What is Metabolism?

Our body is a factory which is superbly effective. It accepts raw material (food), burns some for power generation, uses some for finished goods output, routes the rest for storage, and discards waste and by-prodcucts. Your stored inventory still keeps it fresh. The body relies on these stored raw materials to create compounds and supply is replenished by the ingestion of nutrients.

Do you ever wonder how the biological factory in your body reacts to changing supply and demand? It hums beautifully together with all processes in equilibrium under usual circumstances. When supply exceeds demand, the body will store excess raw materials in inventory. If supply does not meet demand, the body must rely on these stored resources to fulfill its needs. Your biological factory never stops; and all of your factory operations are active at all times via a storage or energy-production cycle.

Those processes are known collectively as metabolism. Whereas other metabolic processes break down molecules for energy extraction. Others are synthesizing the building blocks to create new molecules. Thousands of chemical reactions happen every moment in cells through the body to conduct metabolic processes. The metabolic locations that are most involved include the liver, muscle and brain cells.

Those processes are known collectively as metabolism. Whereas other metabolic processes break down molecules for energy extraction. Others are synthesizing the building blocks to create new molecules. Thousands of chemical reactions happen every moment in cells through the body to conduct metabolic processes. The metabolic locations that are most involved include the liver, muscle and brain cells. The pathways to metabolism are never fully inactive. Their operation ebbs and flows continuously in response to internal and external events. Imagine, for example, that your professor keeps you late and that you only have five minutes to get to your next lesson, that your body keeps breaking down and extracting glucose from the banana you ate recently. The glucose is formed into branched chains for your body to fix

The cell is the metabolic processing center

Cells are the metabolic "job centre." While our bodies are made up of different cell types (liver, lungs, brain, muscle cells in the kidney), most have a similar structure. There are two main parts of the basic animal cell: the cell nucleus and a membrane – enclose space called the cytoplasm. When we zoom in for a closer look we see that the cytosol fills the cytoplasm with a semifluid. There are several organelles circulating inside the cytosol, small groups conducting complex metabolic functions. A large number of these capsule-like mitochondria organelles are power-generating pathways that contain a lot of essential energy.

Organelles

Endoplasmic reticulum (ER)

An extensive membrane system extending from the nuclear membrane.

Rough ER: the outer membrane surface contains ribosomes, the site of protein synthesis.

Smooth ER: Devoid of ribosomes the site of lipid synthesis.

Golgi apparatus

A system of stacked membrane-encased discs.

The site of extensive modification, sorting and packaging of compounds for transport.

Lysosome

Vesicle containing enzymes that digest intracellular materials and recycle the components.

Mitochondrion

Contains two highly specialized membranes, an outer membrane and highly folded inner membrane. Membranes separated by narrow intermembrane space. Inner membrane encloses space called mitochondrial matrix.

Often called the plant of the cell. Site from where most of the energy from carbohydrate, protein and fat is captured in ATP (adenosine triphosphate).

About 2,000 mitochondria in a cell.

Ribosome

Site of protein synthesis.

Nucleus

Contains genetic information in the base sequences of the DNA strands of the chromosomes.

Site of RNA synthesis-RNA needed for protein synthesis.

Enclosed in a double-layered membrane.

Cytoplasm

The semifluid inside the cell membrane.

Site of glycolysis and fatty acid synthesis.

Cell membrane

A double-layered sheet, made up of lipid and protein that encases the cell.

Controls the passage of substances in and out of the cell.

Contains receptors for hormones and other regulatory compounds.

Think of a bowl of thick vegetable soup with a single meatball floating in it, to recall the key parts of a cell. Think of the broth for our example as having a runny, jellylike consistency and the bowl as thinking fluid structure with the consistency of a broad wet book. Similar to the way a cell membrane encloses a cell, the bowl surrounds and retains the mix. The meatball represents the cell nucleus, and the cytoplasm is the remaining mixture. This cytoplasmic broth consists of a thick, semiliquid (cytosol) fluid and vegetables (organelles). Think of those kidney beans among the vegetables as mitochondria.

Enzymes, which are catalytic proteins, speed up chemical reactions in metabolic pathways. Many enzymes are inactive unless they are combined with certain smaller molecules called cofactors, which usually are derived from a vitamin or mineral. Vitamin-derived cofactors are also called coenzymes. All the B vitamins form coenzymes used in metabolic reactions.

Who are the key energy players?

Some compounds play repetitive roles in metabolic activity. Adenosine triphosphate (ATP) is the fundamental molecule of energy used to control cellular functions, and is also known as the basic currency of energy. Two additional molecules, NADH and FADH, are important couriers that carry energy for ATP synthesis. A similar body of energy. NADH delivers biosynthesizing capacity.

ATP: the body's energy currency

Your body must turn the energy in food into a readily accessible form— ATP for power is requires. This universal energy currency kick-starts other processes of energy emancipation. Such as the breakdown of glucose and fatty acids, and driving processes that consume energy, such as building up glucose from other compounds. Note that they make large molecules from smaller ones, such as building a brick building.

ATP production is the fundamental aim of the energy producing pathways for metabolism. Just like the ancient Romans may argue that all roads lead to Rome, you can assume that the energy-generating pathways of your body lead to the development of ATP, with a few exceptions.

The ATP molecule has three phosphate groups that are bound to an organic compound called adenosine. Since breaking the bond between the groups of phosphates releases tremendous energy. ATP is a molecule which is rich in energy. Cells can use this energy to power biological work. When the first phosphate bond is formed by a metabolic reaction, it breaks down ATP into adenosine diphosphate (ADP) and pyrophosphate (P). Breaking the remaining releases of phosphate bonds will provide an equivalent amount of energy and breaks down ADP to monophosphate adenosine (AMP) and P.

Since the reaction can go either way. ATP is interconvertible with ADP. ADP binds P while extracting energy from starch, protein, and fat, forming a phosphate bond, and storing energy in a new molecule of ATP. ATP releases P as the reaction moves in the opposite direction, breaking a phosphate bond and releasing energy when reforming ADP. This freed energy will fuel biological activities such as movement, active transportation through cell membranes, biosynthesis and amplification of signals.

The ADP pool of the body is a small energy reservoir that is instantly available, rather than a long-term energy reserve. An ATP molecule's average lifetime is less than one minute, and the production of ATP increases or decreases in direct relation to energy requirements. You use about 40 kilograms of ATP in 24 hours at rest (an average rate of about 28 grams per minute). By comparison, you can use as much as 500 grams per minute if you are exercising strenuously.

NADH and $FADH_2$: The body's Energy Shuttles

When metabolic reactions break down the nutrients, they release high-energy electrons. Additional reactions transfer energy from those electrons to ATP. High-energy electrons take a trip on different molecular carriers to access the ATP production site. Nicotinamide adenine dinucleotide (NAD), a derivative of vitamin B niacin, is one of the major electron accepters. There are several energy transfer points in the metabolic pathways where a NAD accepts two high-energy electrons and two hydrogen ions (two protons to form NADH+H.

The other major electron acceptor is the flavone adenine dinucleotide FAD a vitamin riboflavin derivative of B. Whoever FAD accepts two electrons of high energy it takes up two protons and forms FADH.

Breakdown and release of Energy

The full carbohydrate, protein, and fat catabolism for energy occurs through many pathways. Though different pathways initiate the breakdown of these nutrients, the process of citric acid and the electron transport chain ultimately continue through two common catabolic pathways. The first summary of the pathways that catabolize glucose is given here. It then discusses the steps which start fat and protein breakdowns.

Extracting energy from carbohydrate

Cells extract useful energy from carbohydrate through four main glycolysis pathways, the conversion of pyruvate to acetyl CoA, the cycle of citric acids and the chain of electron transport. Even though glycolysis and the process of citric acid produce small amounts of energy, the electron transport chain is the main production site for ATP.

Glycolysis

Glycolysis (the "glucose splitting") is an anaerobic mechanism that needs no oxygen. A series of reactions in the cytosol breaks each 6-carbon glucose molecule into two 3-carbon pyruvate molecules thus generating relatively little energy.

Just like the pump needs priming, the input of two ATP molecules is needed for glycolysis to begin. In later stages, separate, different reactions produce energy-rich NADH and release four ATP molecules. While it absorbs and releases glycolysis, it does produce more than it uses. Glycolysis is rapid but a comparatively limited amount of ATP is released. Two pyruvates allow the glycolysis of one glucose molecule.

While most glycolytic reactions can flow in any direction, some reactions are one-way, irreversible. Those one-way reactions avoid backward running of glycolysis.

How about the other basic, fructose and galactose sugars? They are typically broken down in liver cells by glycolysis, and are not generally accessible to other tissues. And if at intermediate points fructose and galactose join glycolysis, the end result is the same as for glucose. One glucose, fructose, or galactose molecule creates two NADHs, a combination of two ATPs and two pyruvates. When glycolysis completes the pyruvate to the mitochondria interior, the power generations of the cell are used for further processing.

Fat burns in a flame of Carbohydrate

Beta-oxidation Acetyl CoA will join the cycle of citric acid only when the breakdown of fat and carbohydrate is synchronized. No oxaloacetate available, the cycle of citric acid can't continue with acetyl CoA. Conditions such as starvation and intake of high-fat, low-carbohydrate diets can deplete oxaloacetate, blocking entry of acetyl CoA. This redirects the acetyl CoA to form a family of compounds known as ketone. Ketone bodies can be developed with common high-protein diets that are low in carbohydrate but high in far too.

Reactions in the mitochondria need to ensure a sufficient supply of oxaloacetate for fatty acid oxidation to proceed efficiently and unchecked. These reactions immediately transform certain pyruvate to oxaloacetate rather than to the CoA acetyl. Since carbohydrate (glucose) is the pyruvate's original source and hence this oxaloacetate, scientists coined the adage "fat burns in carbohydrate flame"

Extracting energy from protein

Since protein plays a crucial role in both structure and function, proteins and amino acids are not considered primary energy sources. Amino acids have the primary and special function of acting as a building block for the synthesis of body protein and nitrogen-containing compounds. However, when energy production fails due to a lack of carbohydrate and fat available, protein comes to rescue. Of example, energy needs take precedence during starvation, because the body breaks down protein and extracts energy from the building blocks of amino acids.

A process called deamination first strips off the amino group (-NH2) leaving a carbon skeleton to use amino acids as an energy source. The liver rapidly absorbs the amino group into ammonia first and then into urea which is excreted in urine by the kidneys. When you eat more protein than you need, the extra nitrogen is excreted in your kidneys and your liver uses carbon skeletons to generate energy glucose or fat. They can end up gaining weight instead, much to the dismay of bodybuilders, as they attempt to create muscle by drinking protein drinks in private.

Regulation of Metabolism

Just as the cruise control on your car regulates the vehicle’s speed within a narrow range, your body tightly controls the reactions of our metabolic pathways. Whether highly or minimally active, each pathway proceeds at just the right speed, not too fast and not too slow. How does our body achieve this remarkable control? Although a number of strategies operate simultaneously, certain hormones are the master regulators.

Hormones of Metabolism

Hormones are chemical messenger helping to decide whether metabolic activity favors catabolic (breakdown) or anabolic (building) pathways. Insulin, glucagon, cortisol, and epinephrine are the main regulatory hormones.

The pancreas is the chief of (anabolic) storage unit that secretes insulin. Its purpose is to reduce the amount of glucose in the blood, thereby promoting carbohydrate use and storage (as glycogen). Since insulin promotes the use of glucose over fat, it's said that its acts save weight. In addition, insulin stimulates the storage of fat in adipose tissue, cellular amino acid absorption, and assembly of these amino acids into proteins. Moreover, it avoids protein oxidation in the body.

The pancreas even secretes glucagon, the team's (catabolic) master in breakdown. The task of Glucagon is to increase the amount of glucose in circulation; it induces hepatic glycogen breakdown. The adrenal glands secrete two other members of the breakdown team-the cortisol and the epinephrine hormones.

Cortisol facilitates the degradation of gluconeogenic amino acids and helps to increase the activity of the enzymes that cause gluconeogenic reactions. Epinephrine promotes glycogen transfer to muscle glucose, increasing the amount of glucose available. Every team's activities ebb and flow in response to the amounts of nutrients available. While both the storage teams and the breakdown teams have always been involved, storage dominates in times of abundance, and breakdown dominates when required.

Survival priorities and Potential Energy Sources

Starvation confronts your body with several dilemmas. Where will it get energy to fuel survival needs? Which should it burn first-fat, protein, or carbohydrate? Can it conserve its energy reserves? Which tissues should it sacrifice to ensure survival?

Your body’s first priority is to preserve glucose-dependent tissue red blood cells, brain cells, and the rest of the central nervous system. Your brain will not tolerate even a short interruption in the supply of adequate energy. Once your body depletes its carbohydrate reserves, it begins sacrificing readily available circulating amino acids to make glucose and ATP.

Your body's second priority is to maintain muscle mass. In the face of danger, we rely upon our ability to mount a fight-or-flight response. This survival mechanism requires a large muscle mass, allowing us to move quickly and effectively. Your body grudgingly uses muscle protein for energy and breaks it down rapidly only in the final stages of starvation.

Although your body stores most of its energy reserves in adipose tissue, triglycerides are a poor source of glucose. Although your body can make a small amount of glucose from the glycerol backbone, it cannot make any glucose from fatty acids. As a consequence, your body's primary energy stores-fat-are incompatible with your body's paramount energy priority- glucose for your brain. To meet this metabolic challenge, your body's ant starvation strategies include a glucose sparing mechanism. It shifts to fatty acids and ketone bodies to fuel its needs. In time, even your brain adapts as most, but not all, brain cells come to rely on ketone bodies for fuel.

Nutrition Science in Action

Fuel of distance walking

Observations: Humans naturally select a preferred walking speed (PWS), and the body's fuel selection can be critical to the total distance traveled. The body primarily uses carbohydrate (CHO) to fuel short, intense bursts of activity and uses fat to fuel endurance exercise. Lean humans store far more energy as fat than as CHO, and the choice of fuel may produce a 30-fold difference in the distance traveled.

Hypothesis: Naturally, humans choose a desired walking pace (PWS), and selection of the body's fuel can be crucial to the overall distance traveled. The body uses carbohydrate (CHO) mainly to fuel short, intense activity bursts, and fat is used to fuel endurance exercise. Learn humans store far more energy as fat than CHO, and choosing fuel will result in a 30-fold difference in the distance traveled. Humans select a chosen walking pace that uses fat mainly as fuel and does not deplete carbohydrate stocks.

Experimental plan: Recruit 12 balanced grown-ups. Time the subjects as they walk four laps around a 53-meter track, at their natural pace. After 10 minutes of rest, subjects walk for 10-

minute intervals on a level treadmill at 3, 2, 4, 0, 4, 8, 5, 6, 6, 4 and 7.2 km / h (kph). During each step, using indirect calorimetric calculation of fat and CHO oxidation.

Results: Proven theory. Natural PWS was 4.7kph for subjects. CHO oxidation levels remain small at speeds under 4.8kph, and fat oxidation is the primary fuel. At an altitude of around 4.8kph and above. The oxidation of CHO increases suddenly and grows rapidly.

Conclusion and discussion: The key finding of this study was that capable participants naturally selected a walking pace just below the preceding pace and a sudden increase in CHO oxidation, which would rapidly deplete small CHO stores in the body.

In a historical sense, when faced with walking away from a region of food shortage, people able to pick the walking pace naturally resulting in the greatest range will offer survival advantage. In addition, minimizing the depletion of CHO will protect the capacity of the individual to participate in burst behavior to avoid predators or catch preys during the trek.