Bio Factsheet

Number 41

The Role of the Liver in Homeostasis

The liver helps to regulate the composition of the blood and is, therefore, a major homeostatic organ.

1. Blood glucose levels

The liver is the organ which effectively regulates blood glucose level. It can rapidly take up or release glucose if the blood glucose level changes. The hormones which control this activity are produced in the pancreas.

If the level of glucose in the blood **increases**, this is detected by beta cells in the Islets of Langerhans of the pancreas. These cells release **insulin**, which reduces the blood glucose level. Insulin travels around the body in the blood and has a particular effect on the cells in the **liver**, **muscles** and in **adipose tissue**.

The liver takes up more glucose, converts glucose to glycogen, fatty acids and triglycerides, and uses glucose in glycolysis to release energy (Fig 1). These three processes reduce blood glucose levels.

If the level of glucose decreases, this is detected by **alpha cells** in the Islets of Langerhans of the pancreas. These alpha cells release **glucagon**. Glucagon also travels around the body in the blood and also affects cell membranes.

Under the influence of glucagon, the liver produces glucose by converting it from glycerol and by converting non-carbohydrate sources, such as amino acids from protein breakdown in muscle, into glucose. The formation of new glucose from non-carbohydrate sources is known as **gluconeogenesis**.

Fatty acids, which are released from muscles under the action of glucagon are used as an energy source for these reactions (Fig 2).

Clearly, the liver is not the only organ which is influenced by insulin and glucagon, but it does have a major role to play in glucose regulation because:

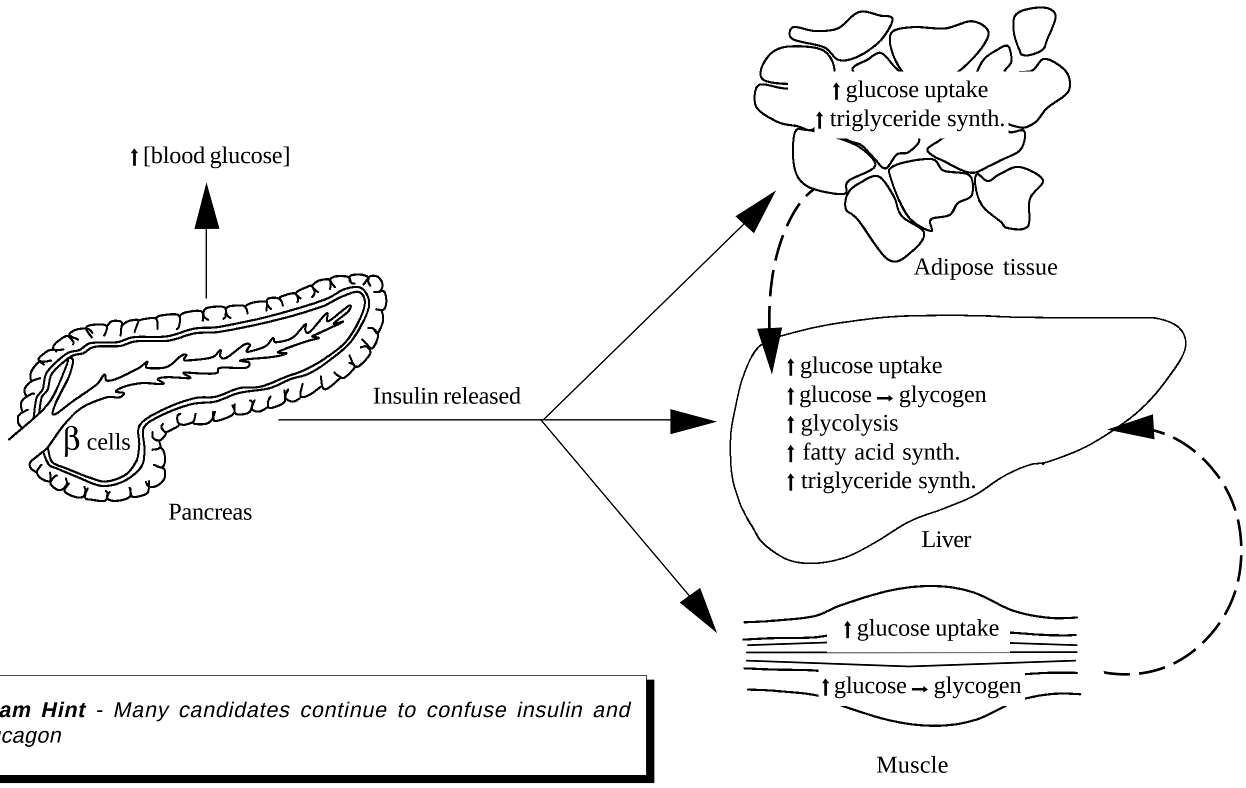
- it is the largest organ in the body
- it is the first organ to receive sugar-rich blood from the intestines
- it is a major store of glycogen.

Insulin, therefore, has a great effect on liver cells and liver cells contain high concentrations of the enzymes responsible for converting glucose into glycogen and glycogen into glucose.

Why is glucose regulation necessary?

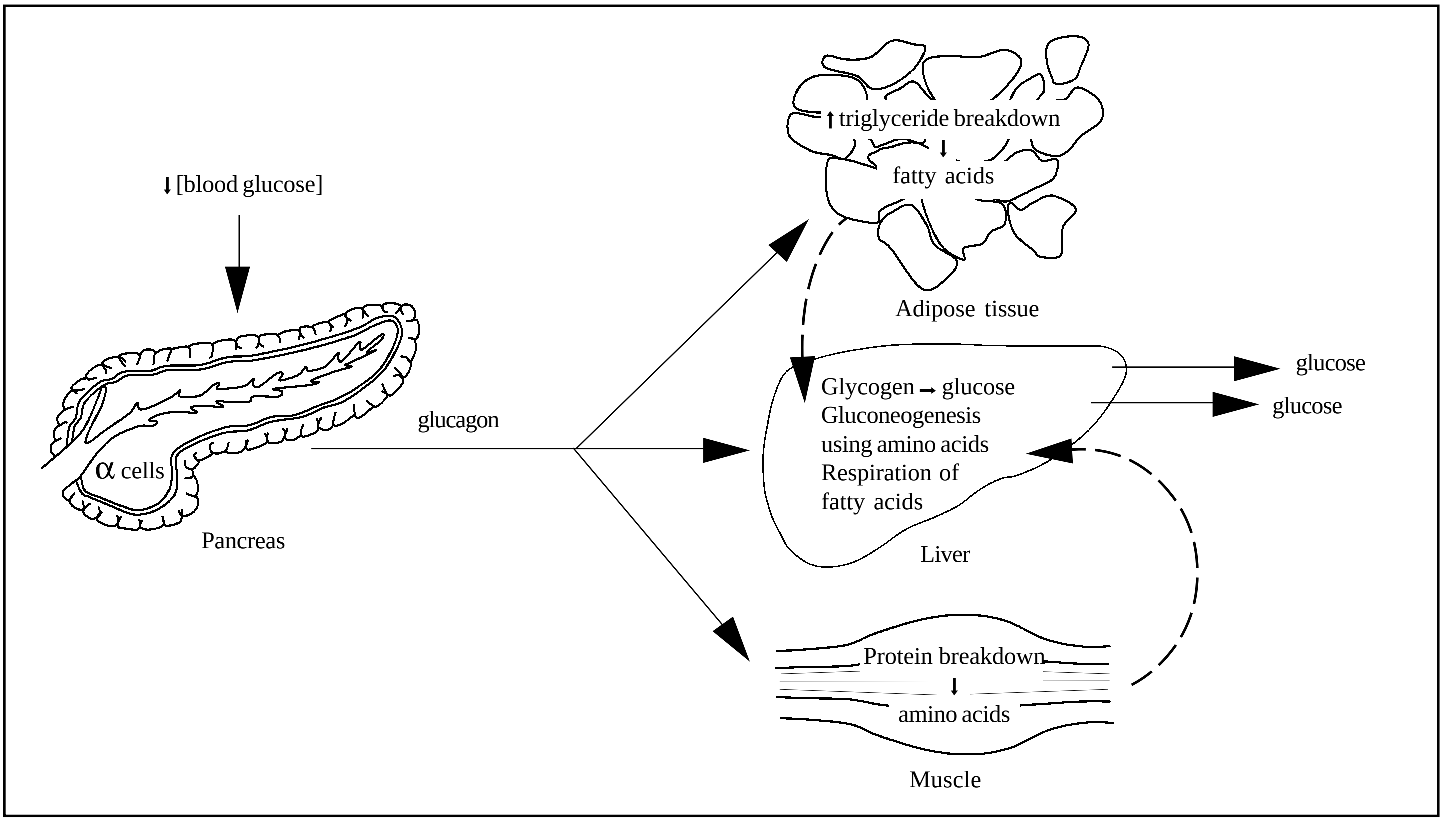
Glucose is needed as a respiratory substrate to maintain metabolic rate. Excess glucose would decrease the osmotic pressure of cells, drawing water out of body cells, causing dehydration. Conversely, insufficient glucose means that the metabolic rate cannot be maintained and both the brain and red blood cells – which have specific requirements for glucose – would be unable to function properly. The brain is the major single consumer of glucose in the body and red blood cells lack mitochondria and therefore cannot generate their own ATP.

Fig 1. How insulin reduces blood glucose levels



***Exam Hint** - Many candidates continue to confuse insulin and glucagon*

Fig 2. How glucagon increases blood glucose levels



2. **Regulation of amino acids**
Animals cannot store proteins. Ingested proteins are digested in the stomach and small intestine. The amino acids which are released are absorbed in the ileum and are transported to the liver via the hepatic portal vein. If daily intake exceeds requirements (e.g. in growth and metabolism) the excess amino acids must be removed. It is the liver which is responsible for this process.

There are three possible fates of excess amino acids:

(a) Deamination
The amine (NH_2) group of the amino acid is removed and converted into ammonia (NH_3), which is extremely toxic to the central nervous system (CNS). The ammonia is, therefore, rapidly combined with carbon dioxide – another excretory product - and forms urea ($CO(NH_2)_2$) in the **ornithine cycle**. The removal of the amine group of amino acid leaves an organic acid residue. This is usually used as a substrate in respiration – in other words it is used as a source of energy. Alternatively, it may be used as a starting point for the manufacture of glucose.

(b) Transamination
Humans need 20 amino acids – eight of which are termed essential amino acids because they cannot be manufactured by the body. The other twelve which can be made by the body are produced by converting one type of amino acid into another – transamination.

(c) Used in the production of plasma proteins

3. **Regulation of body temperature**
The hepatocytes (liver cells) are metabolically very active and therefore produce a lot of heat. Such heat is used by endotherms to maintain a constant body temperature.

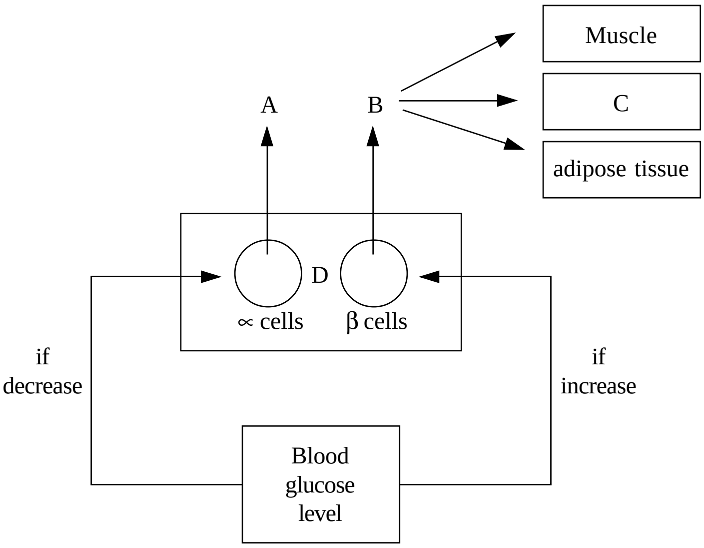
Homeostasis is the maintenance of a stable internal environment. Besides the three major functions outlined above, the liver helps to maintain this stable internal environment in many ways (Table 1).

Table 1. Summary of liver functions

Function	Description
Storage of vitamins	Vitamin D (for calcium absorption), vitamin A (for retinal production), vitamin B_{12} (manufacture of haemoglobin and coenzymes) and vitamin E.
Storage of minerals	K^+, Cu^{2+}, Fe^{2+}, all of which are important for enzyme function.
Manufacture of plasma proteins	Albumin, fibrinogen, globulin, prothrombrin and clotting factors.
Detoxification	The liver is responsible for the breakdown of toxic substances including hydrogen peroxide, hormones (e.g. testosterone), alcohol and drugs.
Breakdown of old red blood cells	In the embryo, before bone marrow has fully developed, the liver is responsible for the formation of red blood cells.
Regulation of cholesterol	Most of the cholesterol in the liver is converted into bile salts, which are incorporated into bile and stored in the gallbladder.
Manufacture of bile	For emulsification of fats, which accelerates their digestion by lipases.
Synthesis of triglycerides	From excess carbohydrates and proteins.

Practice Questions

1. The diagram shows some of the stages in the regulation of blood glucose concentration.



(i) Substance A (1 mark)

(ii) Substance B (1 mark)

(iii) Organ C (1 mark)

(iv) Organ D (1 mark)

(b) Explain why glucose may be detected in the urine of people who suffer from diabetes mellitus (3 marks)

2. Explain why the metabolism of proteins yields ammonia and urea whilst the metabolism of carbohydrates yields carbon dioxide and water (2 marks)

3. Read the passage and answer the questions that follow.

Artificial Pancreas
Scientists are developing a biosenser which aims to detect blood glucose levels, translate this into an insulin requirement, and then be capable of supplying continuous injections of insulin.

The biosenser must give a linear response over a range of blood glucose concentrations, must be specific for glucose and be unaffected by the changing concentrations of other metabolites.

(a) Why is the biosenser termed an Artificial Pancreas? (1 mark)

(b) Explain how insulin reduces blood glucose levels (2 marks)

(c) How are biosensers able to be substrate specific? (2 marks)

Answers

Semicolons indicate marking points

1. (a) (i) Glucagon;

(ii) Insulin;

(iii) Liver;

(iv) Pancreas;

(b) insufficient/no insulin produced;
blood glucose level increases;
kidney unable to absorb all glucose;

2. Proteins contain N;
Carbohydrates only contain C, H, O;

3. (a) Cells in pancreas detect changes in blood glucose concentrations;

(b) Increases uptake by liver;
Increased glucose to glycogen/fatty acids;
Increased respiratory use;

(c) Use enzymes;
Active site specific to shape of substrate;

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