NUTRITION AND METABOLISM

Metabolism - the sum of the chemical changes that occur in the cell and involve the breakdown (catabolism) and synthesis (anabolism) of stored energy sources.

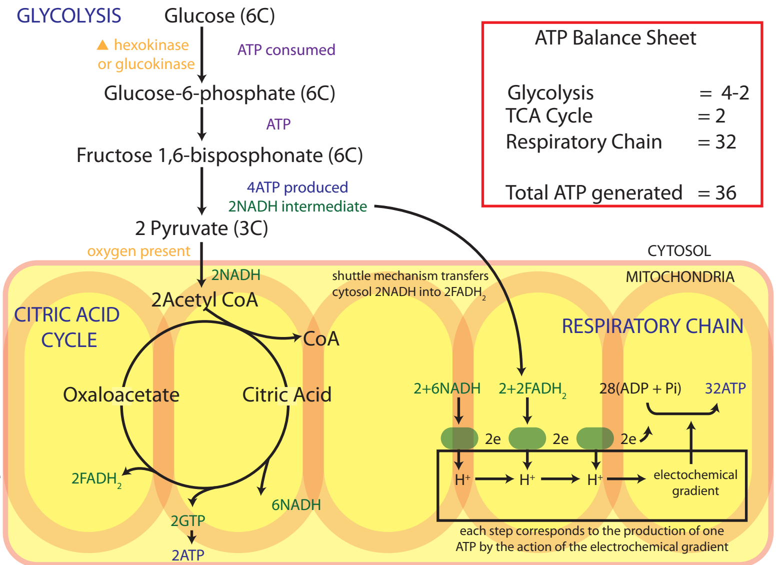
Basal Metabolic Rate is defined as the rate of energy production by the body measured under a defined set of conditions which is usually at rest (physical and mental), room temperature, 12 hours after a meal. The result is produced as a percentage of a standard value which is derived from studies of normal healthy people. Measurement of the metabolic rate takes place using a method called calorimetry. This may be done directly by measuring the amount of heat produced by the body in an Atwater chamber, the metabolic rate is the amount of heat produced per hour. More commonly the metabolic rate is determined indirectly by putting people on a closed circuit breathing system, with CO2 removed by a soda lime scrubber and the rate of oxygen consumption measured by change in volume. Oxygen consumption is proportional to the metabolic rate because most of the energy in the body is derived from oxidative phosphorylation, which uses a set amount of oxygen to produce a set amount of energy. For every litre of oxygen consumed the body produces (uses) 4.82 kcals of energy. If the oxygen consumption is 250ml/min (15L/hr) then the metabolic rate is 72.3 kcals/hr. This is often further refined by dividing the figure by the body surface area which for a 70kg male is $1.73m^2$. This gives an average BMR of approximately 40 $kcal/m^2/hr$.

Factors that influence metabolic rate There are a range of factors which affect metabolic rate. Common sense indicates that the most important factors are activity and body mass, people who are more active use more energy (hence BMR is measured at rest) and those with a greater mass will have a greater BMR (this is easily managed by dividing BMR/weight to enable useful comparison). The body surface area is also an important factor. Gender influences BMR via this factor, women, who generally have a higher proportion of fat:muscle have a decreased BMR however this is negated if lean body mass is considered. Age is also an important factor. Neonates have a BMR roughly double an adult BMR due to the increased growth needs on a weight controlled basis. The increased BMR continues throughout the growth period gradually declining by a annual rate 2% in adult years due to increased fat levels and decreased lean tissue. After a meal, the BMR rises for 4-6 hours by about 10-15%, an effect known as the specific dynamic action (SDA) of food. Starvation decreases BMR because a reduced cell mass and tissue metabolism. Climatic factors also influence BMR with people living in the tropics having a lower BMR when compared to temperate regions. Hormones such as thryoxine and adrenaline increasing BMR. Pregnancy and breast feeding also increase BMR.

- Activity
- Body Mass
- Body Surface Area
- Gender (due to BSA)
- Age
- Post prandial state
- Starvation (decreases)
- Climatic Factors
- Adrenaline/thyroxine
- Pregnancy/breast feeding

Carbohydrate Metabolism The principle product of digestion and absorption is glucose (although fructose and galactose are also important). It is absorbed via the portal system and some is stored as glycogen in liver before being released sytemically where is may be stored in muscles as glycogen, or metabolised to give CO2 and H2O with the associated release of energy and ATP production. Carbohydrates provide 40-50% of the bodies energy requirements (fat 40-50% and protien 10-15%). Some tissues (such as skeletal and cardiac muscle) can function without glucose by utilising fatty acid oxidation but other tissues (such as nervous and blood cells) are obligatory users of glucose and cannot survive without it. Glucose is transported into cells down a concentration gradient by transporters (GLUT 1-5). With GLUT 4 is insulin dependent and is found in muscles, the others are independent.

Glucose is metabolised by two sequential pathways. The first is the glycolysis pathway (AKA Meyer-Embden) which uses 2 ATP, produces 4 ATP (plus some NADH which is transported into the mitochondria (changing to $FADH_2$) for the respiratory chain) and essentially splits the 6 carbon glucose molecule into two 3 carbon pyruvate molecules. An alternative pathway to glycolysis is the pentose shunt which provides ribose-5-phosphate for nucleotide synthesis. The second important pathway in glucose metabolism is the citric acid cycle (AKA Krebs cycle or TCA). The main purpose of this cycle to to create reduced NADH and $FADH_2$ which then enter the respiratory chain for oxidative phosphorylation. The TCA cycle also provides one GTP molecule per glucose which can convert an ADP to ATP.



ATP Balance Sheet

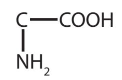
Glycolysis	= 4-2
TCA Cycle	= 2
Respiratory Chain	= 32
Total ATP generated	= 36

When there is excess glucose present in the circulation insulin stimulates storage as glycogen. Hepatic glycogen is the body's glucose buffer. With prolonged fast, heaptic glycogen stores become exhausted in 24-48 hours. Release of glucose from glycogen (glycogenolysis) is usually due to a fall in BSL and this is mediated by the balance of the hormones glucagon and insulin (which are released from A and B cells respectively in the islets of langerhans in the pancreas). Other hormones which effect this process are the catecholamines noradrenaline and adrenaline. The other major store of glycogen in the body is muscle. This is usually stimulated by calcium release from the sarcoplasmic reticulum.

Fat metabolism In adipose tissue fat (triglycerides) forms the major energy store of the body. Triglycerides are as the name suggests composed of a glycerol molecule and three fatty acids. It is absorbed from the GIT via the lymphatic system in chylomicrons which are large lipoprotiens which do not pass through the liver. Chylomicrons are hydolysed peripherally by lipoprotien lipases under the influence of insulin (especially 2-3 hrs post meal) and the fatty acids are deposited in adipose tissues. The quantity of adipose tissue appears to be under the influence of the polypeptide hormone leptin. Fatty acids (and gylcerol) may be latter mobilised in a process called lipolysis which releases the FFAs (bound to albumin) into the circulation for uses as an energy substrate. This occurs under the influence of hormone sensitive lipase, which is stimulated by catecholamines (adrenaline and norad) and inhibited by insulin. Fatty acids are used as metabolic fuel by peripheral tissues including skeletal muscle and myocardium. Fatty acids are oxidised in the mitochondria by beta oxidation which results in the formation of acteyl CoA. This may then enter the citric acid cycle. Longer chain fatty acids can only penetrate the mitchondria if they are linked to carnitine which is synthesised in the liver and kidney. In the absence of exogenous energy substrate glycogen stores are exhausted in 24-48hrs. As the nervous tissue can usually utilise only glucose the body begins to breakdown protiens in a process called gluconeogenesis (discussed below). After 4-10 days of starvation the brain partially adapts to obtain up to 2/3 of its energy from ketone bodies, acetoactate and beta-hydroxybutyrate. These ketone bodies are synthesised in the liver from FFAs.

Protien metabolism Protiens are made up of amino acid chains connected by amide bonds to carbon groups. All 20 common amino acids (which includes the 10 essential acids not able to by synthesised by the body) contain the common amino acid group shown adjacent. The average daily required intake of protiens is 30-50g. Large protiens have their peptide linkages broken down in the stomach by the action of pepsins and in the small intestine under the influence of pancreatic enzymes such as trypsin and enzymes within the intestinal mucosa. Transport into the enterocytes may be dependent or independent of sodium as a cotransporter. Most protiens are large and therefore require active or cotransport to enter cells. In the body amino acids are usually stored in the form of protien with large stores exisitng in the muscle, the liver and to a lesser extent the GIT and kidneys. The major types of protiens in the plasma are albumin which is important in providing oncotic pressure, globulins which have a diverse range of functions including immunity and fibrinogen which is the precursor for fibrin at the end of the coagulation pathways. Most of the plasma protiens are formed in the liver. Insulin normally stimulates protien synthesis and maintains protien balance, although other hormones such as growth hormone, insulin-like growth factor, glucocorticoids and thyroxine are also important. When there is an excess of protien it is usually converted into fat, energy or glycogen by a process of deamination, literally the removal of the amine groups. This produces ammonia which is removed from blood when it enters the urea cycle and is usually excreted in the urine. In starvation states when fat stores and carbohydrate stores are exhausted, protien may be utilised in an inefficent process called gluconeogenesis which converts protien to glucose or glycogen.

Basic Amino Acid



Vitamins A vitamin is an organic compound needed in small quantities for normal metabolism that cannot be manufactured in the cells of the body. They are stored to a slight extent in all cells and to a major extent in the liver. ADEK are the fat soluble vitamins. There are extensive stores of A which is important in vision, it is derived directly from animal consumption and as a precursor from vegetable foodstuffs in the form of carotenoid pigments. Vitamin D is the subject of extensive research and plays a central role in calcium metabolism. E is believed to play a role in reproduction and fat oxidation. K is important in the liver for the formation of clotting factors. B is present in a number of forms. B_1 (thiamine) is important in the metabolism of fats and amino acids and deficiencies have significant pathological consequences. B_2 riboflavin contibutes to FAD production. B_{12} coalbumin promotes red cells production and maturation. Folic acid is important in the synthesis of purines and thymine. Niacin (nicotinic acid) contributes to NAD production. Vitamin C (ascorbic acid) is important in developing strong collagen fibres. The three most important trace elements are iodine, zinc and flourine.

Christopher Andersen 2012