Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International Advanced Level

Centre Number	Candidate Number

Time 1 hour 45 minutes

Paper reference **WBI15/01**

Biology

International Advanced Level
Unit 5: Respiration, Internal Environment, Coordination and Gene Technology

You must have:
Scientific article (enclosed), scientific calculator, ruler, HB pencil

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- **Show all your working in calculations and include units where appropriate.**

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- Good luck with your examination.

Turn over ▶

Pearson

Answer ALL questions.

Write your answers in the spaces provided.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Aerobic respiration involves four main stages:

glycolysis, link reaction, Krebs cycle and oxidative phosphorylation.

(a) One product of all three stages shown in the table is ATP (adenosine triphosphate).

Complete the table to show one other product of each stage.

(3)

Stage	One other product
glycolysis	
Krebs cycle	
oxidative phosphorylation	

(b) An incomplete equation for the aerobic respiration of a substrate is shown below.

Complete the equation by inserting the numbers on the dotted lines to balance it.

(2)

$$C_{57}H_{104}O_6 + \ldots\ldots\ldots O_2 \rightarrow \ldots\ldots\ldots CO_2 + 52\ H_2O$$

(c) One molecule of glucose contains 2867.48 kJ of energy.

One molecule of glucose generates a maximum of 38 molecules of ATP in aerobic respiration.

A molecule of ATP contains 30.51 kJ of usable energy. Usable energy is available for chemical reactions in the cell.

(i) Which reaction releases energy from ATP?

(1)

☒ **A** the conversion of ADP to ATP

☒ **B** the phosphorylation of ADP

☒ **C** the hydrolysis of ATP

☒ **D** the removal of adenosine molecules from ATP

(ii) Calculate the maximum percentage of energy in a glucose molecule that can be converted to usable energy in ATP.

(2)

Answer ..... %

(iii) Describe what happens to the energy that is not converted to usable energy in a muscle cell.

(2)

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(d) Describe how oxygen is involved in the production of ATP on the cristae in the mitochondria.

(2)

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(Total for Question 1 = 12 marks)

2 The nervous system of an organism enables it to respond to a stimulus.

(a) A reflex action is a rapid involuntary movement in response to a stimulus.
The response to a pinprick in a finger is an example of a reflex action.

(i) Which component of the nervous system continues a reflex arc immediately after the receptor has been stimulated by the stimulus?

(1)

☒ **A** motor neurone

☒ **B** relay neurone

☒ **C** Schwann cell

☒ **D** sensory neurone

(ii) Which pathway shows a reflex arc?

(1)

☒ **A** muscle → receptor → brain

☒ **B** muscle → spinal cord → brain

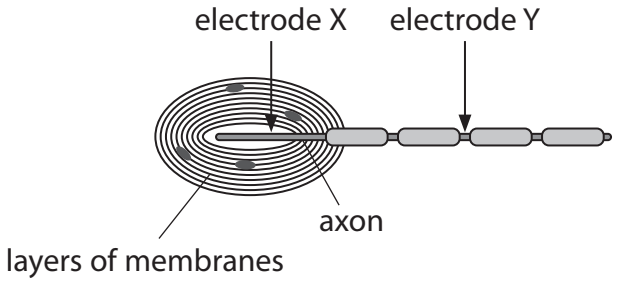
☒ **C** receptor → spinal cord → muscle

☒ **D** spinal cord → brain → muscle

(b) Pacinian corpuscles are pressure receptors found in the skin of the fingertip.

The effect of different pressures applied to the finger tip, on electrode potentials across the axon membrane of the neurone of a Pacinian corpuscle was investigated.

The diagram shows the structure of a Pacinian corpuscle and the location of electrodes, X and Y, used to measure axon membrane potentials.



The table shows the results of the investigation.

Pressure applied to the fingertip	Membrane potential at electrode X / mV	Membrane potential at electrode Y / mV
None	−70	−70
Low	−60	−70
Medium	+20	+40
High	+40	+40

(i) Describe how the resting potential of −70mV is maintained in the axon when no pressure is applied.

(3)

(ii) Suggest how a change in pressure at the Pacinian corpuscle causes an action potential in the axon.

(3)

(iii) Explain why the membrane potential at electrode Y was the same when medium or high pressure was applied to the fingertip.

(3)

(Total for Question 2 = 11 marks)

3 Many neurones in the human nervous system are myelinated.

(a) A myelinated axon conducts impulses faster than a non-myelinated axon of the same diameter.

Explain this difference.

(3)

(b) Polyneuropathy is a disorder that damages the myelin sheath of neurones throughout the body.

One symptom is muscle weakness. Muscle weakness is the reduced strength in one or more muscles.

Suggest how damage to the myelin sheaths of neurones can lead to muscle weakness.

(2)

(c) Dementia is a condition associated with the ongoing decline of brain functioning. There are many types of dementia.

The relationship between myelin in brain tissue and types of dementia has been investigated.

The mean quantity of myelin in samples of brain tissue from groups of people with types of dementia and from a control group was measured.

The table shows the results of this investigation.

Group	Mean quantity of myelin in a brain tissue sample / a.u.	Standard deviation
Control (no dementia)	52	± 3.2
Patients with vascular dementia	25	± 5.9
Patients with Alzheimer's dementia	32	± 4.1
Patients with Lewy Body dementia	42	± 5.0

A student concluded that there was a relationship between the quantity of myelin in the brain of a person and whether or not they had dementia.

Comment on the validity of this conclusion.

(2)

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(Total for Question 3 = 7 marks)

4 The kidney is involved in the process of homeostasis in a mammal.

(a) Antidiuretic hormone (ADH) is required for homeostasis.

How many of these parts of the kidney respond to ADH?

- Bowman's capsule
- collecting duct
- loop of Henle
- proximal tubule

(1)

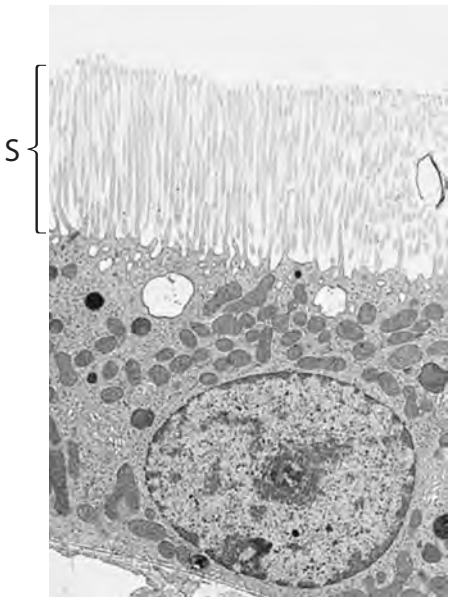
☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

(b) The electron micrograph shows a transverse section of part of a proximal tubule.



(Source: https://veteriankey.com/solute-reabsorption/)

(i) Name the process by which the fluid moves from the plasma into the renal tubule (nephron).

(1)

.....

(ii) Name the structures labelled S.

(1)

.....

(c) A student compared the left renal veins of two individuals.

(i) The diameter of the left renal vein of one individual was 4.71 mm.

Calculate the cross-sectional area of this vein.

(2)

Answer ..... mm^2

(ii) The cross-sectional area of the left renal vein of the second individual was 0.194 cm^2.

Calculate the difference in the cross-sectional area in the left renal vein of these two individuals.

(1)

Answer .....

(d) The table shows the concentration of glucose and urea in the blood plasma, glomerular filtrate and urine of an individual.

Substance	Concentration in blood plasma / g dm^{-3}	Concentration in glomerular filtrate / g dm^{-3}	Concentration in urine leaving collecting duct / g dm^{-3}
glucose	1.50	1.50	0.00
urea	0.30	0.30	21.00

Explain the concentration of glucose and urea in the urine.

Use the information in the table to support your answer.

(3)

(e) An individual produced 0.83 cm^3 of urine each minute.

Calculate the volume of urine produced by this individual in 24 hours.

Assume the urine production is at a constant rate.

Give your answer in dm^3, to two significant figures.

(2)

Answer ..... dm^3

(Total for Question 4 = 11 marks)

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5 (a) The body length of the medicinal leech decreases when touched.

(Source: © Mit Kapevski/Shutterstock)

The body length of the leech decreases less each time the leech is touched.

(i) What is the name of this effect?

(1)

- ☒ **A** absorption
- ☒ **B** adaptation
- ☒ **C** habituation
- ☒ **D** sensitivity

(ii) Why is it an advantage for the leech to respond in this way?

(1)

- ☒ **A** it filters out what is important and what is not important to react to
- ☒ **B** it enables the animal to react more quickly to the stimulus
- ☒ **C** it keeps the habitat of the animal protected
- ☒ **D** it helps the animal find food more easily

(b) The photograph shows a fiddler crab.

(Source: © Jay Gao/Shutterstock)

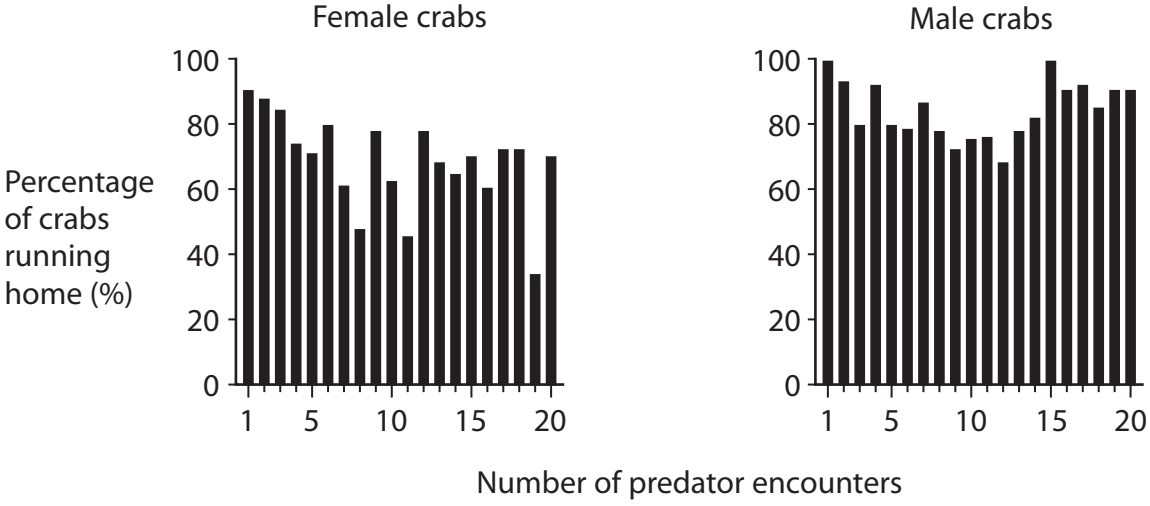
In an experiment, the fiddler crab was used to investigate responses to a predator. The responses by females and males were compared.

A predator approached a group of female crabs from one direction.

The percentage of crabs running home was recorded. This was repeated 20 times.

This experiment was repeated with a group of male crabs.

The graphs show the percentage of crabs running home for both groups of crabs against the total number of times each group of crabs encountered a predator.



(i) Comment on the results of this experiment.

(3)

(ii) Which statistical test would be used to analyse the effect of the increase in the number of predator encounters on the percentage of crabs running home?

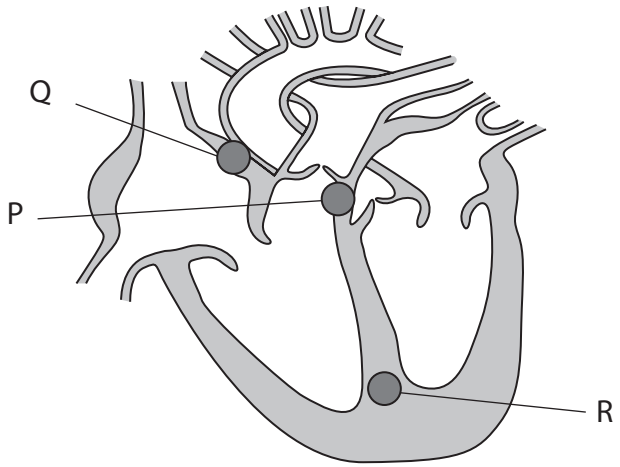
(1)

- ☒ **A** correlation coefficient
- ☒ **B** Hardy-Weinberg
- ☒ **C** index of diversity
- ☒ **D** Student's t-test

(Total for Question 5 = 6 marks)

6 In humans the sinoatrial node, atrioventricular node and bundle of His are involved in regulation and coordination of the cardiac cycle.

(a) The diagram shows a human heart.



(i) Which **one** of the following statements is correct?

(1)

- ☒ **A** Q is the sinoatrial node (SAN) and R is the atrioventricular node (AVN)
- ☒ **B** Q is the sinoatrial node (SAN) and P is the atrioventricular node (AVN)
- ☒ **C** Q is the bundle of His and R is the sinoatrial node (SAN)
- ☒ **D** R is the sinoatrial node (SAN) and P is the Purkinje fibres

(ii) The electrical impulse that initiates the cardiac cycle begins without the need for a nerve impulse.

What is the term for this process?

(1)

- ☒ **A** diastole
- ☒ **B** myogenic
- ☒ **C** polarisation
- ☒ **D** systole

(b) A football player undertook regular exercise as part of a training programme.

During exercise there is a change in the duration of the cardiac cycle.

(i) Explain why there is a change in the cardiac cycle during this exercise.

(3)

(ii) The table shows the effect of the training programme on the cardiac output and resting heart rate of this football player.

When measurements were made	Cardiac output / $cm^3\ min^{-1}$	Resting heart rate / bpm
Before training	4500	72
After training	4500	51

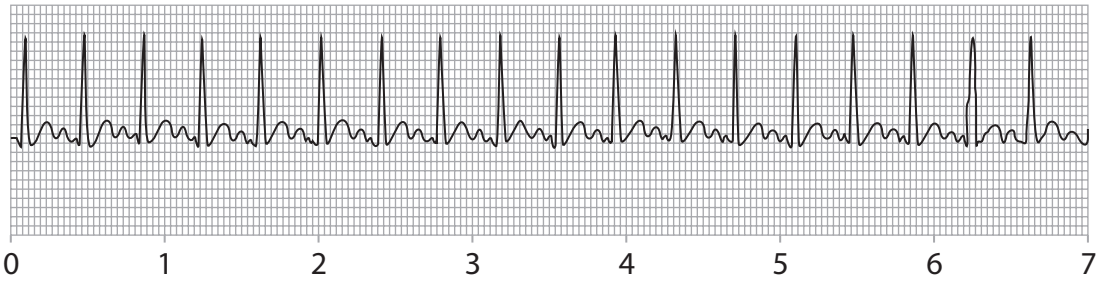
Calculate the stroke volume of this football player, after training.

(1)

Answer ..... cm^3

(iii) After training, the footballer had an ECG.

This ECG trace is shown in the diagram.

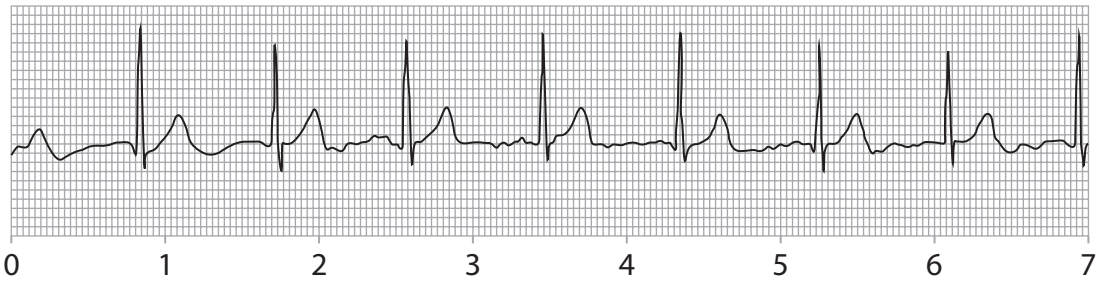


Calculate the heart rate of the footballer using the ECG in this diagram.

(1)

Answer .....

(iv) Two hours later a second ECG was recorded.



Comment on the changes that have occurred in the activity of the heart as shown in these two ECG traces.

(3)

(Total for Question 6 = 10 marks)

7 Animals and plants can respond to light.

(a) The photograph shows the front of a human eye.

(Source: © SCIENCE PHOTO LIBRARY)

(i) The size of the pupil changes when moving from dim to very bright light.

Explain how this change occurs.

(3)

(ii) Describe the role of rhodopsin in causing changes in the polarisation of rod cells.

(4)

*(b) Exposure to light controls the germination of seeds and the direction of growth of plants.

In an investigation the seeds of plantains were exposed to light.

The seeds were first exposed to red light and then to far-red light.

The percentage of seeds that germinated when exposed to different periods of red and far-red light was recorded.

The results are shown in the table.

Exposure to red light / min	**Percentage germination (%)**						
	Exposure to far-red light /seconds						
	1	**5**	**10**	**15**	**30**	**60**	**960**
32	100	20	14	6	4	6	10
16	92	30	40	28	30	33	20
8	100	62	50	57	44	47	56
4	100	67	60	57	40	37	92

Comment on the effect of red and far-red light on the germination of these seeds and the processes that occur in their cells.

Use the information in the table to support your answer.

(6)

(Total for Question 7 = 13 marks)

8 The scientific document you have studied is adapted from an article in Journal of Cachexia, Sarcopenia and Muscle entitled *Skeletal muscle performance and ageing*. (Tieland, 2018).

Use the information from the scientific document and your own knowledge to answer the following questions.

(a) Describe the structure of a skeletal muscle fibre (paragraph 2).

(3)

(b) Explain how myokines may exert endocrine effects on organs such as the liver (paragraph 3).

(3)

(c) Explain why the changes that occur to muscle structure and composition in the elderly can affect their ability to rise from a chair (paragraph 4).

(4)

(d) Explain why Ca^{2+} binding to troponin C allows muscle fibres to contract (paragraph 5).

(3)

(e) Explain how the 'high-energy phosphates' provide the energy necessary for muscle activity (paragraph 11).

(2)

(f) Suggest explanations for the effects that a 'reduction in tendon stiffness' resulting from ageing could have on the movement at a joint (paragraph 12).

(3)

(g) Suggest how myostatin might act as a negative regulator of muscle growth (paragraph 13).

(2)

(Total for Question 8 = 20 marks)

TOTAL FOR PAPER = 90 MARKS

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Pearson Edexcel International Advanced Level

Time 1 hour 45 minutes

Paper reference **WBI15/01**

Biology

International Advanced Level
Unit 5: Respiration, Internal Environment, Coordination and Gene Technology

Scientific article for use with Question 8

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Scientific article for use with Question 8

Skeletal muscle performance and ageing – Tieland 2018

1. The world population is ageing rapidly. Since 1980, the number of people aged 60 years and over has doubled to approximately 810 million. The elderly population will continue to grow to approximately 2 billion in 2050. As society ages, the incidence of physical performance limitation will increase as well. In western society, as much as 42% of those over 60 years of age have difficulties in performing activities of daily living (e.g. walking speed or standing up from a chair), and >30% are confronted with physical disabilities. These physical limitations increase the risk of falls, institutionalization, co-morbidity, and premature death.

2. While there are a number of contributors to physical limitations with advancing age, one of the more prominent contributors is undoubtedly a reduction in skeletal muscle performance. One of the hallmark changes of ageing that is linked to reductions in muscle performance is the loss of skeletal muscle mass, which is commonly referred to as sarcopenia.

   The body consists of more than 500 skeletal muscles which are controlled by the nervous system and which connects and supports the skeletal system. Skeletal muscles consist of muscle fibres, each containing sarcomeres, which are the smallest repeating functional units in the muscle. Via a series of complex events, sarcomeres are responsible for muscle contraction and relaxation. This allows the body to perform a wide variety of different movements, ranging from fast and powerful movements to small and fine motions. Since skeletal muscles are responsible for all the voluntary movements, logically, skeletal muscles are essential for optimal physical performance. Physiological changes, such as a loss of motor units, changes in fibre type, muscle fibre atrophy, and reduced neuromuscular activation, could affect the velocity, force, and strength of movements, leading to reduced physical performance, potentially leading to functional disability and institutionalization.

3. Not only are skeletal muscles important for physical performance, they are also an important contributing factor in maintaining optimal health throughout life. As such, skeletal muscles are involved in different metabolic pathways. Since muscles are the primary site for the insulin-stimulated glucose uptake from the blood, the muscles are crucial in maintaining glucose homeostasis. Muscles are also involved in other metabolic functions providing a site for fatty acid metabolism and glycogen synthesis. Metabolic disturbances in muscle could, therefore, lead to insulin resistance, the metabolic syndrome, and obesity. Furthermore, muscles interact with other organs via the excretion of myokines, which can exert autocrine, paracrine, or endocrine effects. Myokines support the metabolic function of different tissues, such as the bones, pancreas, liver, and adipose tissue. The metabolic function of skeletal muscle and the role of myokines both illustrate the importance of the muscles in maintaining optimal health throughout life.

4. At the myocellular level, many studies have reported a substantial decrease in muscle fibre size in the elderly. This reduction in muscle fibre size has been shown to be fibre type specific, with 10–40% smaller type II fibres observed in the elderly as compared with young adults. In contrast, type I muscle fibre size seems to be largely sustained with ageing. The type I, or slow twitch fibres, are recruited first and, as such, are mainly responsible for endurance-type activities. The type II, or fast twitch fibres, are recruited later and predominantly responsible for higher intensity or highly fatiguing activities. The reduction in type II fibres may therefore result in a decline in muscle strength in the elderly and may decrease the ability to rise from a chair or to lift a heavy load.

The decline in type II muscle fibre size is reported in some studies to be accompanied by an age-related reduction in type II muscle fibre satellite cell content and function. These satellite cells are the stem cell of human muscular tissue and essential for skeletal muscle fibre growth, repair, and regeneration throughout human life. The specific reduction in type II muscle fibre satellite cell content and function could therefore possibly represent a key factor responsible for specific type II muscle fibre atrophy with ageing.

The primary cause of skeletal muscle loss is the disruption in the regulation of skeletal muscle protein turnover, leading to a negative balance between muscle protein synthesis and muscle protein breakdown.

In addition to the pronounced muscle atrophy, a reduction in the force per unit area of skeletal muscle is also observed at the single fibre and whole muscle level in the elderly. For instance, when the rat plantar flexor muscle group is electrically stimulated (eliminating the potential neural impairments in force production) and force is expressed relative to muscle mass (controlling for size), aged rats (24 months) exhibit a 34% reduction in 'muscle quality'.

5. Excitation–contraction coupling (E-CC) involves the physiological processes that convert the neural signal for muscle activation (i.e. the muscle fibre action potential) into muscle contraction and subsequently into force development. Briefly, the action potential spreads throughout the muscle via the t-tubular system, activating the voltage-sensitive dihydropyridine receptors, which subsequently open the ryanodine receptors. This releases Ca^{2+} from the sarcoplasmic reticulum (SR) that binds to troponin C creating cross bridge formation, leading to muscle contraction and consequently to force production. After the contraction phase, Ca^{2+} is returned to the SR by the SR Ca^{2+} pump, allowing the muscle to relax. Theoretically, disruption at any point in the E-CC process results in reduced muscle performance.

6. In addition to changes in the E-CC processes, there are several other physiological contributors to reduced muscle quality with one being age-related changes in the muscle architectural structure. Skeletal muscle displays a strong structure–function relationship by which several architectural characteristics factor into its functional capacity.

7. With regard to muscle energetics, the vast majority of studies have focused on the effects of ageing on aerobic metabolism (i.e. mitochondrial function or oxidative phosphorylation). There is evidence that aerobic capacity, measured by the peak treadmill oxygen consumption (peak VO2), which is the maximal ability to use oxygen to meet the energy demands of physical activity, may decline at an accelerated rate already after the age of 20, with a rate up to >20% per decade in community-dwelling men and women over 70.

8. The vast range of motions and forces that humans can achieve arises from the activity of more than 600 skeletal muscles, which are under the control of the nervous system. After processing sensory information about the body and its surroundings, the motor centres of the brain and spinal cord generate neural commands that effect coordinated, purposeful movements. The process is complex, as the nervous system is a cellular network of up to 10 billion neurons and 60 trillion synapses communicating together. The discharge behaviour of these neurons, including the motor neuron, represents a complex interplay between the excitatory and inhibitory synaptic inputs they receive and the cells' intrinsic electrical properties. The patterns of interneuronal connections and communication, as well as the discharge behaviours, are not permanently fixed; they show variability and can be reorganized.

9. Motor systems are organized hierarchically, with each level concerned with a different decision. The highest and most abstract level, likely requiring the prefrontal cortex, deals with the purpose of a movement. The next level, which is concerned with the formation of a motor plan, involves interactions between the posterior parietal and premotor areas of the cerebral cortex.

10. The premotor cortex conveys the spatial characteristics of a movement based on sensory information arising from the posterior parietal cortex about the situation (i.e. the environment) and about where the body is in space. The lowest level coordinates the space and time details of the muscle contractions needed to execute the planned movement. These supportive motor regions include the contralateral sensorimotor cortex, supplementary motor area, and the cingulate cortex. Control circuits located in the cerebellum and basal ganglia are then initiated to trigger activity in descending motor tracts, which signals the spinal interneurons and lower motor neurons to contract skeletal muscle fibres to produce movement.

11. Mitochondria are important cellular organelles that are responsible for the production of energy by both aerobic and anaerobic respiration and oxidative phosphorylation.

    Not only the mitochondrial content is important for elderly skeletal muscle performance, the mitochondrial function (i.e. the ability to produce ATP) is important as well. High-energy phosphates (i.e. ATP and creatine phosphate) provide the chemical energy necessary to satisfy the energy cost of cross-bridge cycling and ion pump activity during muscle contraction and are therefore important for performance.

12. The adult human skeletal system consists of 206 bones, as well as a network of tendons, ligaments, and cartilage that connects them. The skeletal system provides form, support, and stability to the body, and when coupled with the muscular system, it permits movement. The basic fundamentals of form-function relationships suggest that any fundamental change in form (e.g. skeletal alignment) will affect elderly skeletal muscle performance.

    In addition to skeletal aspects, connective tissue changes are also occurring with advancing age. These age-related changes include a reduction in tendon stiffness and in Young's modulus (the ratio of stress, or force per unit area, and strain, which is the ratio of deformation over initial length), suggesting that a deterioration in tendon material properties accounts for most of the decline in stiffness. During locomotion, the muscle-tendon system functions as a spring when the muscle lengthens while activated, before subsequently shortening. Thus, this unit effectively act as a shock absorber (i.e. they cyclically absorb and recover elastic recoil energy). Accordingly, changes in tendon properties likely alter the muscle spring properties and affect the degree of shortening of muscle fibres and the rate of force development upon contraction and, as such, physical performance in older adults.

13. Next to the role of hormones, inflammation, and insulin resistance, other biological factors may also be involved in elderly skeletal muscle performance. Several studies emphasize the important role of genetics on physical performance later in life. For instance, a twin study on the role of genes in physical performance in elderly (>75 years) found that about 33–50% of the variation in physical performance in elderly women could be attributed to age-related genetic factors. An example of age-related gene modulations is the reduced expression of vitamin D, as a low vitamin D level is associated with lower muscle mass and impaired physical performance. Another example is the two-fold higher level of myostatin protein and myostatin mRNA in elderly, compared with younger controls, which was associated with lower fat-free mass. Myostatin is a protein that acts as a negative regulator of muscle growth and has been linked to the development of sarcopenia. Inhibition of myostatin has been suggested as a promising therapeutic therapy for sarcopenia, which could affect skeletal muscle performance.

14. The ageing process is associated with a decline in appetite and food intake known as anorexia of ageing. Approximately, 21% of the older adults present with anorexia of ageing, and it is even more prevalent in frail and institutionalized elderly people. Anorexia and subsequent weight loss have been associated with adverse health outcomes, such as falls, immobility, and sarcopenia. Anorexia is closely related to malnutrition, which is highly prevalent among hospitalized elderly patients. Collectively, both macronutrients and micronutrients play an important role in impaired skeletal muscle performance in elderly.

15. The loss of exercise capacity with ageing is the net result of lack of regular physical exercise (i.e. inactivity), age-related functional, metabolic, and structural changes in the skeletal muscle and the neuromotor control, and disease-related functional impairment resulting from catabolic effects of chronic systemic illness (e.g. heart failure, COPD, and cancer). Developing a clear understanding of the many factors affecting elderly skeletal muscle performance and physical function has major implications for scientists, clinicians, and health professionals who are developing therapeutic interventions aiming to enhance muscle function and/or prevent mobility and physical limitations and, as such, support healthy ageing.

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