Unit 1 - Anatomy and Physiology

Assessment Outcomes

AO1 – Demonstrate knowledge of body systems, structures, functions, characteristics, definitions and other additional factors affecting each body system.

AO2 – Demonstrate understanding of each body system, the short- and long-term effects of sport and exercise on each system and additional factors that can affect body systems in relation to exercise and sporting performance.

AO3 – Analyse exercise and sports movements, how the body responds to short-term and long-term exercise and other additional factors affecting each body system.

AO4 – Evaluate how body systems are used and how they interrelate in order to carry out exercise and sporting movements

AO5 – Make connections between body systems in response to short-term and long-term exercise and sport participation. Make connections between muscular and all other systems, cardiovascular and respiratory systems, energy and cardiovascular systems.

Learning Aim E – The effect of exercise & sports performance on the energy system

Learning objectives

E1 – To understand the role of adenosine triphosphate (ATP) for muscle contraction during exercise.

E2 – To be able to describe the ATP-PC (alactic) system in exercise and sports performance.

E3 – To understand the lactate system in exercise and sports performance.

E4 – To identify the components of the aerobic system in exercise.

E5 + E6 – To understand the adaptations and additional factors of the energy system in response to exercise.

Energy for exercise

Watch me

How does the body continually provide energy for exercise?

Energy for exercise

We need a constant supply of energy so that we can perform everyday tasks. The more exercise we do the more energy is required.

The **intensity** and **duration** of an activity play an important role in the way in which energy is provided.

The role of ATP in exercise

Adenosine Triphosphate (ATP) is the usable form of energy in the body.

The energy from foods that we eat, such as carbohydrates, has to be converted into ATP before the potential energy in them can be used.

An ATP molecule consists of adenosine and 3 Phosphates

Adenosine

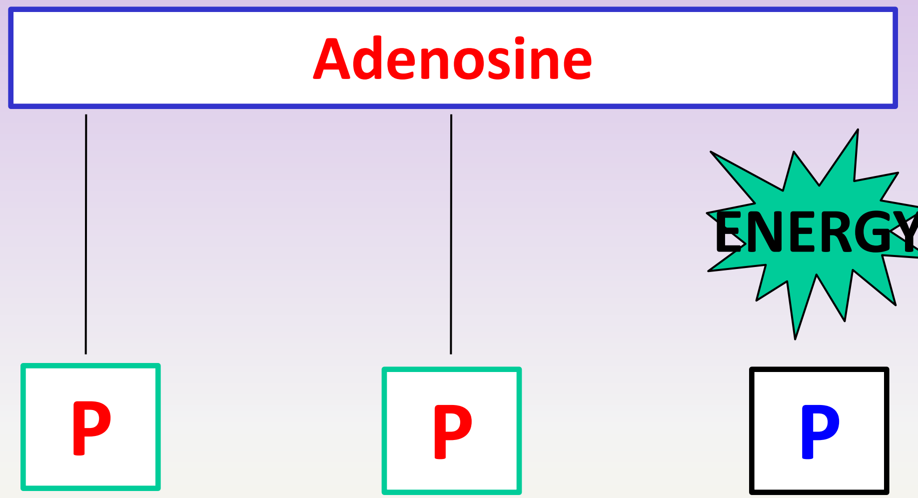
P **P** **P**

The role of ATP in exercise

Energy is released from ATP by breaking down the bonds that hold this compound together.

Enzymes are used to break down ATP.

ATP-ase is the enzyme used to break down ATP into ADP (adenosine diphosphate) and a single phosphate.



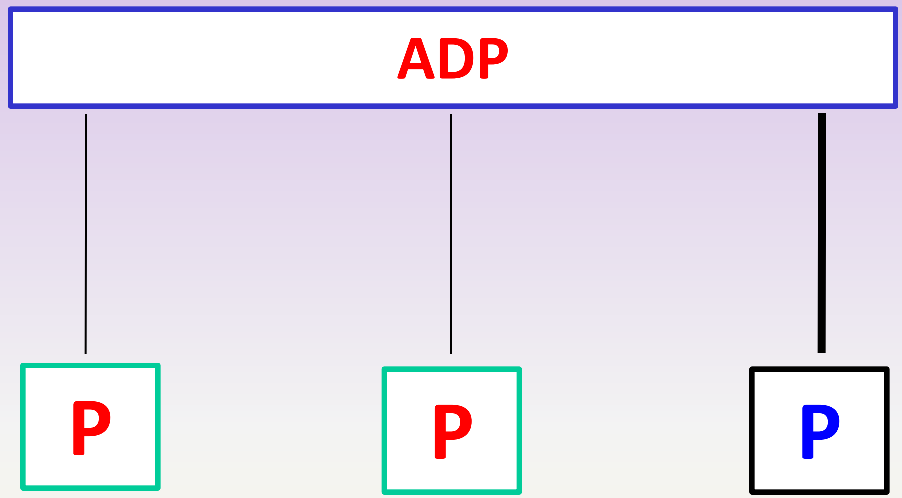
This type of reaction is an exothermic reaction.

Think. Pair. Share – What is meant by an exothermic reaction?

The role of ATP in exercise

ATP within muscle fibres are used up very quickly (2-3 seconds) and therefore needs to be replenished (resynthesized) immediately.

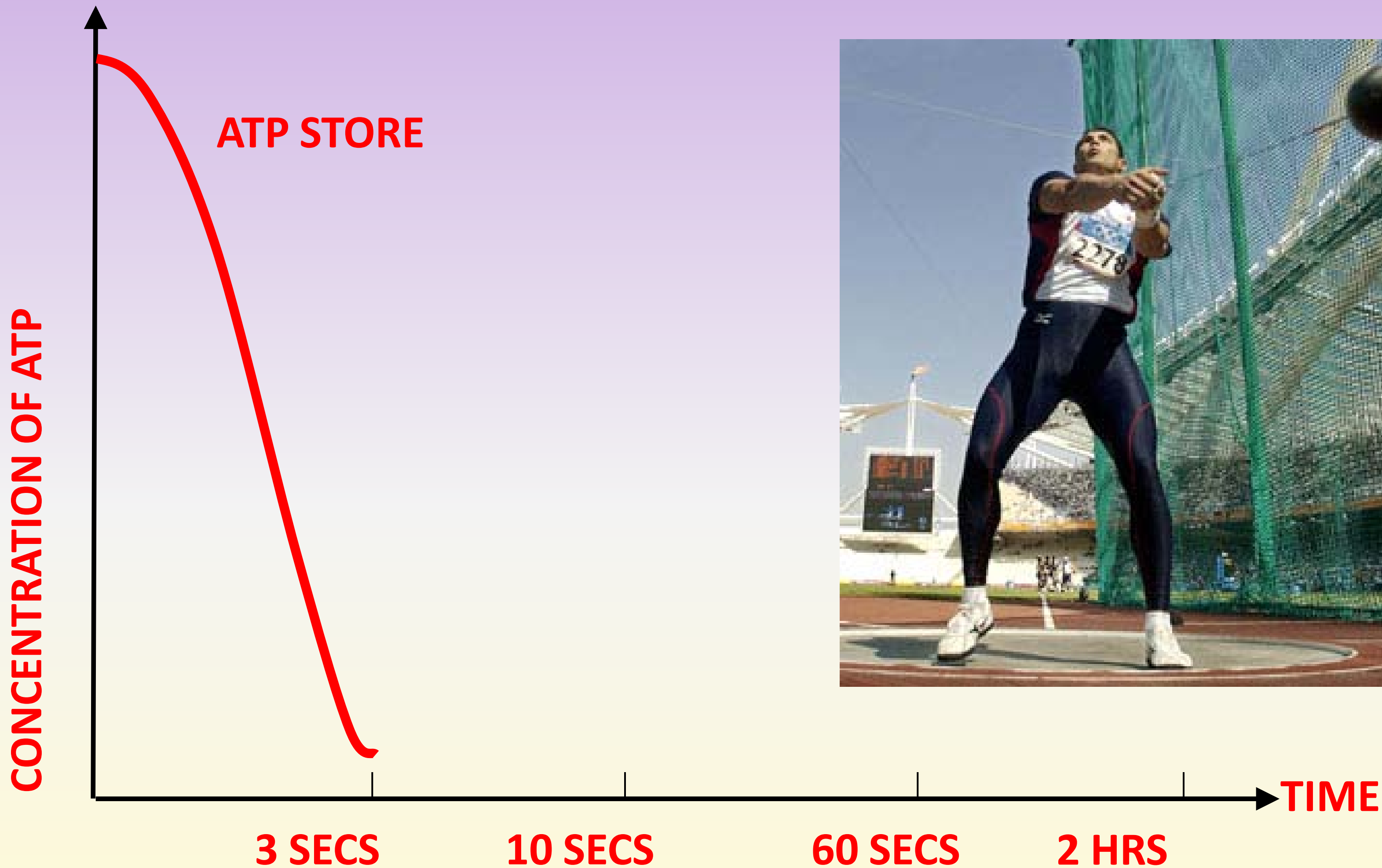
For ATP to be rebuilt an **endothermic reaction** has to occur. This is a chemical reaction which absorbs energy.



Resynthesis of ATP is done through the joining of ADP and a single phosphate. This energy regeneration is only possible through one of three energy systems.

The role of ATP in exercise

ATP can provide several powerful contractions lasting only 2-3 seconds. This can be shown on a graph similar to the one below.



Energy systems

There are three energy systems that regenerate ATP:

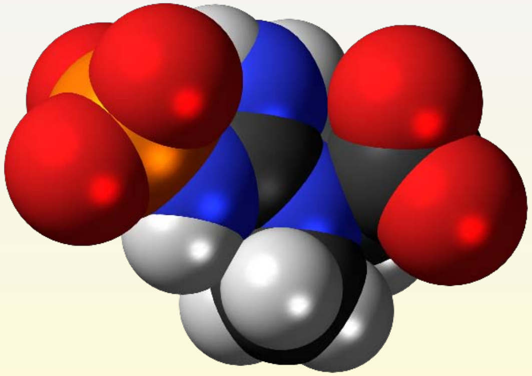
- The ATP-PC (alactic) system
- The lactate (anaerobic) system
- The aerobic system

Each energy system is suited to a particular type of exercise depending on the intensity and duration and whether oxygen is present.

ATP-PC (alactic) system

Depleted ATP stores trigger the release of creatine kinase which causes phosphocreatine (PC) to be broken down **anaerobically**.

Phosphocreatine is an energy-rich chemical produced naturally by the body. This compound found in the sarcoplasm of the muscles.



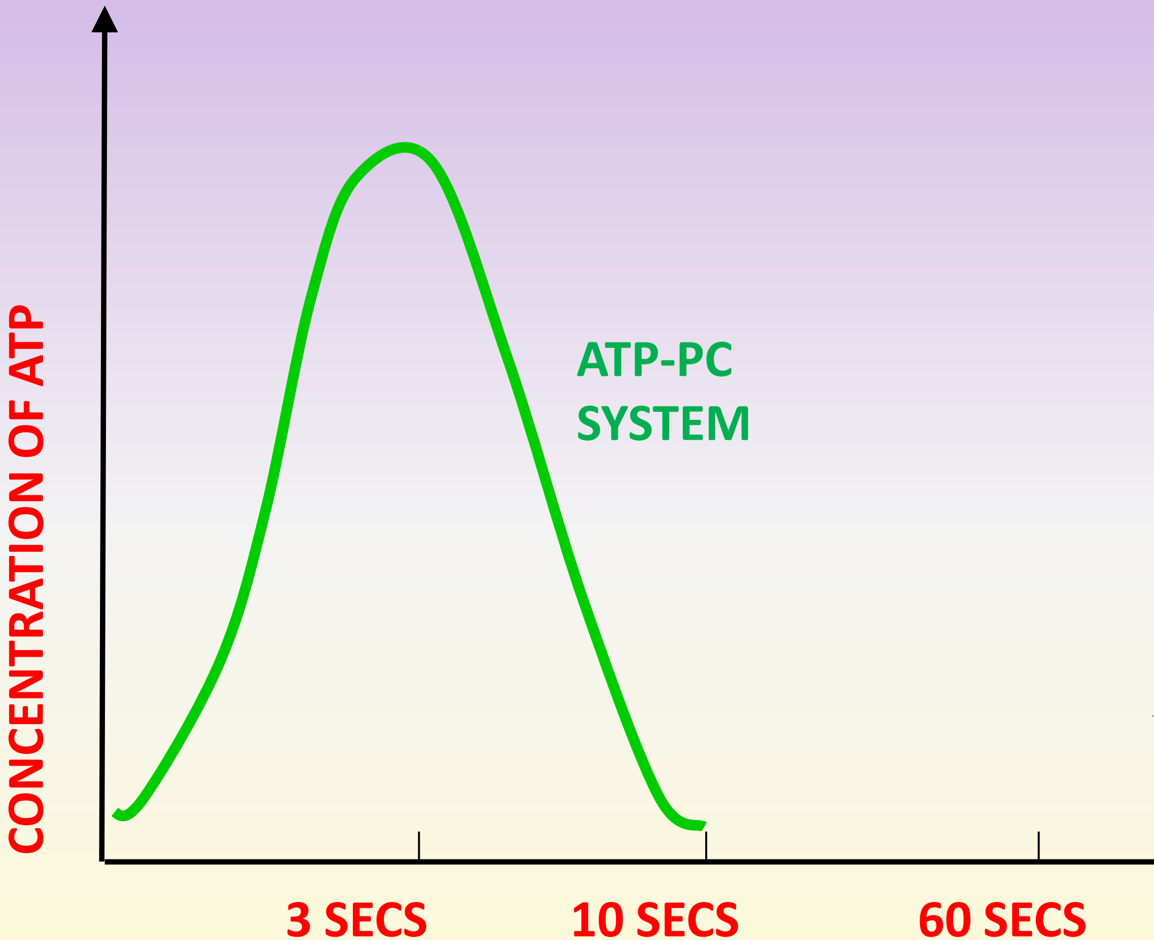
ATP-PC (alactic) system

Phosphocreatine's (PC) rapid availability is important for providing contractions of high power, such as in the 100 m or in a short burst of intense activity during a longer game *(e.g. a fast break in basketball)*

However, there is only enough PC to last for up to **10 seconds** and it can only be replenished when the intensity of the activity is sub-maximal.

ATP-PC (alactic) system

The ATP-PC system energy production peaks at 3-5 seconds and can be shown on a graph similar to the one below.



ATP-PC (alactic) system

For every one molecule of PC broken down there is enough energy released to create one molecule of ATP.

This is not very efficient system but it does have the advantage of not producing by-products and its use is important in delaying the onset of the lactic anaerobic system.

This breaking down of PC to release energy is a coupled reaction.

The Lactate System

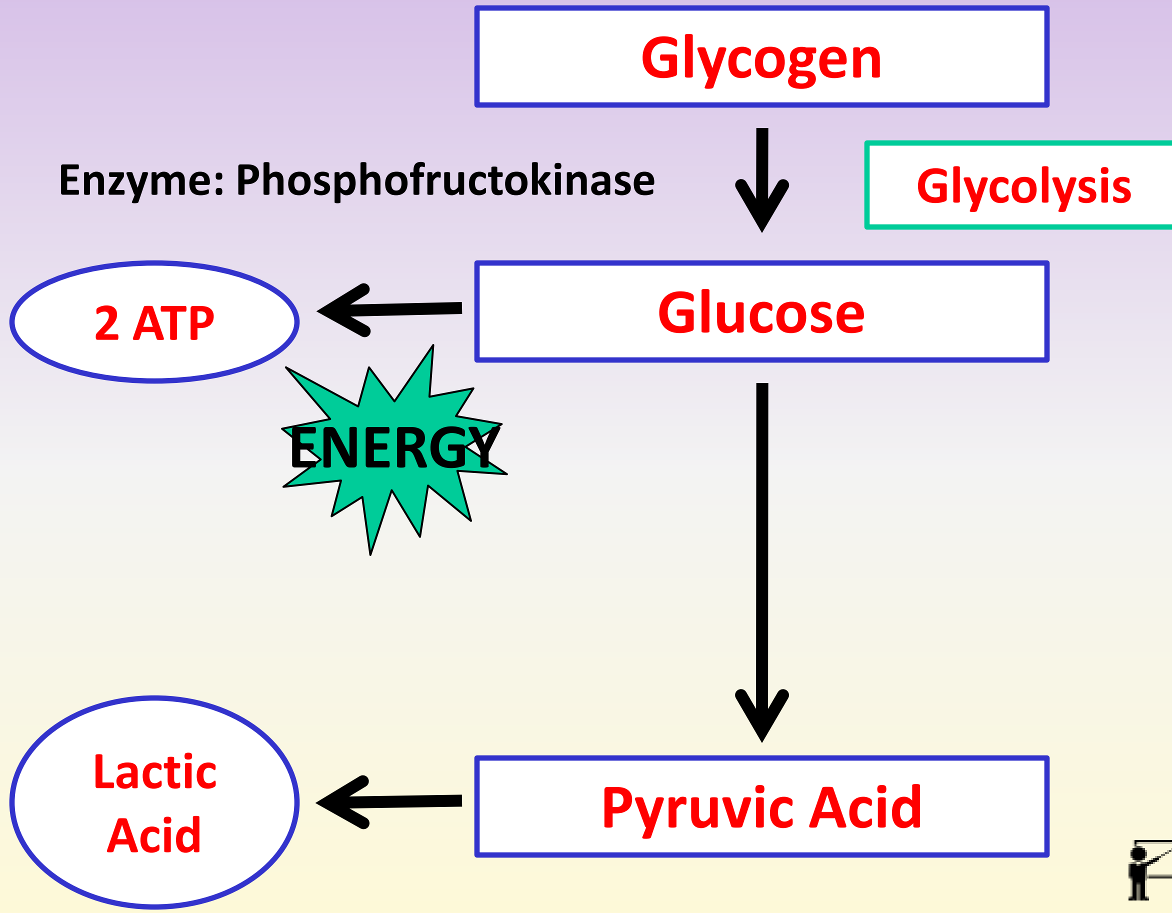
The lactate system provides energy for high-intensity anaerobic activities lasting up to 3 minutes but peaking at 1 minute.
i.e. Cycling sprint events or a counter attack in football.

Think. Pair. Share - What other athletes/events will predominantly use this system?

The Lactate System

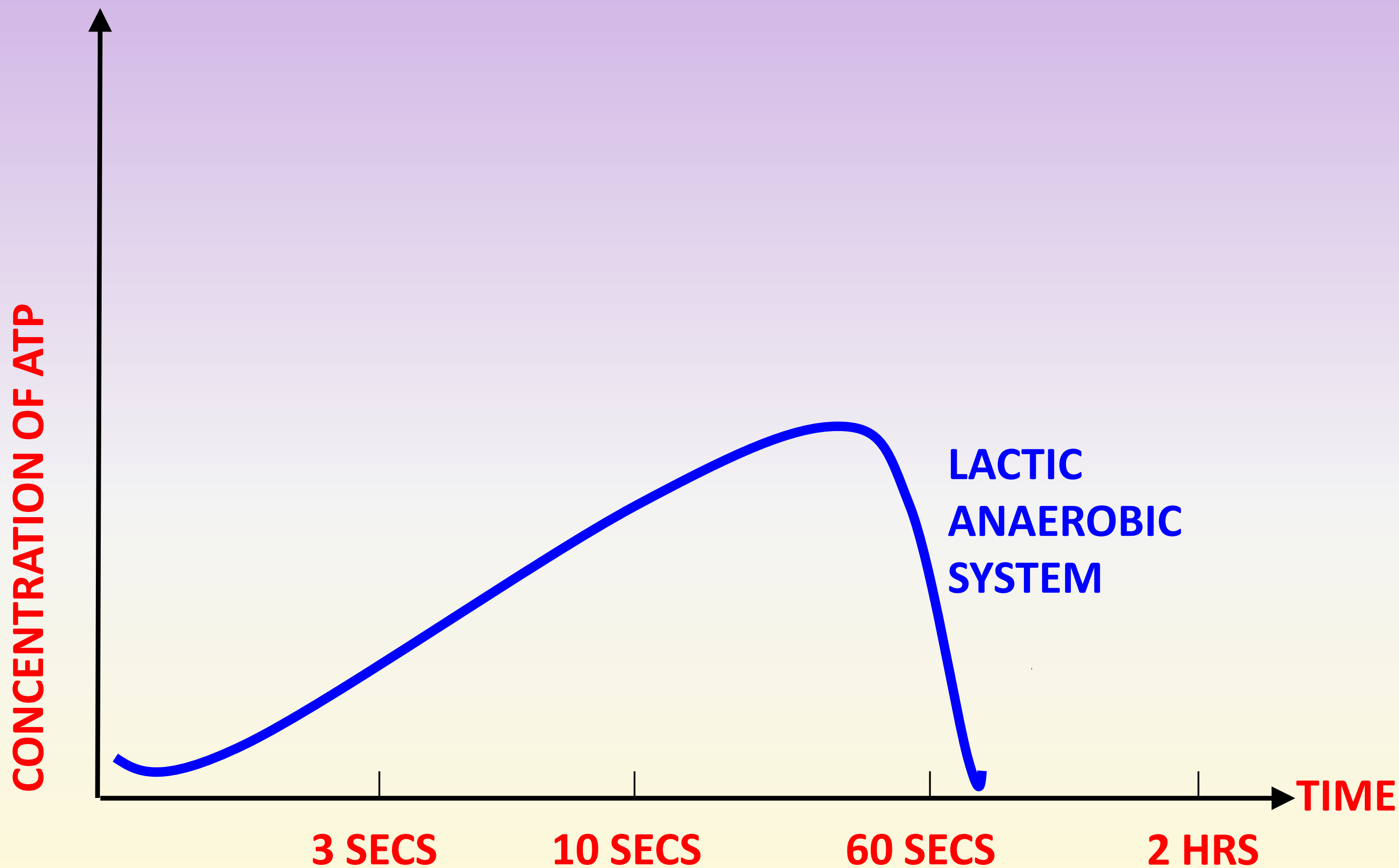
Once PC is depleted (at around 10 seconds) the lactate anaerobic system takes over and regenerates ATP from the breakdown of glucose.

This process is called **glycolysis**. The lactate system is sometimes referred to as **anaerobic glycolysis**, due to the **absence of oxygen**.



The Lactate System

The lactate system can accumulate lactic acid quickly and therefore impede muscle contraction and cause fatigue.



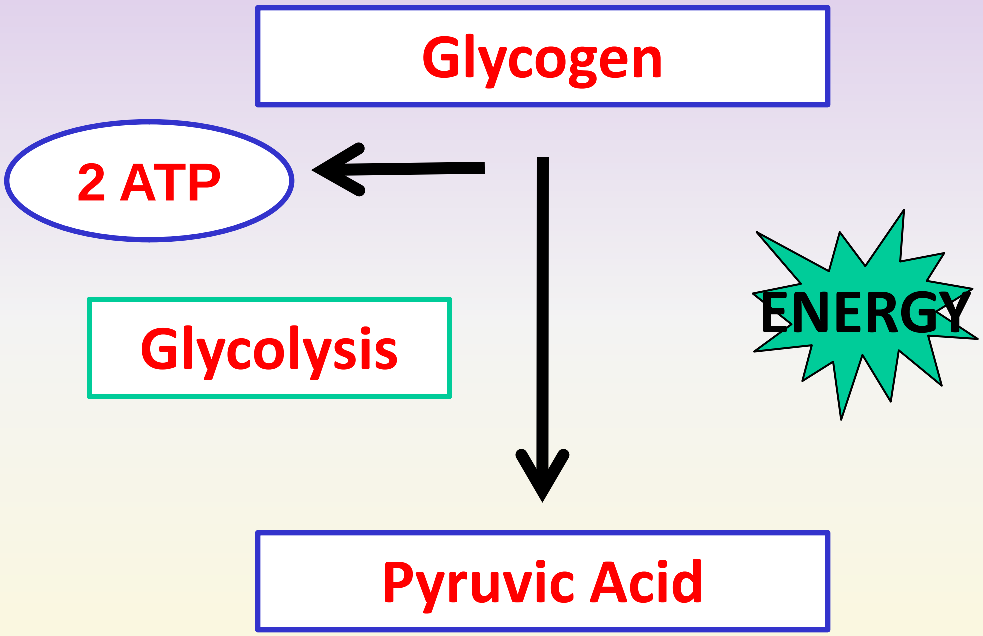
Aerobic system

Aerobic system of energy production needs oxygen to function. The complete oxidation of glucose can produce up to 38 molecules of ATP and has 3 distinct stages.

Aerobic system

<u>1st Stage – Aerobic glycolysis:</u>

This process is the same as anaerobic glycolysis but occurs in the presence of oxygen. Lactic acid is not produced and the pyruvic acid is converted into a compound called acetyl-coenzyme-A (acetyl CoA).



Aerobic system

Acetyl Co-A moves to the mitochondria within the muscle cell where the remaining stages are activated.

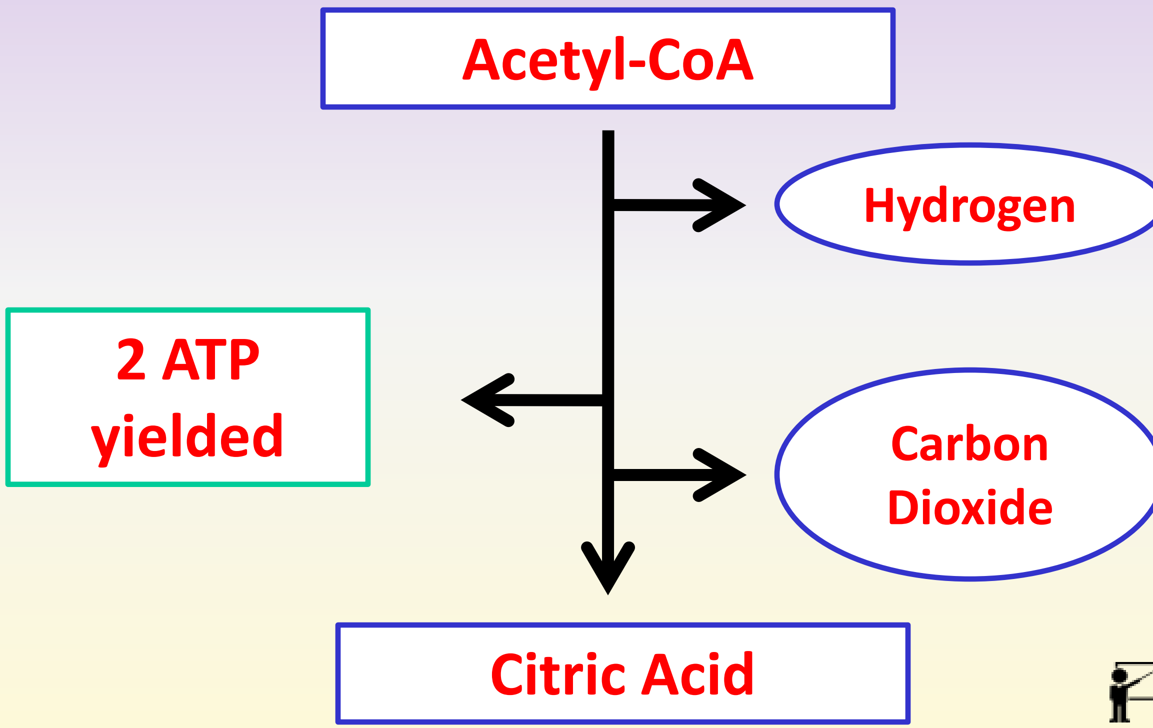
Aerobic system

2nd Stage – Kreb's cycle (citric acid cycle):

Once the pyruvic acid diffuses into the matrix of the mitochondria a complex cycle of reactions occurs in a process known as the Krebs cycle.

The reactions produces two molecules of ATP, as well as carbon dioxide.

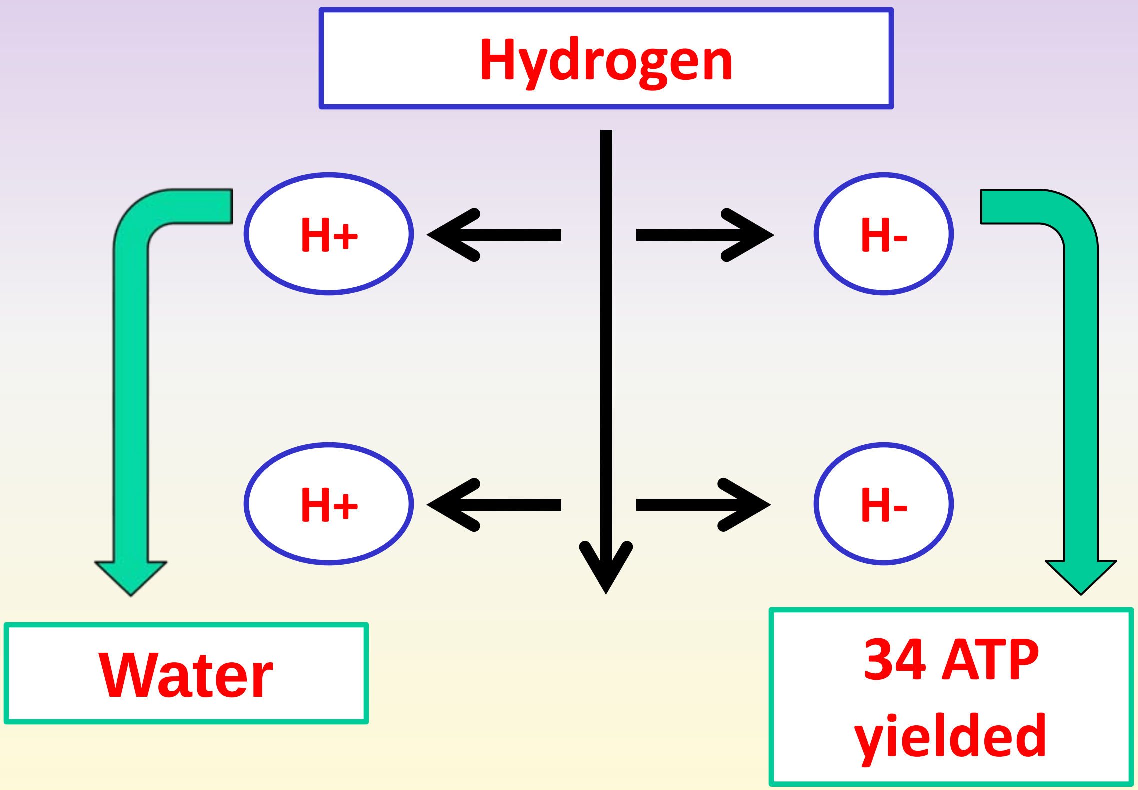
Hydrogen is taken to the electron transport chain.



Aerobic system

3rd Stage - Electron transport chain:

Hydrogen is carried to the electron transport chain by hydrogen carriers. This occurs in the cristae of the mitochondria. The hydrogen splits into hydrogen ions and electrons and these are charged with potential energy.



The hydrogen ions are oxidised to form water, while providing energy to resynthesise ATP. Throughout this process, **34 ATP** molecules are formed.

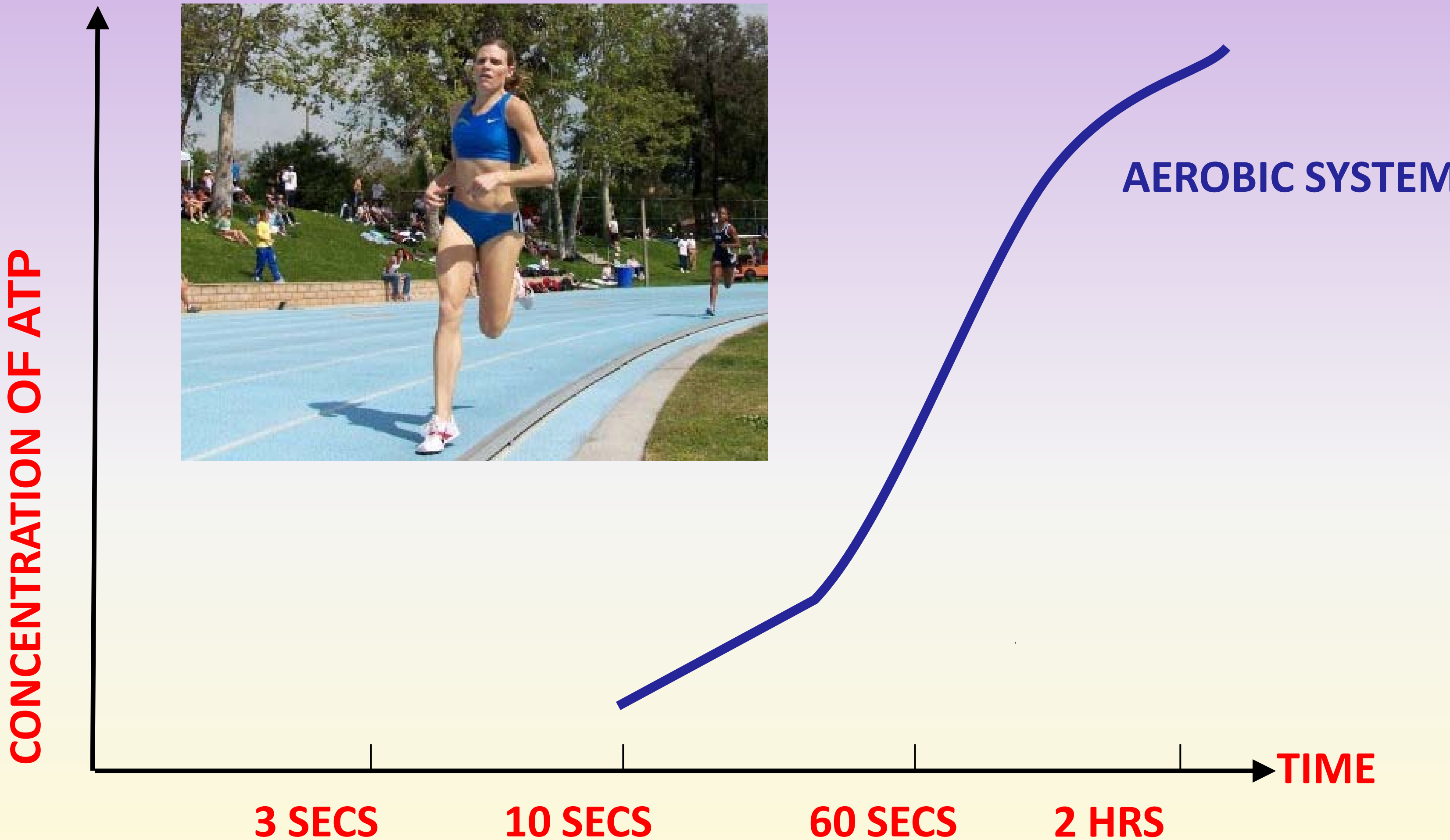
Aerobic system

Total energy yield from the aerobic system is....

38 molecules of ATP

Aerobic system

The graph below shows the aerobic system ATP concentration over time.



Energy Systems in Combination

All the energy systems contribute during all types of activity but one of them will be the predominant energy provider.

The **intensity** and **duration** of the activity are the factors that decide which will be the main energy system in use.

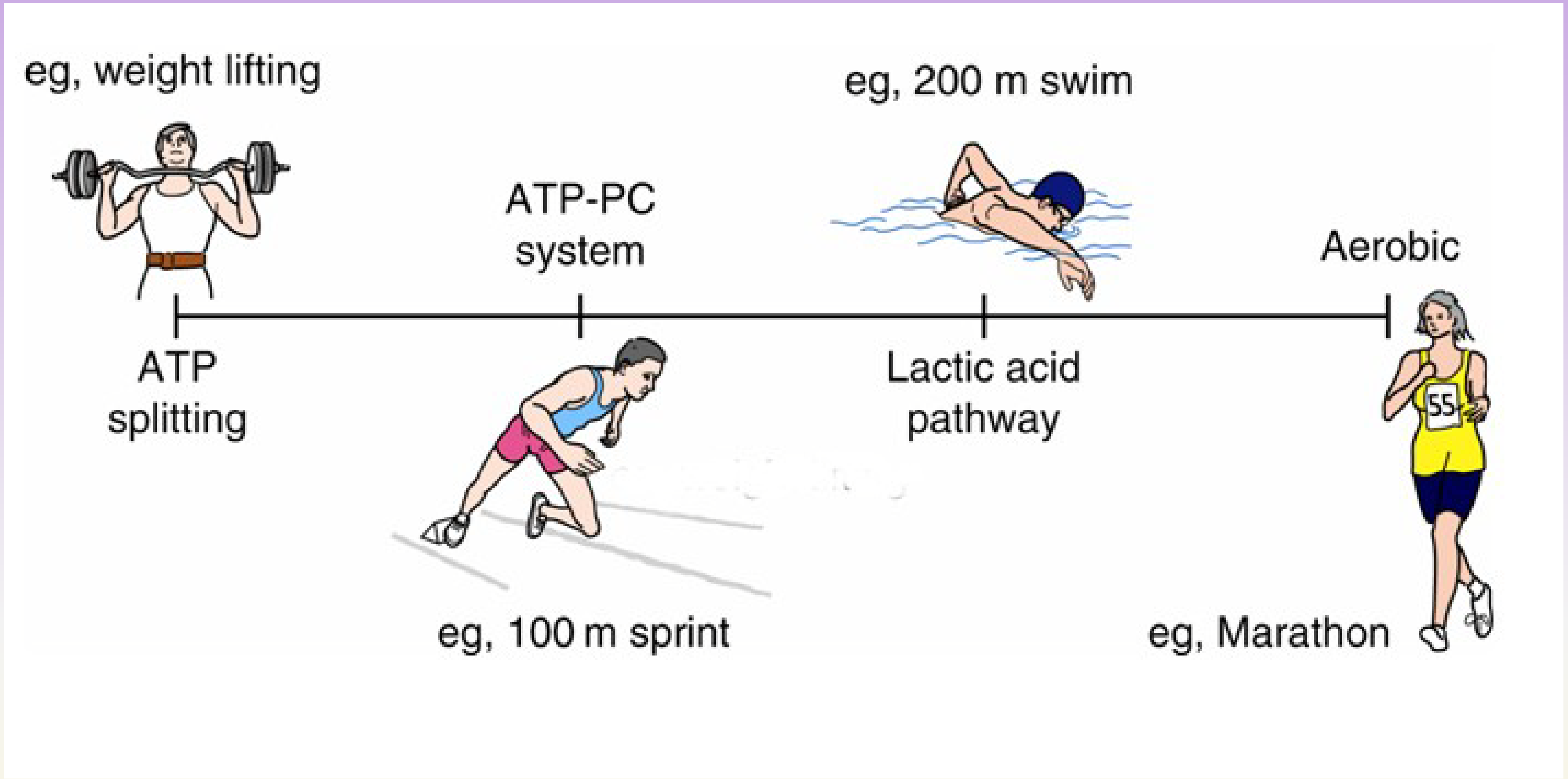
Think. Pair. Share – What energy system would an 800m runner utilise during their race?

Energy Systems in Combination

800m race:

- ATP-PC System – Start of race.
- Aerobic System – Majority of race.
- Lactate System – Sprint finish.

Energy Systems in Combination



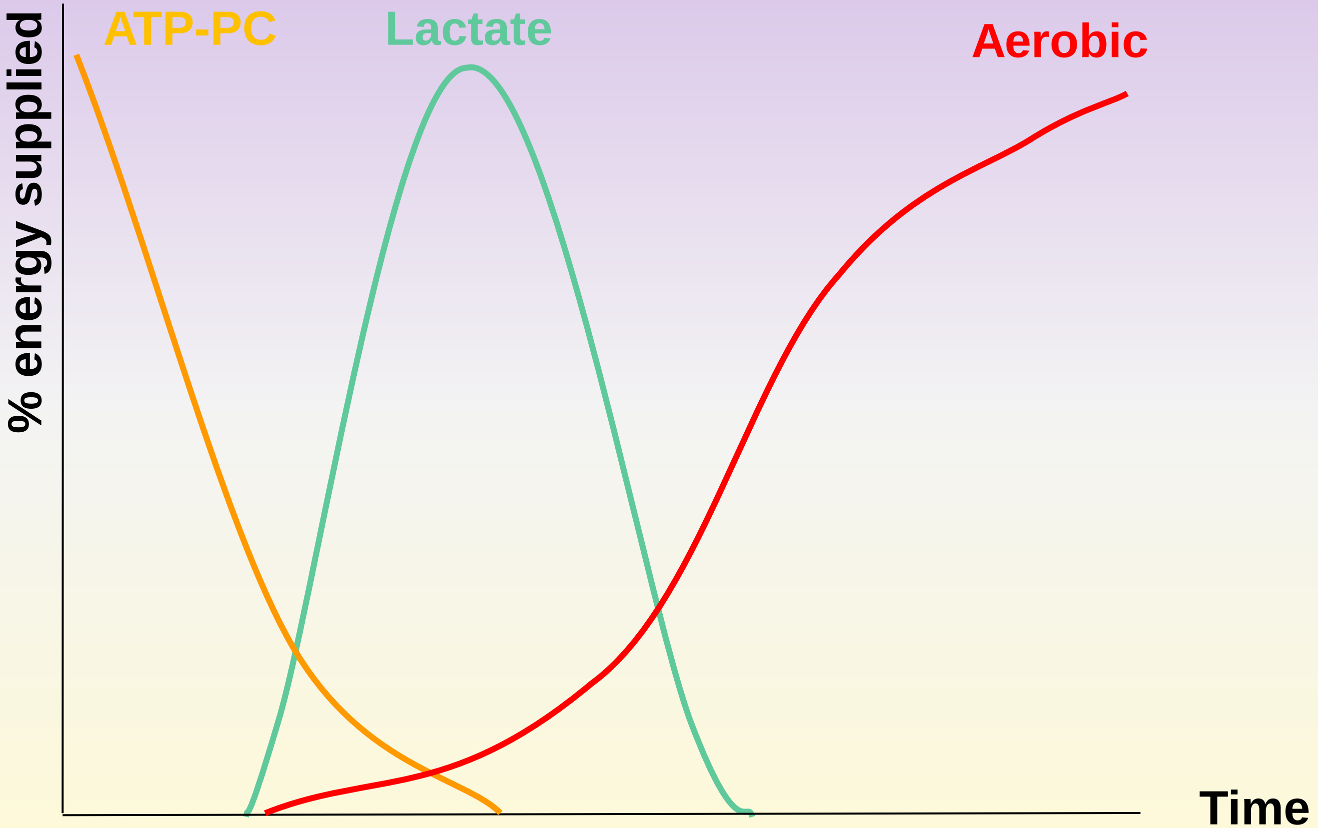
Think. Pair. Share – How many other sports can you place on the energy continuum?

Energy Systems in Combination

This is where the exercise intensity changes frequently. *i.e. a basketball player is required to walk, run, sprint and jump at various points in the game.*

Energy Systems in Combination

The point at which an athlete moves from one energy system to another is known as a threshold. This depends on the exercise intensity and fuel available.



Energy Systems in Combination

The ATP-PC/lactate threshold is the point at which the ATP-PC energy system is exhausted and the glycoltic system takes over.

As a midfielder, performers would need to make short 3 second sprints to get free or beyond a defender (ATP-PC) but will also need the lactate system to make recovery runs back to help defend.

Energy Systems in Combination

The lactate/aerobic threshold – this would occur when the ball is in phases of play away from the player. A performer will still track and scan players movement but at a lower intensity.

Sufficient oxygen will be available throughout to allow for ATP resynthesis.

Adaptations of the energy systems to exercise

Long term exercise allows the body's energy systems to adapt to the demands placed on it. Training can be made specific to each of the systems so that performers can sustain physical activity for longer.

Increased creatine stores:

Training causes the body to adapt and develops the ability to store more creatine in the muscle. This will benefit the ATP-PC system and any event requiring fast and powerful movements.

Adaptations of the energy systems to exercise

Increased tolerance to lactic acid:

Anaerobic training stimulates the muscle to become more tolerant to lactic acid. A better capillary network will aid lactate clearance due to a greater volume of blood supply to working tissues.

Aerobic energy system:

Improvements in the cardiovascular system will allow for an increased oxygen delivery and waste products removal.

Adaptations of the energy systems to exercise

Increased use of fats as an energy source:

Fat is the primary energy source for low intensity exercise. Fat oxidation also increases if exercise extends to long durations. Trained athletes will burn fats more readily as a fuel than non trained individuals.

Buffering capacity to lactic acid is also improved with higher fitness levels as is the ability to utilise FFA's before glycogen stores.

Adaptations of the energy systems to exercise

Increased storage of glycogen and increased number of mitochondria:

Muscles will increase the number of mitochondria contained within them and therefore improve their oxidative capacity. Muscles also develop the ability to store glycogen and therefore extending the anaerobic glycolysis process.

Additional factors affecting the energy systems

There are two main factors when considering the energy systems:

1. **Diabetes and hypoglycaemic attacks:**
   Diabetes is a condition where glucose levels cannot be regulated by the body. Insulin is the hormone responsible for the glucose entering the body's cells to be utilised. This can affect performance as the preferred energy system may not accessible.

Hypoglycaemia is where the body's blood glucose levels are too low. This can be as a result of too much insulin, missing a meal or exercising too hard.

Additional factors affecting the energy systems

A child's bodily energy systems are not as fully developed as an adults. It is therefore more difficult for children to remove waste products such as lactic acid.

It is a general recommendation that children do not undertake anaerobic exercise.

Apply it!

What has stuck with you?

Explain the effects of insufficient oxygen supply on the breakdown of glucose for ATP resynthesis.

Using a sporting example, describe the energy systems that would be used at different points in the game

Energy systems

Explain the main energy systems for a 100m sprinter

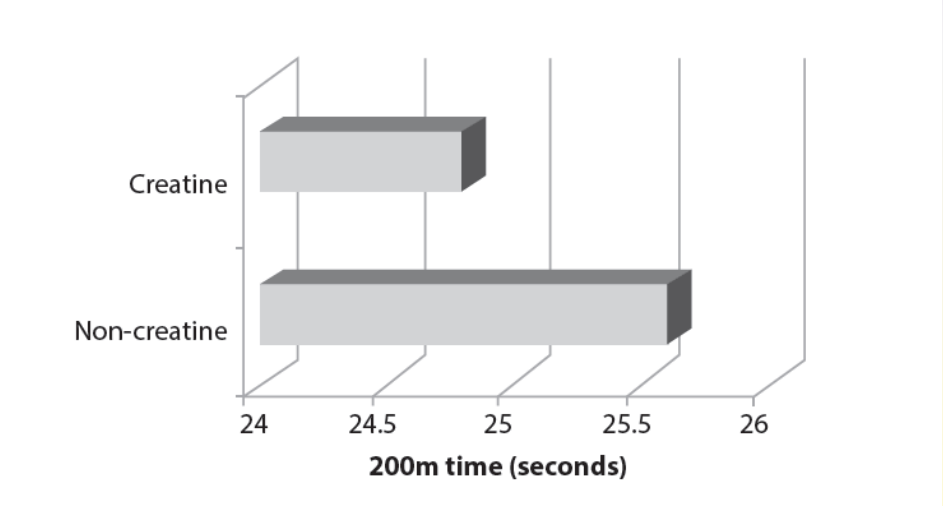
Describe the aerobic energy system?

Practice it!

Exam questions

1. Abi is a competitive sprinter who regularly competes in 100m and 200m races. Some of her rivals are using a creatine supplement to enhance their performance. Abi also decides to use a creatine supplement. Figure 1 shows Abi's 200m personal best sprint times before and after creatine supplementation.

Explain why increasing creatine stores may have an impact on Abi's sprint time. (3)



Practice it!

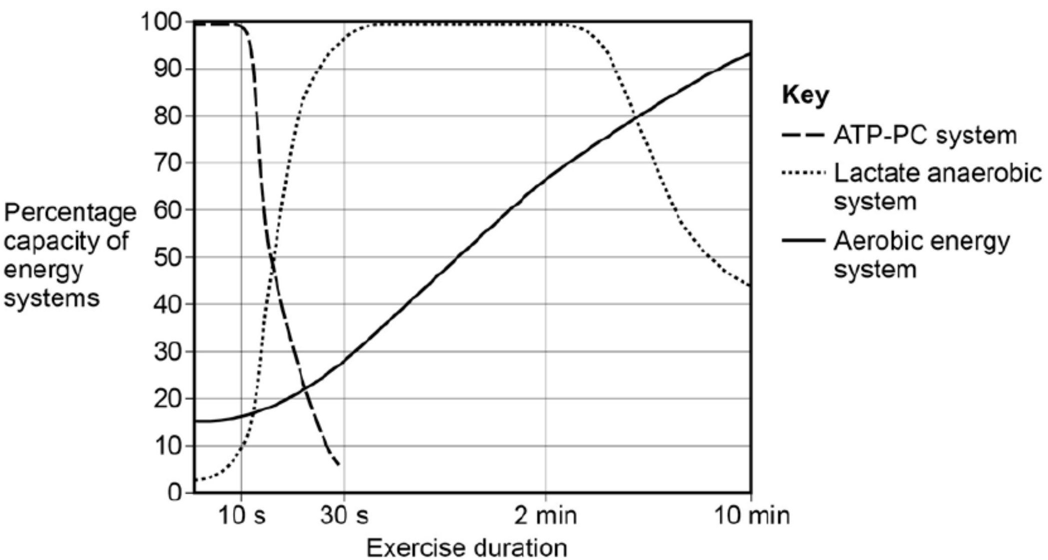
Exam questions

2. Table 2 shows the times of an elite athlete for a 100m, 400m and 3000m race. Figure 2 shows the relative contribution of the energy systems on the energy continuum.

Table 2

Event	100m	400m	3000m
Time	10.49 secs	47.40 secs	8:06.11

Figure 2



Using Figure 2, analyse and evaluate the contribution of each energy system for each event identified in Table 2.

[15 marks]

Practice it!

Marks Scheme:

1. Storage of Phosphocreatine (PC) is limited, thus limiting the capacity of the PC system (1) PC system only lasts for around 8-10 seconds and the 200m lasts longer (1) PC supplementation increases the capacity of the ATP-PC system (1)

Practice it!

Marks Scheme:

2. AO1 – Knowledge - Identified and described the energy systems, eg ATP-PC system involves the breakdown of PC to form ATP. The aerobic system uses oxygen to release energy. The aerobic system has a higher ATP yield than the other systems. (No reference to times from table is required).

AO2 – Application - Identified and explained the contribution of each system in the three events, eg in the 100m event, the athlete will predominantly use the ATP PC system to create ATP. There is also some contribution from the lactate anaerobic system. This is because the ATP-PC system can create ATP for 8–10 seconds and the race only takes 10.49 seconds to complete. This involves the breakdown of glucose anaerobically to form pyruvic acid and then lactic acid which is also known as anaerobic glycolysis.

AO3 – Analysis/Evaluation - Linked the contribution of each energy system to the demands of the event, eg 100m uses ATP-PC system which is an anaerobic system to create ATP as it is a sprint event and the performer runs as fast as they can and so intensity is maximal. When ATP is made through the breakdown of PC in the ATP-PC system, ATP is produced very quickly explaining, the 100% capacity in Figure 2.