

Dr. Bbosa Science

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## Homeostasis:

The term **homeostasis** (from a Greek word meaning staying the same) is used to mean **maintenance of static or constant conditions in the internal environment** of the body. It describes all mechanisms by which a constant environment is maintained in the body.

### Why homeostasis is necessary

It is so because cells can only function properly within narrow ranges of conditions. The body has to keep proper concentration of oxygen, glucose, osmotic pressure, temperature, pH, the different electrolytes such as potassium and sodium and other nutrients in the body to allow the cells function efficiently.

### Mechanism of homeostasis

1. **Negative Feedback:** is a mechanism whereby deviation from a set norm causes a corrective mechanism to restore the norm. For example, increase in the concentration of glucose in blood initiates mechanism that brings the concentration back to normal.

An efficient negative feedback mechanism is the one that detects small changes from the norm and responds fast to prevent big fluctuations from the set point

For the corrective mechanism to work there must be

1. **Reference point-** The set level at which the system operates
  2. **Detector** – signals the extent of any deviation from the reference point.
  3. **The controller (brain)-** coordinates the information from various detectors and sends out instructions which will correct the deviation.
  4. **Effector** – brings about the necessary changes needed to return the system to the reference point.
  5. **Feedback loop-** informs the detector about the necessary changes in the system as a result of action taken by effector.
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2. **Positive feedback:** is a mechanism whereby the deviation from the norm causes further deviation. When a person is caught up in a burning building, high temperature

increases the activity of enzymes which result into further heat production. Positive feedback mechanism leads to death.

### **The homeostatic control of glucose.**

The normal concentration of glucose in human blood is approximately 90mg per 100 cm<sup>3</sup>, and even after the heaviest carbohydrate meal rarely exceeds 150mg per 100cm<sup>3</sup>. After absorption from the gut various things can happen to glucose in the body.

- It is broken down into carbon dioxide and water, particularly in active tissues such as the muscles.
- It may be built into glycogen and stored.
- It may be converted into fats and stored in the body's fat depots.
- If glucose is in short supply, glycogen may be broken down into glucose.

The concentration of glucose in the blood and tissue fluids at any moment is determined by the relative extent to which these different processes occur in the body. For example, if there is too much glucose, as after a large meal rich in carbohydrates, the cells convert the surplus glucose, the liver cells convert glycogen lowering its concentration in blood. When the concentration of glucose is lowered in blood, the liver cells convert glycogen into glucose, thereby raising the glucose concentration in the body.

In prolonged deficiency, glucose may be formed from non-carbohydrate source, including fat and proteins. This is called **gluconeogenesis**. This explains the wasting away of tissues, which occur in extreme starvation. This is because the body resort to converting its tissue proteins into carbohydrates.

### **The role of the pancreas.**

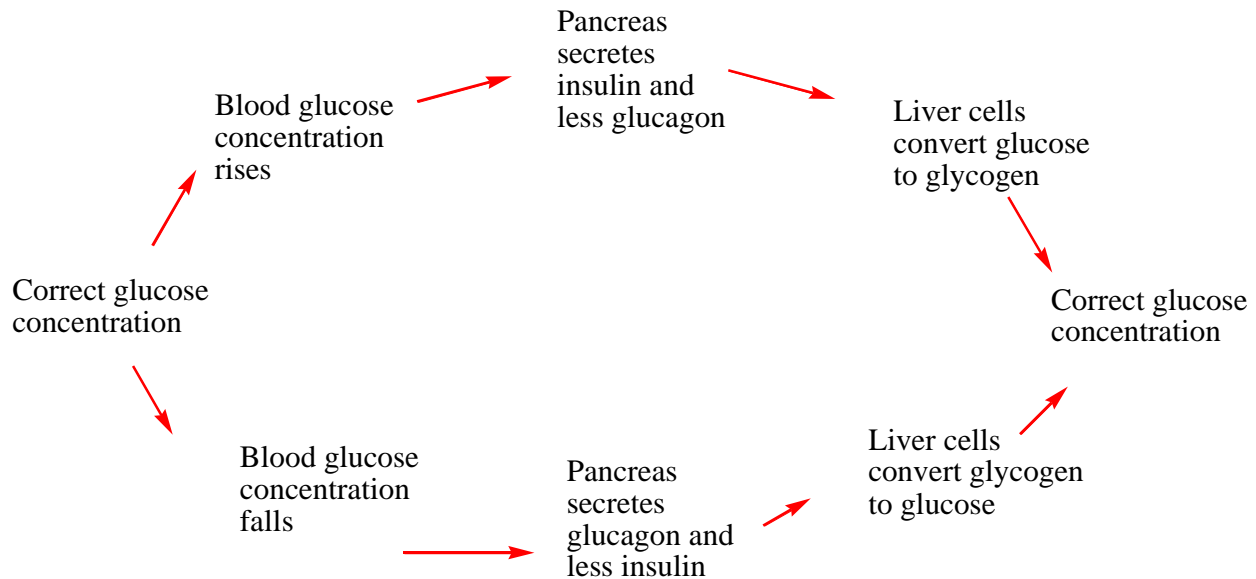
High concentration of glucose in blood triggers the pancreas to secrete the hormone insulin from **β-cells of islets of Langerhans**. This insulin exerts its effect lowering the blood glucose level mainly by

- increasing the conversion of glucose to glycogen and fat by the liver cells.
- inhibits the formation of glucose from glycogen and non-carbohydrate sources (gluconeogenesis).
- Increasing oxidation of glucose into carbon dioxide and water.

Low concentration of glucose in blood triggers the pancreas to secrete the hormone glucagon from **α-cells of islets of Langerhans** and inhibits secretion of insulin. This increases the concentration of glucose by

- Causes liver cells to convert glycogen and fat by the liver cells.
- Promotes gluconeogenesis or the formation of glucose from glycogen and non-carbohydrate sources

The homeostatic scheme of control of glucose in mammalian body is shown below



**Diabetes mellitus** is a disease condition caused by inability of an individual's pancreas to produce enough insulin.

It is characterised by increased in the blood glucose concentration (hyperglycaemia), and glucose appears in urine (glycosuria). The production of urine increases and the patient may suffer from intense thirst. Later symptoms include severe loss of the body mass, muscular waste and skin lesions. If untreated the patient goes into a **diabetic coma** and dies.

**Diabetes mellitus** is controlled by appropriate doses of parenteral insulin.

A sub-normal glucose concentration is called **hypoglycaemia**. If this is uncorrected, it causes a person to go into coma. Hypoglycaemia is particularly liable to occur during fasting, and one of glucagon's main functions is to counteract this.

### **Cells that secrete insulin and glycogen:**

By suitable staining techniques of islets of Langerhans two types of secretory cells can be distinguished in the islets: **alpha cells and beta cells** figure below:

The alpha cells located in the peripheral part of the islet, secrete glucagon, whereas the more centrally placed beta cells secrete insulin. Both hormones are secreted into blood capillaries within the islet; from which they pass into the general circulation to control the secretion of insulin.

Positive feedback

This is a destabilising mechanism that intensifies a change in the body physiological condition.

Examples

(i) Child birth

During labour release of oxytocin intensifies and speeds up contraction. The increase in contraction causes more oxytocin to be released and the cycle goes on until the baby is born.

(ii) Blood clotting

Once a vessel is damaged, platelets start to cling to injured site release chemicals that attract more platelets. The platelets continue to pile up and release chemical until a clot is formed.

### Exercise

1. An efficient physiological homeostatic mechanism is one which
  - A. Allow large fluctuation
  - B. Responds to deficiency faster than excess
  - C. Responds to small fluctuation
  - D. Allow positive feedback
2. Which one of the following pairs of hormones when released increase the level of blood sugar in the body?
  - A. Secretin and insulin
  - B. Adrenalin and glucagon
  - C. Insulin and antidiuretic hormone
  - D. Secretin and thyroxine
3. Which of the following is not involved in a physiological homeostatic process?
  - A. Positive feedback mechanism
  - B. Receptor
  - C. Effector
  - D. Control mechanism
4. Which of the following is not homeostatically regulated in the body?
  - A. Glucose
  - B. Water
  - C. Carbon dioxide
  - D. Fat

5. Which one of the following is not a requirement for the working of a physiological homeostatic mechanism?
- A. Receptors.
  - B. Skin capillaries.
  - C. Control mechanisms.
  - D. Effectors.
6. The islets of Langerhans in the pancreas secretes hormones important for regulation of
- A. carbon dioxide in blood
  - B. blood protein
  - C. blood sugar
  - D. insulin

**Section B**

7. (a) (i) What is meant by negative feed feedback in homeostasis? (2marks)

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(ii) Give two characteristics of an efficient homeostatic system (2marks)

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8.(a) Outline the general feature a physiological homeostatic system must have. (3marks)

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(b) What are the qualities of an efficient homeostatic system) (2marks)

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9. 2011/2/1) (a) Figure 1 shows the average blood glucose levels in the three major vessels of the liver of an individual, who had meals at 7.00 am and 1.00pm. use the information to answer the questions that follow

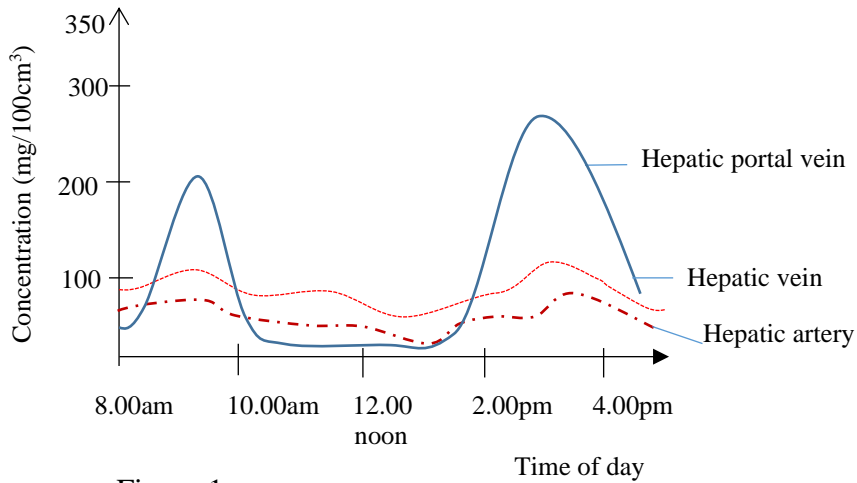
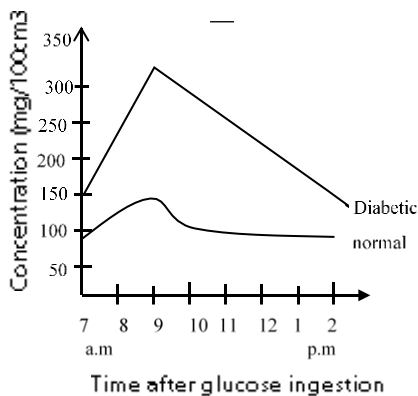


Figure 1

- (i) Compare the levels of glucose in:
  - Hepatic artery and hepatic vein (4marks)
  - Hepatic artery and hepatic portal vein (4marks)
- (ii) Explain the differences in the level of glucose in the
  - Hepatic artery and hepatic vein (9marks)
  - Hepatic artery and hepatic portal vein (9marks)

(b) The figure shows the blood levels in a normal and diabetic individual, after both individual were gives a sugar solution at 7.00 a.m. Study and answer the questions that follow (11marks)



- (i) Compare the levels of glucose between the two individuals (5marks)
- (ii) Give explanation for the observed pattern of the levels of blood glucose in the two individuals (5marks)

(iii) What is the significance of the physiological process illustrated in the figure 1 and 2

10. (a) What is meant by negative feedback mechanism in the body process? (3mark)

(b) Describe how each of the following affects the metabolism of carbohydrates

(i) insulin (3marks)

(ii) adrenaline (3marks)

(c) Describe how hormones from the ovary and pituitary gland interacts to control the human menstruation cycle.

Answers to objective question

1. C    2. B    3. A    4. A    5. B    6. D

7. (a) Negative feedback is a control system that reverses a deviation from a set point

(b) It must have receptors

It must have a control mechanism

Others

It must have effectors

It must have a norm (set point)

8. (a) outline the general features a physiological homeostatic system must have

- Receptor mechanism capable of detecting changes in the environment
- Control mechanism that initiates corrective mechanism
- Effector that carry out the corrective mechanism

(b) What is the qualities of an efficient homeostatic system?

It responds quickly to small fluctuations from the set point

9(a) (i) hepatic artery and hepatic vein

### Similarities

- In both, the blood glucose level increases gradually after a meal.
- In both, the blood glucose levels reach a maximum within 2 hours of having a meal.
- In both, the blood glucose levels decrease gradually after about 2 hours of having a meal.
- In both, blood glucose levels never drop to zero.
- Between 10:00am and 12:00 non, the blood glucose levels in each remain almost constant.

### Differences

- Hepatic vein has a higher level than the hepatic artery at all times.
  - Hepatic artery and hepatic portal vein.

### Similarities.

- In both, blood glucose level increases after a meal, reaching maximum within 2 hours of having a meal.
- In each, the blood glucose levels remain fairly constant between 10: 00an and 12:00 noon.
- In both, blood glucose levels decrease after about 2 hours of having meals.



## Differences.

Hepatic artery	Hepatic portal vein
<ul style="list-style-type: none"><li>- Higher glucose level initially.</li><li>- Increases more gradually after a meal.</li><li>- Reaches a lower maximum after each meal.</li><li>- Decreases gradually after about 2 hours of having meal.</li><li>- Between 10:00am and 1:00pm glucose level is higher.</li></ul>	<ul style="list-style-type: none"><li>- Lower glucose level initially.</li><li>- Increases more rapidly after a meal.</li><li>- Reaches a higher maximum value after each meal.</li><li>- Decreases rapidly after about 2 hours of having a meal.</li><li>- Between 10:00am and 1:00pm glucose level is lower.</li></ul>

### (ii) Hepatic artery and hepatic vein

The source of the glucose present in the blood is mainly from the alimentary canal and gluconeogenesis in the liver.

The hepatic artery brings oxygenated blood to the liver from the abdominal aorta while the hepatic vein drains blood from the liver into the inferior vena cava. As such, blood in the hepatic artery has passed through more organs and therefore has had more glucose removed from it. On the other hand, the hepatic vein is separated from the alimentary canal only by the liver and hepatic portal vein and is therefore closer to the source. Hence it contains more glucose than blood in the hepatic artery.

Hepatic artery and hepatic portal vein.

The hepatic artery carries oxygenated blood to the liver from the abdominal aorta while the hepatic portal vein drains blood from the alimentary canal into the liver. As such, blood in the hepatic portal vein contains a much higher content of glucose than the hepatic artery because it carries glucose that has been absorbed from the alimentary canal into blood stream. The hepatic artery, on the other hand, contains blood that has travelled through several body organs and has had more glucose removed from it for utilization in the organs.

- Between 10:00am and 1:00pm, the hepatic artery contains more glucose because its glucose content is independent of absorption from the alimentary canal; it depends on the body's homeostatic mechanisms. On the other hand, the glucose level in the hepatic portal vein depends on its absorption from the alimentary canal, which within this time has little glucose left for absorption.
- Immediately after a meal, the blood glucose level in the hepatic portal vein increases rapidly because it directly receives the glucose absorbed from the alimentary canal. However, the blood glucose level in the hepatic artery increases gradually after the meal because it is subject to the body's homeostatic mechanisms.

(b) Similarities.

- In both, blood glucose levels are above zero at 7:00am.
- In both, blood glucose levels increase after being given the sugar solution to a maximum value and then decrease.

Differences

Diabetic	Normal
<ul style="list-style-type: none"> <li>- Higher glucose level at all times.</li> <li>- Glucose level increases rapidly after the sugar meal and reaches a higher maximum in about 2 hours.</li> <li>- Decreases gradually after about 2 hours and never attains a constant value.</li> </ul>	<ul style="list-style-type: none"> <li>- Lower glucose levels at all times.</li> <li>- Glucose level increases gradually after the sugar meal and reaches a lower maximum in about 1 ½ hours.</li> <li>- Decreases gradually after about 1 ½ hours and attains a constant value within about 3 hours.</li> </ul>

(ii). – both individuals have blood glucose levels above  $0mg/100cm^3$  initially because glucose has to be in the circulation of sustain metabolic functions.

- Increase in the glucose concentration after the sugar meal in both individuals is due to the direct absorption of glucose into the blood stream from the alimentary canal however, that of a normal individual increases gradually because the blood sugar level is more under

homeostatic control than in a diabetic individual.

- In a normal individual, an increase in the blood glucose level as a result of the sugar meal stimulates the Islets of Langerhans in the pancreas to secrete the hormone insulin. Insulin acts on the cells of the liver, muscles and adipose tissue to reduce the blood sugar level.
- A diabetic individual produces either none or insufficient amounts of insulin so that the homeostatic control of blood glucose is impaired. As a result, a diabetic individual always has higher blood glucose levels which always fluctuate and never attain a constant value as in the normal individuals.

(c). it ensures that the body cells are always continually supplied with the correct amount of glucose required for normal cell function.

It ensures that the blood contains the correct amount of glucose necessary for maintaining the correct osmotic pressure.

It indicates that the liver plays the key role in regulating the blood glucose levels.

It indicates that regulation of blood glucose level should occur quickly for the body organs to function normally.

10. (a) Negative feedback is a mechanism of homeostasis in which a change in the quantity of a homeostatically controlled parameter from the norm sets up physiological processes that cause a change in the quantity of the parameter in opposite direction to return it to normal.

(b) (i) effects of insulin

- it increases the rate of uptake of glucose by muscle and fat cells through a number of glucose channels in the cell surface membrane.

- Insulin increases the utilization of glucose by the cells in the process of respiration.

Insulin increases the rate at which glucose is converted to glycogen in the liver and muscle cells (glycogenesis).

Insulin inhibits the formation of glucose from non-carbohydrates sources in the liver (gluconeogenesis) and also inhibits the process of glycolysis.

(ii) Effects of adrenaline

- It increases the rate of conversion of glycogen to glucose. This increases the blood sugar content.
- It increases the rate of production of glucose from non-carbohydrate sources in the liver.
- It increases the rate of utilization in the muscle cells in the process of respiration.

(c). in this question, you are meant to identify the hormones produced by the ovary and pituitary gland during the menstrual cycle and illustrate how they interact to bring about the events of the menstrual cycle.

Hormones produced by the ovary include progesterone and oestrogen while the pituitary gland produces luteinizing hormones (LH) and follicle stimulating hormone (FSH) which interact as shown to control events of the menstrual cycle.

During the early menstrual phase, levels of oestrogen and progesterone fall. This induces the pituitary gland to secrete FSH and LH.

Increased levels of FSH stimulate one or more Graafian follicles to start growing. It also stimulates follicle cells to secrete oestrogen. The levels of oestrogen in blood increase gradually for a few days and reaches the peak on the 12<sup>th</sup> day of the cycle. High oestrogen concentration inhibits FSH secretion which induces increased production of LH within 12hrs.

The high LH causes ovulation with subsequent formation of corpus luteum.

During the post ovulatory phase, corpus luteum secretes progesterone. Progesterone acts on the uterine wall to promote cellular proliferation in preparation for implantation and also maintains corpus luteum.

High levels of progesterone and oestrogen inhibit the secretion of LH and FSH.

If fertilization occurs, the corpus luteum degenerates. Progesterone level reduces markedly and the uterine wall is shed in menstruation. This initiates events of the next cycle (i.e. this is day 1 of the next cycle).