**HOMEOSTASIS**

5 AUGUST 2015

**Section A: Summary Notes**

- All cells in a multi-cellular organism are surrounded by a liquid called **tissue fluid**.
- Tissue fluid makes up the internal environment of the body.
- An optimal internal environment has to be maintained for body enzymes to function properly.
- Homeostasis is the process of maintaining a constant, optimal internal environment.
- In order for the body to function at its optimal level, various factors associated with the tissue fluid have to be kept constant. These factors are:
  - Carbon dioxide concentration
  - Glucose concentration
  - Water and mineral salt concentration
  - Urea concentration
  - Oxygen concentration
  - pH
  - Temperature

- Homeostasis works through a negative feedback mechanism.
- A negative feedback system has three parts:
  1. A receptor that detects the move away from the normal concentration and alerts the appropriate control center.
  2. A control center that processes the information and initiates a response.
  3. An effector that corrects the imbalance and brings the conditions back to normal.

- You need to be able to describe the control of:
  - Glucose
  - Carbon dioxide
  - Water and salts

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**Diagram:**

1. **Stimulus:** Produces change in variable.
2. **Change detected by receptor.**
3. **Input:** Information sent along afferent pathway to control center.
4. **Output:** Information sent along efferent pathway to effector.
5. **Response of effector feeds back to influence magnitude of stimulus and returns variable to homeostasis.**
The regulation of glucose in the blood

- Remember negative feedback mechanisms control the blood glucose level.
- The concentration of glucose must be carefully regulated at all times.
- Too much glucose in the blood can cause water to move out of the cells by osmosis.
- Diabetes mellitus is a disorder of the endocrine system that causes a high concentration of glucose in the blood.
- Too little glucose can leave one feeling weak and dizzy.
- The blood glucose levels are regulated by two hormones, insulin and glucagon, and they are produced in the pancreas.

The regulation of carbon dioxide in the blood

- Carbon dioxide is a toxic waste product of cellular respiration and has an effect on the pH of blood.
- Chemoreceptors in the wall of the aorta and jugular blood vessels are sensitive to changes in the levels of CO₂ in the blood.
The regulation of water content in the blood

- The hormone ADH (anti-diuretic hormone) released by the pituitary gland/hypophysis and regulates the water content of the blood
- The kidneys control the water volume and salt concentration in the body.
The regulation of the salt content in the blood

- the hormone aldosterone regulates the concentration of sodium ions ($\text{Na}^+$) and potassium ions ($\text{K}^+$)

TEMPERATURE REGULATION

- The human skin plays an important role in the regulation of body temperature
Body temperature must be kept constant in homoeothermic organisms like birds and mammals.

Optimal body temperature in humans is between 36.6 °C and 37 °C.

Remember that all cells, antibodies, enzymes and most hormones are made of protein, and proteins are sensitive to temperature and pH.

If the temperature is too high, the proteins will denature and be unable to function.

If the temperature is too low, the proteins will become inactive. So, the human body must work hard to keep the temperature constant.

The hypothalamus stimulates various systems to regulate the body temperature. When the body is hot, the hypothalamus will stimulate the pituitary to release more ADH and less thyroxin. When the body is cold, the opposite will take place.

<table>
<thead>
<tr>
<th>Hot day</th>
<th>Cold day</th>
</tr>
</thead>
<tbody>
<tr>
<td>The body gets hot:</td>
<td>The body gets cold:</td>
</tr>
<tr>
<td>• You need <strong>more</strong> water in the blood to make <strong>more</strong> sweat to cool you down</td>
<td>• You need <strong>less</strong> water in the blood as you do not need to produce sweat</td>
</tr>
<tr>
<td>• <strong>More</strong> ADH is released by the pituitary gland to keep <strong>more</strong> water in the blood</td>
<td>• <strong>Less</strong> ADH is released by the pituitary gland to keep <strong>less</strong> water in the blood</td>
</tr>
<tr>
<td>• Blood vessels near the surface of the skin <strong>dilate</strong> (vasodilation), so <strong>more</strong> blood reaches the sweat glands</td>
<td>• Blood vessels near the surface of the skin <strong>constrict</strong> (vasoconstriction), so <strong>less</strong> blood reaches the sweat glands</td>
</tr>
<tr>
<td>• <strong>More</strong> sweat evaporates, cooling the skin and the blood in the vessels near the surface of the skin</td>
<td>• No sweat evaporates, so there is no cooling of the skin and the blood in the surface vessels</td>
</tr>
<tr>
<td>• This means that you will produce <strong>more</strong> concentrated urine (less water in the urine)</td>
<td>• This means that you will produce <strong>less</strong> concentrated urine (dilute urine)</td>
</tr>
</tbody>
</table>
Section B: Practice Questions

Question 1
The table below shows how body temperature is regulated by the hypothalamus by influencing heat production and heat loss.

<table>
<thead>
<tr>
<th>BODY TEMPERATURE (°C)</th>
<th>HEAT PRODUCTION (JOULES PER SECOND)</th>
<th>HEAT LOSS (JOULES PER SECOND)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36,4</td>
<td>320</td>
<td>5</td>
</tr>
<tr>
<td>36,6</td>
<td>260</td>
<td>5</td>
</tr>
<tr>
<td>36,8</td>
<td>150</td>
<td>35</td>
</tr>
<tr>
<td>36,9</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>37,0</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>37,2</td>
<td>90</td>
<td>180</td>
</tr>
<tr>
<td>37,4</td>
<td>90</td>
<td>310</td>
</tr>
</tbody>
</table>

1.1. Are the blood vessels that supply blood to the skin constricted or dilated when the body temperature is 36.4 °C? (1)
1.2. Explain the advantage of the diameter of the blood vessels (constricted/dilated) mentioned in your answer to QUESTION 1.1 (4)
1.3. Heat loss is the greatest at 37.4 °C. Explain how the body is able to increase heat loss. (4)

Question 2
Study the graph below showing the changes in the glucagon concentration during exercise.

2.1. Describe the trend for the changes in the glucagon level over time. (3)
2.2. Explain the changes in the level of glucagon from 0 to 10 minutes. (3)
2.3. Taking into account the pattern for glucagon concentration from 0 to 10 minutes in the graph above, what will you expect to happen to the insulin concentration for the same period? (1)
2.4. Explain why people with diabetes mellitus have very little glycogen in their liver and muscle cells. (3)
Question 3

The diagram below shows a section through the mammalian skin.

![Diagram](image)

3.1 Give labels for parts A, B and C. (3)

3.2 Describe how parts B and C play a role in reducing the body temperature back to normal when it increases above the norm. (6)

Question 4

The graphs below show the results of an investigation into the internal body temperature of a human. The subject rested in a temperature controlled chamber at 45°C and, at the time shown, ate a quantity of crushed ice. Graph A shows the variation in internal temperature with time. Graph B shows the variation in sweating with time (measured in arbitrary units).

![Graph A](image)

![Graph B](image)

4. 1 What was the subject's approximate internal body temperature over the first 25 minutes? (1)

4. 2 What was the subject's approximate rate of sweating between the first 25 minutes? (1)

4. 3 State briefly what happened to the following between the 25th and the 60th minute
   a. Internal body temperature
   b. Rate of sweating (4)

4. 4 During the first 10 minutes after eating the ice, the skin temperature rose sharply, despite the fact that the body temperature dropped?
   c. Identify the major source of heat which caused the rise in skin temperature (1)
   d. What facts evident from the study of the graphs would lead you to the conclusion that the temperature detector controlling sweating is NOT located in the skin? (1)
   e. Where in the body is the temperature detector which controls sweating? (1)
Question 5

Jack loves salt. He always put salt on his food.

5.1. Explain why Jack may suffer from high blood pressure. (3)
5.2. How does his body attempt to maintain a constant salt concentration in his blood? (4)
5.3. Can Jack’s body maintain the balance of salt if he always puts large amounts of salt on his food? Explain your answer. (2)

Question 6

The kidneys normally start to excrete glucose when the glucose level exceeds about 180mg per 100 cubic cm of blood. At this point glucose appears in the urine. Two individuals A and B, fasted for several hours and were given 50g glucose dissolved in 150cm$^3$ of water at 06h00. The glucose level of the blood was determined at the same time and subsequently every half hour for two and a half hours. The results of the glucose test are shown in the graph below.

6.1. What is the difference in the blood glucose level of individual A and B at 07:00? (1)
6.2. Why was the testing continued for only two and a half hours? (2)
6.3. Would a test have revealed glucose in the urine of individual B at 06:30? Give a reason for your answer. (2)
6.4. Name the disease individual A probably has. (1)
6.5. Experiments have shown that a drug called ALLOXAN destroys certain cells in the body. If individual B takes the drug ALLOXAN, results of B are similar to that of individual A. State the probable location and function of the cells which are destroyed by ALLOXAN. (3)
Section C: Solutions

Question 1

1.1 Constricted

1.2
- Less blood flows to the skin
- so less heat is lost to the environment by radiation
- Less sweat is formed because less blood flows to the sweat glands
- therefore less evaporation of sweat
- and hence less cooling of the skin
- Body heat is conserved

Any

1.3
- Hypothalamus is stimulated
- sends message to the blood vessels of the skin to dilate
- vasodilation occurs
- More blood flows to the surface of the skin
- More heat is lost by radiation from the skin surface
- More sweat is formed because more blood flows to the sweat glands
- and therefore more heat is lost by increased evaporation of sweat

Any

Question 2

2.1
- The blood glucagon levels increase from 100 to 210 (picograms/ml)
- from 0 to 20 min
- and become constant thereafter

Any

2.2
- during exercise more energy is needed
- therefore the rate of cellular respiration increased
- Increased cellular respiration requires more glucose
- hence more glucacon is secreted
- to stimulate the conversion of glycogen to glucose

Any

2.3 Decrease

2.4
- The lack of insulin/defective insulin
- decreases the conversion of glucose to glycogen

Any
Question 3

3.1. A – Sweat pore✓
   B – Sweat gland✓
   C – Blood vessel✓

3.2.
- Impulses sent from hypothalamus✓ to C (blood vessels)
- Blood vessels dilate✓/vasodilation occurs
- More blood carrying heat comes to the skin surface✓
- and therefore more heat is lost from the body✓ (any 3)

- B (Sweat glands) produce more sweat✓
- When sweat evaporates from the skin surface✓
- More heat is lost from the skin✓/it cools the body
- leading to a drop in the body temperature✓ (any 3)

Question 4

4. 1 37.5°C✓
4. 2 255 units✓
4. 3 a. Dropped to 37°C within 10 minutes,✓ then started rise until it reached 37.5°C again✓
   b. decreases rapidly to 25 units within 10 minutes✓ then started to rise to normal within 15 minutes✓
4. 4 a. increased blood flow to the skin✓
   b. the graph for sweating closely follows the graph for body temperature and not the graph for skin temperature✓
   c. hypothalamus✓

Question 5

5.1. Too much✓ sodium causes more water retention in the body✓ which leads to an increase in blood volume✓, which results in a higher blood pressure✓ (3)
5.2. When the salt concentration is high the blood pressure also increases, aldosterone production increases✓.
5.3. Less sodium is retained✓ and less water follows the sodium✓. Blood volume decreases and this lowers the blood pressure✓
5.4. Yes✓ as the process of negative feedback will always try to correct the levels to maintain homeostasis✓ but the other side effects could cause more damage over time (2)

Question 6

6.1. 75mg/100cm³✓
6.2. After two and a half hours the level would return be back to normal✓
6.3. No. ✓ the glucose level is only 100mg/cm³/or it does not exceed 180mg/cm³ (2)
6.4. Diabetes mellitus✓
6.5. Pancreas/islets of Langehans✓ secrete insulin which stimulates the conversion of glucose to glycogen in the liver and muscles✓ which promotes the absorption of glucose into cells✓ (3)