**Q1.**(a)     Describe the roles of calcium ions and ATP in the contraction of a myofibril.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(Extra space)** ................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(5)**

(b)     ATP is an energy source used in many cell processes. Give **two** ways in which ATP is a suitable energy source for cells to use.

1 .....................................................................................................................

........................................................................................................................

2 .....................................................................................................................

........................................................................................................................

**(2)**

**(Total 7 marks)**

**Q2.**Read the following passage carefully.

|  |  |  |
| --- | --- | --- |
|  | A large and growing number of disorders are now known to be due to types of mitochondrial disease (MD). MD often affects skeletal muscles, causing muscle weakness. |  |
|  | We get our mitochondria from our mothers, via the fertilised egg cell. Fathers do not pass on mitochondria via their sperm. Some mitochondrial diseases are caused by mutations of mitochondrial genes inside the mitochondria. Most mitochondrial diseases are caused by mutations of genes in the cell nucleus that are involved in the functioning of mitochondria. These mutations of nuclear DNA produce recessive alleles. | 5 |
|  | One form of mitochondrial disease is caused by a mutation of a mitochondrial gene that codes for a tRNA. The mutation involves substitution of guanine for adenine in the DNA base sequence. This changes the anticodon on the tRNA. This results in the formation of a non-functional protein in the mitochondrion. | 10 |
|  | There are a number of ways to try to diagnose whether someone has a mitochondrial disease. One test involves measuring the concentration of lactate in a person’s blood after exercise. In someone with MD, the concentration is usually much higher than normal. If the lactate test suggests MD, a small amount of DNA can be extracted from mitochondria and DNA sequencing used to try to find a mutation. | 15 |

Use information in the passage and your own knowledge to answer the following questions.

(a)     Mitochondrial disease (MD) often causes muscle weakness (lines 1–3). Use your knowledge of respiration and muscle contraction to suggest explanations for this effect of MD.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(Extra space)** ................................................................................................

........................................................................................................................

........................................................................................................................

**(3)**

Two couples, couple **A** and couple **B**, had one or more children affected by a mitochondrial disease. The type of mitochondrial disease was different for each couple.

None of the parents showed signs or symptoms of MD.

•        Couple **A** had four children who were all affected by an MD.

•        Couple **B** had four children and only one was affected by an MD.

(b)     Use the information in lines 5–9 and your knowledge of inheritance to suggest why:

•        all of couple **A**’s children had an MD

•        only one of couple **B**’s children had an MD.

Couple **A** ........................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

Couple **B** ........................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(Extra space)** ................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(4)**

(c)     Suggest how the change in the anticodon of a tRNA leads to MD (lines 10–13).

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(Extra space)** ................................................................................................

........................................................................................................................

........................................................................................................................

**(3)**

(d)     If someone has MD, the concentration of lactate in their blood after exercise is usually much higher than normal (lines 15–17). Suggest why.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(Extra space)** ................................................................................................

........................................................................................................................

........................................................................................................................

**(3)**

(e)     A small amount of DNA can be extracted from mitochondria and DNA sequencing used to try to find a mutation (lines 18–19).

From this sample:

•        how would enough DNA be obtained for sequencing?

•        how would sequencing allow the identification of a mutation?

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(2)**

**(Total 15 marks)**

**Q3.**          Surgeons sometimes use a drug called pancuronium to stop muscles contracting during an operation.

Pancuronium binds to acetylcholine receptors on muscle fibres.

(a)     Suggest why pancuronium is able to bind to acetylcholine receptors.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

**(2)**

(b)     Pancuronium causes muscle paralysis. Explain how.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

*(Extra space)  ..............................................................................................*

......................................................................................................................

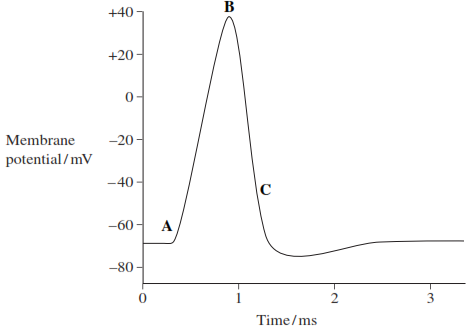
......................................................................................................................

**(3)**

**(Total 5 marks)**

**Q4.**          **Figure 1** shows changes in the membrane potential of a neurone during one action potential.

**Figure 1**

****

(a)     What happens in the membrane to cause the change in membrane potential at time **B**?

.......................................................................................................................

.......................................................................................................................

.......................................................................................................................

.......................................................................................................................

**(2)**

(b)     No further action potential can be produced between times **A** and **C**.

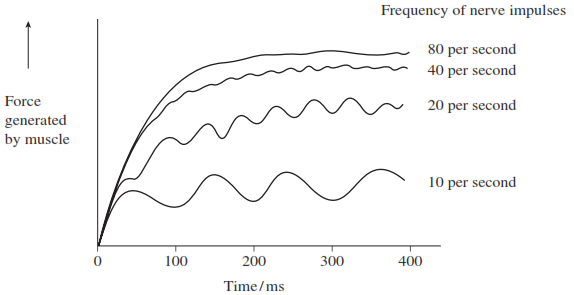
What is the name given to the period between times **A** and **C**?

.......................................................................................................................

**(1)**

(c)     **Figure 2** shows the force generated by a muscle when it was stimulated by different frequencies of nerve impulse.

**Figure 2**

****

A taser is a device used by the police to arrest violent suspects. It fires electrical impulses very similar to action potentials into a suspect. The frequency of the impulses is between 15 and 20 per second.

(i)      Suggest the effect a taser has on a suspect’s muscles.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(ii)     Tasers with frequencies of between 40 and 80 per second are not used, because they are considered too dangerous. Suggest how they might be dangerous to a suspect.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

**(Total 7 marks)**

**Q5.**          (a)     Describe the role of each of the following in muscle contraction.

(i)      Tropomyosin

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(ii)     ATP

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(b)     Explain how muscles maintain posture.

.......................................................................................................................

.......................................................................................................................

.......................................................................................................................

.......................................................................................................................

.......................................................................................................................

.......................................................................................................................

*(Extra space) ................................................................................................*

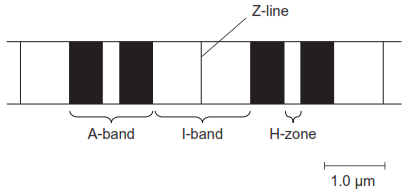
.......................................................................................................................

.......................................................................................................................

**(3)**

**(Total 7 marks)**

**Q6.**          The diagram shows part of a relaxed myofibril.



(a)     When the myofibril contracts, which of the A-band, I-band and H-zone will

(i)      remain unchanged in length...............................................................

(ii)     decrease in length?............................................................................

**(2)**

(b)     The whole myofibril is 21 mm long when relaxed.  Use information from the diagram, and the scale provided, to calculate the number of sarcomeres in the myofibril.

Show your working.

Number of sarcomeres =  ..............................

**(2)**

(c)     Calcium ions are involved in myofibril contraction.  
Describe how.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

*(Extra space)* ...............................................................................................

*......................................................................................................................*

*......................................................................................................................*

**(3)**

**(Total 7 marks)**

**Q7.**          This question should be written in continuous prose, where appropriate.

(a)     Explain how a resting potential is maintained in a neurone.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

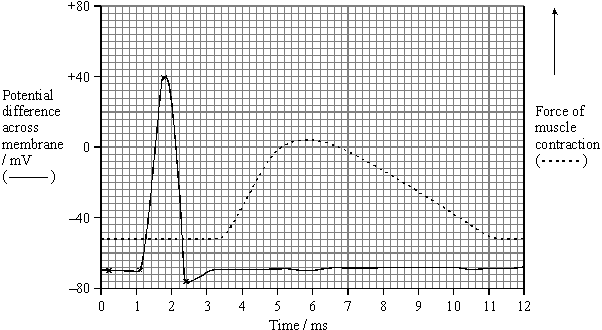
......................................................................................................................

......................................................................................................................

**(4)**

(b)     In an investigation, an impulse was generated in a neurone using electrodes. During transmission along the neurone, an action potential was recorded at one point on the neurone. When the impulse reached the neuromuscular junction, it stimulated a muscle cell to contract. The force generated by the contraction was measured. The results are shown in the graph.

The distance between the point on the neurone where the action potential was measured and the neuromuscular junction was exactly 18 mm.



(i)      Use the graph to estimate the time between the maximum depolarisation and the start of contraction by the muscle cell.

Time ................................ ms

**(1)**

(ii)     Use your answer to part (i) to calculate the speed of transmission along this neurone to the muscle cell. Give your answer in mm per second.

Show your working.

Speed .................................. mm s–1

**(2)**

(iii)     Give **one** reason why the value calculated in part (ii) would be an underestimate of the speed of transmission of an impulse along a neurone.

.............................................................................................................

.............................................................................................................

**(1)**

Acetylcholine is the neurotransmitter at neuromuscular junctions.

(c)     Describe how the release of acetylcholine into a neuromuscular junction causes the cell membrane of a muscle fibre to depolarise.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

**(3)**

(d)     Use your knowledge of the processes occurring at a neuromuscular junction to explain each of the following.

(i)      The cobra is a very poisonous snake. The molecular structure of cobra toxin is similar to the molecular structure of acetylcholine. The toxin permanently prevents muscle contraction.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(ii)     The insecticide DFP combines with the active site of the enzyme acetylcholinesterase. The muscles stay contracted until the insecticide is lost from the neuromuscular junction.

.............................................................................................................

.............................................................................................................

.............................................................................................................

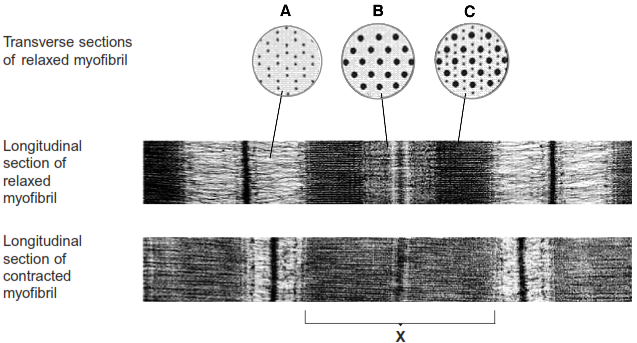
.............................................................................................................

**(2)**

**(Total 15 marks)**

**Q8.**          **Figure 1** shows sections through relaxed and contracted myofibrils of a skeletal muscle. The transverse sections are diagrams. The longitudinal sections are electron micrographs.

**Figure 1**

****

(a)     (i)      The electron micrographs are magnified 40 000 times.  
Calculate the length of  band **X** in micrometres.  
Show your working.

Length of band **X** =..................................... µm

**(2)**

(ii)     Explain the difference in appearance between transverse sections **A** and **C** in **Figure 1**.

.............................................................................................................

.............................................................................................................

**(1)**

(b)     Explain what leads to the differences in appearance between the relaxed myofibril and the contracted myofibril.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

(*Extra space*) .................................................................................................

........................................................................................................................

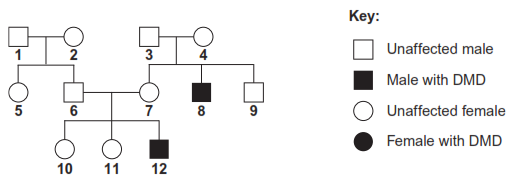
........................................................................................................................

........................................................................................................................

**(4)**

(c)     Duchenne muscular dystrophy (DMD) is a condition caused by the recessive allele of a sex-linked gene. A couple have a son with DMD. They want to know the probability that they could produce another child with DMD. They consulted a genetic counsellor who produced a diagram showing the inheritance of DMD in this family.  
This is shown in **Figure 2**.

**Figure 2**

****

The couple who sought genetic counselling are persons **6** and **7**.

(i)      Give the evidence to show that DMD is caused by a recessive allele.

.............................................................................................................

.............................................................................................................

**(1)**

(ii)     Give the numbers of **two** people in **Figure 2** who are definitely carriers of muscular dystrophy.

.............................................................................................................

**(1)**

(iii)     Complete the genetic diagram to find the probability that the next child of couple **6** and **7** will be a son with muscular dystrophy. Use the following symbols:

**X**D= normal X chromosome  
**X**d= X chromosome carrying the allele for muscular dystrophy  
**Y** = normal Y chromosome

|  |  |  |
| --- | --- | --- |
|  | **6** | **7** |
| *Parental phenotypes* | Unaffected | Unaffected |
| *Parental genotypes* | *..............* | *..............* |
| *Gametes* | *..............* | *..............* |

*Offspring genotypes          .....................................................................*

*Offspring phenotypes        .....................................................................*

*Probability of having a son with DMD ...................................................*

**(4)**

(d)     DMD is caused by a deletion mutation in the gene for a muscle protein called dystrophin. A deletion is where part of the DNA sequence of a gene is lost. People in different families may inherit mutations in different regions of this gene.

Scientists isolated the dystrophin gene from DNA samples taken from children **10**, **11** and **12**. They cut the gene into fragments using an enzyme. The scientists then used two DNA probes to identify the presence or absence of two of these fragments, called **F** and **G**. This allowed them to find the number of copies of each fragment in the DNA of a single cell from each child.

The table shows their results.

|  |  |  |
| --- | --- | --- |
| **Child** | **Number of copies of gene fragment per cell** | |
| **F** | **G** |
| **10** (unaffected girl) | 2 | 1 |
| **11** (unaffected girl) | 2 | 2 |
| **12** (boy with DMD) | 1 | 0 |

(i)      The number of copies of gene fragments **F** and **G** shows that person **12** has DMD.  
Explain how.

.............................................................................................................

.............................................................................................................

**(1)**

(ii)     The number of copies of gene fragments **F** and **G** shows that person **12** is male.  
Explain how.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(iii)     The genetic counsellor examined the scientists' results. He concluded that person **10** is a carrier of DMD but her sister, **11**, is not.

Describe and explain the evidence for this in the table.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

(*Extra space*) ......................................................................................

.............................................................................................................

.............................................................................................................

**(3)**

(e)     Person **12** took part in a trial of a new technique to help people with DMD.

Doctors took muscle cells from person **12**’s father and grew them in tissue culture.

They suspended samples of the cultured cells in salt solution and injected them into a muscle in person **12**’s left leg. They injected an equal volume of salt solution into the corresponding muscle in his right leg. Person **12** was given drugs to suppress his immune system throughout the trial.

Four weeks later, the doctors removed a muscle sample from near the injection site in each leg. They treated these samples with fluorescent antibodies. These antibodies were specific for the polypeptide coded for by gene fragment **G** of the dystrophin gene.

The results are shown in the table.

|  |  |
| --- | --- |
| **Location and treatment** | **Percentage of muscle fibres labelled with antibody** |
| Left leg - injected with cultured cells suspended in salt solution | 6.8 |
| Right leg - injected with salt solution | 0.0 |

(i)      Why was it necessary to treat person **12** with drugs to suppress his immune system?

.............................................................................................................

.............................................................................................................

**(1)**

(ii)     Explain why salt solution was injected into one leg and cultured cells suspended in salt solution into the other.

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(1)**

(iii)     This technique is at an early stage in its development. The doctors suggested that further investigations need to be carried out to assess its usefulness for treating people with DMD.

Explain why they made this suggestion.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

(*Extra space*) ......................................................................................

.............................................................................................................

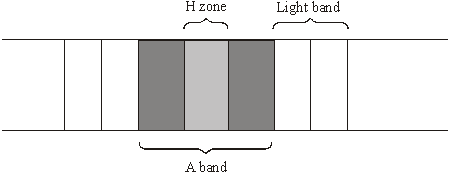
.............................................................................................................

.............................................................................................................

**(4)**

**(Total 25 marks)**

**Q9.**          (a)     The diagram shows the banding pattern observed in part of a relaxed muscle fibril.



(i)      Describe what causes the different bands seen in the muscle fibril.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(ii)     Describe how the banding pattern will be different when the muscle fibril is contracted.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(b)     There is an increase in the activity of the enzyme ATPase during muscle contraction. An investigation into muscle contraction involved measuring the activity of ATPase in solutions containing ATP, myosin and different muscle components. The table shows the results.

|  |  |  |
| --- | --- | --- |
| **Solution** | **Contents** | **ATPase activity / arbitrary units** |
| **A** | ATP, myosin and actin | 1.97 |
| **B** | ATP, myosin, actin and tropomyosin | 0.54 |
| **C** | ATP, myosin, actin, tropomyosin and calcium ions | 3.85 |

(i)      Explain the importance of ATPase during muscle contraction.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(ii)     Using your knowledge of muscle contraction, explain the difference in the results between

**A** and **B**;

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

**B** and **C**.

.............................................................................................................

.............................................................................................................

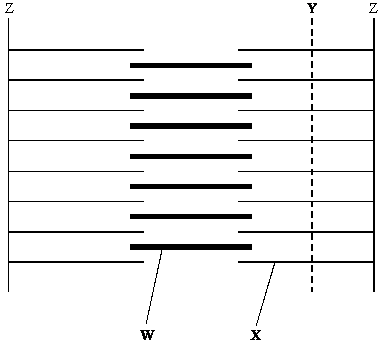
.............................................................................................................

.............................................................................................................

**(2)**

**(Total 10 marks)**

**Q10.          Figure 1** shows a diagram of part of a muscle myofibril.



**Figure 1**

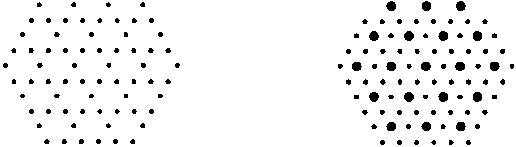
(a)     Name the protein present in the filaments labelled **W** and **X**.

**W** ..................................................................................................................

**X** ...................................................................................................................

**(1)**

(b)     **Figure 2** shows the cut ends of the protein filaments when the myofibril was cut at position **Y**. **Figure 3** shows the protein filaments when the myofibril was cut at the same distance from a Z line at a different stage of contraction.



**Figure 2                                                                    Figure 3**

Explain why the pattern of protein filaments differs in **Figure 2** and **Figure 3**.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

**(2)**

(c)     Describe the role of calcium ions in the contraction of a sarcomere.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

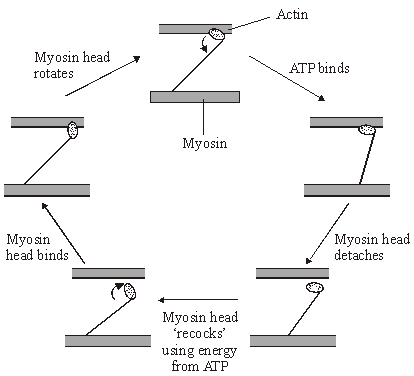
......................................................................................................................

......................................................................................................................

**(4)**

**(Total 7 marks)**

**Q11.**          The diagram shows the stages in one cycle that results in movement of an actin filament in a muscle sarcomere.



(a)     Describe how stimulation of a muscle by a nerve impulse starts the cycle shown in the diagram.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

**(3)**

(b)     Each cycle requires hydrolysis of one molecule of ATP and moves one actin filament 40  nm. During contraction of a muscle sarcomere, a single actin filament moves 0.6 µm. Calculate how many molecules of ATP are required to produce this movement.

Answer ................................................................

**(2)**

(c)     After death, cross bridges between actin and myosin remain firmly bound resulting in rigor mortis. Using information in the diagram, explain what causes the cross bridges to remain firmly bound.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

**(2)**

**(Total 7 marks)**

**Q12.**          (a)     (i)      What is meant by homeostasis?

.............................................................................................................

.............................................................................................................

**(1)**

(ii)     Giving **one** example, explain why homeostasis is important in mammals.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(b)     Cross-channel swimmers may suffer from muscle fatigue during which the contraction mechanism is disrupted. One factor thought to contribute to muscle fatigue is a decrease in the availability of calcium ions within muscle fibres. Explain how a decrease in the availability of calcium ions could disrupt the contraction mechanism in muscles.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

**(3)**

**(Total 6 marks)**

**Q13.**          The flow chart outlines an investigation to determine from where the calcium ions involved in muscle contraction are released.

Calcium ion transport proteins were  
isolated from human tissue.

**↓**

These proteins were injected into a rabbit.

**↓**

The rabbit formed antibodies to the  
proteins. These antibodies were collected  
and labelled with gold particles.

**↓**

Muscle tissue was treated with the  
labelled antibodies and examined with an  
electron microscope. High concentrations  
of gold particles were observed attached  
to the sarcoplasmic reticulum.

**S**       (a)     Labelled antibodies and an electron microscope can be used to produce images locating proteins on the surface of organelles, but cannot be used to observe cross bridge cycling in muscle cells. Explain why.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

**(5)**

(b)     Describe the role of calcium ions and ATP in muscle contraction.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

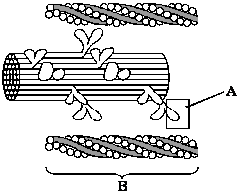
......................................................................................................................

......................................................................................................................

**(5)**

**(Total 10 marks)**

**Q14.          Figure 1** shows part of a sarcomere.



**Figure 1**

(a)     (i)      Name the main protein in structure **B**.

.............................................................................................................

**(1)**

(ii)     Name the structure in box **A**.

.............................................................................................................

**(1)**

(b)     (i)      Describe how calcium ions cause the myofibril to start contracting.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(ii)     Describe the events that occur within a myofibril which enable it to contract.

.............................................................................................................

.............................................................................................................

.............................................................................................................

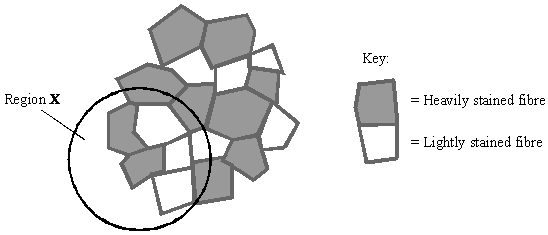
.............................................................................................................

.............................................................................................................

.............................................................................................................

**(3)**

Slow and fast skeletal muscle fibres differ in a number of ways. Slow fibres get their ATP from aerobic respiration while anaerobic respiration provides fast fibres with their ATP. **Figure 2** shows a bundle of fast and slow fibres seen through an optical microscope. The fibres have been stained with a stain that binds to the enzymes which operate in the electron transport chain.



**Figure 2**

**S** (c)     (i)      Describe how you could calculate the percentage of fast fibres in this bundle.

.............................................................................................................

.............................................................................................................

**(1)**

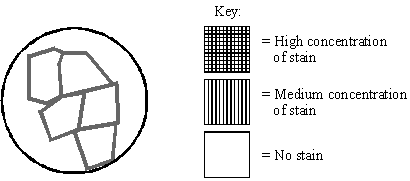
(ii)     The figure calculated by the method in part (c)(i) may not be true for the muscle as a whole. Explain why.

.............................................................................................................

.............................................................................................................

**(1)**

(d)     The fibres in **Figure 3** correspond to those in region **X** of **Figure 2**. They were stained with a substance that binds to enzymes involved in glycolysis. Shade **Figure 3** to show the appearance of the fibres. Use the shading shown in the key.



**Figure 3**

**(2)**

**S** (e)     Recent research has shown that the difference in fibre types is due in part to the presence of different forms of the protein myosin with different molecular shapes.

Explain how a new form of myosin with different properties could have been produced as a result of mutation.

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

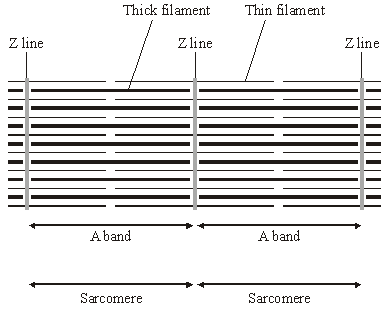
......................................................................................................................

......................................................................................................................

**(4)**

**(Total 15 marks)**

**Q15.**          (a)     **Figure 1** shows part of a myofibril from skeletal muscle.



**Figure 1**

(i)      Describe **two** features, visible in the diagram, which show that the myofibril is contracted.

1 ..........................................................................................................

.............................................................................................................

2 ..............................................................…........................................

.............................................................................................................

**(2)**

(ii)     Explain the role of calcium ions and ATP in bringing about contraction of a muscle fibre.

Calcium ions ................................................................................……

.............................................................................................................

.............................................................................................................

ATP .....................................................................................................

.............................................................................................................

.............................................................................................................

**(3)**

(b)     **Figure 2** shows the structure of a neuromuscular junction.  The vesicles contain acetylcholine.



**Figure 2**

(i)      An action potential is generated at the cell body of the motor neurone.  
Explain how this action potential passes along the motor neurone to the neuromuscular junction.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(3)**

(ii)     When the action potential arrives at the neuromuscular junction, it results in the secretion of acetylcholine into the synaptic cleft. Explain how.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

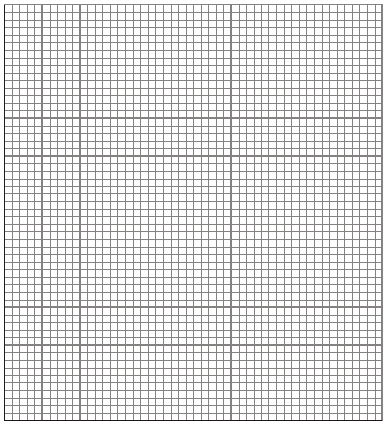
.............................................................................................................

.............................................................................................................

**(3)**

(c)     Between the ages of 20 and 50, 10% of total muscle mass is lost. Between the ages of 50 and 80, a further 40% of the original total muscle mass is lost. Most of the muscle lost consists of fast fibres.

(i)      Plot a graph on the grid below to show the percentage of muscle mass remaining between the ages of 20 and 80. Assume that the rate of muscle loss in each age range is constant.



**(3)**

(ii)     Explain why explosive exercises, such as sprinting and weightlifting, will be more affected by this muscle loss than aerobic exercises, such as jogging.

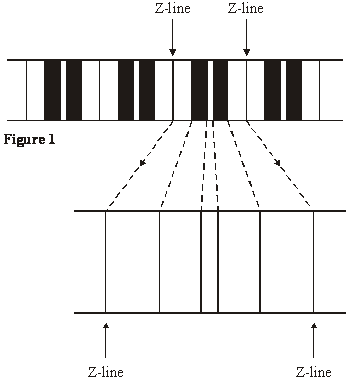
.............................................................................................................

.............................................................................................................

**(1)**

**(Total 15 marks)**

**Q16.**          **Figure 1** shows part of a single myofibril from a skeletal muscle fibre as it appears under an optical microscope.



**Figure 2**

(a)     (i)      Complete **Figure 2** to show the arrangement of actin and myosin filaments in this part of the myofibril as they would appear under an electron microscope. Label the actin and myosin filaments.

**(2)**

(ii)     Why are the details you have drawn in **Figure 2** visible under the electron microscope but not under the optical microscope?

.............................................................................................................

.............................................................................................................

**(1)**

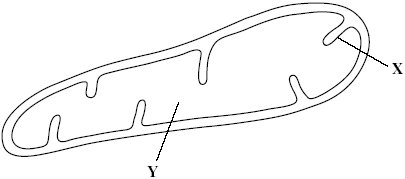
(b)     The myofibril in **Figure 1** is magnified × 8000. A muscle fibre is 40 µm in diameter. Calculate the number of myofibrils which would fit side by side across the diameter of the muscle fibre. Show your working.

Answer .............................................. myofibrils.

**(2)**

**(Total 5 marks)**

**Q17.**The diagram shows a mitochondrion.



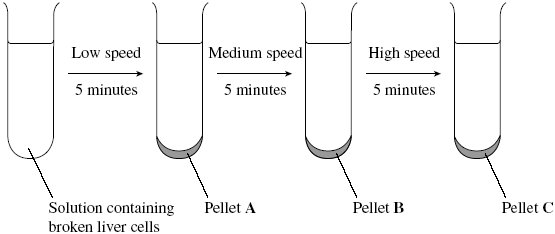
(a)     Name the parts labelled **X** and **Y**.

(i)      **X** .............................................................

(ii)     **Y** ..............................................................

**(2)**

Scientists isolated mitochondria from liver cells. They broke the cells open in an ice-cold, isotonic solution. They then used a centrifuge to separate the cell organelles. The diagram shows some of the steps in the process of centrifugation.



(b)     Suggest which pellet, **A**, **B** or **C** contained the mitochondria.



**(1)**

(c)     Explain why the solution used was

(i)      ice-cold

.............................................................................................................

.............................................................................................................

**(1)**

(ii)     isotonic.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(d)     People with mitochondrial disease have mitochondria that do not function properly.

Some people with mitochondrial disease can only exercise for a short time. Explain why a person with mitochondrial disease can only exercise for a short time.

......................................................................................................................

......................................................................................................................

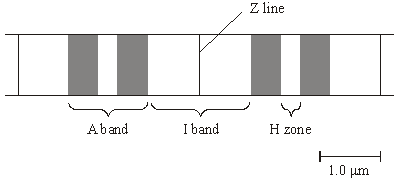
......................................................................................................................

......................................................................................................................

**(2)**

**(Total 8 marks)**

**Q18.**The diagram shows part of a myofibril from a relaxed muscle fibre.



(a)     When the muscle fibre contracts, which of the A band, I band and H zone

(i)      remain unchanged in length,

.............................................................................................................

**(1)**

(ii)     decrease in length?

.............................................................................................................

**(1)**

(b)     Explain what caused the decrease in length in part (a)(ii).

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

**(2)**

(c)     The whole muscle fibre is 30 mm long when relaxed. Each sarcomere is 2.25 µm long when contracted. Use the scale given on the diagram to calculate the length of the contracted muscle fibre in millimetres.

Length of contracted fibre = ...................................... mm

**(2)**

(d)     The table gives some properties of the two different types of muscle fibre found in skeletal muscle.

(i)      Complete the table by writing the words ‘high’ or ‘low’ for the remaining three properties of each type of muscle fibre.

|  |  |  |
| --- | --- | --- |
|  | **Type of muscle fibre** | |
|  | **Type 1** | **Type 2** |
| Speed of contraction | high | low |
| Force generated | high | low |
| Activity of the enzymes of glycolysis | high | low |
| Number of mitochondria |  |  |
| Activity of Krebs cycle enzymes |  |  |
| Rate of fatigue |  |  |

**(3)**

(ii)     The myosin-ATPase of **type 1** muscle fibres has a faster rate of reaction than that in **type 2** fibres. Use your knowledge of the mechanism of muscle contraction to explain how this will help **type 1** muscle fibres to contract faster than **type 2**.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(4)**

**S**(iii)     The blood leaving an active muscle with a high percentage of **type 1** muscle fibres contained a higher concentration of lactate than that leaving a muscle with a high percentage of **type 2** muscle fibres. Explain why.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

**(Total 15 marks)**

**Q19.**(a)     What is the role of phosphocreatine (PC) in providing energy during muscle contraction?

........................................................................................................................

........................................................................................................................

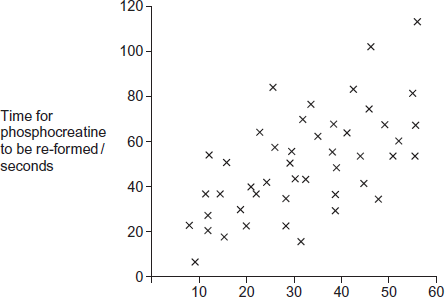
........................................................................................................................

........................................................................................................................

**(2)**

Scientists investigated the time for phosphocreatine (PC) to be re-formed in arm muscles after the same exercise in healthy people of different ages. The exercise involved brief, rapid contractions of arm muscles.

The figure below shows the scientists’ results. Each cross is the result for one person.

  
                                    Age / years

(b)     There is a lot of variation in the time taken for PC to be re-formed in people of a very similar age.

Suggest **one** reason for this variation.

........................................................................................................................

**(1)**

(c)     Use your knowledge of fast muscle fibres to explain the data in the figure.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

*(Extra space)* .................................................................................................

........................................................................................................................

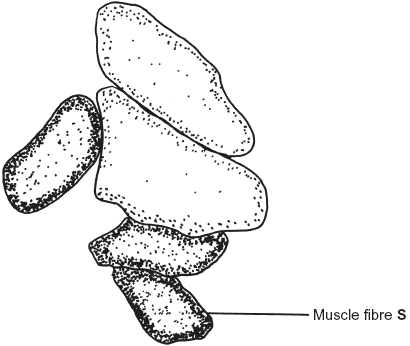
........................................................................................................................

........................................................................................................................

**(4)**

**(Total 7 marks)**

**Q20.**          The drawing is a tracing of a cross-section through skeletal muscle tissue. This muscle contains fast muscle fibres and slow muscle fibres. The section has been stained to show the distribution of the enzyme succinate dehydrogenase. This enzyme is found in mitochondria.



(a)     (i)      Succinate dehydrogenase catalyses one of the reactions in the Krebs cycle. What is the evidence from the drawing that muscle fibre **S** is a slow muscle fibre? Explain your answer.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(ii)     Use evidence from the diagram to describe the distribution of mitochondria inside the slow muscle fibres. Explain the importance of this distribution.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(3)**

(b)     (i)      You could use an optical microscope and a slide of stained muscle tissue to find the diameter of one of the muscle fibres. Explain how.

.............................................................................................................

.............................................................................................................

.............................................................................................................

.............................................................................................................

**(2)**

(ii)     A student found the mean diameter for the slow muscle fibres in a section. Give **two** precautions that she should have taken when sampling the fibres. Give a reason for each precaution.

1 ..........................................................................................................

.............................................................................................................

2 ..........................................................................................................

.............................................................................................................

**(2)**

**(Total 9 marks)**

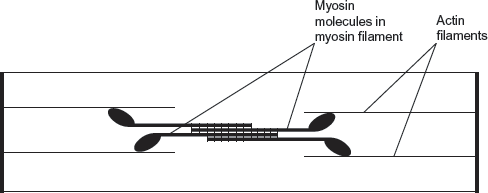
**Q21.**(a)     A sarcomere is made up of different molecules.

Complete the table by naming the molecule that carries out the function described.

|  |  |  |
| --- | --- | --- |
|  | **Function** | **Name** |
|  | Attaches to Z line at the end of the sarcomere |  |
|  | Breaks down ATP |  |
|  | Covers binding site on actin in relaxed myofibril |  |

**(3)**

(b)     The diagram shows the arrangement of actin and myosin in a sarcomere.



One form of muscle disease is caused by a mutated allele of a gene. This leads to production of myosin molecules that are unable to bind to other myosin molecules.

If myosin molecules are unable to bind to other myosin molecules, this prevents muscle contraction.  
Use the diagram and your knowledge of how muscles contract to suggest why.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**[Extra space]** ................................................................................................

........................................................................................................................

........................................................................................................................

**(3)**

**(Total 6 marks)**

**Q22.**(a)    Describe the part played by each of the following in myofibril contraction.

(i)      Tropomyosin

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

**(2)**

(ii)     Myosin

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

**(2)**

(b)     The table shows features of fast and slow muscle fibres.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Feature** | **Fast muscle fibre** | **Slow muscle fibre** |
|  | Type of respiration | Mainly anaerobic | Mainly aerobic |
|  | Glycogen | High concentration | Low concentration |
|  | Capillaries | Few | Many |

Use information from the table to suggest and explain **one** advantage of:

(i)      the high glycogen content of fast muscle fibres

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

**(2)**

(ii)     the number of capillaries supplying slow muscle fibres.

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

**(2)**

**(Total 8 marks)**

**Q23.**It is believed that each person is born with a certain percentage of slow and fast muscle fibres in their skeletal muscles. Most people have about 50% slow fibres and 50% fast fibres.

A sports scientist wondered if these percentages could change over time depending on the type of sport in which a person was involved. He knew from previous investigations that:

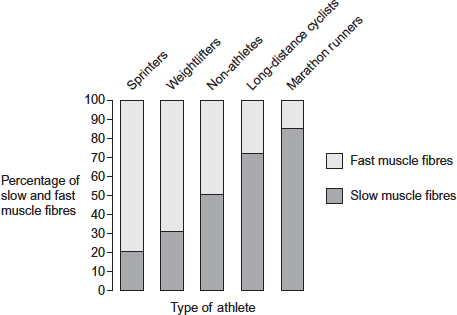
•        the number of mitochondria within a fibre can change

•        the diameter of a fibre can change

•        the number of muscle fibres in a skeletal muscle remains constant over time.

He determined the mean percentages of slow and fast fibres in skeletal muscles of different types of athletes.

His results are shown in the graph below in the form in which he presented them.



(a)     (i)      In which type of athlete would the sports scientist expect to find muscle fibres with the highest number of mitochondria?

...............................................................................................................

**(1)**

(ii)     Explain the reason for your choice of athlete.

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

**(2)**

(b)     The leg muscles of long-distance cyclists are usually larger than the leg muscles of non-athletes.

Suggest why.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**[Extra space]** ................................................................................................

........................................................................................................................

........................................................................................................................

**(3)**

(c)     A reader of the sports scientist’s results stated that ‘the results show that regular weightlifting changes your proportion of slow and fast skeletal muscle fibres.’

Do you agree with this statement? Explain your answer.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

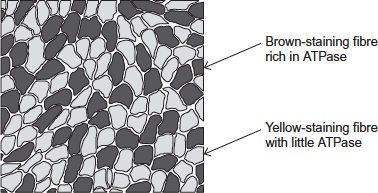
........................................................................................................................

**(2)**

**(Total 8 marks)**

**Q24.**Slow and fast skeletal muscles both contain slow and fast muscle fibres but in different proportions. The proportion can be determined by observing stained sections of muscle under a microscope. The stain used reacts with an ATPase enzyme. Muscle fibres containing a lot of this ATPase stain brown. Fibres containing little ATPase stain yellow.

The diagram shows stained muscle fibres in a section taken from a muscle.



(a)     Both slow and fast muscle fibres contain ATPase.

Explain why.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(2)**

(b)     The tissue in the diagram came from muscle with a high proportion of brown-staining fibres. Was the tissue removed from slow or fast skeletal muscle?

Explain your answer.

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(1)**

(c)     The muscle tissue in the diagram had been stained for viewing with a microscope.

What is the evidence that it had been stained for viewing with an optical (light) microscope? Explain your answer.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

**(2)**

**(Total 5 marks)**

**Q25.**Researchers investigated whether the blood supply to slow and fast muscle fibres in a muscle changes with age. They used diaphragms taken from hamsters (*Mesocricetus auratus*). The diaphragm is in constant use for breathing. They took diaphragms from groups of young, adult and old hamsters.

They removed the diaphragm from each animal and took a sample of muscle tissue.They examined it under an optical (light) microscope. For each sample they selected several fields of view at random. In each field of view, they then counted the number of capillaries associated with each type of muscle fibre.

This allowed the researchers to calculate the mean number of capillaries for each type of muscle fibre, for each age group.

The table below shows the researchers’ results which include standard deviation (SD).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Hamster age group** | **Number of hamsters in group** | **Mean number of capillaries associated with each type of muscle fibre** | |
|  | **Slow fibres (± SD)** | **Fast fibres (± SD)** |
|  | **Young** | 9 | 3.4 (±0.8) | 4.0 (±0.8) |
|  | **Adult** | 10 | 4.7 (±0.2) | 6.3 (±0.4) |
|  | **Old** | 8 | 4.6 (±0.9) | 6.8 (±0.6) |

(a)     Give **four** precautions that the researchers took to make their calculations of mean number of capillaries per fibre reliable.

1 .....................................................................................................................

........................................................................................................................

2 .....................................................................................................................

........................................................................................................................

3 .....................................................................................................................

........................................................................................................................

4 .....................................................................................................................

........................................................................................................................

**(4)**

(b)     The researchers examined the muscle of an animal in the **old** age group. They found one field of view containing only slow muscle fibres. They counted 69 capillaries in this field of view.

(i)      Use a calculation to estimate how many slow muscle fibres were visible in this field of view. Show your working.

Number of slow muscle fibres = ..........................................................

**(2)**

(ii)     The actual number of slow muscle fibres in the field of view was **not** the same as the number you calculated in question (i).

Give **one** reason why.

...............................................................................................................

...............................................................................................................

...............................................................................................................

**(1)**

(c)     A student read the report of the researchers’ investigation. She thought that the investigation was unethical but that a conclusion could still be made.

(i)      Suggest why she thought the investigation was unethical.

...............................................................................................................

...............................................................................................................

...............................................................................................................

**(1)**

(ii)     She concluded that age had a significant effect on the mean number of capillaries per fibre.

Evaluate this conclusion.

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

**(4)**

**(Total 12 marks)**

**M1.**(a)     1.      Calcium ions diffuse into myofibrils from (sarcoplasmic) reticulum;

2.      (Calcium ions) cause movement of tropomyosin (on actin);

3.      (This movement causes) exposure of the binding sites on the actin;

4.      Myosin heads attach to binding sites on actin;

5.      Hydrolysis of ATP (on myosin heads) causes myosin heads to bend;

6.      (Bending) pulling actin molecules;

7.      Attachment of a new ATP molecule to each myosin head causes myosin heads to detach (from actin sites).

**5 max**

(b)     1.      Releases relatively small amount of energy / little energy lost as heat;

*Key concept is that little danger of thermal death of cells*

2.      Releases energy instantaneously;

*Key concept is that energy is readily available*

3.      Phosphorylates other compounds, making them more reactive;

4.      Can be rapidly re-synthesised;

5.      Is not lost from / does not leave cells.

**2 max**

**[7]**

**M2.**(a)      1.      Reduction in ATP production by aerobic respiration;

2.      Less force generated because fewer actin and myosin interactions in muscle;

3.      Fatigue caused by lactate from anaerobic respiration.

**3**

(b)     Couple **A**,

1.      Mutation in mitochondrial DNA / DNA of mitochondrion affected;

2.      All children got affected mitochondria from mother;

3.      (Probably mutation) during formation of mother’s ovary / eggs;

Couple **B**,

4.      Mutation in nuclear gene / DNA in nucleus affected;

5.      Parents heterozygous;

6.      Expect 1 in 4 homozygous affected.

**4 max**

(c)     1.      Change to tRNA leads to wrong amino acid being incorporated into protein;

2.      Tertiary structure (of protein) changed;

3.      Protein required for oxidative phosphorylation / the Krebs cycle, so less / no ATP made.

**3**

(d)     1.      Mitochondria / aerobic respiration not producing much / any ATP;

2.      (With MD) increased use of ATP supplied by increase in anaerobic respiration;

3.      More lactate produced and leaves muscle by (facilitated) diffusion.

**3**

(e)     1.      Enough DNA using PCR;

2.      Compare DNA sequence with ‘normal’ DNA.

**2**

**[15]**

**M3.**          (a)     Pancuronium has similar structure / shape to acetylcholine;

*Reject same ‘re. Acetylcholine / re.receptor’*

Complementary to / fits receptor;

*Ignore ‘active site’*

**2**

(b)     (Pancuronium) not removed from receptor by ACh-esterase /  
not broken down by ACh-esterase;(Pancuronium) prevents ACh from binding / blocks receptor site;ACh (normally) causes opening of Na+ channels / causes action  
potential in muscle fibre;

*Accept converse re. pancuronium*

(Pancuronium) prevents influx of Ca2+ ions (to start contraction);(Pancuronium) prevents unblocking of binding sites on actin;

**3 max**

**[5]**

**M4.**          (a)     Potassium channels open (and K+ ions diffuse out);

*Accept references to sodium channels opening;*

Sodium channels close (and stops Na+ ions diffusion in);

*Leading to depolarisation;*

*Accept sodium pump (starts) to pump out sodium ions*

**2**

(b)     (Absolute) refractory (period);

**1**

(c)     (i)      Causes them to contract;

And relax;

Rapidly/twitch;

**2 max**

(ii)     Cause continuous muscle contraction;

*Accept a reasonable suggestion of harm ‒ linked  
to muscle contraction*

At high force;

Causing failure to breathe/heart stops pumping/  
damage to bones or joints;

**2 max**

**[7]**

**M5.**          (a)     (i)      Blocks myosin binding (site) on actin;

*Accept converse statements*

Moves from binding site on actin due to Ca2+;  
Allowing myosin to bind (to actin) / crossbridge formation;

**2 max**

(ii)     Releases myosin from actin;

*Accept coming / moving away from actin*

Causes myosin head to move / cock;  
Used in active transport of Ca2+;

**2 max**

(b)     Antagonistic muscles / opposing pairs of muscles;  
Working across/at joints;  
Both contract to keep joint/the body at certain angle / upright;  
Isometric contraction;  
Only a few fibres contract to avoid fatigue/slow muscle fibres used;

**3 max**

**[7]**

**M6.**          (a)     (i)      A;

**1**

(ii)     H + I;

**1**

(b)     Correct answer: 7000;

*Accept 6422 to 7608*

*Ignore working*

***OR***

1 sarcomere  =  48 (μm)  and use of  21 (000) μm / use of  21(000);                           16                                                                  3

*Allow 1 mark*

***OR***

Allow for error re. interconversion of mm / μm: e.g.         /        

*Allow 1 mark*

**2**

(c)     Rise in Ca2+ (in muscle cells) / Ca2+ enters (muscle cells) / Ca2+ from SR;

Leading to movement of blocking/inhibiting molecules/troponin/  
tropomyosin;

Expose binding sites on actin/on thin filament;

Allow actin-myosin interaction / cross-bridge formation/allow myosin  
to bind/allow filaments to slide past each other;

Activate ATP-ase (on myosin);

**3 max**

**[7]**

**M7.**          (a)     membrane relatively impermeable / less permeable to sodium ions / gated channels are closed / fewer channels;  
sodium ions pumped / actively transported out;  
by sodium ion carrier / intrinsic proteins;   
inside negative compared to outside / 3 sodium ions out for two potassium ions in;

*(if sodium mentioned but not in context of ions, negate 1 mark)*

**4**

(b)     (i)      1.6;

**1**

(ii)     18 ÷ 1.6 = 11.25;  
multiply by 1000 to convert from ms to s / 11 250;

*(correct method = 1 mark, i.e.  or × 1000)*

*(correct answer based on (b)(i) = 2 marks)*

**2**

(iii)     time for transmission / diffusion across the neuromuscular junction / synapse;  
time for muscle (fibrils) to contract;

**1 max**

(c)     movement by diffusion;  
binding to receptors on (post-synaptic) membrane;  
causing sodium channels to open / sodium ions to move in to muscle (cell);

**3**

(d)     (i)      toxin binds to / competes for / blocks the acetylcholine receptors;  
acetylcholine can not depolarise the membrane / the toxin does not cause depolarisation;

*(allow references to generating action potentials instead of depolarisation, do not allow references to impulses in muscles)*

**2**

(ii)     acetylcholinesterase is unable to breakdown acetylcholine;  
acetylcholine still available to depolarise the membrane /   
generate action potentials in the membrane;

**2**

**[15]**

**M8.**          (a)     Correct answer: 1.25;

*Ignore working*

***OR*** (if wrong answer)

 / = 1 mark

*125 but wrong order of magnitude = 1 mark*

**2**

(ii)     **C** has myosin / thick (and actin / thin) filaments;

***OR***

**A** has only actin / thin (/ no myosin / no thick) filaments;

**1 max**

(b)     When contracted:

Thick & thin filaments/myosin & actin overlap more;

Interaction between myosin heads & actin / cross-links form;

Movement of myosin head;

Thin filaments / actin moved along thick filaments / myosin;

Movement of thin filaments / actin pulls Z-lines closer together;

Displacement of tropomyosin to allow interaction;

Role of Ca2+;

Role of ATP;

*Allow ref. to ‘sliding filament mechanism’ /  
described if no other marks awarded*

**4 max**

(c)     (i)      8 has DMD but 3 and 4 do not / 12 has DMD but 6 and 7  
do not / neither parent has the condition but their child has;

*Allow parents 3 and 4 give 8, parents 6 and 7 give 12*

**1**

(ii)     4 ***AND*** 7;

**1**

(iii)     Parental genotypes:  6 = **XDY** AND 7 = **XDXd**

***AND***

Gametes correct for candidate’s P genotypes ‒ e.g.

**X**Dand **Y** + **X**Dand  **X**d**;**

Offspring genotypes correctly derived from gametes e.g.

**X**D**X**D+ **X**D**X**d+ **X**D**Y** + **X**d**Y**;

Male offspring with MD correctly identified: **X**d**Y**;

Probability = 0.25 / correct for candidates offsprings genotypes;

*Accept ¼ / 1 in 4 / 1:3 / 25%*

*NOT ‘3:1’ / ‘1:4’*

**4**

(d)     (i)      No gene fragment **G**;

**1**

(ii)     Only one copy of gene fragment **F**;

Male has only one X-chromosome / is XY  
(c.f. female has two / is XX);

**2**

(iii)     10 has only one copy of gene fragment **G**;

10 has only one normal X-chromosome / has one abnormal /  
has only one normal allele / has one Xd / is XDXd / is heterozygous;

11 has two normal X-chromosomes / has 2 normal alleles /  
is XDXD / has not got Xd / has 2 copies of (F and) G;

**3**

(e)     (i)      To prevent rejection / prevent antibody production vs. injected cells /  
injected cells have (foreign) antigen (on surface);

**1**

(ii)     Shows effect of cells / not just effect of injection / not just effect of  
salt solution;

**1**

(iii)     Only one person tested so far ‒ need more to see if similar results /  
need more to see if reliable;

Need to assess if new (dystrophin positive) muscle fibres are  
functional / if muscle becomes functional;

Can’t tell how widespread effect is in the muscle / sample taken  
near injection site;

Need to test for harmful side effects;

Need to test if successful for other mutations of dystrophin gene;

Need to assess permanence / longevity of result/insufficient time  
allowed in investigation;

(In this patient) only small response / %;

Further sensible suggestion;

**4 max**

**[25]**

**M9.**          (a)     (i)      A / dark band is mainly due to myosin filaments;

H zone only myosin filaments;

darker band has both types of filament;

light band has only actin filaments;

**2 max**

(ii)     H zone narrows;

light band narrows;

outer darker regions of A / dark band widen;

**2 max**

(b)     (i)      breaks down ATP yielding energy;

used to form / break actomyosin bridges;

**2**

(ii)     **A** and **B**

tropomyosin covers binding site on actin;

no cross bridges formed /   
ATPase activity on myosin head reduced;

**2**

**B** and **C**

calcium ions remove tropomyosin;

binding / calcium ions increase ATPase activity;

**2**

**[10]**

**M10.**         (a)     **W** = myosin  
**X** = actin;

**1**

(b)     myofibril is contracting in **Figure 3** / relaxing in **Figure 2**;  
movement of actin fibres between myosin fibres;

**2**

(c)     interact with / move / touch tropomyosin;

*(allow troponin as alternative)*

to reveal binding sites on actin;

*(not active sites)*

allowing myosin (heads) to bind / touch actin / actinomyosin formed;  
activate ATPase / energy released from ATP;

**4**

**[7]**

**M11.**          (a)     calcium ions;  
bind to / displace tropomysin; *(allow troponin)*reveal binding site on actin;  
myosin binds to exposed sites on actin / actomyosin formed /   
cross bridges form between actin and myosin;  
activates ATPase;

**3 max**

(b)     distance single actin filament moves divided by distance moved  
using 1 ATP;  
15 ATP;

**2**

(c)     respiration stops / no ATP produced;  
ATP required for separation of actin and myosin / cross bridges;

**2**

**[7]**

**M12.**          (a)     (i)      maintaining a constant internal environment;

**1**

(ii)     *one mark for example of factor kept constant; one mark for  
explaining its importance;*

e.g.  
temperature / pH; optimum for enzymes / effect of pH /   
temperature on enzyme activity;

*OR*

water potential / blood glucose;  
effect of osmotic / blood glucose imbalance on cells;

**2 max**

(b)     cannot interact with / move tropomyosin from binding sites on actin;  
*(reject active sites)*myosin(heads) do not bind / actinomyosin not formed;  
does not activate ATPase / energy not released from ATP;

**3**

**[6]**

**M13.**          (a)     1. e.m. gives high resolution due to short wavelength of electrons;  
2. antibodies attach specifically to target proteins;  
3. gold particles are electron dense;  
4. electrons must pass through a vacuum so material must be dead / fixed for e.m.;  
5. cross-bridge cycling requires living cells / metabolism / named aspect-e.g. ATP synthesis;

**5**

(b)     1. Ca2+ removes blocking molecules / uncovers binding site on actin;  
2. correct references to Ca2+ binding to troponin / moving tropomyosin;  
3. allows myosin heads to attach to actin filaments;  
4. allows sliding of the actin and myosin filaments;  
5. binding of ATP causes myosin (head) to detach (from actin);  
6. (hydrolysis of) ATP releases energy;  
7. which changes the configuration / cocking of the myosin head;

**5 max**

**[10]**

**M14.**          (a)     (i)      actin (*Accept* tropomyosin);

**1**

(ii)     myosin head;

**1**

(b)     (i)      Ca2+ binds to [part of] the actin / troponin;  
this causes tropomyosin to be displaced;  
uncovers [myosin] binding sites [on actin] / allows actin to bind;

**max 2**

(ii)     myosin heads bind to actin / cross bridge formation /   
actomyosin formed;  
myosin heads / crossbridges swivel / ratchet mechanism;  
causing actin to slide relative to myosin;  
energy provided by hydrolysis of ATP;

**max 3**

(c)     (i)      (number lightly stained fibres / total number of fibres) × 100;  
(actual numbers are 10 / 18 × 100)

**1**

(ii)     sample not representative / large enough / individual muscle fibres  
different sizes / contain different number of myofibrils;

**1**

(d)     all some stain = 1  
fast dark and slow lighter = 2

**2**

(e)     change in base sequence in DNA / addition / deletion / substitution of a base in DNA of the gene which codes for myosin;  
change in amino acid sequence / primary structure;  
causes a different tertiary structure;  
which alters the binding properties of myosin;

**4**

**[15]**

**M15.**          (a)     (i)      H band not visible / reduced / little / no thick filament / myosin only region / ends of thin filaments / actin close together;  
I band not visible / reduced / little / no thin filament / actin only region;  
A band occupies nearly all sarcomere / thick filament / myosin close to Z line;  
Large zone of thick-thin overlap;

**max 2**

(ii)     *Calcium ions:*Bind to troponin;  
Remove blocking action of tropomyosin /   
expose myosin binding sites;

*ATP:*Allows myosin to detach from actin / to break cross bridge;  
*[allow attach and detach]*Releases energy to recock / swivel / activate myosin head / drive power stroke;

**max 3**

(b)     (i)      Depolarisation of axon membrane / influx of Na+ establishes local  
currents;  
Change permeability to Na+ / open Na+  gates of adjoining region;  
Adjoining region depolarises / influx of Na+;

**3**

(ii)     Depolarisation of (presynaptic) membrane;  
Ca2+  channels open / increased permeability to Ca2+ causing influx of Ca2+ ;  
Vesicles move towards / fuse with presynaptic membrane;

*[If ions mentioned once assume candidate is referring to ions throughout; if no mention of ions penalise once only]*

**3**

(c)     (i)      1.  Correct axes labelled, correct orientation, linear scale;  
2.  Key points (100%, 90% and 50%) plotted correctly;  
3.  Plots joined by straight lines;

*[allow reasonable hand-drawn straight lines]*

**3**

(ii)     Fast fibres used (in explosive exercise);

*[allow reverse for slow fibres]*

**1**

**[15]**

**M16.**          (a)     (i)      Myosin filaments drawn longitudinally in A-band region;  
Actin filaments drawn longitudinally from Z-line to edge of H-zone;

*[Max. 1 mark if Actin and Myosin are not correctly labelled]*

**2**

(ii)     Electron microscope has greater resolution / able to tell two  
close objects apart better / electrons have shorter wavelength /   
higher frequency;

**1**

(b)     Correct answer = 20;

*Allow 1 mark for: ;*

*OR*

*40 ÷ *

**2**

**[5]**

**M17.**(a)     (i)      Crista / inner membrane;

**1**

(ii)     Matrix;

**1**

(b)     B;

**1**

(c)     (i)      Reduce / prevent enzyme activity;

**1**

(ii)     Prevents osmosis / no (net) movement of water;

So organelle / named organelle does not burst / shrivel;

***Q*** *Allow reference to cell rather than organelle for first mark point only.*

*Regard damage as neutral*

**2**

(d)     (Mitochondria) use aerobic respiration;

Mitochondria produce ATP / release energy required for muscles (to contract);

***Q*** *Do not accept reference to making / producing energy.*

**2**

**[8]**

**M18.**          (a)     (i)      A band;

**1**

(ii)     H zone and *I* band;

**1**

(b)     filaments in *I* / thin filaments / actin filaments slide in between myosin /   
thick filament; thin filaments enter H zone / meet in middle of A band /   
pull Z lines closer;

**2**

(c)     correct answer:         22.5 mm ;;                                 = 2 marks  
OR relaxed sarcomere length =  / = 3 m ;           = 1 mark

**2 max**

(d)     (i)      In table:

|  |  |
| --- | --- |
| low | high |
| low | high |
| high | low |

(1 mark per row;;;)

**3**

(ii)     1        overall rate of contraction limited by rate of ATP-splitting;

2        ATPase splits ATP / hydrolyses ATP / converts ATP to ADP  
(+ phosphate);

3        ATP-splitting provides energy for *any TWO from* myosin-actin   
interaction; myosin head movement / actin to move relative  
to myosin; to ‘cock’ myosin head;

**4 max**

(iii)     lactate = product of anaerobic respiration;

type 1 has higher activity of glycolytic enzymes / has lower activity  
of Krebs cycle enzymes / has fewer mitochondria;

**2**

**[15]**

**M19.**(a)     1.      (Phosphocreatine) provides phosphate / phosphorylates;

*Accept Pi or P in circle*

*Reject phosphorus*

2.      To make ATP;

*Accept:*

*ADP + CP → ATP + C*

*Neutral – provides ATP*

**2**

(b)     One suitable suggestion;

eg

1.      Genetic differences;

2.      Level of fitness / amount of regular exercise done / mass of muscle;

3.      Sex;

4.      Ethnicity

5.      Metabolic rate;

6.      Number of fast / slow muscle fibres

*Neutral lifestyle / diet / illness*

**1 max**

(c)     1.      Fast muscle fibres used for rapid / brief / powerful / strong contractions;

2.      Phosphocreatine used up rapidly during contraction / to make ATP;

3.      (As people get older) slower metabolic rate / slower ATP production / slower respiration;

4.      ATP used to reform phosphocreatine;

**4**

**[7]**

**M20.**          (a)     (i)      Contains more / large amount of succinic dehydrogenase;

*Accept “the enzyme” since only one being discussed*

(Slow fibres) have lots of mitochondria / (slow fibres) respire aerobically;

**2**

(ii)     Near edge / outside;

Short distance for diffusion of oxygen / Allows rapid diffusion / more diffusion of oxygen;

*Ignore glucose  
Accept carbon dioxide*

Oxygen used by mitochondria / electron transfer system in mitochondria;

*Accept effect of carbon dioxide on cell e.g. carbon dioxide changes pH / carbon dioxide affects enzymes*

**3**

(b)     (i)      Measure with graticule / eyepiece scale;

Calibrate against something of known size:

***OR***

Estimate / measure field diameter with a scale;  
Estimate number of fibres to cover diameter;

***Q*** *Last point could be a calibrated slide / haemocytometer / red blood cell or reasonable alternative*

*Accept  
Mount on ruler / haemocytometer / graph paper;  
use this to measure size;  
Note position of ruler must be specified and correct*

**2**

(ii)     Equivalent measurements taken;

At random to avoid bias / avoid choice of particular fibres;

Large number to be representative / minimise effect of extremes / of anomalies;

*As a stained slide is provided reject references to safety.  
Ignore reliable*

**2 max**

**[9]**

**M21.**(a)

|  |  |  |
| --- | --- | --- |
|  | **Function** | **Name** |
|  | Attaches to Z line at the end of the sarcomere | **1. Actin;** |
|  | Breaks down ATP | **2. ATPase / myosin (head);** |
|  | Covers binding site on actin in relaxed myofibril | **3. Tropomyosin;** |

*Accept water*

*Accept troponin*

**3**

(b)     1.      Can’t form myosin / thick filaments;

*Neutral: prevents actin and myosin sliding filament action*

2.      Can’t pull / can’t move actin / slide actin past / (myosin) have to be joined / fixed to pull actin;

*Accept: myosin can’t pull on each other*

3.      Myosin moves / if attached doesn’t move;

4.      Can’t move actin towards each other / middle of sarcomere / between myosin / can’t shorten sarcomere / can’t pull Z lines together.

*Accept: contract for shorten*

**3**

**[6]**

**M22.**(a)     (i)      1.      Moves out of the way when calcium ions bind;

*1. Accept shape change with Ca2+*

*1. Donߢt accept just “calcium”*

2.      Allowing myosin to bind (to actin) / crossbridge formation;

*1. Accept presence of calcium ions leads to movement instead of binds*

*Accept references to troponin*

**2**

(ii)     1.      Head (of myosin) binds to actin and moves / pulls / slides actin past;

***Q***

2.      (Myosin) detaches from actin and re-sets / moves further along (actin)

*1. Accept myosin power stroke (to move actin)*

*1. Accept push*

*1. Accept crossbridges form instead of myosin head binds to actin*

*1. Must refer to myosin head or crossbridges*

3.      This uses ATP;

**2 max**

(b)     (i)      1.      (Glycogen broken down) gives (lots of) glucose for glycolysis / anaerobic respiration;

*1. Give if context of anaerobic respiration clear*

2.      Glycolysis / anaerobic respiration not very efficient / only yields 2 ATP per glucose;

*2. Accept anaerobic respiration is a quick source of ATP for exercise*

*2. Accept very little ATP*

**2**

(ii)     1.      (Many capillaries) give high concentration / lots of oxygen / shorter diffusion pathway for oxygen / large surface area for oxygen exchange / diffusion / good glucose supply with little glycogen present;

2.      Allows high rate of / more aerobic respiration ***OR*** prevents build-up of lactic acid / (muscle) fatigue;

*3. Accept idea of aerobic respiration during endurance events / long periods of exercise*

**2**

**[8]**

**M23.**(a)     (i)      (Group) 5 / marathon runners.

*Must only include this group and no other.*

**1**

(ii)     1.      (5 / marathon runners) have highest percentage of slow  
         fibres;

*Maximum of* ***1*** *mark if the wrong fibres have been identified.*

2.      (Slow fibres) use aerobic respiration / aerobic respiration occurs in mitochondria;

*Either approach requires identification of aerobic respiration.*

3.      (Slow fibres) best for endurance / long periods of exercise / to avoid fatigue.

**2 max**

(b)     1.      No (overall) change in number of fibres;

*Reject any suggestion of an increase in number of fibres.*

2.      Increase in diameter of fibres;

*‘Size’ without qualification is insufficient.*

3.      (Due to) training / exercise;

4.      (Long-distance) cyclists have more / higher percentage of slow fibres (than fast);

*A comparison is required to meet this MP.*

5.      Slow fibres of wider diameter than fast fibres;

6.      (Long-distance) cyclists have more mitochondria;

7.      (Long-distance) cyclists have more capillaries (in muscles).

*Idea of ‘more’ (than non-athletes) is required to gain credit.*

*Accept converse (for non-athletes) in MP4, MP6 and MP7.*

**3 max**

(c)     1.      Weightlifting favoured by / weightlifters have a high proportion of  
         fast / low proportion of slow fibres

OR

Weightlifters have more fast / fewer slow fibres than non-athletes;

But (cannot tell because):

*Reward for general statement or comparison with non-athletes.*

*For ‘proportion’, accept percentage (or idea of a ratio).*

2.      Do not know what ‘weightlifters’ (tested) were born with / had before started weightlifting / training

OR

Don’t know if there has been a change (in proportion due to weightlifting / training);

3.      No information about age / gender / number of weightlifters (in  
         sample).

*For this MP, accept another relevant factor that might affect ‘weightlifter’ e.g. weights lifted, sex, diet, ethnicity, country of birth.*

*Ignore general statements about ‘other factors’.*

**2 max**

**[8]**

**M24.**(a)     1.      Splitting / breakdown / hydrolysis of ATP;

2.      (Muscle) contraction requires energy / ATP;

*Accept ‘uses energy’. Reject idea of ‘movement’ of muscles requiring energy.*

*Reject suggestion that ‘energy is produced’.*

3.      Use of ATP by myosin.

*Accept a reference to any use of ATP by myosin. No credit for any further detail.*

**2 max**

(b)     Fast because (lots of) ATPase allows rapid **hydrolysis** of ATP

OR

Slow because (lots of) ATPase allows rapid **synthesis** of ATP.

*Accept either approach as some texts refer to ATPase as the enzyme at the end of the ETC in mitochondria.*

**1**

(c)     1.      Need light to see colour / brown / yellow;

*Requires reference to light.*

2.      Cannot see colour / brown / yellow with electrons / an electron  
         microscope;

*Requires reference to electrons / electron microscope.*

*Accept ‘see black and white with electrons / electron microscope’.*

3.      No organelles are visible.

*Accept appropriate named examples of organelles.*

**2 max**

**[5]**

**M25.**(a)     1.      Fields of view randomly chosen;

2.      Several fields of view;

3.      All same species (of animal / hamster);

*Reject general statements related to sample size. All mark points relate directly to information provided in Resource A.*

*Accept ‘all (Mesocricetus) auratus’.*

4.      Same muscle / organ used / only diaphragm used;

5.      Used at least 8 (animals) in each (age) group.

**4 max**

(b)     (i)      15

*Correct answer = 2 marks.*

*Allow 1 mark for showing*

*69 ÷ 4.6*

*OR*

*answer of 10 / 10.1 (correct calculation using fast in error.)*

**2**

(ii)     1.      (Calculation) used mean (number of capillaries);

2.      Variation in number of capillaries per fibre.

*Note: maximum of* ***1*** *mark for this question.*

*Ignore reference to an anomaly or calculation errors.*

**1 max**

(c)     (i)      (Removing diaphragm means) animals / hamsters are killed.

**1**

(ii)     1.      (Suggests) significant (difference) between young and adult;

*MP1, MP2, MP4 and MP5 can include use of figures but check figures are used correctly.*

2.      (Suggests) not significant (difference) between adult and old;

*Statements related to ‘results being significant / not significant’ do not meet the marking points. It is the difference that is significant or not. However, only penalise this error once.*

3.      For slow **and** fast fibres;

*This MP can be given in the context of either MP1 or MP2 but only allow once. As well as this context there must be a reference to ‘both’ types of fibre.*

4.      (Suggests) significant (difference) between young and old for fast (fibres)  
OR  
(Suggests) not significant (difference) between young and old for slow (fibres);

*All aspects of either approach required to gain credit.*

5.      (Suggests) significant (difference) where means ± SD do not overlap  
OR  
(Suggests) not significant (difference) where means ± SD overlap;

*All aspects of either approach required to gain credit.*

6.      Stats test is required (to establish whether significant or not).

**4 max**

**[12]**

**E3.**          (a)     While most candidates appreciated that the given drug must have been a similar shape to acetylcholine, some spoilt their answer by describing it as being the ‘same’ shape. Many considered this sufficient for it to bind to the acetylcholine receptor, but better candidates explained the complementarity of fit which enabled it to do so.

(b)     Most candidates realised that the drug would block the acetylcholine receptors. Some were careless and described these receptors as being located on a neurone rather than on the muscle fibre. Many went on to explain that Na+ ion channels would not open. Fewer made any reference to the prevention of influx of Ca2+ ions and thus prevention of the unblocking of the myosin binding site on actin. Hardly any referred to the non-breakdown of the drug by choline esterase and hence its persistence in the neuromuscular junction.

**E4.**          In (a), the examiners allowed descriptions of depolarisation or the start of repolarisation of the membrane. Some candidates were confused between sodium, calcium, chloride and potassium ions. Others got the direction of movement of ions in the wrong direction, or by the wrong mechanism. It was not uncommon to see references to membrane potentials being due to sodium ions entering by facilitated diffusion, using energy from ATP. In (b), nearly two thirds of candidates correctly identified the refractory period. There were many good answers to (c)(i). It was pleasing to see that many candidates were able to predict the effect of the taser from the graph. Answers to (c)(ii) were often spoiled by a failure to state how high frequency tasers might be *too dangerous* to use. Many candidates wrote vaguely about damage to muscles, or it being very unpleasant. Better candidates suggested effects such as paralysis of breathing due to continuous contraction of muscles.

**E5.**          Some very good answers were seen to each part of this question. However, for a topic which has been a familiar part of A level for many years, it was disappointing to find over a third of candidates scoring no marks in (a) and (b). There was some evidence of over teaching of topics and some weaker candidates gave very confused accounts. The mark schemes for each part of the question show that candidates only require a few basic facts and ideas to obtain marks. For example in (c), the idea of antagonistic muscles both contracting to hold a joint in a given position.

**E6.**          (a)     Just under half the candidates were able to name the A-band as the part of the myofibril that remained unchanged in length during muscle contraction, while less than 10% knew that both the H-zone and the I-band decreased in length.

(b)     Only 10% of candidates were successful in the calculation of the number of sarcomeres in a myofibril of length 21 mm. A further 14% had the right idea but were unable to interconvert the units micrometres and millimetres. From the scale bar on the diagram it should have been evident that the sarcomere was 3 micrometres in length and hence there were 7000 of them in 21 millimetres.

(c)     The role of calcium ions in muscle contraction was well known, with almost half the candidates scoring full marks. Some told the wrong story — about synaptic transmission and the mobilisation of vesicles of acetylcholine.

**E7.**          (a)     Most candidates appreciated that the charge inside the neurone would be negative compared with the charge outside and they often gave a clear explanation about the pumping movement of sodium ions being the cause of this difference. The impermeable nature of the neurone membrane to the movement of sodium ions was less well understood and very few candidates gave an adequate explanation which compared the relative amounts of sodium ions on both sides of the membrane.

(b)     (i)      Surprisingly few candidates used the graph accurately to give the correct time between depolarisation and the beginning of muscle contraction; 1. 5 ms was a common error, which suggested candidates used the scale on the x axis carelessly. Those candidates who constructed lines on the graph to identify the time period usually got the right answer.

(ii)     Most candidates understood that speed was calculated as distance over time, but very few correctly converted ms to s.

(iii)     This proved to discriminate well. Many candidates gave a valid suggestion about the role of a neuromuscular junction or the time it takes for muscle filaments to move. Unfortunately, a significant number missed the point of the question and discussed different types of neurone, the presence of a myelin sheath, the diameter of neurones, or the distance between nodes of Ranvier.

(c)     A significant number of candidates began the description too early by including the detail about the movement of vesicles containing neurotransmitter towards the presynaptic membrane. Also, some failed to gain a mark by referring to the location of neurotransmitter receptors on the motor end plate rather than on a sarcolemma or a cell membrane. The depolarisation of a muscle fibre by the movement of calcium ions is a common misconception.

(d)     Both parts of this question were answered well by a large proportion of candidates.

**E8.**          (a)     Most candidates measured band X (the A-band in an electron micrograph of a myofibril) correctly. Many did not then understand that they had to divide this by the stated magnification. Among those who did, many had problems interconverting millimetres and micrometres and were often several orders of magnitude out. Only one quarter of candidates were entirely successful.

In part (ii), most candidates knew the correct distribution of actin and myosin filaments in the two distinct bands of the myofibril. One unusual, and erroneous, concept expressed by a number of candidates was that one part of the myofibril was contracted at the same time as the other part was relaxed.

(b)     Many candidates gave a full and clear account of the process of muscle contraction, including the roles of ATP, calcium ions, tropomyosin, the attachment of the myosin head to actin and its movement causing the actin filament to slide along the myosin. Weaker candidates just described how the appearance of the various bands changed when the myofibril contracted rather than offering the required explanation. Almost one-third of candidates scored full marks.

(c)     Using information from the pedigree diagram showing the inheritance of Duchenne muscular dystrophy (DMD) over three generations, almost two-thirds of candidates cited the production of a child with muscular dystrophy by unaffected parents as evidence for the condition being caused by a recessive allele. However, less than half the candidates were able to identify two carriers from the diagram.

In completion of the genetic diagram, common errors included switching the genders of the two parents, giving the male parent a genotype that would have resulted in him having muscular dystrophy, incomplete assignment of phenotypes to the offspring genotypes (both gender and having / not having DMD were important) and, having shown that 25% of the offspring would be expected to be male with DMD, to then halve this figure to 12.5 %. Additional, incorrect, answers on the probability line, e.g., ‘25% or 1 : 4’, failed to gain the mark. Despite this, almost one-third of candidates scored full marks in this section.

(d)     Just over half the candidates answered part (i) correctly, realising that the complete absence of one of the gene fragments indicated that the person would suffer from DMD. In part (ii), these candidates realised it was the single copy of the other gene fragment (compared with two copies in each of his sisters) that indicated the person concerned was male as he had just one X-chromosome while his sisters had two. Only about one-fifth of candidates were able to tell the complete story, although some two-thirds got half-way.

Part (iii) differentiated very well between candidates who gave varying degrees of appropriate detail in their answers. The most able noticed that one of the girls had two copies of one of the gene fragments while her sister, having but a single copy of this fragment, must have been the carrier as she would have had one normal X chromosome (hence being healthy herself) and one carrying the mutation responsible for DMD. Approximately one quarter scored full marks, although nearly two-thirds were able to make at least two of the three points required.

(e)     Far too many candidates failed to use appropriate terminology in part (i). There were no marks available for stating that the ‘immune system’ (given in the question) ‘fought against’ / ‘attacked’ the implanted cells. Terms such as *rejection*, *antibody* and *antigen* were required. Less than half the candidates used such terms.

Similarly, in part (ii), there was no mark available for merely stating that the injection with salt solution served as a ‘control’. The purpose of the control was required, e.g., so that the effect of the cells injected into the other leg became apparent, or to show it was not just the salt solution that had caused the effect in the other leg. Approximately half the candidates gave the appropriate detail.

In part (iii), there was plenty of scope for candidates to explain the limitations of the given investigation and to suggest appropriate further work that could be done. Candidates made general points about the limited sample size (i.e., just *one* individual), the short time period allowed to assess the effect of the treatment, or they made specific points relating to the given size of the response, the fact that success had so far been achieved only for this particular mutation, that only a measure of the *presence* of the appropriate type of muscle cells had been performed with no information about their ability to function, etc. The question differentiated very well amongst candidates who took varying amounts of care in selecting information, in assessing the reliability of the data and in applying their knowledge and understanding of how an investigation should be carried out in order to obtain reliable results and to draw valid conclusions. Although almost 90% of candidates were able to make at least one valid point, only 3% scored all 4 marks.

**E9.**          This question proved to be a good discriminator enabling the very best candidates to score maximum marks.

(a)     Most candidates obtained both marks in part (i) by correctly linking the banding pattern to the presence of myosin and actin filaments. Weaker candidates often failed to name the protein filaments present in muscles. In part (ii), slightly fewer candidates gained maximum marks. A common error was to suggest that the A band increased in length often negating one of the correct responses for decrease in length of the H zone or light band.

(b)     This proved more troublesome, but most candidates were able to gain at least two marks out of the six available. In part (i), many candidates appreciated the role of ATPase in the breakdown of ATP to yield energy. Most candidates referred to the use of this energy in the formation or breakdown of actomyosin bridges. In part (ii), better candidates provided excellent details on the role of tropomyosin, calcium ions and ATPase activity in muscle contraction. Weaker candidates often gained a single mark for appreciating that tropomyosin covered the binding site on actin but provided rather confused descriptions of the role of calcium ions. A common error amongst these candidates was to refer to ‘an active site’ rather than a binding site.

**E10.**          (a)     Very few candidates did not achieve this mark.

(b)     The majority of candidates correctly identified the figure showing a muscle myofibril in contraction and gave a valid reason for their choice, but some candidates did not make it absolutely clear which figure they were referring to. A common misconception was to describe the shortening of protein filaments rather than filaments sliding across one another to shorten a sarcomere.

(c)     Most candidates obtained at least two marks, usually for stating that calcium ions touch tropomyosin, which allowed bridges to form between the protein filaments. Few candidates made it clear that exposed myosin binding sites were located on actin filaments, and a significant number incorrectly referred to binding sites as active sites. Only a small proportion of candidates went further and explained how the energy for contraction is provided from ATP.

**E11.**          This question was well answered.

(a)     Even the weakest candidates realised that calcium ions were involved, and the majority were able to explain fully the changes which occur before actin is able to bind with myosin.

(b)     Many candidates gained full marks. The most common errors related to the inability to convert ìm to nm. A significant number did not attempt to answer the question.

(c)     Many candidates scored full marks. A significant number did not read the question carefully enough and wrote about the role of ATP in the recocking of the myosin head.

**E12.**          This question produced a wide range of marks. Nevertheless, it was generally well answered by the majority of candidates.

(a)     (i)      Although many candidates obtained this mark, there were a number of vague definitions which did not clearly link homeostasis to the internal environment.

(ii)     Candidates had little difficulty giving one example of homeostasis, usually referring to thermoregulation or control of the blood glucose concentration. Most candidates who obtained a second mark referred to the effect of change of temperature on enzyme activity.

(b)     There were many excellent descriptions of the role of calcium in muscle contraction. However, there were a few common errors and omissions. There were frequent references to ‘active site’ rather than ‘binding site’ and a significant number of candidates did not mention actin. A minority of candidates attempted to answer this question in terms of the role of calcium in synaptic transmission.

**E13.**          (a)     A full answer to this section required reference to several different aspects – the resolving power of the electron microscope, the need for tissue to be alive to demonstrate a physiological process but to be dead to be viewed in the electron microscope, and the specificity of antibodies (with gold particles attached) to label only certain structures. It was rare to find such an holistic view.

Some candidates appeared to have forgotten about the existence of the transmission electron microscope, explaining that only the outer surfaces of muscle fibres could be observed rather than any cross-bridge cycling that occurred within them. Others erroneously felt that, although the resolving power of the electron microscope was good, it was not good enough to observe crossbridges between muscle protein filaments.

(b)     The roles of calcium ions and of ATP in muscle contraction were generally well known by most candidates. Some over-emphasised the part played by calcium ions in transmission of the impulse to the muscle rather than in the contraction process itself. However, details of the removal of the blocking molecules from sites on the actin and the combination of the myosin head with these sites, followed by movement and release of the myosin head, were generally included.

A common omission was that ATP would need to be split into ADP and phosphate if its energy were to be made available.

**E14.**          (a)     (i) and (ii) A majority of candidates were able to identify A as the myosin head, although rather fewer were able to name actin as the main protein in the thin filament.

(b)     In general, the responses to this section of the question revealed a pleasing level of knowledge and understanding.

(i)      Many candidates, including otherwise weaker candidates, were able to describe the role of calcium ions in binding to troponin and removing tropomyosin from the myosin binding sites on the actin molecule.

(ii)     Again, a good number were able to describe the role of ATP and the two proteins in bringing about contraction of the myofibril.

(c)     (i)      Only better candidates realised that to calculate the percentage of fast fibres, the number of fast fibres (lightly stained fibres) must be divided by the *total* number of fibres and this figure then multiplied by one hundred. Many weaker candidates multiplied the ratio of the two fibres by one hundred.

(ii)     Most candidates could explain that the figure obtained might not be typical as different regions of a muscle may have different proportions of the two fibres, or because the sample used is such a small one as to be not necessarily reliable.

(d)     Only really able candidates realised that *all* the fibres would undergo glycolysis, whether respiring aerobically or anaerobically. However, those respiring anaerobically would undergo glycolysis only (and not any further stages of the aerobic pathway) and so produce the enzymes used in glycolysis in greater concentrations.

(e)     Many candidates interpreted this question as another concerning natural selection, despite the clear instruction to explain how a new form of myosin could be *formed as a result of mutation*. Good candidates were able to explain how alterations to the base sequence of DNA could result in a different mRNA and, as a result, a different primary structure of the protein. They then went on to explain how this would result in different folding of the molecule, tertiary structure and properties as a result.

**E15.**          (a)     In part (i), rather too many candidates failed to refer to the diagram in their answers. “The sarcomere has shortened” was the most common example of a factually correct statement which failed to answer the question. The role of ATP continued to cause confusion. There were many answers describing the role of ATP as attracting the myosin to the actin, clearly beyond the bounds of any degree of uncertainty.

(b)     Part (i) was the only question on the paper that was universally badly answered, with over 90% of candidates scoring one or zero. It was not easy to determine whether candidates were misinterpreting the question or simply did not understand how the impulse is propagated. Part (ii) produced better responses with many candidates gaining all three marks. Candidates who used incorrect charges on the ions, e.g. Ca+ or Ca2-, failed to gain marks and would have been better off writing the words ‘calcium ions’. Another common error was to have the calcium ions being released as opposed to entering.

(c)     Although well answered, the graph in part (i) brought up several issues. Candidates making errors in graphs should be encouraged to obtain an additional sheet of graph paper from the invigilators and attach it to their script. Several candidates failed to gain marks because their final offering was not discernable from several previous attempts. Candidates should also be encouraged to use sharp pencils and rulers in constructing graphs. A level biology follows IOB guidelines on the construction of graphs and in this case failure to join the plots with straight lines was not rewarded. In this question, straight lines were required by the data presented in the stem anyway. In (ii), most candidates gave a correct response.

**E16.**          (a)     Although in general part (i) was attempted, marks were not always obtained by candidates. A common error was to draw actin and myosin in roughly the correct places relative to each other but to pay little attention to the lines aligning the space for response and the drawing of the myofibril. Part (ii) was well understood and most candidates were able to recall the main advantages of electron microscopes.

(b)     This calculation produced fewer correct responses than the calculation later in the question paper. From the responses given it was apparent that few candidates were able to comprehend what they were being asked to do and did not measure the width of the sarcomere at 16mm. Those candidates that did make this measurement mostly went on to calculate the correct answer of 20.

**E17.**(a)     (i) Rather disappointingly only approximately half the candidates correctly named part **X** as a crista or as an inner membrane. Common incorrect responses included ‘fold’ ‘villi’ and ‘microvilli’.

(ii)     Even fewer candidates correctly named part **Y** as the matrix. A common incorrect response was ‘cytoplasm’.

(b)     The majority of candidates correctly suggested that pellet **B** would contain mitochondria.

(c)     (i)      Most candidates realised that using an ice-cold solution would reduce or prevent enzyme activity. However, a significant minority of candidates suggested that this denatured enzymes.

(ii)     Many candidates started by providing a definition of the term isotonic and then explained that using an isotonic solution prevents net movement of water.  
However, most of these candidates referred to water movement into or out of ‘cells’ and did not obtain the second mark for explaining that organelles would not burst or shrivel.

(d)     Very few candidates obtained both marks for this question. Although many candidates gained a mark for stating that mitochondria produce ATP or release energy, a significant number referred to ‘energy being produced’. Few candidates referred to aerobic respiration or linked exercise to muscles. There were a number misconceptions concerning respiration particularly in relation to ‘energy being used’ in respiration and to mitochondria providing oxygen during respiration.

**E18.**          (a)     Most candidates correctly selected the A band in part (i) although several also added the H zone, whereas few scored for part (ii) because they only selected the I band.

(b)     The sliding filament theory appeared to be understood well although many candidates included superfluous material about calcium ions, tropomyosin and troponin.

(c)     The omission of responses here by several candidates, or inappropriate calculations by many others once again highlighted a lack of confidence and competence in the application of mathematical skills. A few were able to calculate the relaxed length of a sarcomere but it was the only better candidates who could use this to calculate the length of a contracted fibre.

(d)     Nearly all the candidates could recall the correct information required for part (i). Equally, they demonstrated a thorough knowledge of muscle contraction so many scored marks for appropriate descriptions of myosin-actin interaction and myosin head movement in part (ii). However, fewer actually applied their knowledge to the specific questions asked. Thus, some responses contained no reference to the role of myosin-ATPase. Of those that did, many believed that the enzyme had a direct effect on the myosin rather than through the hydrolysis of ATP. There were several references to the enzyme causing the production of ATP. As in part (b), many included explanations about calcium ions, tropomyosin and troponin.

In part (iii), the majority of the candidates understood that lactate was a product of anaerobic respiration but examiners found few responses that included reasons why type 1 muscle fibres should have a higher rate. There were many references to lactate being broken down to release energy.

**E19.**(a)    About 50% of students obtained both marks in this part. Some got confused between ADP and ATP and others failed to score one of the marks because of references to phosphorus being transferred.

(b)     Nearly 70% of students obtained the mark in this part. The examiners ignored vague references to things such as lifestyle, diet and illness.

(c)     This part produced an almost perfect distribution of marks between 0 and 4. The best answers identified that it takes longer to re-form phosphocreatine (PC) as people get older. Students then linked this to slower metabolism, respiration or ATP production as people get older. They also identified that the type of exercise identified would involve fast muscle fibres that contain a lot of PC and that this requires ATP to be re-formed. The mark a student obtained depended on how far they got with this story. A common error appeared to relate to misinterpretation of the graph, with students suggesting older people had more PC, so it took longer to re-form.

**E20.**          (a)     Many candidates produced sound answers to part (i), successfully linking succinate dehydrogenase concentration to aerobic respiration and hence to slow twitch fibres. Although most responses to part (ii) referred to the peripheral distribution of the enzyme, they often failed to provide a satisfactory explanation of the importance of this distribution. Comments about the diffusion of ATP into and out of cells were frequent.

(b)     There were many poor answers to part (i) in spite of the fact that estimating the size of objects viewed with a microscope is a specification requirement. Candidates who had the necessary practical experience tended to offer appropriate responses, illustrating the importance of practical work in this specification. Others persisted in quoting impracticable approaches based on the equation relating magnification to observed and actual size. Although, in part (ii), many candidates suggested that random sampling would avoid bias, few offered the suggestion that the sample should be large enough to be representative. There were many instances of candidates failing to appreciate that they had been provided with a prepared slide and therefore that answers such as taking muscle from different areas of the body were inappropriate. Many weaker candidates opted for an approach based on safety. The numerous comments about “not cutting yourself” were judged inappropriate.

**E21.**(a)     This required factual recall of components of the sarcomere. Just over 50 percent obtained all three marks. Students who failed to score often had the correct names but associated with the wrong function.

(b)     This proved very challenging to many and almost 40 percent failed to score. Some excellent answers were seen. These students understood that myosin molecules are bound tail to tail so that their heads can pull actin filaments towards the centre of the sarcomere and thus shorten the sarcomere. Obviously, if the tails fail to bind to each other, this will not happen; in fact, the myosin molecules would move rather than the actin. Many students simple wrote about the sliding filament theory but without relating this to the question.

**E22.**(a)     (i)      About a third of students explained at length how tropomyosin *prevents* contraction,rather than explaining its role *in contraction*. Some of these students obtained one or both marks by going on to describe what happens during contraction.

(ii)     About forty percent obtained one mark for describing how the myosin head pulls actin past itself. A similar percentage went on to obtain a second mark for either describing the ratchet mechanism, or the role of ATP. The remainder tended to get confused between the roles of actin, myosin, troponin and tropomyosin.

The specification requires students to know the general properties of slow and fast muscle fibres. In general, fast fibres are used for movements that involve brief, intensive contraction (eg sprinting) and slow fibres are used for more protracted contraction (eg long-distance running). The intention was for students to bring this knowledge to bear in (b), when using the information in the table.

(b)     (i)      About half of students obtained one mark for this question, for stating that glycogen is a source of glucose for anaerobic respiration (glycolysis). Only a few went on to note that a high concentration of glycogen provides a lot of glucose, or very rapidly supplies glucose, for a rapid rate of anaerobic respiration. The mark could also be gained for noting the advantage of this rate being high, ie it overcomes the fact that anaerobic respiration provides little ATP.

(ii)     Many students obtained one mark for noting that many capillaries would provide a *good* supply, or a *lot* of oxygen. As in (i), few went on to link this to maintaining a high rate of aerobic respiration.

**E23.**(a)     (i)      Nearly all students scored this mark; the wording in the resource should have been used, ‘long distance runners’ is not the name of the group.

(ii)     This was generally well answered and 2 marks were common. Mark point 3 was the least often awarded.

(b)     This was well answered, although mark point 2 was not always awarded, even though it was attempted, due to lack of reference to ‘diameter’; students often referred to ‘thickness’ instead.

(c)     Most students scored mark point 1 and many went on to give mark point 2 or 3.

**E24.**(a)     Most students achieved mark point 1 but better answers were required to score both marks. Some students went on to state that muscles used ATP but ‘contraction’ was stipulated in the marking point. Some very good answers were seen with all three marking points given, together with extra detail about use of ATP by myosin.

(b)     A lot of information was required in the answer to award this mark point: the muscle type; the hydrolysis / synthesis of ATP; and the fact that a high concentration of ATPase allows this to be rapid. Not many students managed to include all these requirements.

(c)     The majority of students scored one mark here but a full explanation was required to gain two marks. Mark point 1 was commonly seen but the explanation in mark point 2 was less often seen. Some students noticed the lack of visible organelles.

**E25.**(a)     It was vital that students used the information that was provided in the resource accurately rather than giving generalised methods of making data reliable. Mark points 1 and 2 could be awarded when given in a single statement such as, ‘several fields of view were selected at random’. In mark point 3 ‘species’ was essential, ‘same breed’ is not equivalent. Mark point 5 needed to be specific to the resource, i.e. that at least 8 animals were used in each group. General statements about each group having lots / large number of hamsters were insufficient.

(b)     (i)      Most students successfully carried out this calculation.

(ii)     Mark point 1 was most commonly seen. In this instance, ‘The calculation used an average’ was acceptable as equivalent to mean, as it demonstrates the correct understanding.

(c)     (i)      The occasional student suggested that this investigation was unethical as the hamsters would be in pain or stressed but the vast majority realised hamsters would be killed.

(ii)     Students encountered many problems with this question. Many only discussed changes ‘as the hamsters got older / younger’, rather than using the specific age groups. Some only discussed whether there was a change, or what the change was, rather than discussing the significance of this difference. Many students seemed unaware that it is not the ‘results’ that are deemed significant or not but the ‘differences between the results’. It was surprising at A2 that not more students achieved mark points 5 and 6. It was expected that students who had calculated standard error and 95% confidence limits in Stage 2 of this ISA would realise that standard deviation is insufficient to determine significance.