The Metabolic system

**Metabolism** is the term used to describe the many chemical reactions that are involved in the utilisation of nutrients in the body. If these reactions are investigated more closely, it will be found that they may be placed into one of two categories known as anabolism (building more complex compounds from the simple ones resulting from digestion) and metabolism (breaking down of these complex compounds to produce energy for normal body functions).

These reactions are quite complex and the important aspects only are covered here. Discussion will be confined to the three major dietary inclusions of carbohydrates, fat and protein. The minerals, vitamins and other nutrients are not discussed.

Metabolism of carbohydrates

The only carbohydrate found in the blood is **glucose**. A certain concentration of glucose is necessary in the blood stream for normal activity. Any excess glucose is stored. If the body is glucose deficient, body reserves are then used to make up the supply to demand. This means that when carbohydrates are digested they are broken down to glucose. Glucose is stored as glycogen in the liver and large quantities are also found in the muscles. Excess glucose can also be converted to fat for storage. Glucose is oxidised to produce energy, and carbon dioxide and water are produced as by-products. A small amount of carbohydrate is also found in cell protoplasm.

After eating, the complex carbohydrates are broken down into glucose that is absorbed from the alimentary canal into the capillaries of the villi of the small intestine and then into the portal vein en-route to the liver. Here some of it is stored as **glycogen**. The remainder enters the systemic [circulatory system](http://www.poultryhub.org/physiology/body-systems/circulatory-system/) (blood system for the body) and is transported to the tissues. Its presence in the blood causes an increase in the blood sugar level. This glucose is removed from the blood by the tissue cells to be oxidised to provide energy or is stored as glycogen in the muscles or as fat in other tissues for future use. The concentration of sugar in the blood then falls to what is called the resting level.

**Glucose Demand**

Because of the continuing demand for sugar by the tissues, glucose is continually being removed from the blood. If this is not replaced on a continuous basis, the blood sugar level will very quickly fall to critical levels. However, to overcome this problem, the body continuously replenishes the blood glucose level from the glycogen stored in the liver. In this way the level of glucose in the blood is maintained. Liver stores are maintained in the absence of glucose by the conversion of non-carbohydrate material, mainly protein, and to a certain extent, fat to glycogen. During vigorous activity, muscle glycogen is consumed to produce energy, and in the absence of enough oxygen, lactic acid is produced. If too much lactic acid is formed in this process, it enters the blood stream and is transported back to the liver where it is re-converted back to glycogen.

Metabolism of fat

After digestion, the fatty acids and glycerol are absorbed into the lymphatic system of the intestines. These enter the vena cava near the heart and hence into the blood stream. Fat may be stored in large quantities in the connective tissue under the skin and adjacent to certain organs. Indirectly, fat may be converted into glycogen and even protein in the liver. Fat may also be stored in the liver.

**Fat Is Energy And A Building Block For Cells**

Fat is oxidised to provide energy, with carbon dioxide and water being the by-products. Fat is only used for this purpose when most of the stored glycogen has been used. Thus fat is a reserve of concentrated energy for use when other sources fail while glycogen is being called upon all of the time. Fat molecules form part of the cell membranes that are found on the outside of the protoplasm and cytoplasm (of the cells). It helps to impart elasticity to the membrane as well as contributing to its semi-permeable nature.

Metabolism of protein (Amino acids)

Proteins are absorbed as amino acids from the intestine into the capillaries of the villi and thence into the portal system en-route to the liver where most are removed. Consequently there is very little change in the blood protein level after the consumption of food. There is very little protein stored in the body. Small amounts can be mobilised from the blood, muscle and liver. If excess protein is consumed, most of it is converted to glucose or fat for use in providing energy or stored for future energy demand.

**Amino acids** consist mainly of carbon, hydrogen, oxygen and nitrogen. There are small quantities of other elements such as sulphur in some. When the amino acids are converted to glucose or fat, the nitrogen is removed first in the liver and converted into urea. This is then transported in solution to the kidneys for elimination from the body as urine. After eating, there is an increase in the amount of urea in the blood which indicates that the excess amino acids have been converted in the liver. The kidneys and muscles can also remove the nitrogen but the product is ammonia and not urea.

The remaining compound contains mainly carbon, oxygen and hydrogen and can be oxidised to provide energy, carbon dioxide and water. It can be converted to glucose or fat as well and either oxidised or stored as previously described. Proteins form a very important part of cell protoplasm and the amino acids from the blood may be combined in a number of ways to form different cellular and plasma proteins. Protein is found in many areas of the body other than muscles and is the basis of many body compounds including the enzymes involved in digestion and the antibodies used in fighting infection.

**Cells Recycle Amino Acids**

Some of the proteins of the tissue cells and the plasma proteins are constantly breaking down and liberating amino acids into the blood stream. These amino acids together with those from the food are used to build other protein to replace those broken down, or they may be oxidised to form glucose or fat. In this way, there is a regular turnover of body protein that remains constant in amount, in the normal adult. During growth, there is an increase in body protein due to the increase in the number of cells in the growing body.

Control of carbohydrate metabolism and blood sugar level

The body hormonal system mainly control metabolism and the following hormones are involved:

1. **Natural growth hormone:** This hormone is produced by the anterior pituitary gland and stimulates those reactions concerned with the increase in blood sugar. It slows down the uptake of glucose by the tissue cells but increases the amount of glycogen deposited in the muscles.
2. **Insulin:** This hormone is produced by the Islets of Langerhans in the pancreas and lowers the level of blood sugar by speeding up its storage as well as slowing down those reactions that add glucose to the blood.
3. **Glucagon:** This hormone is produced by the Islets of Langerhans and has the opposite effect to insulin by tending to raise blood sugar.
4. **Cortisone and Hydrocortisone:** These hormones are produced by the adrenal cortex and cause a rise in the level of sugar in the blood and a rise in liver glycogen.
5. **Adrenalin and Noradrenaline:** These are produced by the adrenal medulla and during periods of emergencies stimulate the breakdown of liver glycogen and cause a rise in blood sugar level to supply the energy required very quickly.
6. **Thyroid hormone:** This hormone is produced by the thyroid gland and has an effect on metabolism in a general way.

The actual level of glucose in the circulating blood is the result of a delicate balance between all of these hormones. If this balance is upset, there is a change in the blood sugar level. Perhaps the most common upset is due to damage to the Islets of Langerhans leading to a reduction in the amount of insulin and glucagon produced. Subsequently, there is a rise in the level of blood sugar and the glycogen stores become depleted and sugar may appear in the urine.

Control of fat and protein metabolism

Since the metabolism of carbohydrate, fat and protein are so intimately related, most of the hormones described previously influence the storage or breakdown of all of these substances as well as the conversion of one to another.

Metabolic rate

There are a number of factors that affect the metabolic rate which is the rate of energy production in the body. It depends upon sex, age and the level of activity:

1. Sex: females have a lower metabolic rate than males
2. Age: the young have a higher metabolic rate in proportion to size than do adults. The young need energy for both growth and activity
3. Activity: The greater the activity level, the greater will be the demand for energy and hence the metabolic rate increases to cope