Study session 1

The endocrine system – structure and function

Objectives

On completion of this study session you should be able to:

- list the endocrine glands and describe their main functions, both as individual glands and as part of an interrelated endocrine system.

In this programme we are comparing the endocrine system to a juggling show. When you’re learning to juggle you start with one ball and add more as you build your confidence. We’re going to do the same by building up your knowledge of each gland before putting the whole endocrine system together.

Now that you’ve worked through the first exercise you should have a basic outline of the endocrine system. Let’s have a look at the individual glands in more detail.

We’re not trying to provide you with a textbook on the endocrine system. Instead, we will be considering the way that endocrine disorders may appear in pharmacy practice and encourage you to think about the way you can support people who are living with these disorders.

So we’re starting with some basic revision – giving you the key points as we see them for the different endocrine glands. If you would like more detail, then refer to the key references that are mentioned throughout the programme.

Basic terminology

The letters ‘RH’ in a hormone acronym stand for releasing hormone. A releasing hormone stimulates the release of the relevant hormones. For example, growth hormone-releasing hormone (GHRH) stimulates the release of human growth hormone, while gonadotropin-releasing hormone (GnRH) stimulates the release of follicle-stimulating hormone and lutenising hormone.

The letters ‘IH’ in a hormone acronym stand for inhibiting hormone. An inhibiting hormone inhibits the release of the relevant hormones. For example, prolactin-inhibiting hormone (PIH) inhibits the release of prolactin.

Hormones whose names end in ‘trophic’, ‘tropic’ or ‘tropin’ are hormones that only target other endocrine glands.

The letters ‘SH’ in a hormone acronym stand for stimulating hormone, for example, thyroid stimulating hormone (TSH) stimulates the thyroid gland.
1.1 The hypothalamus

The hypothalamus is located in the brain and is considered to be the ultimate ‘master gland’ of the endocrine system. It links the autonomic nervous system and the endocrine system to keep the body in equilibrium.

It is largely responsible for regulating:
- growth and development
- body temperature
- hunger and thirst
- sexual behaviour
- defensive reactions such as fear and anger.

It exerts its endocrine effect by controlling the pituitary gland.

Endocrine hormones are generally released directly into the fluid surrounding the secretory cells in the glands and are carried to their target tissues in the bloodstream. However, the hypothalamus is connected to the pituitary gland by a portal system which enables the hypothalamic hormones to be delivered directly (and quickly) to the pituitary gland.

The hypothalamus achieves control with five releasing hormones and two inhibiting hormones. The sole role of these hormones is to control the pituitary gland.

The releasing hormones are:
- growth hormone-releasing hormone (GHRH)
- thyrotropin-releasing hormone (TRH)
- gonadotropin-releasing hormone (GnRH)
- prolactin-releasing hormone (PRH)
- corticotropin-releasing hormone (CRH).

The inhibiting hormones are:
- growth hormone-inhibiting hormone (GHIH)
- prolactin-inhibiting hormone (PIH).

It also synthesises two other hormones:
- oxytocin (OT)
- antidiuretic hormone (ADH).
Exercise 2

Let’s start our juggling analogy. You’ve now got the first ‘ball’: an overview of the ‘control’ gland, the hypothalamus.

a. The hypothalamus regulates homeostasis by using a combination of nerve impulses and endocrine hormones. What do you think might be the main differences between using nerve impulses and endocrine hormones to regulate homeostasis?

b. Select words from the pile to make up the names of the hypothalamic hormones. You may use some words more than once and others not at all.

<table>
<thead>
<tr>
<th>Releasing hormones</th>
<th>Inhibiting hormones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>Inhibin</td>
</tr>
<tr>
<td>Lutenising</td>
<td>Hormone</td>
</tr>
<tr>
<td>Thyrotropin</td>
<td>Inhibiting Follicle</td>
</tr>
<tr>
<td>Releasing</td>
<td>Thyroid</td>
</tr>
<tr>
<td>Prolactin</td>
<td>Relaxin</td>
</tr>
<tr>
<td>Human</td>
<td>Glucagon</td>
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<tr>
<td>Adrenocorticotropic</td>
<td>Corticotropin</td>
</tr>
<tr>
<td>Mineralocorticoid</td>
<td></td>
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</tbody>
</table>

Turn to the end of the study session for suggested answers.
1.2 The pituitary gland

The pituitary gland responds directly to hormones produced by the hypothalamus, so it largely regulates the same functions. It also plays a role in regulating the body’s fluid levels and milk production, and childbirth in women. The pituitary gland exerts its effects by releasing seven hormones that mainly target other endocrine glands such as the thyroid, ovaries or testes, and the adrenal glands. However, it also secretes hormones that target tissues in the liver, mammary glands and brain.

The seven anterior pituitary hormones are:

- human growth hormone (hGH) – targets cells throughout the body
- thyroid-stimulating hormone (TSH) – targets the thyroid gland
- adrenocorticotropic hormone (ACTH) – targets the adrenal glands
- follicle-stimulating hormone (FSH) – targets the ovaries and testes
- lutenising hormone (LH) – targets the ovaries and testes
- prolactin (PRL) – targets the mammary glands; regulates lactation in conjunction with estrogens, progestogens, hGH and OT
- melanocyte-stimulating hormone (MSH) – targets the brain; may affect brain activity but its role is poorly understood; very high levels cause skin pigmentation.

Two of the posterior pituitary hormones are:

- antidiuretic hormone (ADH) – targets the kidneys, sweat glands, arterioles; maintains blood volume by decreasing water loss through urination and sweating
- oxytocin (OT) – targets the uterus and mammary glands; promotes uterine contractions during labour; promotes milk delivery (let down) from the mammary glands; in men and non-pregnant women it may promote parental behaviour and mediate the sexual pleasure response.

In focus: Human growth hormone

Human growth hormone (hGH) has a profound effect on a wide range of body systems. It is the most abundant anterior pituitary hormone and targets numerous tissues including the liver, muscle, cartilage and bone in order to promote growth. Cells respond by producing and releasing insulin-like growth factors (IGFs) which cause cells to grow and multiply. IGFs also increase the rate of protein synthesis and reduce the rate of protein breakdown. In children and adolescents this promotes the growth of bones and skeletal muscle; in adults it helps to maintain muscle and bone mass, as well as promoting healing and repair.

The growth factors released by hGH also affect the metabolism of lipids and carbohydrates which, in turn, may affect glucose regulation.

Exercise 3

So now you have added the second ‘ball’: the pituitary gland. Let’s see how you get on with ‘juggling’ these two glands: the hypothalamus and the pituitary.

a. Spike is a teenager. Everyone says he’s had a growth spurt recently. What sequence of hypothalamic and pituitary hormones do you think was involved?
b. Stuart has had a sperm test. The results were normal. What sequence of hypothalamic and pituitary hormones do you think was involved?

## Memory Test

Here in random order are the acronyms for a selection of hypothalamic and pituitary hormones. Can you write them out in full?

- GHRH
- TSH
- OT
- GnRH
- ACTH
- PRH
- hGH
- FSH
- LH
- PRL
- ADH

*Turn to the end of the study session for suggested answers.*

*Turn to the end of the study session for the answers.*
1.3 The pineal gland

FIGURE 3 The pineal gland

The pineal gland releases melatonin in response to sunlight and darkness. Because of this, it is believed to have a role in controlling circadian rhythm.

Melatonin is believed to set the body clock. It is also a powerful antioxidant. However, its role is not fully understood.

What we do know is that high levels of melatonin tend to promote sleepiness, and that levels increase greatly during sleep and drop just before waking. Melatonin levels also decline with age.

Exercise 5

Mavis works night shifts at her local supermarket. At first she really struggled: some nights she could barely stay awake. But when she got home in the morning she couldn’t sleep at all, despite being tired after work.

What might be happening to Mavis’s endocrine system?

Turn to the end of the study session for suggested answers.
1.4 Feedback and other control mechanisms

Now that we’ve explored some of the major endocrine glands let’s look at how the endocrine system regulates itself. Endocrine glands tend to release their hormones in short spurts. When the gland is stimulated it increases the frequency of these spurts in order to increase the levels of hormone in the blood.

As we’ve already seen, endocrine glands may be stimulated by a number of factors:

- the presence of releasing or stimulating hormones from other endocrine glands
- environmental factors such as heat, cold, stress and physical exertion
- internal factors such as changes in blood lipid, glucose or electrolyte levels
- positive feedback mechanisms – where the outcome of the hormone’s activity actually promotes further secretion.

But once an endocrine gland has been stimulated, how does it know when to stop? There are a number of feedback mechanisms that will trigger a reduction in the release of a particular hormone:

- the presence of inhibiting hormones from other endocrine glands
- changes in environmental factors
- changes (usually back to normal) of internal factors such as changes in blood lipid, glucose or electrolyte levels
- negative feedback mechanisms – where the presence of high levels of hormone caused by the stimulation are detected and actually cause production to slow down.

Sensitivity of the target tissue may also influence the extent to which endocrine hormones can exert their effects. Endocrine hormones are able to exert an effect on their target tissues because they link to the appropriate receptors. In the presence of large quantities of hormone, the number of receptors tends to decrease, making the target tissue less sensitive. This is called down-regulation. However, the opposite is also true, so that when there is a deficiency of a particular hormone, the target tissue creates more receptors, making it more sensitive. This is called up-regulation.
1.5 The thyroid gland

FIGURE 4 The thyroid gland

- The thyroid gland releases three hormones: triiodothyronine (T3), thyroxine (T4) and calcitonin (CT).
- It synthesises and stores enough T3 and T4 to last up to 100 days. (It is the only endocrine gland that stores such a large quantity of its hormones.)
- Calcitonin is released directly from the thyroid gland in response to changes in blood calcium levels.
- T3 and T4 are regulated via a negative feedback mechanism mediated by the hypothalamus.
- High levels of iodine in the blood also inhibit the release of thyroid hormones.
- T3 has three iodine atoms and T4 has four. Once T4 reaches its target cells it is converted into T3, so both hormones exert the same effect on the body: they increase basal metabolic rate. When the metabolic rate increases, cells give off heat and body temperature increases. Therefore, T3 and T4 have a vital role in regulating body temperature.
- The gland is stimulated by factors that increase the body’s energy demand, eg, low external temperature, low blood sugar, pregnancy and by high altitude.
- T3 and T4 increase the use of glucose and lipids to produce energy. They also reduce blood cholesterol levels. The thyroid hormones, in conjunction with hGH and insulin, also promote body growth, particularly in the nervous and skeletal systems.
- The thyroid hormones increase the effects of some of the stimulant adrenal hormones.
- Calcitonin reduces the blood calcium and phosphate levels by reducing the rate of calcium release from bone tissue. It also increases the uptake of calcium and phosphates into the bone. It works closely with the parathyroid hormones, so we’ll be revisiting this hormone in the next study session.
- The release of calcitonin is inhibited by low levels of calcium in the blood.

Exercise 6

So, we now have four ‘balls’ in the air – let’s juggle!

a. Sandra went to Wimbledon to watch the tennis and got drenched by a sudden thunderstorm. She’s now wet and cold. How might Sandra’s endocrine system respond?
b. Bav is starting a trek up to the Everest base camp as part of his gap-year adventures. How might his endocrine system respond?

Exercise 7
Hormone stacks
Move these hormones to the relevant gland:

<table>
<thead>
<tr>
<th>GHRH</th>
<th>TSH</th>
<th>GnRH</th>
<th>ACTH</th>
<th>T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>hGH</td>
<td>T4</td>
<td>PRL</td>
<td>TRH</td>
<td>CT</td>
</tr>
</tbody>
</table>

Turn to the end of the study session for the answers.
The parathyroid glands play a major role in regulating blood calcium levels. They also affect the regulation of blood magnesium and phosphate levels.

The parathyroid glands release one hormone: parathyroid hormone (PTH). The release is controlled directly by changes in the levels of calcium in the blood: low blood calcium levels stimulate the release of parathyroid hormones; high blood calcium levels inhibit their release. The hypothalamus and anterior pituitary do not regulate the release of parathyroid hormone.

Parathyroid hormone increases the activity of osteoclasts—the bone cells that break down the bone matrix to release calcium into the bloodstream. So when blood calcium levels are low the parathyroid glands release PTH. This stimulates osteoclast activity to release calcium from the bone matrix into the bloodstream. As the blood calcium level increases, the release of PTH is inhibited and osteoclast activity goes back to ‘normal’.

During bone resorption, phosphate is also released into the bloodstream. Parathyroid hormone decreases the rate at which the calcium and magnesium are transferred from the blood into the urine. However, it significantly increases the rate at which phosphate is transferred from the blood into the urine. The rate of phosphate excretion exceeds the rate of phosphate release by PTH.

Parathyroid hormone promotes the formation of calcitriol by the kidneys (the active form of vitamin D). This increases the absorption of dietary calcium, phosphate and magnesium from the gastrointestinal tract into the bloodstream.
Exercise 8

We now have five ‘balls’ in the air – how are you doing? Let’s try a few exercises.

Mary’s mum has been nagging her about the state of her fingernails: ‘Just look at those white spots – you’re not getting enough calcium. I know that you don’t eat properly, it’s no use pretending.’

‘Load of rubbish,’ retorts Mary as her mum retreats to the fridge. ‘You’re so behind the times.’

‘I may not have your education,’ says her mum, unconcernedly, ‘but I do know how to feed a body! Here’s a glass of milk and a cheese sandwich – we’ll soon fix your nails.’

a. If Mary’s blood calcium levels are low, how will her endocrine system help her to make the best of the dietary calcium being provided by her mum?

_________________________________________

b. If Mary’s blood calcium levels are fine, what effect might her calcium-rich meal have on her blood calcium levels?

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c. Calcitonin and parathyroid hormone both regulate calcium levels by affecting the activity of osteoclasts in bone tissue. What effect does calcitonin have on osteoclast activity?

_________________________________________

_________________________________________
Exercise 9

Penny yells at her dad to stay upstairs as she wades through the scummy brown water that has flooded her living room. She is worried that he might pick up a bug from the water – after all, he is 75.

a. What part does the endocrine system play in maintaining immunity?
b. Is Penny right to be worried about her father’s age in this context?

<table>
<thead>
<tr>
<th>Exercise 10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEMORY TEST</strong></td>
</tr>
<tr>
<td>Here, in random order, are the acronyms for a selection of the hormones we’ve explored so far. Can you write them out in full? How did you get on?</td>
</tr>
<tr>
<td>PRH</td>
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<tr>
<td>PTH</td>
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<tr>
<td>hGH</td>
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<td>CRH</td>
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<td>T3</td>
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<tr>
<td>GHIH</td>
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<td>FSH</td>
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<tr>
<td>LH</td>
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<tr>
<td>ADH</td>
</tr>
</tbody>
</table>

*Turn to the end of the study session for suggested answers.*

*Turn to the end of the study session for the answers.*
1.8 Hormones – chemical classification

Fortunately, hormones can be classified into two straightforward groups:

- **Lipid-soluble hormones.** These are not easily circulated in water-based blood plasma unless they are bound to a ‘carrier’ – these are known as transport proteins. Transport proteins increase the water-solubility of lipid-soluble hormones; they also slow down the loss of ‘free’ hormone via the kidneys and urine.

A small fraction of the lipid-soluble hormone will be present in the bloodstream in its ‘free’ form. This ‘free’ hormone can pass from the bloodstream to its target tissues in order to achieve the response. When this happens, more ‘free’ hormone is released from the transport proteins. This means that there is always a ‘reservoir’ of lipid-soluble hormone in the bloodstream.

Lipid-soluble hormones include the steroid hormones, thyroid hormones and nitric oxide.*

- **Water-soluble hormones.** These are readily circulated in the blood plasma and do not need a transport protein. Water-soluble hormones may be classified into three main groups:
  - **Amine hormones** such as epinephrine and norepinephrine
  - **Peptide and protein hormones** such as ADH, hGH and insulin (you may also come across the words ‘glycoprotein hormones’: these are protein hormones that have an additional carbohydrate group – eg, TSH)
  - **Eicosanoid hormones** such as prostaglandins and leukotrienes.

Don’t worry if some of these hormones are unfamiliar to you. We’ll come back to them as we work through the rest of the glands.

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*Footnote: There is still some debate over whether nitric oxide should be classed as a hormone.*
1.9 The adrenal glands

The adrenal gland is split into two distinct regions: the adrenal cortex (outer layer) and the adrenal medulla (inner layer). The adrenal cortex releases hormones that are essential for life; they regulate fluid and electrolyte homeostasis. The adrenal medulla releases the main ‘stress’ hormones: epinephrine, norepinephrine and low levels of dopamine.

**Adrenal cortex**

The adrenal cortex exerts its effects by releasing three distinct types of hormone:
- mineralocorticoids – these regulate the body’s ‘mineral’ balance
- glucocorticoids – these regulate the body’s glucose balance
- androgens – these have a masculinising effect (even in women).

**Adrenal medulla**

The adrenal medulla releases hormones that intensify the action of other parts of the nervous and endocrine system in response to ‘stress’ – ie, the ‘fight or flight’ response, in which:
- the heart rate increases
- the force of the heartbeat increases
- blood flow to and from the heart increases
- blood pressure increases
- blood flow to the liver and fatty tissues increases (enables fat to be converted to energy)
- blood flow to the brain increases and boosts alertness
- blood glucose levels increase
- blood flow to the skeletal muscles increases
- the airways are dilated.

The secretory cells of the adrenal medulla are modified nerve cells, so they receive fast nerve impulses and release hormones immediately. The adrenal medulla has a rich blood supply, so the hormones can readily enter the circulation. This combines the speed of transmission of the nervous system and the widespread distribution and longer duration of action of the endocrine system.
Exercise 11

Now that we’ve got seven glands we can really juggle.

It was a hot day in July and Julie’s fitness-mad husband had decided to take them on a morning trek to the top of a nearby beauty spot. Three hours later it was approaching noon and Julie was tired, thirsty, and a bit lost. At least she wasn’t sweaty any more, and her previous frantic search for a loo seemed irrelevant now. She wished, for the hundredth time, that they’d brought some water with them.

What endocrine response might be going on in Julia’s body?

Exercise 12

Hormone stacks

Move these hormones to the relevant gland:

<table>
<thead>
<tr>
<th>TRH</th>
<th>Norepinephrine</th>
<th>CRH</th>
<th>hGH</th>
<th>Cortisol</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSH</td>
<td>Aldosterone</td>
<td>LH</td>
<td>ACTH</td>
<td>Epinephrine</td>
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<table>
<thead>
<tr>
<th>Hypothalamus</th>
<th>Anterior pituitary</th>
<th>Adrenal cortex</th>
<th>Adrenal medulla</th>
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Turn to the end of the study session for suggested answers.

Turn to the end of the study session for the answers.
1.10 Stress and the body

Stress is a big word. Definitions run from the vague sense of pressure that we’re put under by our day-to-day lives (known as ‘eustress’) right through to major shock and trauma (known as ‘distress’).

Stress is generally triggered by factors known as stressors which disturb the body. These stressors are many and varied but commonly include heat and cold, trauma, illness, and strong emotional reactions. Of course, their effect will vary from person to person – one man’s terror is another man’s extreme sport!

When dealing with eustress the body is able to cope with the stressor in order to maintain a reasonable homeostatic balance. You may have occasions where the fight or flight response is triggered and then quickly subsides when the stressor is removed.

In distress, the stressor is extreme or prolonged. This triggers a three-stage response:

1. **Fight or flight response**. The body is ‘flooded’ with epinephrine and acquires large amounts of energy and oxygen so that it is literally ‘ready for action’. Non-essential functions are inhibited; these might include digestion, urination and reproduction. The renin-angiotensin-aldosterone pathway is activated so that blood volume increases and blood pressure increases. The fight or flight reaction is generally short-lived.

2. **Resistance reaction**. This reaction is initiated by the hypothalamus; this tells us that it will have a longer-lasting effect. The purpose of the resistance reaction is to provide the body with resources (such as energy) after the main ‘burst’ of the fight or flight response. It is a complex reaction which involves the hypothalamic stimulation of the pituitary gland (hGH), adrenal cortex (cortisol) and thyroid glands (T3 and T4). The net result of these hormones is to release energy which the body can use to maintain metabolism, repair damage and reduce inflammation.

3. **Exhaustion**. You can probably work out for yourselves that exhaustion happens when the body’s resources have been used up and are no longer able to respond to the ‘prompting’ of the hormones that are released during resistance. Prolonged ‘exhaustion’ is harmful and can result in muscle wastage, immune-system suppression and gastrointestinal ulcers. You may be able to think of other illnesses that have been attributed to stress.

**Exercise 13**

As he turned around to tell Julie to keep up, Peter tripped on a stone. He flung his arms out to keep his balance but it was no use: he fell heavily with a horrible grinding sound from his ankle. He lay there for a moment, heart pumping, and gulping in great lungfuls of air. At first he didn’t feel the pain in his ankle but it soon became apparent. Peter never knew how he managed to trek back on his badly sprained ankle, but he seemed to find the strength from somewhere.

What endocrine responses might be involved in Peter’s case?
1.11 Hormone–hormone interactions

Given the complexity of the body’s stress response, it seems like a good time to revisit the relationships between endocrine hormones.

We’ve explored feedback and control mechanisms – arguably, the most important of these involve other hormones.

Hormone–hormone interactions can be classified into three types:

- **Permissive.** This is where the action of the first hormone permits the second hormone to exert a more powerful effect. (We’ve just seen this in the body’s stress response.) Epinephrine will promote some breakdown of lipids (lipolysis) to generate energy, but if there is even a small amount of thyroid hormone in the system then epinephrine can promote lipolysis much more strongly.

- **Synergistic.** This is where the action of two hormones together is greater than the effect of each hormone by itself. An example of this might be the joint action of follicle-stimulating hormone (FSH) and oestrogen, neither of which is strong enough by itself to promote ovum development.

- **Antagonistic.** This is where one hormone opposes the action of another – a good example would be insulin and glucagon. (We’ll have a look at their effects in the next study session.)
1.12 The pancreas

What the pancreas does
There are four types of endocrine cell in the pancreatic islets, each secreting a different pancreatic hormone.
The release of these hormones is largely controlled by variations in blood glucose levels.
Somatostatin is chemically identical to GHIH. Its action varies as it targets different cells.
The relationship of these four hormones isn’t fully understood.

What the four cells do
- Alpha cells (glucagon) targets liver cells
- Beta cells (insulin) targets cells throughout the body
- Delta cells (somatostatin) targets adjoining alpha and beta pancreatic cells and gastrointestinal tract
- F cells (pancreatic polypeptide) targets adjoining pancreatic cells and the gall bladder

What the hormones do
Glucagon targets the liver to break down glycogen, lipids and proteins to form glucose. The net effect is to increase blood glucose levels. It is inhibited by high blood glucose and by somatostatin.
Insulin targets cells to take up and use free glucose; to convert glucose to glycogen; to increase protein and lipid synthesis from glucose, and to slow down glycogen breakdown. The net effect is to decrease blood glucose levels. It is inhibited by low blood glucose levels and by somatostatin.
Somatostatin inhibits the production of glucagon and insulin and slows the absorption of nutrients from the gastrointestinal tract. It is inhibited by pancreatic polypeptide.
Pancreatic polypeptide inhibits the release of somatostatin, inhibits the contraction of the gallbladder, and inhibits the secretion of digestive enzymes from the pancreas. It is inhibited by high blood glucose levels.

Exercise 14
Well done – now that we’ve got eight glands to juggle with we can really put on a show!
Grace has had a hard day. As she walks to the train station she remembers her brief lunch so long ago. She passes a tempting doughnut stall; a couple of doughnuts would give her just the boost she needs to get through the long journey home.
What effect will the doughnuts have on Grace’s pancreatic enzymes?
Exercise 15

MEMORY TEST – PART A

Here in random order are the acronyms for a selection of hormones. Can you write them out in full? How did you get on?

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
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<tbody>
<tr>
<td>hGH</td>
<td>TSH</td>
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<td>FSH</td>
<td>PRH</td>
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<td>TF</td>
<td>ACTH</td>
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<td>PRL</td>
<td>ADH</td>
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<td>THF</td>
<td>RH</td>
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<td>LH</td>
<td>T3</td>
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<td>OT</td>
<td>GHRH</td>
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<tr>
<td>T4</td>
<td>MSH</td>
</tr>
<tr>
<td>CT</td>
<td>GnRH</td>
</tr>
<tr>
<td>GHIIH</td>
<td>PTH</td>
</tr>
<tr>
<td>PIH</td>
<td>CRH</td>
</tr>
</tbody>
</table>
### MEMORY TEST – PART B

Now match the hormones you’ve identified to the relevant gland:

<table>
<thead>
<tr>
<th>Hypothalamus</th>
<th>Anterior pituitary</th>
<th>Posterior pituitary</th>
</tr>
</thead>
<tbody>
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<tr>
<td>Thyroid and parathyroid</td>
<td>Thymus gland</td>
<td>Pancreatic islets</td>
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<tr>
<td>Adrenal cortex</td>
<td>Adrenal medulla</td>
<td>Pineal gland</td>
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Add these hormones as well: melatonin, aldosterone, epinephrine, insulin, cortisol, glucagon.

*Turn to the end of the study session for the answers.*
1.13 The ovaries and the testes

**FIGURE 9 The ovaries**

Produced in the ovaries, oestrogens target a range of tissues in the body to promote and maintain the female reproductive system, including the development of the breasts and secondary sex characteristics. They work closely with progesterone to regulate the reproductive cycle and prepare the body for pregnancy. They also increase protein synthesis and decrease blood cholesterol.

Progesterone works with oestrogens to prepare the endometrium for implantation. It also prepares the mammary glands for milk production. High levels of progesterone inhibit the release of GnRH and LH.

Inhibin inhibits the release of FSH and has some inhibitory effect on LH.

Relaxin inhibits the contraction of the uterine smooth muscle during pregnancy. During labour it dilates the cervix and makes the pubic symphysis more flexible.

**FIGURE 10 The testes**

Produced in the testes, testosterone eclipses the weak androgen effect of the adrenal cortex in men. It stimulates the descent of the testes at birth, regulates sperm production, promotes the secondary sex characteristics, and maintains these in adults. Inhibin inhibits the release of FSH and has some inhibitory effect on LH.
1.14 **Hormones – further classification**

One of our learning objectives is to help you gain confidence in the language that is used in endocrinology. So let’s look at some of the terminology you may come across when you’re talking to endocrine specialists or reading endocrine textbooks.

Endocrine hormones are released directly into the fluid that surrounds individual endocrine cells. This fluid is called **interstitial fluid**. The majority of hormones then pass into the bloodstream where they are carried to their target tissues. These hormones are known as **circulating hormones**.

However, some hormones do not move from the interstitial fluid to the bloodstream. These hormones – which are known as **local hormones** – can only exert their effects on nearby cells.

The journey of a hormone from its secretory cell to its target tissue gives us another basis for classification: **paracrines** act on cells nearby in the same tissue that secreted them, while **autocrines** act on the same cell that secreted them.

The significance of this is that local hormones tend to be short-acting and are inactivated quickly. Circulating hormones tend to have longer-lasting effects and may stay in the bloodstream for some time. Circulating hormones are generally inactivated by the liver before being excreted by the kidneys.

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1.15 **Putting it all together**

By now we hope you agree with us that the endocrine system is remarkable – it has a role in regulating most of the body’s systems and has far-reaching effects. However, we know that it’s easy to lose yourself in the plethora of intertwining hormones and their acronyms. So, to finish off this study session, here’s a summary of how the endocrine system affects the body.
<table>
<thead>
<tr>
<th>Body system</th>
<th>The endocrine system’s contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>All body systems</td>
<td>Works with the nervous system to regulate the activity and growth of target cells. Regulates metabolism and glucose production and manages energy resources.</td>
</tr>
<tr>
<td>Skin</td>
<td>Androgens stimulate hair growth and activate sebaceous glands.</td>
</tr>
<tr>
<td>Skeletal system</td>
<td>hGH and insulin-like growth factors promote bone growth. Oestrogens help to complete bone development and maintain bone mass. PTH and calcitriol regulate blood calcium. Thyroid hormones are essential to the development and growth of the skeleton.</td>
</tr>
<tr>
<td>Muscular system</td>
<td>Epinephrine increases blood flow to exercising muscles. PTH maintains calcium, which is needed for muscle contraction. Insulin and glucagon (among others) regulate the energy supply to muscle fibres. hGH, growth factors and thyroid hormones maintain muscle mass.</td>
</tr>
<tr>
<td>Nervous system</td>
<td>Thyroid hormones, insulin and hGH are important to the growth and development of the nervous system. PTH maintains calcium, which is needed for generating and transmitting nerve impulses. Melatonin controls the circadian rhythm.</td>
</tr>
<tr>
<td>Cardiovascular system</td>
<td>Erythropoietin promotes red blood cell production. Aldosterone and ADH increase blood volume (and blood pressure). Epinephrine increases the heart rate and force of the heartbeat. Other hormones increase blood pressure during exercise and other stresses.</td>
</tr>
<tr>
<td>Immune system</td>
<td>Glucocorticoids reduce inflammation and the immune response. Thymic hormones promote the development of T-cells.</td>
</tr>
<tr>
<td>Respiratory system</td>
<td>Epinephrine dilates the airways during exercise and/or stress. Erythropoietin regulates the amount of oxygen the blood can carry by increasing the number of red blood cells.</td>
</tr>
<tr>
<td>Digestive system</td>
<td>Epinephrine reduces activity in the digestive tract. Gastrin, cholecystokinin (CCK) and glucose-dependent insulinotropic peptide (GIP) help to regulate digestion. Calcitriol promotes the uptake of dietary calcium. Leptin suppresses the appetite.</td>
</tr>
<tr>
<td>Urinary system</td>
<td>ADH, aldosterone and ANP* adjust the rate of water and electrolyte loss via the urine.</td>
</tr>
<tr>
<td>Reproductive system</td>
<td>GnRH, FSH and LH regulate the ovaries and testes to produce the main sex hormones. Oestrogens and progesterone work together to regulate the ovarian cycle and prepare the body for pregnancy. Testosterone regulates sperm production. Prolactin promotes milk secretion. OT promotes uterine contractions and the ejection of milk from the mammary glands.</td>
</tr>
</tbody>
</table>

*ANP refers to Atrial Natriuretic Peptide.
Exercise 16

We mentioned right at the start of this programme that we had to expend some brain power in order to understand the complexity of the endocrine system and its interrelationships.

So, complete this study session by expending some more of your own brain power in our endocrine brain-teasers.

Try to spot as many endocrine responses as you can as our domestic drama unfolds...

Turn to the end of the study session for suggested answers.

Mel Jones dashed around the garden one more time, anxiously checking the last of the arrangements for the annual family barbecue.

‘Will you sit down?’ said Dave, her husband, in exasperation.

‘No time for that!’ snapped Mel. ‘They’ll be here in a minute and you know how fussy they are.’

‘It’s only your mum and dad that are fussy,’ said Dave, ‘and you’ll never get the place clean enough for them. Now, come and sit down for a bit.’

‘OK,’ said Mel, reluctantly.

She sank gratefully onto a spotless garden chair. Truth to be told, she was exhausted: she’d been up since 5am getting the place ready; then, when she tried to have a nap later, she just couldn’t get to sleep.

‘Have a cuppa,’ said Dave, generously. ‘And why not have something to eat as well?’

‘Hardly worth it,’ said Mel offhandedly, thirstily gulping down her tea. ‘We’ll be barbecuing soon – I’ll eat then.’

‘Eat now!’ said Dave firmly, pushing a bowl of cereal into her hands. ‘You’ll collapse if you don’t have some breakfast.’

‘If I sit down now I may not be able to get started again,’ grumbled Mel, but she did feel better for the tea and the food. She’d been on the go all morning and hadn’t stopped for a bite to eat or drink.

‘Don’t worry, love,’ soothed Dave. ‘It’s only family, the place looks great, and the kids can finish off.’

Dave looked fondly at his son, Jez, who seemed to have grown a foot in height over the summer holidays. He remembered how tiny Jez had been when he was born. He’d never forget when Jez had emerged, all red and squalling – he’d felt a surge of feeling like he’d never felt before. He shuddered at the thought of ever letting his kids down.

‘…then there’s our Kylie’s boyfriend, so we’ll have about 20 people in all. Are you sure we’ve got enough food?’

‘Eh?’ said Dave as he came out of his daydream and tuned back in to the conversation. Enough food? He grinned. Mel looked good enough to eat. He reached
down and gave her a hug followed by a noisy, sloppy kiss. Their daughter, Kylie, flounced away, revolted.

‘PMT,’ said Mel, shaking her head ruefully.

‘Do you think she’s stopped growing?’ asked Dave, noticing how Jez towered over his sister.

‘She’s stopped growing **up,**’ said Mel pointedly, gesturing expansively away from her chest. ‘Though I’m not sure about growing **out**!’

Dave looked at Mel’s chest with interest.

‘Fancy a quickie?’ he leered, hopefully.

‘No chance!’ Mel laughed.

Dave prepared his most persuasive wheedle, but before he could start he heard cries from the front gate.

‘Mum, Dad. Gran’s here, and Auntie Ruth.’

‘Always early,’ sighed Mel. ‘Get the barbie going, Dave.’

‘Haven’t you grown?’

Jez groaned. Why did his relations keep saying that? Did they think he hadn’t noticed?

‘And is that a beard?’ a shrill girl’s voice giggled.

‘Uh, yeah,’ growled Jez.

‘Ohh, your voice is so deep!’ teased another of Kylie’s friends.

‘Grub’s up!’ yelled Dave, saving Jez from more embarrassment.

Everyone rushed to the barbecue. It was a vegetarian’s nightmare! Dave dished out a stack of sausages and steaks and everyone got down to some serious munching. Halfway through serving people Dave looked up and said, ‘Oops, ’scuse me, have to pay a visit.’

‘Is he all right?’ whispered Gran loudly. ‘He’s been in and out of the loo all afternoon.’

‘It’s the beer,’ said Mel resignedly. ‘It always takes him that way.’

‘Not like your dad, then. I can’t get him to drink hardly anything, alcohol or not.’

‘What are you two plotting?’ said Ruth, Mel’s sister. ‘Can I join in?’

‘Just talking about the men,’ laughed Mel.

‘Do you mind if I just feed Robbie?’ asked Ruth.

‘Hah, we did it in private in my day,’ muttered Gran, wandering off.

‘Don’t mind her,’ said Mel reassuringly. ‘How’s it been?’

‘Oh, you know,’ said Ruth. ‘Breast-feeding’s a bit time-consuming, but I’m going to stick with it for another couple of months, then we’ll see.’

‘Have you had any problems with your milk?’ asked Mel, who’d never had enough with her own babies.
‘Are you kidding?’ said Ruth. ‘It’s like ruddy Niagara Falls when Robbie latches on. No wonder he’s thriving.’

Ruth smiled at her round, contented baby. Mel looked fondly at her own teenage children.

The sisters were so lost in their thoughts that they didn’t notice the first roll of thunder rumbling overhead. The next minute the summer storm washed over them. The rain was torrential – there were even hailstones.

‘Get inside!’ yelled Mel at her guests.

‘It’ll pass!’ shouted Jez, dancing in the rain with the rest of the kids.

Mel turned to her mum and dad who were already soaked. ‘You’re freezing,’ she said, concernedly. ‘Get inside and warm up.’

The next minute there was a bright flash, a crash and a thump of thunder that seemed to shake the house. It went on forever.

‘The kids!’ shrieked Mel. She ran outside, her heart pumping wildly.

She met the kids halfway: they were running towards the house at top speed. A chorus of hysterical babbling greeted her: ‘It was so close!’ ‘It could have hit us!’ ‘It blew a hole in next door’s roof!’ ‘It could have been us!’

Mel breathed deeply. She looked at the hysterical kids and her mind abruptly cleared. They seemed unhurt apart from Jez, who had a gash in his hand.

‘I’ll fix that now,’ said Mel calmly. It didn’t look too deep and a bit of antiseptic should do the trick. Jez was young, and he’d never had an infection in his life. She had no doubt that he’d heal.

‘Dave, put the kettle on,’ said Mel. ‘What everyone needs now is some sweet tea to calm their nerves.’

A few hours later Mel and Dave were musing over the day. To their relief, everyone had gone home unhurt, and the kids had scattered to each other’s haunts. Mel felt utterly washed out.

‘I know what’ll perk you up!’ said Dave lasciviously.

‘David Abraham Jones, is that all you can think about?’

‘Yep,’ said Dave, unapologetically. ‘We’re alive, we’re alone – and we’re too old to get pregnant. Best time of our lives!’

Mel smiled.
Summary

In this study session we provided a brief revision of the different glands in the human body. We have used a series of real life situations to help you consider how the endocrine system has an impact on daily living.

Intended outcomes

By the end of this study session you should be able to:

<table>
<thead>
<tr>
<th>Learning objective</th>
<th>Well can you?</th>
</tr>
</thead>
<tbody>
<tr>
<td>List the endocrine glands and describe their main functions, both as individual glands and as part of an interrelated endocrine system.</td>
<td></td>
</tr>
</tbody>
</table>

Further reading


Suggested answers

Exercise 2 (page 11)

a. What do you think might be the main differences between using nerve impulses and endocrine hormones to regulate homeostasis?

<table>
<thead>
<tr>
<th>Nervous system</th>
<th>Endocrine system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local and specific because neurotransmitters are released at the site of action</td>
<td>Hormones generally released into the whole circulation away from the site of action</td>
</tr>
<tr>
<td>Tend to target specific cells in muscles, glands and other neurones (nerve cells)</td>
<td>Broad-ranging action – can regulate virtually all types of cells throughout the body</td>
</tr>
<tr>
<td>Very fast response (thousandths of a second)</td>
<td>Relatively slow response (seconds, hours or days)</td>
</tr>
<tr>
<td>Generally brief duration of action (thousandths of a second)</td>
<td>Generally longer duration of action (seconds, hours or days)</td>
</tr>
</tbody>
</table>

b. Hormone word search

Releasing hormones:
- Growth hormone-releasing hormone
- Thyrotropin-releasing hormone
- Gonadotropin-releasing hormone
- Prolactin-releasing hormone
- Corticotropin-releasing hormone

Inhibiting hormones:
- Growth hormone-inhibiting hormone
- Prolactin-inhibiting hormone

Exercise 3 (page 12)

a. Spike is a teenager. Everyone says he’s had a growth spurt recently. What sequence of hypothalamic and pituitary hormones do you think was involved?

In order to stimulate growth the hypothalamus secretes growth hormone-releasing hormone (GHRH) which stimulates the release of human growth hormone (hGH) from the anterior pituitary. In response to the presence of hGH the target tissues release insulin-like growth factors which will enable growth to accelerate.

b. Stuart has had a sperm test. The results were normal. What sequence of hypothalamic and pituitary hormones do you think was involved?

The hypothalamus starts to produce gonadotropin-releasing hormone (GnRH) at puberty. GnRH stimulates the release of follicle-stimulating hormone (FSH) from the anterior pituitary gland. In males, FSH promotes sperm production.
Exercise 4 (page 13)

MEMORY TEST

- GH = Growth hormone-releasing hormone
- TSH = Thyroid-stimulating hormone
- OT = Oxytocin
- GnRH = Gonadotropin-releasing hormone
- ACTH = Adrenocorticotropic hormone
- PRH = Prolactin-releasing hormone
- hGH = Human growth hormone
- FSH = Follicle-stimulating hormone
- LH = Luteinising hormone
- PRL = Prolactin
- ADH = Antidiuretic hormone

Exercise 5 (page 14)

What might be happening to Mavis’s endocrine system?

We think Mavis’s body clock is having trouble adapting to her work pattern. Darkness is a trigger to melatonin release, which we know tends to promote sleep. However, Mavis is working nights so she is struggling to overcome this influence. Bright sunlight inhibits melatonin, so during the day Mavis is lacking in the hormone that would help her to sleep.

Exercise 6 (page 16)

a. Sandra went to Wimbledon to watch the tennis and got drenched by a sudden thunderstorm. She’s now wet and cold. How might Sandra’s endocrine system respond?

Sensory input about Sandra’s lowered body temperature and metabolic rate will be received by the hypothalamus. This releases thyroid-releasing hormone (TRH), which stimulates the release of thyroid-stimulating hormone (TSH) from the anterior pituitary. The thyroid gland releases T3 and T4 which increase the basal metabolic rate and generate heat.

b. Bav is starting a trek up to the Everest base camp as part of his gap-year adventures. How might his endocrine system respond?

In high altitude the body’s energy demand increases, so that is likely to stimulate the release of more thyroid hormones. If it is cold on the way to base camp that will also stimulate the release of thyroid hormones.

We can assume that the trek to base camp will be quite strenuous – this is likely to stimulate the release of hypothalamic hormones. Remember that the hypothalamus is a ‘control’ gland, so the conditions that Bav encounters won’t just affect the release of thyroid hormones.
Exercise 7 (page 17)

Hormone stacks

<table>
<thead>
<tr>
<th>Hypothalamus</th>
<th>Anterior pituitary</th>
<th>Thyroid gland</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHRH</td>
<td>TSH</td>
<td>T3</td>
</tr>
<tr>
<td>GnRH</td>
<td>ACTH</td>
<td>T4</td>
</tr>
<tr>
<td>TRH</td>
<td>PRL</td>
<td>CT</td>
</tr>
</tbody>
</table>

Exercise 8 (page 19)

a. If Mary’s blood calcium levels are low, how will her endocrine system help her to make the best of the dietary calcium being provided by her mum?

If the parathyroid gland detects low blood calcium levels it will release parathyroid hormone (PTH). PTH can increase blood calcium levels via a number of mechanisms. One of these is the release of calcitriol by the kidneys. Calcitriol increases the absorption of dietary calcium from the intestine.

b. If Mary’s blood calcium levels are fine, what effect might her calcium-rich meal have on her blood calcium levels?

The parathyroid glands are regulated by variations in the levels of calcium in the blood. If Mary’s blood calcium levels are elevated then the release of parathyroid hormones will be inhibited. This means Mary’s calcium-rich meal will make little difference to her blood calcium levels.

c. What effect does calcitonin have on osteoclast activity?

Calcitonin reduces osteoclast activity in order to decrease blood calcium levels.

d. What effect does parathyroid hormone have on osteoclast activity?

Parathyroid hormone increases osteoclast activity in order to increase blood calcium levels.

Exercise 9 (page 20)

a. What part does the endocrine system play in maintaining immunity?

The thymus does not synthesise T-cells but it does use thymic hormones to bring T-cells to maturity. T-cells are an important part of the body’s immune response.

b. Is Penny right to be worried about her father’s age in this context?

There are many factors that might affect her dad’s immune status. His thymus gland will be a fraction of the size that it was when he was a youngster, but there is
considerable ‘redundancy’ in the production of T-cells and only a small proportion of those that become mature will migrate from the thymus to become part of the immune response. We also know that the thymus gland will continue to produce T-cells into old age. So we’ve got no reason to believe that this part of his immune system is compromised.

**Exercise 10 (page 21)**

**MEMORY TEST**

- PRH = Prolactin-releasing hormone
- PTH = Parathyroid hormone
- hGH = Human growth hormone
- CRH = Corticotropin-releasing hormone
- T3 = Triiodothyronine
- GHIH = Growth hormone-inhibiting hormone
- FSH = Follicle-stimulating hormone
- LH = Lutenising hormone
- ADH = Antidiuretic hormone

**Exercise 11 (page 24)**

*What endocrine response might be going on in Julia’s body?*

We think Julie might be a bit dehydrated; it’s a hot day, she’s been doing some physical exercise, and she hasn’t had anything to drink. We also know that she has been sweating.

It is likely that her dehydration will have triggered the renin-angiotensin-aldosterone (RAA) pathway. This will result in two outcomes:

- The release of angiotensin II will cause Julie’s arterioles to constrict in order to bring up her blood pressure.
- The release of aldosterone will cause the kidneys to reabsorb water and sodium in order to increase blood volume.

Julie mentioned that she’d stopped sweating and no longer felt the need to urinate. This may be the effect of antidiuretic hormone being secreted by the posterior pituitary gland in response to dehydration.
Exercise 12 (page 24)

Hormone stacks

<table>
<thead>
<tr>
<th>Hypothalamus</th>
<th>Anterior pituitary</th>
<th>Adrenal cortex</th>
<th>Adrenal medulla</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRH</td>
<td>hGH</td>
<td>Cortisol</td>
<td>Norepinephrine</td>
</tr>
<tr>
<td>CRH</td>
<td>TSH</td>
<td>Aldosterone</td>
<td>Epinephrine</td>
</tr>
<tr>
<td>LH</td>
<td>ACTH</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Exercise 13 (page 25)

What endocrine responses might be involved in Peter’s case?

We think Peter is experiencing the initial ‘fight or flight’ response that is mediated by epinephrine. His body needed to respond quickly to try to avert his fall so a ‘burst’ of epinephrine would have increased his energy levels and heart rate, his airways would have dilated so that he could take in more oxygen, and his blood supply would be targeted to his muscles.

Peter’s body then goes into the resistance reaction which enables him to keep going after the shock of the fall and the subsequent trauma to his ankle. The resistance reaction means that his body is awash with hormones as a result of a cascade set off by the hypothalamus. These include:

- cortisol (from the adrenal medulla) – to generate energy, to help to repair damage and to reduce inflammation
- hGH from the anterior pituitary – to generate even more energy
- thyroid hormones – to supply yet more energy.

We expect it will take a while for him to recover. The resistance reaction means that the body is using up its resources (such as energy stored in fat and proteins) at a fast rate. It will take Peter a few days to replenish the resources that his body used during the emergency.

Exercise 14 (page 27)

What effect will the doughnuts have on Grace’s pancreatic enzymes?

Prior to her snack it is likely that Grace will have been producing glucagon, which would have helped her body to release energy from glycogen. (Other hormones may also have helped her body to maintain her energy levels when she was fasting – can you list a few of them?)

Doughnuts are a rich source of carbohydrate so they will stimulate the release of insulin. In addition, glucose-dependent insulinotropic peptide (GIP) will be produced by the
intestine in response to the presence of glucose in the gastrointestinal tract – this will also trigger the release of insulin. Insulin will enable Grace’s body to use the energy provided by the doughnuts and store any excess glucose in the form of glycogen.

As Grace’s blood-glucose levels start to rise after eating her doughnuts, the production of glucagon will be inhibited. Once her blood glucose falls back to normal the production of insulin will be inhibited – it’s a bit like the two sides of a child’s see-saw.

Exercise 15 (page 28)

MEMORY TEST

Part A
- hGH = Human growth hormone
- PRH = Prolactin-releasing hormone
- PRL = Prolactin
- TRH = Thyrotropin-releasing hormone
- OT = Oxytocin
- MSH = Melanocyte-stimulating hormone
- GHIH = Growth hormone-inhibiting hormone
- CRH = Corticotropin-releasing hormone
- TSH = Thyroid-stimulating hormone
- TF = Thymic factor
- ADH = Antidiuretic hormone
- LH = Luteinising hormone
- GHRH = Growth hormone-releasing hormone
- CT = Calcitonin
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- FSH = Follicle-stimulating hormone
- ACTH = Adrenocorticotropic hormone
- THF = Thymic humeral factor
- T3 = Triiodothyronine
- T4 = Thyroxine
- GnRH = Gonadotropin-releasing hormone
- PIH = Prolactin-inhibiting hormone
**Part B**

<table>
<thead>
<tr>
<th>Hypothalamus</th>
<th>Anterior pituitary</th>
<th>Posterior pituitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRH</td>
<td>hGH</td>
<td>ADH</td>
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<td>GnRH</td>
<td>ACTH</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Thyroid and parathyroid</th>
<th>Thymus gland</th>
<th>Pancreatic islets</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>TF</td>
<td>Insulin</td>
</tr>
<tr>
<td>PTH</td>
<td>THF</td>
<td>Glucagon</td>
</tr>
<tr>
<td>T3</td>
<td></td>
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<tr>
<td>T4</td>
<td></td>
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<table>
<thead>
<tr>
<th>Adrenal cortex</th>
<th>Adrenal medulla</th>
<th>Pineal gland</th>
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<tbody>
<tr>
<td>Aldosterone</td>
<td>Epinephrine</td>
<td>Melatonin</td>
</tr>
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<td></td>
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</tr>
</tbody>
</table>

**Exercise 16 (page 33)**

Mel Jones dashed around the garden one more time, anxiously checking the last of the arrangements for the annual family barbecue.

‘Will you sit down?’ said Dave, her husband, in exasperation.

‘No time for that!’ snapped Mel. ‘They’ll be here in a minute and you know how fussy they are.’

‘It’s only your mum and dad that are fussy,’ said Dave, ‘and you’ll never get the place clean enough for them. Now come and sit down for a bit.’

Mel has been dashing around, so her body will have been using energy. That might involve glucagon to release glucose and thyroid hormones to increase her basal metabolic rate.

‘OK,’ said Mel, reluctantly.

She sank gratefully onto a spotless garden chair. Truth to be told, she was exhausted: she’d been up since Sam getting the place ready; then, when she tried to have a nap later, she just couldn’t get to sleep.
We’re assuming that it is summertime, so Mel may not have found it too difficult to wake up early – melatonin is inhibited by strong sunlight and there is a drop in blood levels just before waking. Unfortunately, it sounds as if Mel’s body clock is not allowing her to have a nap.

‘Have a cuppa,’ said Dave, generously. ‘And why not have something to eat as well?’

‘Hardly worth it,’ said Mel offhandedly, thirstily gulping down her tea. ‘We’ll be barbecuing soon – I’ll eat then.’

‘Eat now!’ said Dave firmly, pushing a bowl of cereal into her hands. ‘You’ll collapse if you don’t have some breakfast.’

‘If I sit down now I may not be able to get started again,’ grumbled Mel, but she did feel better for the tea and the food. She’d been on the go all morning and hadn’t stopped for a bite to eat or drink.

‘Don’t worry, love,’ soothed Dave. ‘It’s only family, the place looks great, and the kids can finish off.’

Mel hasn’t had anything to eat or drink during her busy morning so it is likely that her RAA pathway will be busy maintaining her fluid levels. ADH may also be involved, suppressing urination in response to relatively high blood electrolytes. Milk in her cereal will provide dietary calcium, but whether that is taken up will depend on her existing calcium levels: if they are low then PTH will promote the release of calcium from the bones and calcitriol from the kidneys to increase the absorption of dietary calcium.

Dave looked fondly at his son, Jez, who seemed to have grown a foot in height over the summer holidays. He remembered how tiny Jez had been when he was born. He’d never forget when Jez had emerged, all red and squalling – he’d felt a surge of feeling like he’d never felt before. He shuddered at the thought of ever letting his kids down.

hGH will have been a major contributor to Jez’s growth since infancy, though the thyroid hormones will have been a major contributor to the development of his nervous and skeletal systems. Dave’s paternal feelings may have been boosted by OT.

‘…then there’s our Kylie’s boyfriend, so we’ll have about 20 people in all. Are you sure we’ve got enough food?’

‘Eh?’ said Dave as he came out of his daydream and tuned back in to the conversation. Enough food? He grinned. Mel looked good enough to eat. He reached down and gave her a hug followed by a noisy, sloppy kiss. Their daughter, Kylie, flounced away, revolted.

‘PMT,’ said Mel, shaking her head ruefully.

‘Do you think she’s stopped growing?’ asked Dave, noticing how Jez towered over his sister.
‘She’s stopped growing up,’ said Mel pointedly, gesturing expansively away from her chest. ‘Though I’m not sure about growing out!’

Dave looked at Mel’s chest with interest.

‘Fancy a quickie?’ he leered, hopefully.

‘No chance!’ Mel laughed.

We’ve got a few sex hormones exerting their influence here. It sounds as if Kylie’s menstrual cycle is operating, so that will involve LH, FSH, oestrogens and progesterone. It sounds as if Dave’s testosterone is increasing his sexual desire. Of course, testosterone is at the end of the GNRH/LH/FSH cascade.

Dave prepared his most persuasive wheedle, but before he could start he heard cries from the front gate.

‘Mum, Dad. Gran’s here, and Auntie Ruth.’

‘Always early,’ sighed Mel. ‘Get the barbie going, Dave.’

‘Haven’t you grown?’

Jez groaned. Why did his relations keep saying that? Did they think he hadn’t noticed?

‘And is that a beard?’ a shrill girl’s voice giggled.

‘Uh, yeah,’ growled Jez.

‘Ohh, your voice is so deep!’ teased another of Kylie’s friends.

‘Grub’s up!’ yelled Dave, saving Jez from more embarrassment.

Jez is displaying some secondary sex characteristics. These will largely have been mediated by testosterone at puberty though weak androgens from the adrenal cortex may have played a part. His androgens may also have contributed to a growth spurt just before puberty.

Everyone rushed to the barbecue. It was a vegetarian’s nightmare! Dave dished out a stack of sausages and steaks and everyone got down to some serious munching.

People are eating a meal so it is likely that gastrin will be being produced to aid digestion. It’s a protein-rich meal so the pancreas may be secreting pancreatic polypeptide (which inhibits somatostatin), and this may speed the rate at which nutrients are absorbed from the gastrointestinal tract. Pancreatic polypeptide and CCK will help people to feel ‘full’ after Dave’s feast.

Halfway through serving people Dave looked up and said, ‘Oops, ‘scuse me, have to pay a visit.’

‘Is he all right?’ whispered Gran loudly. ‘He’s been in and out of the loo all afternoon.’

‘It’s the beer,’ said Mel resignedly. ‘It always takes him that way.’

‘Not like your dad, then. I can’t get him to drink hardly anything, alcohol or not.’
Dave’s ADH release has been inhibited by alcohol so it’s not surprising that he is urinating more frequently. Because Mel’s dad doesn’t drink very much it is likely that his RAA pathway will be working hard to maintain his fluid and electrolyte levels.

‘What are you two plotting?’ said Ruth, Mel’s sister. ‘Can I join in?’

‘Just talking about the men,’ laughed Mel.

‘Do you mind if I just feed Robbie?’ asked Ruth.

‘Hah, we did it in private in my day,’ muttered Gran, wandering off.

‘Don’t mind her,’ said Mel reassuringly. ‘How’s it been?’

‘Oh, you know,’ said Ruth. ‘Breastfeeding’s a bit time consuming, but I’m going to stick with it for another couple of months, then we’ll see.’

‘Have you had any problems with your milk?’ asked Mel, who’d never had enough with her own babies.

‘Are you kidding?’ said Ruth. ‘It’s like ruddy Niagara Falls when Robbie latches on. No wonder he’s thriving.’

Ruth smiled at her round, contented baby. Mel looked fondly at her own teenage children.

Now we have all the hormones involved in lactation. The most obvious is PRL but that won’t produce lactation by itself: you also need the whole LH/FSH/oestrogens/progesterone cascade. OT will promote the release of milk (‘letdown’) from the mammary glands; this is stimulated by suckling. Of course, OT may also be promoting some of their parental caring responses.

The sisters were so lost in their thoughts that they didn’t notice the first roll of thunder rumbling overhead. The next minute the summer storm washed over them. The rain was torrential – there were even hailstones.

‘Get inside!’ yelled Mel at her guests.

‘It’ll pass!’ shouted Jez, dancing in the rain with the rest of the kids.

Mel turned to her mum and dad who were already soaked. ‘You’re freezing,’ she said, concernedly. ‘Get inside and warm up.’

Mel is worried about her parents being cold but it is likely that their thyroid hormones are already working to increase their metabolic rate and generate heat. Remember that the thyroid gland stores a large supply of thyroid hormones so that they will be readily available.

The next minute there was a bright flash, a crash and a thump of thunder that seemed to shake the house. It went on forever.

‘The kids!’ shrieked Mel. She ran outside, her heart pumping wildly.
She met the kids halfway: they were running towards the house at top speed. A chorus of hysterical babbling greeted her: ‘It was so close!’ ‘It could have hit us!’ ‘It blew a hole in next door’s roof!’ ‘It could have been us!’

Mel breathed deeply. She looked at the hysterical kids and her mind abruptly cleared. They seemed unhurt apart from Jez, who had a gash in his hand.

*Now we have the fight or flight response mediated by epinephrine and norepinephrine. Remember that this is a short-lived response to get the body out of danger – it certainly got the kids out of the garden!*

‘I’ll fix that now,’ said Mel calmly. It didn’t look too deep and a bit of antiseptic should do the trick. Jez was young, and he’d never had an infection in his life. She had no doubt that he’d heal.

‘Dave, put the kettle on,’ said Mel. ‘What everyone needs now is some sweet tea to calm their nerves.’

Jez’s T-cells may be involved in fighting off any bacteria that have contaminated his wound. This is a link to the thymic hormones. Mel doesn’t mention pain but it is likely that the cells around the wound are producing prostaglandins. Leukotrienes may also be present to ‘flag up’ any contamination that needs the attention of the white blood cells.

A few hours later Mel and Dave were musing over the day. To their relief, everyone had gone home unhurt, and the kids had scattered to each other’s haunts. Mel felt utterly washed out.

Mel’s feeling of being ‘washed out’ may just be down to the fact that she’s had a busy day. However, she may also be experiencing the ‘exhaustion’ effect of her stress response to the day’s events. If that is the case, then her body has been awash with hormones during the resistance reaction. It is quite normal for this reaction to continue after the removal of the original stressors as some of the hormones that are released are relatively long-acting.

‘I know what’ll perk you up!’ said Dave lasciviously.

‘David Abraham Jones, is that all you can think about?’

‘Yep,’ said Dave, unapologetically. ‘We’re alive, we’re alone – and we’re too old to get pregnant. Best time of our lives!’

Mel smiled.

*Back to Dave’s testosterone! It sounds as if Mel is past the menopause; however, she will still have her adrenal androgens which may be converted to oestrogens. These will help her libido. OT may increase the sense of pleasure for both of them from the sexual intercourse to follow.*