume is the same on both sides of the membrane.

FIGURE 5: OSMOSIS



The movement of solvent results in diluting the number of solute particles per unit volume in solution B. When the number of solute particles per unit volume is the same on both sides of the membrane, the movement of solvent molecules occurs equally in both directions, i.e. a dynamic equilibrium exists (Figure 6). The two solutions are said to be isotonic to each other.

FIGURE 6: TWO SOLUTIONS IN DYNAMIC EQUILIBRIUM



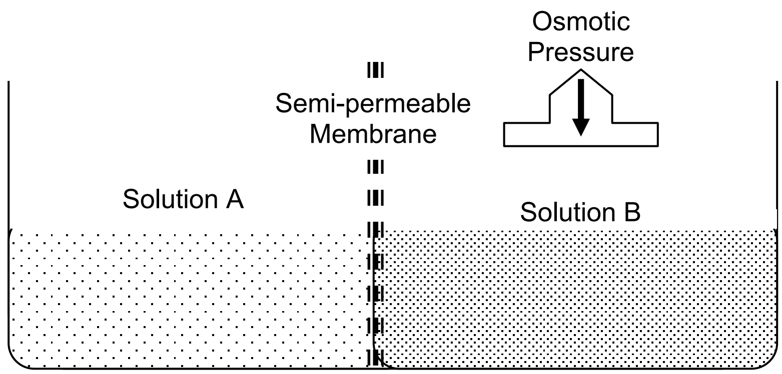
Osmosis and diffusion occur simultaneously. The processes work together in an attempt to equalize the concentrations and balance the osmotic pressures of the two solutions by moving solute out of the more concentrated solution and water out of the more dilute solution.

When two solutions of differing concentrations are separated by a semi-permeable membrane there is a 'pulling force' which draws water through to the more concentrated side, i.e. higher solute concentration. The amount of pressure that would be required to prevent this movement of water is referred to as the **OSMOTIC PRESSURE** of a solution.

The osmotic pressure is determined by the number of particles of solute on the more concentrated side, relative to the side with the lower concentration. The greater the number of particles in the concentrated solution, the more 'pull' there will be to draw the water through the membrane and therefore, the greater the pressure required to prevent that movement.

In Figure 7, solution A has fewer solute particles per unit volume (lower osmotic pressure) than solution B. Solvent will move from solution A to solution B, unless pressure is applied to solution B to prevent osmosis.

FIGURE 7: PREVENTION OF OSMOSIS BY OSMOTIC PRESSURE



The osmotic pressure due to plasma colloids (protein molecules mainly) is specifically referred to as the **COLLOIDAL OSMOTIC PRESSURE** or **ONCOTIC PRESSURE.**

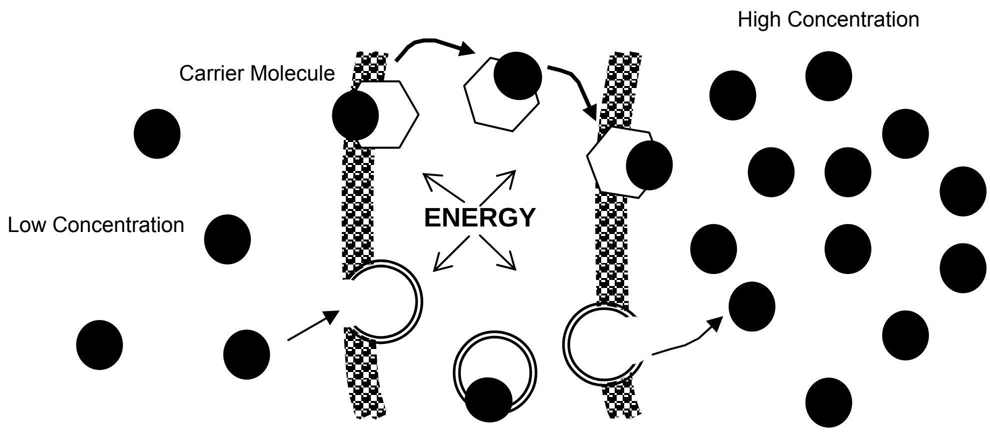
ACTIVE TRANSPORT

The processes of diffusion and osmosis follow the natural tendency of molecules or ions to move from areas of higher to areas of lower concentrations in an attempt to equalize concentrations. However, it is often necessary for the body to move substances in the opposite direction, against the concentration gradient, in order to maintain a higher concentration of a substance on one side of a membrane. The process which moves substances against the concentration gradient is referred to as **ACTIVE TRANSPORT**.

In order to move substances from an area of lower concentration to an area of higher concentration, a carrier substance* is often needed (Figure 8). For example, insulin acts as a carrier substance to transport glucose across the cell membrane, from the blood (ECF) into the cell (ICF).

Energy, in the form of adenosine triphosphate (ATP), must be expended to facilitate the transport (hence the term "active transport").

FIGURE 8: ACTIVE TRANSPORT



Therefore, active transport refers to the movement of molecules or ions from an area of lower concentration to an area of higher concentration of that substance, against the concentration gradient. Some important substances actively transported in the body include ions of sodium, potassium, chloride, hydrogen, calcium and iron, amino acids, and some sugars.

All of the processes discussed are responsible for carrying the molecules of water, foods, gases, wastes, and many kinds of ions between compartments, in and out of the body's cells. Together, they act to maintain a proper chemical and osmotic balance between the intracellular and extracellular fluids.

* The carrier molecule undergoes a structural change as it picks up the substance to be transported. This change requires energy.

FLUID LOSS

In order to maintain fluid balance in the body, the daily intake of fluids must match the daily output. The kidneys excrete the largest quantity of fluid, but fluid also leaves the body through the lungs, skin and gastrointestinal tract. Fluid is replenished in the body by ingestion of liquids and by digestion of foods.

There is a basic minimum daily requirement for fluid of **approximately 2500 mL**. In the healthy individual the total intake by all routes is equal to the total output by all routes.

Injury or disease can cause abnormal increases in water loss and seriously upset the fluid and electrolyte balance of the body. Water loss via the lungs and skin is increased in conditions causing fever or an increased respiratory rate, in hot or dry environments and in skin injuries, e.g. burns. Water loss via the kidneys is increased in conditions involving increased solute excretion such as diabetes mellitus and in conditions in which there is a decrease in antidiuretic hormone (ADH) levels. Serious water and electrolyte loss can also occur from the G.I. tract in the case of severe vomiting or diarrhea.

As previously mentioned, the total fluid volume of the average adult is approximately 42 liters - 28 liters as intracellular fluid (ICF) and 14 liters as extracellular fluid (ECF). Any change in the amount of composition of these fluids may cause serious problems. In the adult, a water loss of 5% by body weight (≈ 2 L) is considered unfavourable, a loss of 10% (≈ 4 L) is considered serious, and a loss of 20% (≈ 8 L) is usually fatal.

Infants and small children need a proportionately larger fluid intake and output in relation to adults since they have a greater body surface area in proportion to mass and an increased metabolic rate. Also, infants have immature kidneys which require proportionately more water to excrete metabolic wastes. The younger the child, the smaller his fluid reserve, and therefore the greater his vulnerability to water deficit. Volume depletion in infants and small children can also be estimated based on body weight loss. A water loss of 2-4% by body weight is considered mild, a loss of 5-9% is considered moderate, and a water loss of over 10% is considered to be severe.

Clinical vignette

1. Normal saline is used to fill the intravascular space for patients who are hypovolemic or hypotensive. Because normal saline is isotonic, it will equilibrate in both the intravascular and extravascular space. Hypovolemic patients have first lost fluid from the intravascular space. Fluid is then shifted from the extravascular space into the intravascular space in an attempt to maintain blood pressure. If necessary, intracellular fluid will shift into the extracellular space as well. In fluid resuscitation, only one third of normal saline will remain in the vascular space.

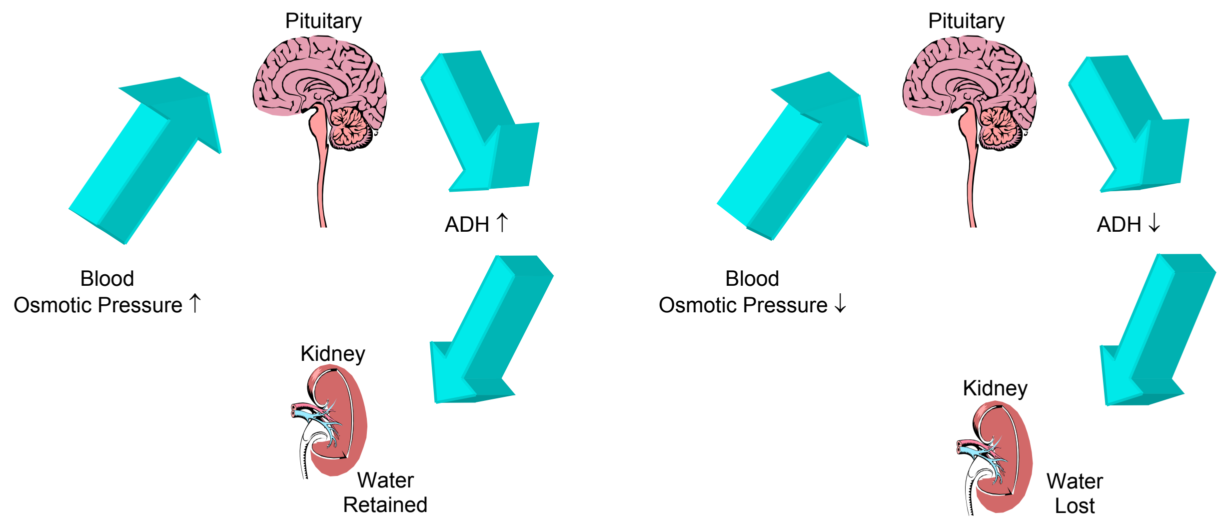
2. 5% dextrose in water (D5W) is a hypotonic solution and therefore is not held within the intravascular space. Rather it diffuses into the extravascular space where the sugar is metabolized by the cells. It is used as a vehicle for administering certain drugs and should not be used in patients who require fluid resuscitation.

ROLE OF THE KIDNEY IN FLUID MOVEMENT

More than any other organ in the body, the kidneys play a major role in regulating fluid and electrolyte balance. This balance or 'homeostasis' is maintained and restored by adjusting the output of these substances according to their intake.

When the extracellular fluid (ECF) volume is too low (due to increased loss or inadequate intake) the kidneys respond by retaining more fluid (excreting less urine). When the extracellular fluid volume is too high, the kidneys respond by excreting more urine. Exactly how this occurs can be understood by examining the effect of ADH and aldosterone on the kidney tubules, (Figures 9 and 10).

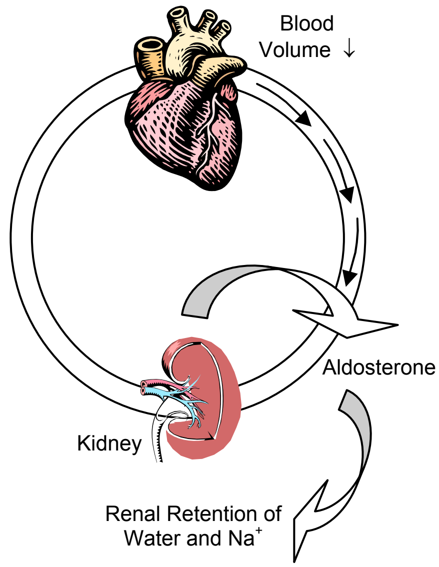
FIGURE 9: ACTION OF ADH ON THE KIDNEY



If the body is dehydrated (Figure 9A), the blood osmotic pressure increases (blood becomes more concentrated). The pituitary gland responds to high osmotic pressure by increasing its production of ADH. The more ADH that is secreted, the more water is retained.

If the body is overhydrated (Figure 9B), the blood osmotic pressure decreases (blood becomes more dilute). The pituitary gland responds to low osmotic pressure by decreasing its production of ADH. The less ADH that is secreted, the more water is lost.

FIGURE 10: ACTION OF ALDOSTERONE ON THE KIDNEY



If the body is dehydrated, there is a resultant decrease in blood volume and blood flow. This decrease in blood volume and flow is sensed by specialized cells in the kidney and results in the increased secretion of aldosterone from the adrenal glands. Aldosterone causes the kidneys to retain sodium (and with it, water) to correct the volume deficit. The reverse process occurs in the case of overhydration, resulting in the loss of sodium and water by the kidney.

CONDITIONS OF FLUID IMBALANCE

VOLUME DEPLETION

Volume depletion is the loss of water from all fluid compartments of the body. As the degree of volume depletion increases, fluid is lost first from the interstitial fluid (ISF), then the intravascular fluid (IVF; plasma), and finally from the intracellular fluid (ICF). Volume depletion usually results from either an inadequate fluid intake or an excessive fluid loss. Some of these conditions are listed in Table 1.

TABLE 1

CONDITIONS LEADING TO VOLUME DEPLETION

INADEQUATE FLUID INTAKE	EXCESSIVE FLUID LOSS
o inability to swallow o coma o unavailability of water o extreme debilitation and illness o mechanical devices and intubation	o chronic vomiting o severe diarrhea o diabetes mellitus o diabetes insipidus o kidney failure o fever o hemorrhage o hyperventilation o drainage from wounds and suctioning o burns

Two entirely different disorders can occur when one is assessing a patient with a fluid and/or electrolyte disorder:

- One is a disorder of total volume, e.g. volume overload, volume depletion
- The other is a disorder of water balance, e.g. water relative to salt, as in hyponatremia (↓Na+) or hypernatremia (↑Na+).

The diagnosis of volume status is made clinically, while the diagnosis of water balance disorders is made in a laboratory.

Dehydration is a vague term but in its strictest sense refers to a loss of water from the body.

When assessing a patient clinically we are concerned about his volume status and a patient is therefore more accurately described as being volume depleted rather than dehydrated (water depleted).

Volume depletion can be recognized by watching for changes in body temperature (increased), postural vital signs (decreased blood pressure, increased pulse rate), skin turgor, and by observing the appearance of the skin and the mucous membranes of the mouth for dryness.

Signs and symptoms of volume depletion to watch for include:

- thirst
- dry skin
- dry mucous membranes
- sunken eyes (especially in infants)
- sunken fontanel (infants)
- low grade fever
- increased pulse rate
- poor skin turgor (turgor in the skin of the forehead may be a better gauge of fluid status than the back of the hand in the elderly)
- hypotension
- altered mental status

Clinical vignette

The most reliable way of confirming volume depletion is by testing postural or orthostatic vital signs. The pulse and blood pressure are tested first with the patient in a supine position and then in an upright position. If volume depletion is present, the pulse will increase and the blood pressure will decrease when the patient is put in an upright position.

Especially susceptible to volume depletion are individuals with a relatively low proportion of total body water, such as infants, the elderly, and the obese. Volume depletion is potentially serious clinically because it involves not only a change in water balance, but a change in electrolyte balance as well (most importantly - sodium, potassium, chloride and bicarbonate).

VOLUME OVERLOAD

Edema refers to the presence of excess extracellular fluid (from plasma) in the interstitial spaces or fluid compartment. This abnormal accumulation of fluids produces noticeable swelling or "puffiness" in some tissues, particularly in the lower extremities or dependant areas of the body. By the time edema is noticeable, the adult patient will have accumulated about 4.5 kg (≈ 4.5 L) of extra fluid. Any condition which results in excessive retention of salt and water or in a decrease in plasma proteins (especially albumin) can lead to edema. In each case, excess water moves from the plasma into the tissues in an attempt to equalize the osmotic pressure. Some conditions leading to edema are listed in Table 2.

TABLE 2 CONDITIONS LEADING TO EDEMA	
<u>LOW PROTEIN LEVELS</u>	<u>EXCESSIVE FLUID/SALT RETENTION</u>
o malnutrition (↓ intake)	o heart disease e.g. congestive heart failure
o liver disease (↓ synthesis)	o kidney disease
o kidney disease (loss in urine) e.g. nephrosis	o pregnancy
o severe burns	o anti-diuretic medications

PHYSIOLOGICAL ROLES OF ELECTROLYTES

Body fluids contain two types of dissolved substances:

- those that dissociate or ionize in solution, called electrolytes, e.g. $NaCl^-$
- those that do not dissociate, called non-electrolytes, e.g. glucose

The term electrolyte refers specifically to the fact that solutions of these substances will conduct an electric current.

Each of the fluid compartments of the body has a particular composition by electrolytes which are unique to that fluid. The principal extracellular electrolytes are ions of sodium, chloride, calcium, and bicarbonate, while the principal intracellular electrolytes are ions of potassium, magnesium, and phosphates and ionized proteins. In the extracellular fluid (plasma and ISF), the main cation is sodium and the main anion is chloride. Inside the cell (ICF) the main cation is potassium and the main anion is monohydrogen phosphate. The distribution of these electrolytes is summarized in Table 3.

TABLE 3 RELATIVE DISTRIBTION OF ELECTROLYTES	
EXTRACELLULAR FLUID	
CATIONS (+)	ANIONS (-)
Sodium *Na^+	Chloride *Cl^-
Calcium Ca^{++}	Bicarbonate HCO_3-
Potassium K^+	Protein-
Magnesium Mg^{++}	Biphosphate PO_4^{2-}
	Sulphate SO_4^{2-}
	Organic acids-
INTRACELLULAR FLUID	
CATIONS (+)	ANIONS (-)
Potassium *K^+	Biphosphate *HPO_4^{2-}
Magnesium Mg^{2+}	Protein-
Sodium Na^+	Sulphate SO_4^{2-}
	Bicarbonate HCO_3-
	Chloride Cl^-
* Major or dominant anions and cations in each fluid.	

In clinical usage, the term electrolyte is used to refer to the four ions in plasma that most greatly affect water and acid-base balance (Na^+, K^+, Cl^- and HCO_3^-), and increasingly, Ca^{++}. These electrolytes profoundly influence water distribution, osmotic pressure, acid-base balance and neuromuscular irritability. Each has its own special functions in the body and although some play larger roles than others, all are necessary for the maintenance of health.

Sodium (Na^+) is the major extracellular cation and therefore plays a major role in determining extracellular fluid volume and osmotic pressure. Because it represents about 90% of all the extracellular cations, it is especially important in the transmission of electrical impulses in nerve and muscle fibers. Since sodium ions are exchanged for hydrogen ions in the acidification of the urine, sodium has a role in pH regulation. It is also involved to some degree in regulating cell membrane permeability. Excessive levels of sodium ions in the blood (hypernatremia) produce symptoms of extreme muscle irritability, dry, sticky mucous membranes, flushed skin and intense thirst; while symptoms of low blood sodium levels (hyponatremia) include lethargy, muscle weakness, edema, decreased urinary output, and mental confusion leading to coma.

Potassium (K^+) is the major intracellular cation, and it plays a major role in the regulation of muscle irritability. Potassium ions are crucial to the normal functioning of the heart muscle by allowing the muscle to contract properly and to rest properly in the diastolic phase (between contractions). K^+ is also somewhat associated with pH balance in that it is freely exchanged with hydrogen ions when the body is responding to an acid-base disturbance. Both high and low blood potassium levels are potentially threatening because of their effect on cardiac muscle. High levels of potassium in the blood (hyperkalemia) cause heart arrhythmias (progression: peaked T → flattening of the P waves → QRS widening → slowing of the heart rate, heart blocks, etc), weakening of cardiac contractility and eventually heart failure. Low blood potassium levels (hypokalemia) produce symptoms of cardiac excitability including tachycardia and ectopy (e.g. premature ventricular complexes), improper heart contractions, poor circulation, muscle cramps and eventually weakness and loss of muscle tone. Hypokalemia may also lead to cardiac arrest (usually due to anoxia created by paralysis of the respiratory muscles).

Chloride (Cl^-) is the major extracellular anion, and like sodium, plays an important role in the maintenance of extracellular fluid volume and osmotic pressure. The excretion and reabsorption of chloride ions is also related to acid-base regulation.

Calcium (Ca^{++}) is well-known for its important role in the formation of bones and teeth. It is a crucial factor in blood coagulation and in the activation of some enzymes. It also assists in the transmission of nerve impulses and the proper contraction of muscle fibers. It acts to decrease neuromuscular activity.

Bicarbonate (HCO_3^-) acts as a buffer-base in the bicarbonate/carbonic acid buffer system. This is the most important buffer in the blood and plays the key role in maintaining the body's acid-base balance. Bicarbonate ions (HCO_3^-) react with free hydrogen ions (H^+) in the body fluids to form undisassociated carbonic acid ($H_2CO_3^-$). In this way, acid (H^+) can be neutralized and carried to the kidneys for excretion. High levels of bicarbonate in the blood lead to a condition of metabolic alkalosis and symptoms of nausea, vomiting, diarrhea, confusion, irritability and agitation leading to coma. Low blood levels of bicarbonate lead to a condition of metabolic acidosis and the accompanying symptoms of headache, drowsiness, nausea, vomiting, diarrhea, stupor, and eventually, coma.

ADVANCED LIFE SUPPORT
PRECOURSE
FLUIDS AND ELECTROLYTES

SELF-ASSESSMENT

MARKS

1. Differentiate between:

[2] a) intracellular fluid (ICF) and extracellular fluid (ECF)

[2] b) intravascular fluid (IVF) and interstitial fluid (ISF)

2. Define the terms:

[1] a) osmotic pressure

[1] b) oncotic pressure.

[3] 3. Complete the following chart:

	Diffusion	Osmosis	Active Transport
Type of substance moving			
Direction of movement			
Energy requirements			

[4] 4. Fill in the blanks:

Body fluid accounts for about (a)__________________% of the total body weight of an adult. Expressed in liters, the total fluid volume of the average adult is approximately (b)_______________________(L). The amount of body fluid as a percentage of total body weight varies from person to person with (c)_____________________ and with (d) _______________________. In infants, body fluid comprises about (e) ______ % of total body water.

In disease conditions, water loss can be estimated based on percentage of body weight lost. In an adult, a fluid loss of (f) ___________ % is considered serious, and a loss of 20% is usually fatal. Infants and small children are especially susceptible to volume depletion due to their smaller fluid reserve. In an infant, a fluid loss of (g)_____________ % is considered moderate, while a loss of (h) _____________% is considered to be severe.

[1] 5. Name the two main hormones which act on the kidney to regulate fluid and electrolyte balance.

[3] 6. Define the terms:

a) dehydration

b) edema

c) volume depletion.

[2] 7. Complete the following chart:

	EXTRACELLULAR FLUID	INTRACELLULAR FLUID
Major Cation		
Major Anion		

[8] 8. State two physiological functions for each of the following:

a) sodium

b) potassium

c) chloride

d) calcium

[2] 9. State the major physiological function of bicarbonate.

[2] 10. Explain the rationale for using normal salinerather than 5% D/W for infusion on the volume-depleted patient.

30 Total

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FLUIDS AND ELECTROLYTES

SELF-ASSESSMENT ANSWERS

1. a) Intracellular fluid: The fluid which circulates inside the body's cells.

   Extracellular fluid: The fluid which circulates outside the body's cells.

   b) Intravascular fluid: The portion of extracellular fluid located within the blood vessels (blood plasma).

   Intestinal fluid: The portion of extracellular fluid found between the cells and blood vesels and in the tissue spaces.

2. a) Osmotic Pressure: The amount of pressure that would be required to prevent the movement of water (osmosis) across a semi-permeable membrane when two solutions of different concentrations are separated by that membrane.

   b) Oncotic Pressure: The osmotic pressure due specifically to the presence of plasma colloids, e.g. proteins. Also referred to as "Colloidal Osmotic Pressure".

1. (1 mark for each column correct).

	Diffusion	Osmosis	Active Transport
Type of substance moving	Molecules & ions (usually solute)	Water (solvent)	Molecules & ions (solute)
Direction of movement	With the concentration gradient; from area of higher to lower conc. Of that substance.	With the concentration gradient; from area of higher to lower conc. of water (i.e. from more dilute to more concentrated solution)	Against the concentration gradient; fram areof lower to higher conc. Of that substance.
Energy requirements	Passive process (no energy required)	Passive process (no energy required)	Active process (energy is required)

4. a) 60%
   b) 42 L
   c) age (or fat content)
   d) fat content (or age)
   e) 80%
   f) 10%
   g) 5-9%
   h) over 10%

5. antidiuretic hormone (ADH) and aldosterone.

6. a) Dehydration: A condition in which there is a net loss of water from the fluid compartments of the body.

b) Edema: A condition in which the interstitial (tissue) spaces contain an excessive amount of extracellular fluid; characterized by swelling and puffiness of the tissues.

c) Volume depletion: A clinical term, referring to findings which indicate that circulatng volume is diminished.

7.

	EXTRACELLULAR FLUID	INTRACELLULAR FLUID
Major Cation	Na^+	K^+
Major Anion		HPO_4^-

8. a) Sodium (any two of):

- maintenance of osmotic pressure and ECF volume ` transmission of nerve and muscle impulses
- pH regulation (acidification of urine)
- regulation of cell membrane permeability

b) Potassium:

- regulation of muscle irritability (especially cardiac muscle)
- pH regulation (acidification of urine)

c) Chloride:

- maintenance of osmotic pressure and ECF volume ` acid-base regulation (excretion with NH4+ ions and reabsorption alternately to HCO3- ions)

d) Calcium (any two of)

- formation of bones and teeth
- blood coagulation
- enzyme activation
- transmission of nerve impulses
- contraction of muscle fibers
- control of neuromuscular activity

9. Bicarbonate - part of the major blood buffer system, (i.e. the bicarbonate/carbonic acid buffer system)

10. More normal saline than 5% D/W stays in the intravascular space, since normal saline is isotonic and 5% D/W becomes hypotonic once the dextrose component is taken up by the cells. Fluid remaining in the intravascular space then increases the circulating volume.

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EVALUATION

Upon completion of this module, please fill in and return this form to your base hospital co-ordinator.

Your comments will help to ensure that this unit is a useful learning module. Please indicate any problems that you may have encountered. All suggestions for improvement are welcomed.

1. How long did it take to complete this module? Please estimate.

   Reading ____________ hours
   Self assessment ____________ hours
   Total time ____________ hours

2. Were the objectives of the module clearly stated?

   [ ] yes [ ] no
   If no, please comment.

3. Did you see any of the resource materials?

   [ ] yes [ ] no
   If yes, which items ______________________________
   ____
   ____
   Were they helpful? ______________________________

4. Were the reference notes adequate?

   [ ] yes [ ] no
   If no, please comment.

5. Were the reference notes easy to follow?

   [ ] yes [ ] no
   If no, please comment.

6. Were the examples provided satisfactory?

[ ] yes [ ] no

If no, please comment.

7. Were any of the self-assessment questions poorly worded?

[ ] yes [ ] no

If yes, please specify.

1. Was the level of the module satisfactory for your program of study?

[ ] yes [ ] no

If no, please comment.

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9. General comments or suggested improvements.