Maintaining a balance

Part 6: Maintaining water balance
So far in this module, you have been studying the internal mechanisms that are responsible for maintaining the balance in organisms. In this part you will move out into the external environment of organisms, to look at some adaptations they have evolved to sustain life in different ecosystems.

In this part you will have the opportunity to learn to:

- identify the role of the kidney in the excretory system of fish and mammals
- outline the role of the hormones, aldosterone and ADH (anti-diuretic hormone), in the regulation of water and salt levels in blood
- define enantiostasis as the maintenance of metabolic and physiological functions in response to variations in the environment and discuss its importance to estuarine organisms in maintaining appropriate salt concentrations
- describe adaptations of a range of terrestrial Australian plants that assist in minimising water loss.

In this part you will have the opportunity to:

- present information to outline the general use of hormone replacement therapy in people who cannot secrete aldosterone
- perform a first-hand investigation to gather information about structures in plants that assist in the conservation of water
- analyse information from secondary sources to compare and explain the differences in urine concentration of terrestrial mammals, marine fish and freshwater fish
- use available evidence to explain the relationship between the conservation of water and the production and excretion of concentrated nitrogenous wastes in a range of Australian insects and terrestrial mammals
- process and analyse information from secondary sources and use available evidence to discuss processes used by different plants for salt regulation in saline environments

In Part 5, you learnt about the functioning of the kidneys to control excretion of wastes and osmosregulation. In this part you will learn about how osmoregulation occurs due to coordination by the endocrine system (hormonal system).

Two hormones are involved in the regulation of the levels of salt and water in the body. These are:
- anti-diuretic hormone (ADH) and
- aldosterone.

**Anti-diuretic hormone**

Anti-diuretic hormone (ADH) is secreted by the posterior pituitary gland and acts mainly on the collecting tubules (collecting ducts) of the kidneys. It makes these tubules more permeable to water so that more water is reabsorbed back into the bloodstream meaning that less is lost in the urine. The result of ADH is to make urine more concentrated, since it contains less water but the same amount of urea.

If the water level in the blood is lower than normal, this is detected by the hypothalamus in the brain, which in turn stimulates the secretion of ADH. If the water level in the blood is higher than normal, the hypothalamus inhibits secretion of ADH. This is a feedback system which regulates body water levels in response to water intake and loss.
The diagram below shows the feedback system controlling the regulation of body fluid concentration by anti-diuretic hormone.

Hormonal regulation of body fluid levels by ADH.
Aldosterone

Aldosterone is secreted by the adrenal gland, which is a small structure on top of each kidney. This gland consists of two parts - the cortex and the medulla. Steroid hormones with a variety of functions are secreted by the cortex, while the medulla secretes adrenalin.

Aldosterone is a steroid hormone from the cortex of the adrenal gland and its primary function is to increase the reabsorption of sodium ions (Na\(^+\)) or potassium ions (K\(^+\)) in the loop of Henle and distal tubules of the nephron. For example, if Na\(^+\) ions are in lower than normal concentration in the blood, less sodium is excreted as these ions are moved from the nephron into the surrounding capillaries by active transport and water also moves as a result of osmosis. This increases the blood volume and so maintains blood pressure, as well as the sodium ion levels of the body fluids.

Maintenance of blood pressure is essential to the efficient transport of materials around the body and in the functioning of many organs, including the kidneys themselves. Blood pressure determines the filtration rate from the glomerulus into the Bowman’s capsule of the nephrons of the kidney.

Aldosterone secretion is also controlled by a feedback system, but this system is complicated by a number of influences on the action of the adrenal cortex, including the secretion of hormones from the pituitary. The system is much more complex than the regulation of body water involving ADH.

However, in general terms, changed secretion rates of aldosterone in response to changes in the ionic composition of the blood and/or in blood pressure act to maintain homeostatic control of blood pressure and ionic composition of the body fluids.

Do Exercise 6.1.

Adrenal cortex hormone replacement therapy

Although their incidence is not high, a number of medical conditions can affect the normal functioning of the part of the adrenal gland (the adrenal cortex) which produces the hormone aldosterone. Conditions which affect the adrenal cortex directly are relatively uncommon and functioning of this part of the adrenal gland is more often impaired by diseases or medications which affect the adrenal cortex indirectly, often through the action of the pituitary. The pituitary produces a hormone
that influences the secretion of hormones from the adrenal cortex, including aldosterone.

Addison’s disease is a disease affecting the adrenal cortex. It can be caused as a result of tuberculosis, but often appears to have an autoimmune basis. John F. Kennedy, the former president of the United States who was assassinated in 1963, had Addison’s disease. People suffering from this disease produce insufficient levels of all adrenal cortex hormones and require multiple hormone replacement therapy, including a synthetic form of aldosterone (fludrocortisone).

All of the hormones secreted by the adrenal cortex are steroids and are produced from cholesterol. They include:

• hormones which are involved with the metabolism of fats and protein to increase blood sugars and liver glycogen. They appear to be involved in coping with long-term stress in animals
• hormones involved in the control of blood pressure and body fluid composition, especially aldosterone
• certain sex hormones whose exact functions are unknown, but are probably involved in the development of secondary sexual characteristics, such as body hair in males.

Present information, in the form of a summary of the information given above, to outline the general use of hormone replacement therapy in people who cannot secrete aldosterone.

Do Exercise 6.2 now.

You now know a lot about the processes of excretion and osmoregulation in mammals, but what about other organisms?
Both plants and animals need adaptations and mechanisms for maintaining stable concentrations of water and salts.

In other animals

Consider osmoregulation in fish and other animals, and some specialised adaptations of Australian animals for conserving water.

Osmoregulation and excretion in fish

Fish use lots of water to remove wastes. You will remember that bony fish excrete mainly ammonia from their kidneys as a nitrogenous waste product. Ammonia is very soluble and very toxic, but fish avoid poisoning because they have access to plenty of water in which to dilute the ammonia and they get rid of urine very quickly from their bodies. They have no bladder to store urine and so urinate continuously.

Sharks and rays are fish that have a skeleton made of cartilage rather than bone. They excrete urea by continuous urination.

Because they live in water, you would think that fish would have no problem in regulating the level of water in their body fluids. However, if you think harder about it, you will realise that fish need to osmoregulate because their body tissues contain substances in different concentrations from their surroundings.
Saltwater fish

Fish living in salt water, in the sea or estuaries, have a higher concentration of water in their bodies than occurs in the water around them; they constantly lose water to their surroundings due to osmosis.

In the sea, water rapidly leaves the body of a fish by osmosis, especially through the membranes of the gills. The fish ‘drinks’ and takes in water with its food to replace this water loss.

You probably know that humans should not drink salt water to replace their water losses because their kidneys would not be able to get rid of the salts quickly enough to maintain normal salt balance. However, fish have special cells in the gills that can excrete excess salt back into the water by active transport. Their kidneys also excrete quite concentrated urine; that is, they excrete urine with a low water content.

Freshwater fish

Freshwater fish have the opposite problem – water is constantly taken up from the surrounding water, where the concentration of water is much higher than in the body fluids of the fish. Fish have the added disadvantage that their gills have a huge surface area in contact with the water to carry out gaseous exchange, but as a result this area also permits osmosis to occur very efficiently.

Being a fish in freshwater is a bit like being in a ‘leaky boat’; water keeps coming in, and unless you keep bailing it out you are in trouble.

Bailing it out is exactly what the fish does. Its kidneys work very efficiently to constantly produce large quantities of very dilute urine. It loses some salts in its urine in this way, but is able to take these up, even although they are in very lower concentration in the surrounding water. What is the process involved? Yes, this movement against the concentration gradient is brought about by active transport in specialised cells in their gills.

Fish that move between salt and fresh water

A number of fish species which live in Australian rivers move freely between salt and fresh water. For example, the native bass (Macquaria novemaculeata) lives mainly in the freshwater sections of the coastal rivers of eastern Australia, from Fraser Island in Queensland to Wilson’s Promontory in Victoria. It returns to the estuaries of these rivers in winter to breed.
The two native eel species also migrate between fresh and marine waters. So how do these species cope with the osmotic changes they encounter in these different environments?

The eels and bass, which move between fresh and salt environments, are capable of changing their responses to their changing environments.

The figure below summarises the responses of fish species living in freshwater (Australian bass) and in saltwater (sea mullet, *Mugil cephalus*) to enable them to cope with their osmotic environment.

Osmoregulation in fish.
Now complete these tasks.

1. What organ in fish and mammals is responsible for removing almost all nitrogenous wastes?

2. In the space below, construct a table to compare and explain the differences in urine concentration of terrestrial mammals, freshwater fish and marine (saltwater) fish.

Check your answers.
Osmoregulation in other animals

All vertebrate animals produce metabolic wastes in their livers and excrete them through the kidneys. Reptiles and birds produce their nitrogenous wastes mainly as uric acid. This is not very toxic to them because it does not dissolve well in water. It is excreted as a soft paste, which also helps species living in arid areas to reduce their water losses through their urine.

Next time you see a fresh bird dropping on something, such as a car windscreen, have a closer look at it! It will often be a mixture of white and brown material. The brown material is faeces and the white the urine, which is mainly uric acid. In birds, the digestive system (producing the faeces) and urinary system (producing urine) exit through a single opening to the outside of the body, called the cloaca.

Marine birds and reptiles can get rid of excess salts, taken in by drinking and with their food, by excreting it through active transport from salt glands situated just below their eyes.

Insects also produce uric acid as their major nitrogenous waste. It is produced in structures called fat bodies, which have some similar functions to the livers of vertebrates. The uric acid is concentrated and excreted into the digestive system by finger-like structures called Malpighian tubules.

Many species of Australian insects, such as Bull ants (Myrmecia sp) and the sand grasshopper (Urnisa guttulua) live in arid regions where reduced water loss due to the excretion of uric acid is a distinct advantage for their survival.

Bull ants (Myrmecia sp) excrete uric acid. This is an advantage in arid regions. (Photo: J West)
Adaptations for demanding environments

Over half of the Australian continent is considered to be arid. Under such dry conditions, plants and animals need to carefully balance their water gains and losses in order to maintain the level of water and salts in their tissues.

Some animal adaptations

How are Australian insects and terrestrial mammals adapted to survive in arid environments?

One important adaptation for conserving water is the production and excretion of concentrated nitrogenous wastes. Your task in Exercise 6.3 is to explain why this adaptation is valuable for a range of Australian insects and mammal species.

You will find some information in the sections you have already read within this part. You also looked at some animal adaptations to arid environments in the Preliminary course in Adaptations to the Australian environment. The relevant pages are included in the Additional resources section at the end of this part.

Read through the information provided and highlight any information that will help you to explain examples where producing and excreting concentrated nitrogenous wastes helps Australian animals to conserve water. Then present your information in Exercise 6.3.

Some plant adaptations

You looked at some plant adaptations to arid environments in the Preliminary course in Evolution of Australian biota and Adaptations to the Australian environment. The relevant pages are included in the Additional resources section at the end of this part. Read through these before continuing.

Plant adaptations to reduce water loss

Plants have many adaptations to enable them to conserve water. Many Australian plants, in particular, have evolved features that permit them to survive under dry conditions.
Some plant structures that may be specially adapted for conserving water include:

- leaf surface area
- positioning of stomates
- shape of leaves
- depth and nature of roots
- arrangement of leaves
- thickness of cuticle
- number of stomates
- colour of leaf surface.

Some of these features are shown in the diagram below.

Some plant adaptations for arid conditions.

Use information from within this part and from the Additional materials to complete Exercise 6.4.

**Your own investigation of plant adaptations**

Investigate your local environment, the nearest botanical garden, your own garden or even a local garden centre to find two species of plants which are able to grow under conditions where water is not readily available.
Common plants such as casuarinas (she-oak) and eucalypts (gum trees) are good examples. Both have waxy coverings, thick cuticles, leaves with reduced surface area and extensive root systems. Cacti are obvious examples, but if possible you should try to find native species. There are no native cacti, although some, like the prickly pear (*Opuntia* species), do occur in the wild.

Prickly pear. (Photo: J West).

Collect as much information as you can for the plants you have chosen to investigate about their adaptations for water conservation. Some features that you could observe are listed and shown on the previous page.

If you have a microscope, or access a microscope at your local school or TAFE college, you could count stomates on these species and compare the number with other species not adapted to dry areas. Or, you could count the number of stomates on the upper and lower surfaces of the leaves and compare them.

Present your information about the two plant species you study as a table in Exercise 6.5.

**Plant adaptations to saline environments**

Saline soils occur naturally in Australia, as a considerable amount of the continent was under the sea during the high sea levels between the various ice ages in the Pleistocene Period (2 million to 10000 years ago).
A number of native species of plants can cope with high levels of salt in the soil. For example, some species such as saltbushes can excrete the excess salts which they take up from the soil using special glands in their leaves.

The area affected and the extent of soil salinity has increased dramatically since European occupation of the continent for a variety of reasons, including:

- a rise in the saline water table (artesian groundwater) brought about by clearing of native salt-tolerant trees. These trees previously extracted water from the water table and kept its level lower than it is today
- irrigation water draining into the saline artesian groundwater, causing the water table to rise
- poor drainage, which also raises the level of the saline water table.

As saline water reaches the root zones of crop plants and pasture grasses, they die as they lose water from the roots by osmosis to the more saline soil (since there is a lower concentration of water outside the plant roots than inside). This is exactly the same reason that you can use salt as a weed killer around courtyards and paths.

Some crop plants, like cotton and barley, can tolerate more salty conditions than others, such as fruit trees and lucerne (alfalfa). In areas where soil salinity is a problem, some farmers have been able to switch their crops, but in other areas conditions are so salty that no plants have adaptations to cope with it.

In the Preliminary course you considered some adaptations in mangroves to regulate their internal salt concentrations. Not only do they need adaptations to survive in a highly saline environment. These salt concentrations can vary depending on the tide and the amount of fresh water coming in from the river at the head of the estuary.

Different species of mangroves have different adaptations. For example:

- most species in New South Wales exclude salt from entering the plant
- some species, including the river mangrove, are able to excrete salt through special glands in their leaves
- other species accumulate salt in various parts of the plant, such as the leaves. These leaves drop off with age and therefore the plant gets rid of the accumulated salt.
Write your own outline about processes used by different plants for salt regulation in saline environments.

Adaptations for changing environments

Organisms need adaptations to be able to survive in a changing environment. These changes may be natural variations, such as the changing salt concentrations in estuaries that you considered when you read about adaptations of estuarine fish and mangroves. Environments also change as a result of human activity.

Many organisms are able to maintain a stable internal environment despite changes in external conditions. This is the process called

Salt crystals on the leaves of the river mangrove. (Photo: J West)
homeostasis. But not all organisms can do this completely. The process in such organisms is called enantiostasis.

**What is enantiostasis?**

Although you will have trouble finding the word enantiostasis in any dictionary of biology or first year university textbook, it is used in the syllabus and is defined as:

‘the maintenance of metabolic and physiological functions in response to variations in the environment’.

Extract from *Biology Stage 6 Syllabus 1999* © Board of Studies NSW, originally issued 1999.

In other words, enantiostasis seems to embrace the whole range of adaptations that you have already considered, by which organisms control their internal environments.

Most of the adaptations you have examined have been in organisms that closely regulate their internal environments with respect to their external surroundings. These organisms are often called regulators and the processes they use to maintain stable internal conditions are collectively known as homeostasis:

‘the tendency in an organism towards maintenance of physiological stability’


You may think that there does not seem to be much difference between homeostasis and enantiostasis. You are right!

However, there are a large number of organisms, particularly invertebrate animals and many plants, which tend not to maintain their internal environment at a different level from that of their external environment.

The internal environments of these organisms vary pretty much in line with changes in their surroundings. These organisms are often referred to as conformers rather than regulators. It is a fine distinction, but presumably enantiostasis has been included in the biology syllabus to include these organisms which do not maintain complete homeostasis.

You should learn the definitions of both homeostasis and enantiostasis and understand that all organisms respond to changes in their external environment (that is, carry out enantiostasis) but some organisms do not necessarily tend to maintain stability in their internal environments; that is, not all organisms carry out homeostasis.
So why is the effect of urban development on estuarine communities important? Could Australia do without mangrove ‘swamps’, ‘squishy’ salt marshes and muddy estuaries?

Finally, complete Exercise 6.6.

You have now reached the end of the module. There are many difficult concepts covered in this topic and if you have time, revise some of the concepts before going on.
### Osmoregulation and excretion in fish

1. kidneys

2. Here is an example of a suitable table.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Main wastes in urine</th>
<th>Concentration of urine</th>
<th>Reason(s) for urine concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>mammal</td>
<td>urea, salts and water</td>
<td>dilute to relatively concentrated</td>
<td>urea is not very toxic; water is needed to wash wastes out of body</td>
</tr>
<tr>
<td>freshwater fish</td>
<td>ammonia, water</td>
<td>dilute urine</td>
<td>urine very dilute because of large amounts of water being excreted</td>
</tr>
<tr>
<td>saltwater fish</td>
<td>ammonia, salts</td>
<td>concentrated urine; salts in gills remove most salt</td>
<td>urine must be concentrated to reduce water loss; urine released continuously to reduce toxic effect of ammonia</td>
</tr>
</tbody>
</table>
This section contains extracts from the Preliminary modules called Evolution of Australian biota and Adaptations to the Australian environment.

Introduction

The concentrations of salts and water within the cells and bodies of many living organisms is regulated very precisely. Changes brought about by dehydration or an imbalance of salts (ions) within the cells can quickly lead to the death of an organism. The regulation of water and salts in the body is called osmoregulation.

On land the air is very dry, especially in arid areas and in places where high temperatures and wind greatly increase evaporation. For plants, which must take up CO₂ through their stomates for photosynthesis, water loss can be a severe problem. Terrestrial animals also rapidly lose water to their surrounding environment. This is a problem in birds and mammals which normally use evaporation of water to keep their body temperatures constant in hot environments.

Mammals and birds closely control the losses and gains of water by utilising a variety of adaptations. Drinking water is the main way that species gain water, but they can also obtain water in their food (e.g., fleshy fruits) and some can use metabolic water which is produced during cellular respiration. You should remember the overall equation for respiration.

\[
glucose + oxygen \rightarrow carbon dioxide + water + energy
\]

There are many ways in which water losses can be minimised, including seeking shade to reduce the need to evaporate water for cooling. Reabsorption of water by the kidneys produces more concentrated urine, so that less water is excreted from the body.
Birds, reptiles and insects reduce the amount of water they lose in their urine by excreting a waste product called uric acid, which, unlike the urea excreted by mammals, does not have to be dissolved in water.

Some species, such as the camel, red kangaroo and desert rats and mice, also have cooling structures in their nasal passages. These cause some of the moisture, normally lost when breathing out, to condense and be reabsorbed back into the bloodstream.

**Some animal adaptations for maintaining water balance**

Here is information about adaptations of a common Australian mammal.

**The red kangaroo**

The red kangaroo (*Macropus rufus*) occupies the central and central western areas of Australia. In other words, it lives in an area where summer temperatures are very high and winter temperatures can be below freezing, while rainfall is very low at most times of the year.

**Regulating body temperature**

Once the external temperature is high enough to equal the body temperature of an animal, the only way that the animal can get rid of heat produced by its own metabolic processes is to carry out evaporative cooling by sweating or panting.

You will remember that birds and mammals living in hot dry conditions keep their body temperature constant by evaporating water through sweating or panting. However, they need to balance the water they use in this evaporative cooling against their water intake to maintain regulation of their body fluids (osmoregulation).

In central Australia in the hottest summer temperatures, a red kangaroo lying in the direct sunlight in the middle of the day would need to evaporate around four litres of water per hour to regulate its body temperature. This means that after a couple of hours in the sun it would need to drink eight full litres of water just to keep its body water at a constant level.

Red kangaroos only usually need to drink about every five days and so the species obviously has adaptations which permit it to balance its heat
loss and regulation of body water under such severe conditions. Let’s have a look at how it does it.

As discussed before, water loss has to be balanced by water gain and heat loss to heat gain if the kangaroo is to keep its body temperature and body water levels constant. The animal gains heat from the environment (mainly heat from the sun) and from its own metabolism, including extra heat generated during exercise.

At rest the red kangaroo loses heat by panting. This consists of shallow and rapid breathing passing air over the membranes of the nasal passages. Increased blood flow in vessels supplying these membranes permits a great deal of heat to be lost by evaporation. Sweating is not as efficient a way of losing heat as panting, but the red kangaroo also sweats to lose heat if it needs to exercise during the hot periods of the day.

The kangaroos also have a mass of small blood vessels under the skin on its forelimbs. The kangaroo spreads saliva on its forelimbs and evaporation results in heat loss from these blood vessels. Remember that heat loss is the same as cooling. When you pick up a can of drink out of the fridge it feels cold because your hand is losing heat to the cold can.

**Water balance**

This seems good so far – the kangaroo can get rid of excess heat by panting, spreading saliva and by sweating if necessary – but what about the water it loses in these processes, when it only gets to drink every five days or so? The red kangaroo has other strategies to reduce water losses.

A kangaroo’s kidneys reabsorb a great deal of water, so that its urine is very concentrated and it urinates quite infrequently during hot times. Water is also very efficiently reabsorbed by the large intestine, resulting in very little water being lost in the dry faeces.

You have possibly also heard the saying that mad dogs and Englishmen go out in the midday sun, relating to the times when settlers and explorers moved around in the hottest parts of the day in tropical areas, whereas most indigenous people avoided those parts of the day by seeking shade. The red kangaroo does the same as these indigenous people, seeking out even the slightest shade provided by low shrubs or trees in its environment. It also only moves around in the middle of the day if it really has to, as exercise means the production of more body heat, which must be got rid of by evaporating water.

The red kangaroo then is very well adapted in these ways for living in hot, dry conditions. However, it should be noted that these strategies are not just found in this species. In Australia, other kangaroo and wallaby species, small mammals and birds from dry areas have similar
adaptations, as do animals such as camels, jack rabbits and prairie dogs living in desert conditions in other parts of the world.

Red kangaroos increase heat losses by evaporative cooling by: panting (at rest); sweating (during exercise); and saliva spreading (at rest).

Red kangaroos decrease in heat gain or heat production by: seeking shade and avoiding exercise.

Water conservation adaptations of red kangaroos include: concentrated urine and dried faeces.

The Spinifex hopping mouse

The Spinifex hopping-mouse (Notomys alexis) lives in the deserts of Central Australia. Rainfall is sporadic in the region but the hopping mouse has many adaptations for survival. Water is at premium and free water is rarely available. The Spinifex hopping mouse never drinks and does not have sweat glands. It gets water from the breakdown of starch in its food. Its waste products are extremely concentrated. The faeces are dry and the urine is the most concentrated of any mammal. Mothers produce concentrated milk and even consume the urine of their babies.

His animal conserves water in many ways and this includes the excretion of concentrated nitrogenous wastes.

There are many different species of animals that use the same techniques as the Spinifex hopping mouse including the Bilby and the Mulgara (Dasycercus cristicauda).

Australian plant adaptations

Like animals, plants must also balance their loss of water against that which they take up through their roots. They must evaporate water in hot conditions to keep their leaves cool and to keep water flowing in the xylem so that it can be transported to the leaves to be used in photosynthesis.

As discussed earlier, there are a number of strategies which plants adopt to conserve water, so that they have to take up less from the environment to maintain their body water levels. Below are descriptions of two examples of native Australian species which are adapted to living in arid conditions.

Mulga – a shrubland survivor

Mulga is a type of tall shrub which is found in the shrubland areas of Australia. It makes use of any rain which may fall by having its leaves
arranged so that they catch the falling rain and direct it to the base of the tree, where there are plenty of roots to absorb it.

As well as this adaptation, the roots of the mulga are very long, shallow and spreading, permitting the absorption of as much available water as possible.

These two adaptations increase water gain, but the plant also has strategies for conserving this scarce water. Its leaves have an extremely thick cuticle to reduce the loss of water from the leaf surfaces and its stomates close for longer periods of time each day, especially in the middle of the day when it is hotter, as drought conditions increase. As a result of this, very little water is lost from the species during drought periods. Obviously it must have its stomates open long enough to collect enough carbon dioxide for its photosynthesis, but this aspect of the biology of the species has not been investigated.

**Porcupine grass – a desert grass**

As this native tussock grass often grows in sandy soils, it also has shallow and widely spread roots near the surface to quickly absorb any available rainfall.

The long, narrow leaves of the grass are rolled and the stomates are found at the bottom of pits inside the rolled surface. The diagram following shows the arrangement of these.
The rolling of leaves and sinking of stomates in pits means that a high humidity is maintained around the openings of the stomates and the effects of wind around the stomates is reduced.

You probably remember that high humidity reduces evaporation. This is the main reason that you feel uncomfortable on a hot humid day. The water in your sweat is not evaporating as quickly as it would on a dry day and so your evaporative cooling is not working as well as it should.

Maintaining humidity around the openings of the stomates reduces water loss in this way. It probably means that the porcupine grass also is a bit hotter than it would have been if it hadn’t rolled its leaves, but at least it is conserving water. Its light, shiny leaf surfaces also help here as they reflect a lot of the heat from the sun.

The table below summarises the adaptations which have occurred during evolution of these two native Australian species, permitting them to survive under arid conditions in the grassland areas of Australia. You need to note once more that similar adaptations are also found in dry area grasses and shrubs in other parts of the world.
Summary of adaptations of mulga and porcupine grass plants to hot arid conditions

<table>
<thead>
<tr>
<th>Adaptation to:</th>
<th>Porcupine grass</th>
<th>Mulga shrub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase water gain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• wide expanse of roots</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• leaves direct rainfall to the base of the plant</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>Decrease water loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• impermeable thick waxy cuticle</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• light coloured surface reflects heat</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>• leaves rolled reduce evaporation</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>• stomates sunk in pits reduce evaporation</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>• reduce stomate opening during drought periods</td>
<td>−</td>
<td>+</td>
</tr>
</tbody>
</table>

+ indicates adaptation present
− indicates adaptation either not found or not identified.
Exercises Part 6

Exercises 6.1 to 6.6  Name: _________________________________

Exercise 6.1: Anti-diuretic hormone and aldosterone

Outline the role of the hormones aldosterone and ADH in the regulation of water and salt levels in blood.

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Exercise 6.2: Adrenal cortex hormone replacement therapy

Consider the following chain of events in terms of your understanding of the involvement of the kidneys and hormonal system in the regulation of salt and water balance in a mammal.

Sam is working in the garden on a hot dry summer’s day. She is sweating a lot, which is regulating her body temperature, but she notices that she is also losing water and salts from her body in sweat. Although she has been drinking some water, she has not had to urinate (go to the toilet to release urine) all day. When she finally urinates at the end of the day, she notices that her urine is quite dark in colour.
a) Explain why Sam has not needed to urinate during the day.

b) Why is Sam’s urine a darker colour when eventually she urinates?

c) Describe what could be the result of such heavy work in the heat over a number of days and if Sam does not drink much water in that time.

d) Now imagine that Sam has the disease called Addison’s disease.
   i Name the hormone that Sam would need to treat her disease.
   ii How would she obtain this hormone?
   iii Discuss why treatment with this hormone is important for Sam. (How does it help her? Find out, if you can, if it does any harm.)
Exercise 6.3: Animal adaptations

Explain the relationship between the conservation of water and the production and excretion of concentrated nitrogenous wastes in a range of Australian insects and terrestrial mammals. (You do not have to use all the lines provided.)
Exercise 6.4: Plant adaptations to reduce water loss

Describe some adaptations of a range of terrestrial Australian plants that assist in minimising water loss. (You do not have to use all the lines provided.)
Exercise 6.5: Your own investigation of plant adaptations

Construct a table to present information you have collected about some structures of two plants that assist in the conservation of water. Use the list of features in the materials. Consider any risks that you may encounter while doing this first hand investigation and let your teacher know how you would overcome these.

Exercise 6.6: Adaptations for changing environments

a) Define enantiostasis.

b) Why does a mangrove need to carry out enantiostasis?