Core 2 - the body in motion

**FQ1 - How do the musculoskeletal and cardiorespiratory systems of the body influence and respond to movement?**

Anatomical position:

- Anterior - at front
- Posterior - at back
- Lateral - away from midline of body
- Medial - towards midline of body
- Distal - away from the mass of the body
- Proximal - towards the mass of the body
- Superior - closer to top
- Inferior - closer to bottom
(a) Skeletal system

A1. Major bones involved in movement

1. Cranium
2. Mandible
3. Vertebrae - make up spinal column - cervical (neck), thoracic (shoulder and upper back), lumbar (bottom half of back), sacrum (diamond shaped bone), coccyx (tailbone at the end)
4. Scapula
5. Sternum
6. Ribs/Rib cage
7. Illium (L, higher up the alphabet, higher up the body than ischium)
8. Carpals
9. Phalanges (fingers and toes)
10. Femur
11. Patella
12. Fibula (feeble, smaller bone)
13. Tibia (tough, bigger bone)
14. Phalanges (fingers and toes)
15. Metatarsals (t for toes)
16. Tarsals (ankle)
17. Metacarpals
18. Ischium (S, lower down the alphabet, lower than ilium)
19. Pubis
20. Sacrum
21. Radius (RUUR) In anatomical position order is Radius Ulna, Ulna Radius
22. Ulna (RUUR)
23. Humerus
24. Clavicle

A2. Structure and function of synovial joints

- **Long bones** are longer than they are wide and they function as levers.
- **Short bones** have a short axis and are found in small spaces such as the wrist. They serve as transfer forces.
- **Flat bones** have a broad surface and serve as places of attachment for muscles and to protect vital organs.
- **Cancellous bone** is the spongy or porous inner structure of bone that often contains and protects bone marrow.
- **Bone marrow** is a soft, fatty vascular tissue in which blood cells are made, located in the interior cavities of bones.
- **Articular cartilage** is a firm, smooth, flexible connective tissue that covers the end of bones where they form joints.

1. Patella from the metatarsals - proximal
2. Sternum from the scapula - anterior
3. Metacarpals from the humerus - distal
4. Clavicle from the ilium - superior
5. Ischium from the ilium - inferior

A joint is a junction of two or more bones and is commonly referred to as an **articulation**.

There are 3 types of joints:
- **Immovable or fibrous joints**
  Eg. Cranium.
- **Slightly movable or cartilaginous**
  Eg. Vertebrae and ribs.
- **Freely movable or synovial**
  Eg. Patella

**Tendons join muscles to bones.** Tendons are tough, inelastic cords of tissue that attach muscle to bone.

**Ligaments join bone to bone.** Ligaments are well defined, fibrous bands that connect articulating bones.
**Synovial fluid** acts as a lubricant, keeping the joint well oiled and the moving surfaces apart. As no 2 surfaces fit together perfectly, synovial fluid forms a cushion between them. It also provides nutrition for the cartilage and carries away waste products. During movement more fluid is ‘pumped’ into the join space.

**Hyaline cartilage** is a layer of smooth, shiny cartilage that allows the bones to move freely over each other. This cartilage is thicker in the leg joints, where there is greater weight bearing.

Types of joints:
- Ball and Socket - very wide range of movement (hips and shoulders)
- Hinge - Only moves in two directions (elbow and knee)
- Pivot - twists and spins (vertebrae so that neck can turn)
- Gliding - small bones that glide on top of each other (carpals and tarsals)
- Condyloid - small version of a ball and socket but has a bit less range of movement (metacarpals)
- Saddle - sits in top of humerus (thumb is only saddle joint)

**A3. Join actions, eg. extension and flexion**

*Link each of the following actions to a sporting movement:*

- Shoulder flexion: Diving
- Knee extension: Kicking a ball
- Elbow extension: Throwing a ball
- Hip flexion: Deadlift
- Neck flexion: Front flip
- Shoulder abduction: Lateral dumbbell raises
- Ankle plantarflexion: Jumping
- Ankle dorsiflexion: Kicking a ball
- Shoulder circumduction: Cricket bowling
- Hip adduction: Passing a ball across your body
- Neck rotation: Breathing when swimming freestyle
- Hand pronation: Dribbling a basketball
- Hand Supination: Catching a ball

**Review questions:**

Describe the function of the main structures of a synovial joint. (4 marks)

A synovial joint is a freely moving joint which is made up of ligaments, tendons, synovial fluid and hyaline cartilage.

The role of a ligament in a synovial joint is to attach bone to bone, for example the ACL (anterior cruciate ligament) which joins the femur to the tibia.
The role of a tendon in a synovial joint is to attach muscle to bone, for example the hamstring tendon which joins the hamstring to the tibia.

The role of synovial fluid in a synovial joint is to lubricate the joint, for example the area between the femur and tibia.

The role of hyaline cartilage in a synovial joint is to allow bones to move freely over each other, for example at the bottom of the femur.

Identify the types of bones involved in knee flexion. (3 marks)

Knee flexion is the action that occurs when the angle of the knee joint decreases as a result of a contraction of the hamstring. The bones that articulate at the joint and are involved in knee flexion include the Femur, Patella, Tibia and Fibula. The Femur, Tibia and Fibula are all long bones and the Patella is a short bone.

(b) Muscular system

B1. Major muscles involved in movement

List the LLLL
The major muscles of the muscular system

1. Deltoids
2. Biceps
3. External oblique
4. Wrist flexors
5. Hip flexors
6. Quadriceps
7. Tibialis anterior
8. Pectoralis major
9. Latissimus dorsi
10. Biceps
11. Abdominals
12. Brachioradialis
13. Rhomboid major
14. Latissimus dorsi
15. Iliotibial tract
16. Hamstrings
17. Gastrocnemius
18. Achilles tendon
19. Trapezius
20. Triceps
21. Wrist extensors
22. Gluteus maximus
23. Soleus
List the major skeletal muscles in the following areas of the body:

- Lower half of the upper limb (elbow down) - wrist flexors and wrist extensors
- Upper half of the upper limb (elbow to shoulder) - biceps, triceps and deltoids
- Lower half of the lower limb (knee down) - gastrocnemius, soleus and tibialis anterior
- Upper half of the lower limb (knee to hip) - quadriceps and hamstrings
- Around the shoulder - deltoids and trapezius
- Posterior hip - gluteus maximus
- Anterior trunk including neck - abdominals, pectorals and external obliques
- Posterior trunk including neck - trapezius, latissimus dorsi, erector spinae

Origin and insertion

The **origin** of a muscle is the point of attachment that the muscles makes with the more stationary bone. In most cases this point will be medial or closer to the trunk. For example when doing a bicep curl, the biceps point of origin is the scapula.

The **insertion** is the other attachment point of the muscle. On the moveable end of the bone. This point is often more lateral or further away from the trunk. In the previous example, the point of insertion would be the elbow.

**Palpitation** refers to feeling a muscle or muscle group. Most palpitation would occur close to the surface as they are easily felt. It is easier to palpitate a muscle when moving slightly. Palpitation can be used on surface muscles to locate origin and insertion.

Identifying origin, insertion and action

**Triceps**
- **Origin:** Scapula, humerus
- **Insertion:** Ulna (proximal end)
- **Action:** extension of arm and forearm

**Gastrocnemius**
- **Origin:** femur (distal end)
- **Insertion:** heel bone (posterior)
- **Action:** knee flexion, plantar flexion of foot

**Quadriceps**
- **Origin:** iliac crest, femur
- **Insertion:** tibia (proximal end), patella
- **Action:** flexion of hip, extension of lower leg

**Gluteus Maximus**
- **Origin:** posterior surface of pelvis, sacrum
- **Insertion:** femur
- **Action:** extension and abduction of thigh

**Deltoid**
- Origin: scapula, clavicle
- Insertion: humerus
- Action: abduction of arm

**Biceps Brachii**
- Origin: humerus, scapula
- Insertion: radius
- Action: Flexion of arm and forearm, supination of forearm

### B2. Muscle relationship (agonist, antagonist)

**Introduction**

The role of muscles in the body is to contract. All 600 plus muscles in the body are attached to the bones, and when the muscles contract they are able to use the bones of the body to create movement. Muscles are NOT able to push; they are only capable of pulling.

In every movement a muscle must perform one of three roles, either the agonist, the antagonist or the stabiliser.

The **agonist** muscle is the prime mover or the muscle that causes the action, sometimes there can be more than one in large joint movement.

The **antagonist** muscle has to relax to allow the agonist to create movement and to assist in controlling the movement. The agonist and antagonist muscles work as pairs to create and control action. These pairs can interchange roles depending on the type of movement i.e. flexion or extension.

**Stabilisers** are also known as fixator muscles and stabilise the joint during action.

### B3. Types of muscle contraction (concentric, eccentric, isometric)

When a muscle is stimulated it attempts to contract. There are 3 principal types of muscle contraction;

1. **Concentric contraction** is the most common type of muscular contraction. During this contraction, the muscle shortens, causing movement at the joint.

2. **Eccentric contraction** occurs when the muscle lengthens while under tension. The action often happens with the assistance of gravity.

3. **Isometric contraction** develops when the muscle fibres are activated and develop force, but the muscle length does not change, that is movement does not occur.
What type of contraction occurs for the following?

A). Pushing against a doorframe
Isometric contraction

B). Upward phase of bicep curl
Concentric contraction

C). Downward phase of the bicep
Eccentric contraction

D). Upward phase of the shoulder press
Concentric contraction

E). Upward phase of a chin up
Concentric contraction

F). Supporting yourself on a rock climbing wall
Isometric contraction

c) The respiratory system

C1. Structure and function

My - Mouth/nose
Pet - Pharynx
Lil - Larynx
Tiger - Trachea
Bites - Bronchus
Big - Bronchioles
Apples - Alveoli

Respiration is the process by which the body takes up oxygen (O2) and removes carbon dioxide (CO2). Respiration occurs in all living cells. It uses oxygen as a vital ingredient to free energy from food.

Oxygen from the atmosphere enters the body either through the nose or mouth, when entering through the nose, it passes through the nasal cavities and is warmed, moistened and filtered of any foreign material.

The pharynx is a common passage for air to the trachea or food to the oesophagus leading from the nasal cavity to the larynx at the beginning of the trachea.

The trachea is a hollow tube strengthened and kept open by rings of cartilage. After entering the chest cavity or thorax, the trachea divides into a right and a left bronchus.
(bronchial tube), which lead to the right and left lungs respectively.

The inner lining of the air passages produces mucus that catches and holds dirt and germs. It is also covered with microscopic hairs (cilia) that remove dirt, irritants and mucus through steady, rhythmic movements.

The lungs consist of two bag-like organs, one situated on each side of the heart. They are enclosed in the thoracic cavity by the ribs at the sides, the sternum at the front, the vertebral column at the back and the diaphragm (a dome-shaped muscle) at the base. The light, soft, lung tissue is compressed and folded and, like a sponge, is composed of tiny air pockets.

The left and right bronchi that deliver air to the lungs divide into a number of branches or bronchioles within each lung. These then branch many more times, eventually terminating in clusters of tiny air sacs called **alveoli**. It is in the alveoli where oxygen from the air we breathe is exchanged for carbon dioxide from our blood stream.
C2. Lung function

**Inspiration**
During inspiration the diaphragm contracts and flattens as the intercostal muscles lift the ribs outwards and upwards. This increases volume of the chest cavity, pulling the walls of the lungs outwards, which decreases air pressure in the lungs. In response to this air rushes into the lungs from outside the body.

**Expiration**
During expiration the diaphragm relaxes and moves upwards as the intercostal muscles allow the ribs to return to their resting position. The volume of the chest cavity decreases, increasing air pressure inside the lungs. Air is consequently forced out to make the pressures in and outside the lungs equal. At rest we breathe at a rate of approx 12-18 breaths per minute.

C3. The exchange of gases

When you inspire the lungs suck in air due to the low air pressure inside them caused by the lungs of the wall being pulled outwards. When the air gets into your lungs the alveoli are supplied with high amounts of oxygen and low amounts of carbon dioxide whereas the capillaries arriving to the alveoli are low in oxygen and high in carbon dioxide. These differences result in a pressure difference which therefore causes the oxygen to move from the alveoli across the alveolar-capillary wall and into the blood, where it attaches to haemoglobin in the red blood cells. At the same time carbon dioxide is unloaded into the alveoli and this is called gaseous exchange. Finally during expiration the chest cavity decreases forcing the air out to make the pressure inside and outside equal.

(d) Circulatory system

D1. Components of blood

4 Components of blood:
- Red blood cells
• White blood cells
• Plasma
• Platelets

Blood's main functions include:

• transportation of oxygen and nutrients to the tissues and removal of carbon dioxide and wastes
• protection of the body via the immune system and by clotting to prevent blood loss
• regulation of the body's temperature and the fluid content of the body's tissues.

Blood consists of a liquid component (55% of blood volume) called plasma and a solid component (45% of blood volume) made up of red and white blood cells and platelets.

**Plasma**

Substances such as plasma proteins, nutrients, hormones, mineral salts and wastes are dissolved in the plasma and are necessary for the nourishment and functioning of tissues. Much of the carbon dioxide and very small amounts of oxygen are also carried in a dissolved state in plasma.

**Red blood cells**

Red blood cells are formed in bone marrow. Their main role is to carry oxygen and carbon dioxide around the body. They contain iron and a protein called haemoglobin. Haemoglobin readily combines with oxygen and carries it from the lungs to the cells.

**White blood cells**

White blood cells are formed in the bone marrow and lymph nodes. They provide the body with a mobile protection system against disease. These cells can change shape and move against the blood flow to areas of infection or disease.

**Platelets**

Platelets are tiny structures made from bone marrow cells that have no nucleus. They help to produce clotting substances that are important in preventing blood loss when a blood vessel is damaged.

**D2. Structure and function of the heart**

• Diastole - when the heart fills / expands (remember when an eye dilates it expands).
• Systole - when the blood is pushed out / contracted.
• Arteries - take blood away from the heart. Large and fairly elastic.
Veins - take blood away from the heart.
Capillaries - exchange tissue

**D3. Pulmonary and systemic circulation**

Pulmonary circulation - Is the flow of blood from the heart to the lungs and back to the heart.

Systemic circulation - Is the flow of blood from the heart to body tissue and back to the heart.

**D4. Blood pressure**

What is blood pressure?
- The term blood pressure refers to the force exerted by blood on the walls of the blood vessels.
- The flow and pressure of blood in the arteries rises with each contraction of the heart and falls when it relaxes and refills.
- Blood pressure reflects the quantity of blood being pushed out of the heart (cardiac output) and the ease or difficulty blood passes through the arteries (resistance to flow).

Blood pressure is determined by:
- Cardiac output - as CO increases so does BP
- Volume of blood in circulation - if blood volume increases due to water retention BP will increase. During blood loss, BP will fall.
- Resistance to blood flow - if viscosity (stickiness) of blood increases, resistance will increase. Narrowing of the blood vessels (atherosclerosis) will increase resistance. As deposits build up in artery walls they become less elastic and harder (arteriosclerosis) making it difficult for blood to flow. An increase in resistance, increases BP.
- Venous return - as this affects CO, it also affects BP.

Measuring BP
- BP is measured using a sphygmomanometer and is measured in millimetres of mercury (mm.Hg.). It is expressed as a fraction which represents systolic pressure over diastolic pressure.
- Systolic pressure is the highest (peak) pressure recorded when blood is forced into the arteries during contraction of the left ventricle.
- Diastolic pressure is the minimum or lowest pressure recorded when the heart is relaxing and filling.

The average BP is 120(systolic)/80(diastolic)

**FQ2 - What is the relationship between physical fitness, training and movement**
Physical fitness and training lead to improved physiological responses to exercise and higher skill levels. This, in turn, produces movement efficiency, as participants in physical activity and sport can sustain and recover from physical offer more quickly, and execute skills more consistently, with less effort.

(a) Health related components of physical fitness

My - Muscular strength
Mum - Muscular endurance
Creates - Cardiorespiratory endurance
Fat - Flexibility
Beats - Body composition

A1. Cardiorespiratory endurance

Cardiorespiratory endurance is the ability of the working muscles to take up and use the oxygen that has been breathed in during exercise and transferred to muscle cells. It is commonly referred to as aerobic power. E.g. endurance events (marathon, triathlon).

Fitness test - beep test.

A2. Muscular strength

Muscular strength is the ability to exert force against resistance in a single maximal effort. E.g. weight lifting.

Fitness test - hand dynamometer.

A3. Muscular endurance

Muscular endurance is the ability of the muscles to endure physical work for extended periods of time without undue fatigue. E.g. Cycling, rowing.

Fitness test - sit up test.

A4. Flexibility

Flexibility is the range of motion about a joint or the ease of joint movement. E.g. Gymnastics.

Fitness test - sit and reach test.

A5. Body composition
Body composition is the percentage of fat as opposed to lean body mass in a person. E.g. Diving, swimming.

Fitness test - BMI or calipers (skinfold).

(b) Skill related components of physical fitness

A - Agility
B - Balance
C - Coordination
P - Power
R - Reaction time
S - Speed

B1. Power

The ability to combine speed and strength in an explosive action. E.g. shot put, javelin

Fitness test - vertical jump test.

B2. Speed

The ability to perform body movements quickly. E.g. sprinting.

Fitness test - 35m sprint.

B3. Agility

To move the body from one position and direction to another with speed and precision. E.g. touch football.

Fitness test - illinois agility test.

B4. Coordination

The ability to harmonise the messages from the senses with parts of the body to produce movements that are smooth, skillful and well controlled. E.g. tennis, soccer, AFL.

Fitness test - hand wall toss or stick toss.

B5. Balance

To maintain equilibrium while moving or stationary. E.g. gymnastics.
Fitness test - standing stork test.

**B6. Reaction time**

The time taken to respond to a stimulus. E.g. goalkeeper in soccer.

Fitness test - ruler drop test.

Surfing:
- Balance
- Muscular endurance
- Reaction time

Marathon running:
- Body composition'
- Muscular endurance
- Cardiorespiratory endurance

High jumping:
- Power
- Speed
- Reaction time

Sprinting:
- Power
- Speed
- Reaction time

(c) Aerobic and anaerobic training

**C1. FITT Principle**

- If we perform short sharp movements, the body uses the **anaerobic** pathway (without oxygen) to supply energy.
- If movements are sustained and of moderate intensity, the **aerobic** pathway (with oxygen) supplies the bulk of energy needs.

Aerobic:
- Aerobic means with ‘in the presence of oxygen’
- 90 seconds or more
- Sustained movements e.g. marathon running, 1500m swimming
- Energy pathway - Aerobic

Anaerobic:
- Anaerobic means ‘without oxygen’
- 1 second to about 2 minutes
- Sharp, explosive movements e.g. jumping and lifting
- Energy pathway - ATP-PC

**FITT Principle**

- **Fitness principle** that ensures a program has the quantity or quality of movement necessary to produce the desired physical improvement.
- **Frequency** (how often) 3-5 sessions per week. Aiming to stress the body to cause and adaptation.
- **Intensity** (Amount of effort required to accrue a fitness benefit) aiming to keep inside your target heart rate zone 60%-75% bpm.
- How do we determine this? Hint Max HR.
- **Time** - Length of session and duration of training program.
- A session in the target heart rate zone should last 20-30 minutes and increase to 40 minutes or more if possible.
- Sessions longer than 60 minutes causes the possibility of exhaustion and overuse injuries (elite athletes excepted).
- **Time** duration - 6 weeks is the minimal period for the body’s realisation of a training effect.
- That is, for adaptations to have taken place
- **Type** - movements should link to the sport you are training for, aerobic or anaerobic energy system.
- In general the best type of fitness is continuous exercise that uses the large muscle groups.
- E.g. Running, cycling, swimming or aerobics.
  - **Cardiovascular exercise**
  - Aerobic fitness
  - Draws heavily on oxygen supply, increases breathing rate, heart rate and blood flow to working muscles
  - Large muscle groups
  - Circuit training
  - **Resistance training**
  - Mainly anaerobic fitness
  - Low resistance
  - High repetitions
  - Resistance bands or circuit training
  - Circuit training
  1. Ski jumps (10)
  2. Pushups (20)
  3. Bench step ups (40)
  4. Sit ups (30)
  5. Squat thrusts (15)
  6. Chin ups (10)
7. Free squats (20)
8. Back extensions (15)

**Aerobic training program**

<table>
<thead>
<tr>
<th>FITT Principle</th>
<th>AFL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>3 times per week</td>
</tr>
<tr>
<td>Intensity</td>
<td>Low - moderate keeping the players in the target heart rate zone for as long as possible (60-75%). Short breaks in between activities to maintain heart rate.</td>
</tr>
<tr>
<td>Time</td>
<td>40 minutes</td>
</tr>
<tr>
<td>Type</td>
<td>Continuous exercise. Kicking and hand passing skills with running in between to give and receive a pass. Lasting for 5-7 minutes. Cardiorespiratory fitness.</td>
</tr>
</tbody>
</table>

**Anaerobic system**

- Anaerobic without oxygen
- ATP-PC Adenosine Triphosphate - Phosphate Creatine
- High intensity level over a short period usually less than 2 minutes
- When we sprint we require great amounts of energy and therefore exhaust energy supplies
- This causes us to breath faster to speed up the blood flow and transport oxygen to the working muscles. In the meantime muscles use stored fuel reserves until oxygen is available

**Anaerobic training**

- Training enhances the ability of muscle cells to improve their use of fuel reserves and be more efficient in converting blood sugar to energy during intense exercise. (stored muscle glycogen)
- Interval training where periods of intense work (above 80% MHR) are interspersed with rest periods
- However, anaerobic training generally requires an aerobic foundation, particularly in activities such as sprinting and swimming

To improve anaerobic fitness

- Perform and endure specific anaerobic movements e.g. lifting weights, throwing or jumping
- Practice movements at competition or close to competition speed to encourage correct adaptations
Linking anaerobic training to the FITT principle

- Frequency: 3-5 sessions per week
- Intensity: high with low repetitions
- Time: less than 2 minutes or 90 seconds
- Type: resistance, sprinting, throwing, jumping, plyometrics

### Weight training program (anaerobic)

<table>
<thead>
<tr>
<th>FITT Principle</th>
<th>Weight lifting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>3 times per week</td>
</tr>
<tr>
<td>Intensity</td>
<td>High intensity - Above 85% target heart rate. Long breaks to allow your ATP system to rejuvenate and get rid of lactic acid</td>
</tr>
<tr>
<td>Time</td>
<td>20-60 minutes</td>
</tr>
<tr>
<td>Type</td>
<td>Squats, bench press, lat pulldown, bicep curls, tricep dips. Targeting power and strength</td>
</tr>
</tbody>
</table>

### (d) Immediate physiological responses to training

<table>
<thead>
<tr>
<th>Physiological response (Name and define)</th>
<th>What happens during exercise</th>
<th>Why does this response occur</th>
<th>What is the difference between a trained V untrained athlete?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate - the number of times a heart beats per minute</td>
<td>As the intensity of exercise increases so will heart rate</td>
<td>It has to work harder to pump more oxygenated blood to the muscles which require it</td>
<td>Trained athletes will have a lower resting heart rate and their heart rate won’t increase as much when exercising compared to an untrained athlete</td>
</tr>
<tr>
<td>Stroke volume - the amount of oxygenated blood pumped by the left ventricle in one contraction</td>
<td>Stroke volume increases during exercise</td>
<td>Stroke volume increases because the body needs more oxygen which is received from the blood</td>
<td>Stroke volume is lower in trained athletes</td>
</tr>
</tbody>
</table>
Explain the effect of increased lactate levels and cardiac output at the beginning of exercise (5 marks)

The body has a number of physiological responses to exercise. Two of these include lactate levels and cardiac output.

Lactate levels are the amount of lactic acid build up in your muscles. Lactate levels increase once the lactate inflection point is past as a result of increased intensity. The effect of increased lactate levels is that muscles fill up with lactic acid which prevents them from contracting normally at the intensity that’s required.

Cardiac output is the amount of blood the heart pumps through the circulatory system in one minute. Cardiac output would increase during exercise due to a rise in heart rate and stroke volume. The effect of increased cardiac output is that blood is pushed around the body faster allowing muscles to get more oxygen to help them contract.

<table>
<thead>
<tr>
<th>Ventilation rate - the rate and depth of breathing measured in breaths per minute</th>
<th>Ventilation rate increases during exercise. Can also increase prior to exercise due to anticipation</th>
<th>Ventilation rate increases to get more oxygen into the body and remove more carbon dioxide</th>
<th>Ventilation rate is lower in trained athletes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactate level - concentration of blood lactate</td>
<td>Lactate level increases during exercise and increase as intensity increases</td>
<td>Lactate accumulates during anaerobic exercise when it is being used to break down glucose and then becomes a waste product. Due to insufficient oxygen available to the muscles and cannot be removed faster than it enters.</td>
<td>Lactate levels build up slower in trained athletes</td>
</tr>
<tr>
<td>Cardiac output - the amount of blood the heart pumps through the circulatory system in one minute</td>
<td>Cardiac output increases during exercise</td>
<td>Cardiac output rises due to increased heart rate and stroke volume</td>
<td>Cardiac output is lower in trained athletes</td>
</tr>
</tbody>
</table>
D1. Heart rate

Heart rate is the number of times your heart beats in a minute. Heart rate responds to training by increasing from the resting value and is often used to set or determine the intensity of the training session. For example, an athlete might train for 20 minutes at 80% maximal heart rate (MHR).

D2. Ventilation rate

Ventilation rate is a measure of how many breaths a person takes per minute, and is also known as the respiratory rate. As with the heart rate, an athlete's ventilation rate will have an immediate increase in response to training. This is for the same reason that there is an increase in HR, the body is responding to the increasing concentration of carbon dioxide in the blood. In order to remove the carbon dioxide, your body has to breathe it out. By increasing your respiratory rate your body increases the amount of carbon dioxide removed, while at the same time increasing the amount of oxygen inspired.

D3. Stroke volume

Stroke volume is the amount of blood in mL pumped out of the left ventricle of the heart per contraction. The stroke volume of each ventricle is often the same so that the right ventricle pumps the same amount of blood to the lungs as the left ventricle pumps to the body. Stroke volume’s immediate response to training is to increase. The average human has a stroke volume of around 70 mL, this volume can double during exercise at high intensities.

D4. Cardiac output

Cardiac output is the amount of blood pumped out of the left ventricle in a minute. It can be calculated by multiplying the stroke volume by the heart rate and is usually given in litres per minute. Since we already know that stroke volume and heart rate both increase in response to training, it goes without saying that cardiac output also increases in response to training.

D5. Lactate levels
Lactate levels refers to the amount of lactate and/or lactic acid in your blood. Lactic acid is produced by the lactic acid energy system and is quickly converted to lactate before being transported to your liver where it is converted to glucose. During exercise lactate levels rise in proportion to the intensity of the training.

**FQ3 - How do biomechanical principles influence movement?**

**Biomechanics** is a science concerned with forces and the effect if these forces in and within the body.

You need to understand how biomechanical principles can be “manipulated” to gain an advantage or overcome an obstacle.

**a) Motion**

**A1. The application of linear motion, velocity, speed, acceleration, momentum in movement and performance contexts**

- **Motion** is the movement of a body from one position to another.
- **Linear motion** takes place when a body and all parts connected to it travel the **same** distance in the **same** direction and at the **same** time. Swimming 50m, running 100m sprint - straight line from start to finish. Example: swimming technique which causes someone to alter from their straight line path, therefore increasing the distance that they travel.
- **Velocity** is equal to displacement divided by time and is not really important in sport (not being tested on it).
- **Speed** is equal to the distance covered by the time taken.
  
  \[
  \text{Speed} = \frac{\text{Distance}}{\text{Time}}
  \]

- **Acceleration** is the rate at which velocity changes in a given amount of time. It is the ability to increase speed quickly.
- **Momentum** refers to the quantity of motion that a body possesses. **Momentum = mass * velocity. Mass** is the amount of matter in a body. Linear momentum and angular momentum.

**Questions**

Describe the principle of acceleration. Support your answer with an example. (3 marks)
Discuss how the application of linear motion principles can enhance swimming performance. (5 marks)

Linear motion takes place when a body and all parts connected to it travel the same distance, direction and time. For example, a 50m swimmer who applies the principles of linear motion will have a smaller distance to travel and therefore be at an advantage. A negative is if you have bad technique you might swim side to side, forcing you to take a longer distance to get to the end of the pool and putting you at a disadvantage. A recommendation would be to apply biomechanical analysis to the swimmer’s technique to improve the straightness of their strokes and allow them to travel in a linear motion.

(b) Balance and stability (maintaining equilibrium)

B1. Centre of gravity

Centre of gravity is the point at which the weight is evenly distributed and about which the object is balanced.

The impact of height of centre of gravity on performance

<table>
<thead>
<tr>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>• In high jump, centre of gravity shifts up to get over the bar</td>
<td>• A centre in basketball with a high centre of gravity will have lower stability</td>
</tr>
<tr>
<td>• Summersault moving it outside of your mass to rotate</td>
<td></td>
</tr>
<tr>
<td>• Lower centre of gravity in a rugby scrum gives you better stability or help to change directions in tennis when receiving a serve</td>
<td></td>
</tr>
</tbody>
</table>
B2. Line of gravity

The line of gravity is an imaginary vertical line passing through the centre of gravity and extending to the ground.

Movement results in a momentary state of imbalance, causing the body to move in the direction of the imbalance.

B3. Base of support

The base of support refers to an imaginary area that surrounds the outside edge of the body when it is in contact with a surface.

Wide base of support = stability

Narrow base of support = instability

The impact of base of support on performance

<table>
<thead>
<tr>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Wide base of support for sumo wrestling meaning they are more</td>
<td>● Narrow base of support in surfing means less balance and stability</td>
</tr>
</tbody>
</table>
**Fluid mechanics**

Fluid mechanics is a branch of mechanics that is concerned with properties of gases and liquids impacting movement.

**C1. Flotation, centre of buoyancy**

**Flotation**

- To float is the ability to maintain a stationary position on the surface of the water.
- To float you must have an equal weight pushing up as is pushing you down.

**Body density**

- Body density or mass per unit of volume also impacts our ability to float.
- Upper body (lungs) low density - float!
- Lower body (bones and muscle) high density - sink!

**Centre of buoyancy**

- Centre of buoyancy is the centre of gravity of a volume of water displaced by an object when it is immersed in that water.
- Buoyancy is the force pushing you up.
- Gravity (mass) is pushing you down.
- Greater your mass (high density - muscles, bones) the less buoyant you are.

**C2. Fluid resistance**

- Stable and it will be harder to push them
- Ballet narrow base of support allows them to rotate easier
- Narrow base of support when bracing for a tackle increases the chance of the getting bowled over
When a body or object moves it encounters a resisting force from that medium. **Drag** is the force that opposes the forward motion on a body or object, reducing its speed or velocity. Drag depends on:
- Fluid density
- Shape
- Surface
- Size of frontal area
Surface drag or skin friction refers to a thin film of the fluid medium sticking to the surface area of the body or object through which it is moving. The boundary layer is the layer of fluid whose speed is reduced because it is attached to the surface of an object that is moving through it. Laminar flow is a streamlined flow of fluid with no evidence of turbulence between layers.

**Lift** is the component of a force that acts at right angles to the drag.

**Profile drag and wake**
- Profile drag (form of pressure drag) refers to drag created by the shape and size of a body or object.
- A wake is an area of turbulence behind an object moving through fluid.

**Magnus Effect**

The magnus effect explains why spinning objects such as cricket and golf balls deviate from their normal flight paths.

Spinning causes the formation of pockets of high and low pressure. The size of the pressure pockets depends on the speed of rotation and roughness of the surface.

**D1. How the body applies force**
A force is a push or a pull acting on a body
We can apply forces to things such as the ground, a ball and weights
When we apply a force we are confronted by opposing forces such as gravity, air resistance and friction.
Forces can be internal - muscles and joints or external - being punched in boxing
There are 2 types of forces - applied forces and reaction forces
Applied forces are generated by muscles working on joints eg: to a running track or gym equipment such as a barbell

D2. How the body absorbs force

- Reaction forces are the force that oppose this eg: the track surface reacting to the force created by the leg muscles and joints
- The greater the force the runner can produce. The greater the resistance from the track = fast time to cover the distance.
- “For every action there is an equal and opposite reaction” - Newton’s third law

- Power is the ability of muscle groups to contract at speed.
- Power = work (strength) / time

- Forces exerted on the body are absorbed through the joints which bend and flex in response to the impact eg: collecting a rebound in basketball or stopping a bounce on a trampoline.
- When the body lands on a surface it exerts a force. In response the surface exerts a force back. If our joints did not bend to allow the dissipation of the forces by the muscles then it would cause injury.
- The body also absorbs forces while catching objects.

D3. Applying force to an object

When applying force to an object there are a number of considerations.
1. Amount of force being applied to an object - greater the force the greater the acceleration of the object.
2. If the mass of an object is increased then a greater force is needed to move an object the same distance - ball becoming wet or water logged - AFL.
3. Objects of greater mass require more force to move them than objects of smaller mass. - size and mass of equipment in relation to size of athlete. Shot put V tennis ball.

Forces are also created as the body rotates around an axis. These are known as centripetal & centrifugal forces.

Centripetal - force directed towards the centre of a rotating body - cyclist in velodrome or hammer throw (person pulling the ball in)
Centrifugal - force directed away from the centre of a rotating body - sliding to outside as you turn a corner in a car