CHAPTER – 4

Systems of Energy

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Energy is needed for maintenance and growth of everyday activities and exercise. The amount of energy required during exercise by the body depends on the intensity and duration of exercise.
Energy production is both time and intensity related. Running at a very high intensity, as in sprinting, means that an athlete can operate effectively for only a very short period of time. Running at a low intensity as in gentle jogging, means that an athlete can sustain activity for a long time period. Training introduces another variable, and the sprinter who uses sound training principles is able to run at a high intensity for longer periods. Similarly, the endurance athlete who uses sound training methods can sustain higher intensities during a set period. There is a relationship between the exercise intensity and the energy source.

Energy Pathways

We divided the running requirements of various sports into the following “energy pathways”:

1) Anaerobic Energy System

- Adenosine Tri Phosphate (ATP)
- Creatine Phosphate (CP)
- Lactic Acid

2) Aerobic Energy System

First, we discuss the anaerobic energy system.

1) Anaerobic Energy System

When the oxygen required by the body cannot be met, the body will switch to a different energy system (**the anaerobic energy system**) which produces energy without the use of oxygen.

This system relies on the release of energy from food stores in the body without the use of oxygen. This type of energy system is used in short bursts of intensive activity and results in the accumulation of a waste product called lactic acid which results in muscle fatigue.

- **Adenosine Tri Phosphate (ATP):** a complex chemical compound formed with the energy released from food and stored in all cells, particularly muscles. Only from the energy released by the breakdown of this compound can the cells perform work. The breakdown of Adenosine Tri Phosphate (ATP) produces energy.

- **Creatine Phosphate (CP):** a chemical compound stored in muscle, which when broken down aids in the manufacture of Adenosine Tri Phosphate **(**ATP). The combination of Adenosine Di Phosphate (ADP) and Creatine Phosphate (CP) produces Adenosine Tri Phosphate **(**ATP).

- **Lactic Acid (LA):** a fatiguing metabolite of the lactic acid system resulting from the incomplete breakdown of glucose. Although excessive lactate production is part of the extreme fatigue process, it is the protons produced at the same time that restrict further performance.

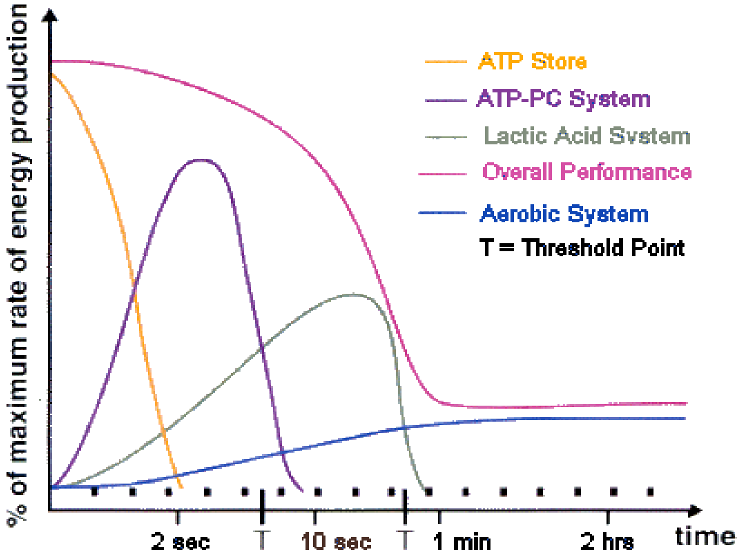
These energy pathways are time duration restricted. In other words, once a certain time elapses that specific pathway is no longer used. There is some controversy about these limitations but the consensus is:

Duration	Classification	Energy Supplied by
1 to 4 seconds	Anaerobic	ATP (in Muscles)
4 to 10 seconds	Anaerobic	ATP + CP
10 to 45 seconds	Anaerobic	ATP + CP + Muscle Glycogen
45 to 120 seconds	Anaerobic, Lactic Acid	Muscle Glycogen
120 to 240 seconds	Aerobic + Anaerobic	Muscle Glycogen + Lactic Acid
240 to Onwards seconds	Aerobic	Muscle Glycogen + Fatty Acids

The result of muscle contraction produces Adenosine Di Phosphate (ADP) which when coupled with Creatine Phosphate (CP) regenerates Adenosine Tri Phosphate (ATP).

Creatine Phosphate (CP) is stored in muscles. Actively contracting muscles obtain Adenosine Tri Phosphate (ATP) from glucose stored in the blood stream and the breakdown of glycogen stored in the muscles. Exercise for longer periods requires the complete oxidation of carbohydrates or fatty acids in the mitochondria. The carbohydrate store lasts approximately 90 minutes and the fatty acid store lasts several days.

All three energy systems contribute at the start of exercise but the contribution depends upon the individual, the effort applied or on the rate at which energy is used. The following graph depicts how the energy systems contribute to the manufacture of Adenosine Tri Phosphate (ATP) over time when exercising at 100% effort. The thresholds (T) indicate the point at which the energy system is exhausted - training improves the thresholds times.



Adenosine Tri Phosphate (ATP) stores in the muscle lasts for approximately 4 seconds and the resynthesis of Adenosine Tri Phosphate (ATP) from Creatine Phosphate (CP) continues until Creatine Phosphate (CP) stores are depleted, approximately 4 to 10 seconds.

To develop this energy system, sessions of 4 to 10 seconds of high intensity work at near peak velocity are required for instance:

- 10 × 30 metres with recovery of 30 seconds / repetition and 5 minutes / set.
- 15 × 60 metres with 60 seconds recovery
- 20 × 20 metres shuttle runs with 45 seconds recovery

The Anaerobic Lactate (Glycolytic) System

Once the Creatine Phosphate (CP) stores are depleted, the body resorts to stored glucose for Adenosine Tri Phosphate (ATP).

The breakdown of glucose or glycogen in anaerobic conditions results in the production of lactate and hydrogen. The accumulation of hydrogen is the limiting factor causing fatigue in runs of 300 metres to 800 metres.

Sessions to develop this energy system:

- 5 to 8 × 300 metres fast - 45 seconds recovery - until pace significantly slows
- 150 metre intervals at 400 metre pace - 20 seconds recovery - until pace significantly slows
- 8 × 300 metres - 3 minutes recovery (lactate recovery training)

There are three different working units within this energy system:

- **Speed Endurance**
- **Special Endurance 1**
- **Special Endurance 2**

Each of these units can be developed as follows:

	Speed Endurance	Special Endurance 1	Special Endurance 2
Intensity	95 to 100%	90 to 100%	90 to 100%
Distance	80 to 150 metres	150 to 300 metres	300 to 600 metres
No of Repetitions / Set	2 to 5	1 to 5	1 to 4
No of Sets	2 to 3	1	1
Total distance / session	300 to 1200 metres	300 to 1200 metres	300 to 1200 metres
Example	3 × (60, 80, 100)	2 × 150 metres + 2 × 200 metres	3 × 500 metres

2) Aerobic Energy System

The aerobic energy system is usually the first to be used, when you are active, the demand for energy increases, as does the demand for more oxygen by the muscles. This extra demand for oxygen is met by an increase in the rate and depth of breathing and an increase in blood supply due to increased heart rate.

Energy taken during the breakdown of food manufactures Adenosine Tri Phosphate (ATP). The energy required for exercise can be obtained by burning food stores with oxygen (obtained by breathing). This aerobic system works by the breakdown of carbohydrate, fatty acids and some amino acids. This system uses slow twitch fibres and as it requires oxygen it can run for longer.

Muscle fatigue (tiredness) happens when you have burned all the energy sources you have (ATP-PC, glycogen and blood glucose) and you have a build up of lactic acid. In short, if you have no energy (If you have not eaten the right types of food) you will not be able to be active for very long.

The aerobic energy system utilises proteins, fats and carbohydrate (glycogen) for resynthesising Adenosine Tri Phosphate (ATP). This energy system can be developed with various intensity (Tempo) runs. The types of Tempo runs are:

- **Continuous Tempo**
  Continuous Tempo is long slow runs at 50% to 70% of maximum heart rate. This places demands on muscle and liver glycogen. The normal response by the system is to enhance muscle and liver glycogen storage capacities and glycolytic activity associated with these processes.

- **Extensive Tempo**
  Extensive Tempo is continuous runs at 60% to 80% of maximum heart rate. This places demands on the system to cope with lactate production. Running at this level assists the removal and turnover of lactate and body's ability to tolerate greater levels of lactate.

- **Intensive Tempo**
  Intensive Tempo is continuous runs at 80% to 90% of maximum heart rate. Lactate levels become high as these runs boarder on speed endurance and special endurance. Intensive tempo training lays the base for the development of anaerobic energy systems.

Sessions to develop this energy system:

- 4 to 6 × 2 to 5 minute runs - 2 to 5 minutes’ recovery
- 20 × 200m - 30 seconds recovery

- 10 × 400m - 60 to 90 seconds recovery
- 5 to 10 kilometre runs

Energy System Recruitment

Although all energy systems turn on at the same time the recruitment of an alternative system occurs when the current energy system is almost depleted.

The following table provides an approximation of the percentage contribution of the energy pathways in certain sports.

Sports	ATP-CP and LA	LA-O2	O2
Basketball	60%	20%	20%
Field events	90%	10%	
Gymnastics	80%	15%	05%
Hockey	50%	20%	30%
Distance Running	10%	20%	70%
Soccer	50%	20%	30%
Sprints	90%	10%	
Tennis	70%	20%	10%
Volleyball	80%	05%	15%

Metabolism of Food

Our bodies get the energy they need from food through metabolism, the chemical reactions in the body's cells that convert the fuel from food into the energy needed to do everything from moving to thinking to growing.

Metabolism Basics

Specific proteins in the body control the chemical reactions of metabolism, and each chemical reaction is coordinated with other body functions. In fact, thousands of metabolic reactions happen at the same time — all regulated by the body — to keep our cells healthy and working.

Metabolism is a constant process that begins when we are conceived and ends when we die. It is a vital process for all life forms — not just humans. If metabolism stops, a living thing dies.

Here is an example of how the process of metabolism works in humans — and it begins with plants: First, a green plant takes in energy from sunlight. The plant uses this energy and the molecule chlorophyll (which gives plants their green color) to build sugars from water and carbon dioxide in a process known as photosynthesis.

When people and animals eat the plants (or, when they eat animals that have eaten the plants), they take in this energy (in the form of sugar), along with other vital cell-building chemicals. The body's next step is to break the sugar down so that the energy released can be distributed to and used as fuel by the body's cells.

After food is eaten, molecules in the digestive system called enzymes break proteins down into amino acids, fats into fatty acids, and carbohydrates into simple sugars (e.g., glucose). In addition to sugar, both amino acids and fatty acids can be used as energy sources by the body when needed. These compounds are absorbed into the blood, which transports them to the cells.

After they enter the cells, other enzymes act to speed up or regulate the chemical reactions involved with "metabolizing" these compounds. During these processes, the energy from these compounds can be released for use by the body or stored in body tissues, especially the liver, muscles, and body fat.

In this way, the process of metabolism is really a balancing act involving two kinds of activities that go on at the same time — the building up of body tissues and energy stores and the breaking down of body tissues and energy stores to generate more fuel for body functions.

- **Anabolism** or constructive metabolism, is all about building and storing: It supports the growth of new cells, the maintenance of body tissues, and the storage of energy for use in the future. During anabolism, small molecules are changed into larger, more complex molecules of carbohydrate, protein, and fat.

- **Catabolism** or destructive metabolism, is the process that produces the energy required for all activity in the cells. In this process, cells break down large molecules (mostly carbohydrates and fats) to release energy. This energy release provides fuel for anabolism, heats the body, and enables the muscles to contract and the body to move. As complex chemical units are broken down into more simple substances, the waste products released in the process of catabolism are removed from the body through the skin, kidneys, lungs, and intestines.

Several of the hormones of the endocrine system are involved in controlling the rate and direction of metabolism. **Thyroxin**, a hormone produced and released by the thyroid gland, plays a key role in determining how fast or slow the chemical reactions of metabolism proceed in a person’s body.

Another gland, the **pancreas** secretes hormones that help determine whether the body's main metabolic activity at a particular time will be anabolic or catabolic. For example, after eating a meal, usually more anabolic activity occurs because eating increases the level of glucose — the body's most important fuel in the blood. The pancreas senses this increased level of glucose and releases the hormone insulin, which signals cells to increase their anabolic activities.

Metabolism is a complicated chemical process, so it is not surprising that many people think of it in its simplest sense: as something that influences how easily our bodies gain or lose weight. That is where calories come in.

A calorie is a unit that measures how much energy a particular food provides to the body. A chocolate bar has more calories than an apple, so it provides the body with more energy — and sometimes that can be too much of a good thing. Just as a car stores gas in the gas tank until it is needed to fuel the engine, the body stores calories — primarily as fat. If you overfill a car’s gas tank, it spills over onto the roadway. Likewise, if a person eats too many calories, they “spill over” in the form of excess body fat.

The number of calories someone burns in a day is affected by how much that person exercises, the amount of fat and muscle in his or her body, and the person’s Basal Metabolic Rate (BMR). The Basal Metabolic Rate is a measure of the rate at which a person's body “burns” energy in the form of calories, while at rest.

The Basal Metabolic Rate can play a role in someone's tendency to gain weight. For example, a person with a low Basal Metabolic Rate (who therefore burns fewer calories while at rest or sleeping) will tend to gain more pounds of body fat over time, compared with a similar-sized person with an average Basal Metabolic Rate who eats the same amount of food and gets the same amount of exercise.

What factors influence on Basal Metabolic Rate?

Basal Metabolic Rate is inherited. Sometimes health problems can affect Basal Metabolic Rate. But people can actually change their Basal Metabolic Rate in certain ways. For example, exercising more will not only cause a person to burn more calories directly from the extra activity itself, but becoming more physically fit will increase Basal Metabolic Rate as well. Basal Metabolic Rate is also influenced by body composition — people with more muscle and less fat generally have higher Basal Metabolic Rates.