- OXYGEN DEBT
- CONCEPT + PAST PAPER THEORY QUESTIONS
- &
- PDF DOWNLOAD LINK AT THE END OF THE VIDEO

OXYGEN DEBT

- Observe the sprinters in the adjoining video.
- After the race, some seem to breathe heavily while some develop cramps and some seem to be breathing quiet normal

Here is what is happening:
When they are running, their muscles are respiring anaerobically. During anaerobic respiration, glucose breaks down without oxygen. The chemical reaction transfers energy from glucose to the cells. Anaerobic respiration produces lactic acid that enters the blood via diffusion and is transported via the blood plasma .Thus rather than carbon dioxide and water, it is lactic acid that is produced along with a very less amount of energy

ANAEROBIC RESPIRATION EQUATION:

glucose ⟶ lactic acid + energy

$C_6H_{12}O_6 \longrightarrow 2C_3H_6O_3 + \text{energy}$

- **Also carbondioxide is produced due to aerobic respiration. This is detected by the receptors of the brain. . Hence the ventilation is stimulated and there is an increased depth of breathing. As a result the lactic acid is broken down[or oxidised] and converted into glucose/carbondioxide and water. Thus carbondioxide is also expelled out during ventilation. Thus it is also an example of homeostasis**
- **EQUATION FOR AEROBIC RESPIRATION**

glucose + oxygen ⟶ carbondioxide +water + energy

$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$

- Note that the energy released in aerobic respiration is greater than the energy released in anaerobic respiration

It is the lactic acid that produces muscle cramps.

After running sprinters continue to breathe quickly. The extra oxygen they breathe in (the oxygen debt)reacts with the lactic acid in their muscles, breaking it down. As the lactic acid breaks down, the cramps begin to disappear.

Aerobic training strengthens the heart and lungs and improves muscle function. One goal of aerobic training is to enhance sports performance and to improve training response. Aerobic training exercises are any activities that raise heart rate and make breathing somewhat harder. The activity you are doing must be constant and continuous.

Examples of aerobic activities are
Walking or hiking, Jogging or running, Biking, Swimming, Rowing,and In-line skating Cross-country skiing etc
Other activities, when done in a constant and continuous way, can be aerobic, such as tennis, racquetball, squash, and the martial arts. Weight training, however, is not aerobic because it is done in short bursts of a few minutes at a time.

Aerobic training increases the rate at which oxygen inhaled is passed on from the lungs and heart to the bloodstream to be used by the muscles. Aerobically fit athletes can exercise longer and harder before feeling tired. During exercise they have a slower heart rate, slower breathing rate, less muscle fatigue, and more energy.

IGCSE BOARD QUESTIONS-MARKING SCHEMES-SOLUTIONS

QUESTION:1

Some students carried out an investigation on a 16-year old athlete. Table 3.1 shows the results of their investigation on the athlete's breathing at rest and immediately after 20 minutes of running.

Ventilation rate is the volume of air taken into the lungs per minute.

Table 3.1

	at rest	immediately after 20 minutes of running
rate of breathing / breaths per minute	12	20
average volume of air taken in with each breath / dm^3	0.5	3.5
ventilation rate / dm^3 per minute	6.0	.....

(d) (i) Calculate the ventilation rate of the athlete immediately after 20 minutes of running.

Write your answer in Table 3.1. [1]

(ii) Explain why the athlete has a high ventilation rate **after the exercise has finished**.

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[5]

MARKING SCHEME-1

1	requires more oxygen ;		**A** lactate for lactic acid throughout the answer
2	oxygen debt ;		
3	lactic acid produced during exercise ;		
4	(as a result of) anaerobic respiration ;		
5	not enough oxygen supplied, to muscles (during running) ;		
6	lactic acid lowers pH of blood ;		
7	high concentration of carbon dioxide in blood ;		**A** 'need to remove carbon dioxide'
8	from aerobic respiration ;		
9	(carbon dioxide) detected by, brain / receptors ;		
10	(carbon dioxide) stimulates high ventilation rate ;		
11	(carbon dioxide) increases depth of breathing ;		
12	lactic acid is, broken down / respired / converted to glucose ;		
13	ref. to homeostasis ;	[max 5]	

EXPERT SOLUTION:

The athlete has a high ventilation rate after the exercise because he requires more oxygen. This is because ,while running ,his muscles respire anaerobically as not enough oxygen is supplied to the muscles. This results in the formation of lactic acid and lowering of the blood pH. Also there is accumulation of carbondioxide in the athlete's blood due to aerobic respiration. His brain receptors detect the presence of carbondioxide in the blood. Hence the ventilation is stimulated and there is an increased depth of breathing. As a result the lactic acid is broken down and converted into glucose. Thus it is an example of homeostasis where the body maintains the carbondioxide levels .

PLEASE NOTE: [MAX 5] REFERS TO MAXIMUM 5 MARKS AND NOT MAXIMUM 5 POINTS AS HIGHLY MISTAKEN BY MANY

QUESTION:2

(a) In the space below write a balanced chemical equation for anaerobic respiration in muscles.

…… → …… [2]

Some students investigated the breathing of a 16-year old male athlete. Fig. 3.1 shows the pattern of his breathing for 60 seconds when resting. Fig. 3.2 shows the pattern of his breathing while he took some exercise for 60 seconds.

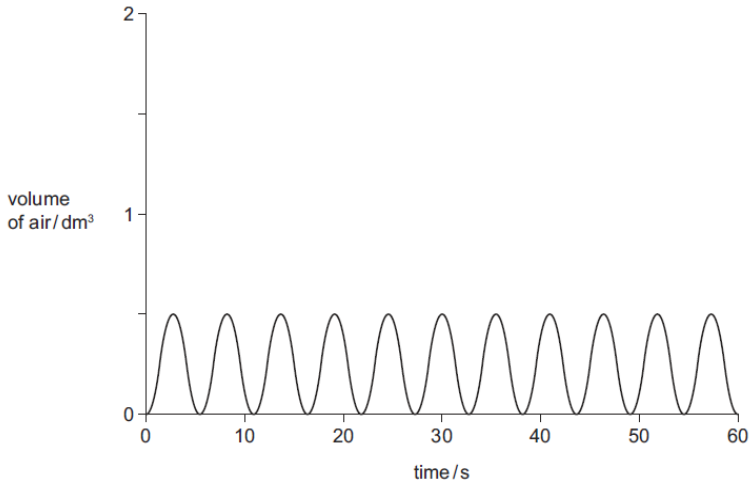

Fig. 3.1

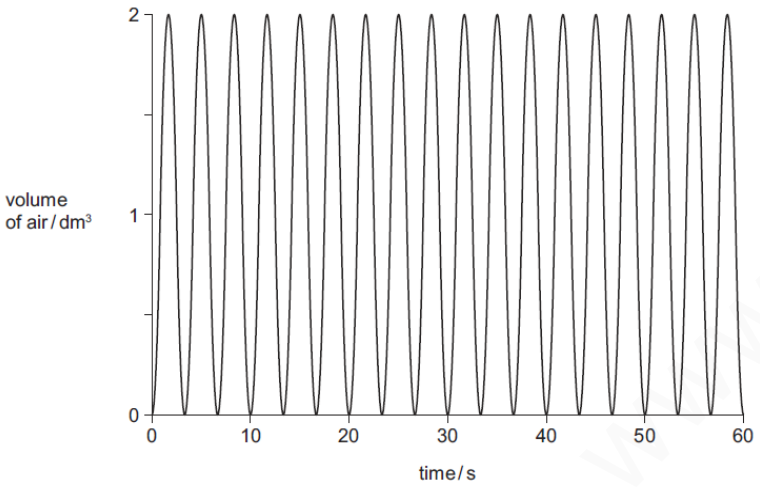

Fig. 3.2

QUESTION PAPER:2

Explain the effect of exercise on the student's breathing.

…… [5]

MARKING SCHEME:2

1	descriptive comment on difference between Fig. 3.1 and 3.2 ; **A** data quote for any one of the results shown in Table 3.1		breathing rate, volume of air, ventilation rate e.g. breathe, fast / faster, deeper **R** heavier
2	muscle ;		
3	respires faster ; **R** breathes faster (as this is for MP1)		**A** more respiration
4	*idea that* more, energy / ATP, released / needed ;		**NOT** more glucose **R** 'energy produced'
5	aerobic respiration ;		
6	*idea that* requires more oxygen ; **A** ref to more oxygenated blood		
7	*idea that* remove more carbon dioxide ;		
	change to breathing maintains		
8	pH of blood ;		
9	oxygen concentration ;		MP8 – MP10 must have idea of maintaining near constant
10	carbon dioxide concentration ;		
11	prevents (much) anaerobic respiration occurring ;		MP11–13 **R** refs. to there being an oxygen debt and paying off oxygen debt as question is about *during exercise* not afterwards, other points especially MP1 to 7 can still be awarded if answer contains refs to oxygen debt unless answer says 'after exercise'
12	prevents build up of, lactic acid / lactate ; **R** removes		
13	prevents oxygen debt ; **R** repays		
14	AVP ; e.g. ref. to homeostasis, contraction of muscle	[max 5]	

QUESTION:3

Exercise that occurs over a longer period of time than weightlifting often involves aerobic respiration as well as anaerobic respiration.

Fig. 4.2 shows the oxygen consumed by an athlete during and after a 5000 metre race.

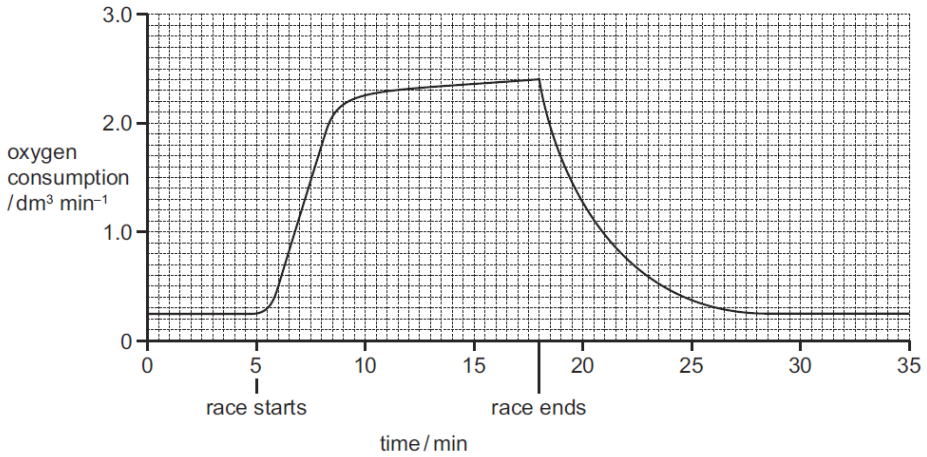

Fig. 4.2

(c) Describe the athlete's oxygen consumption during **and** after the race as shown in Fig. 4.2.

You will gain credit for using the figures in the graph to support your answer.

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after .....

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QUESTION:3 [CONTINUED]

(d) Explain why the oxygen consumption does not return immediately to the resting level after the exercise is finished.

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MARKING SCHEME:3

	During:	
1	oxygen consumption increases as exercise starts	
2	levels off / increase slows down during the race	
3	data quote for consumption during the race	
	After:	
4	starts to decrease, immediately at the end of the race / at 18 minutes	
5	gradually decreases after exercise	
6	rate returns to original / resting level	
7	data quote for consumption after exercise	[max 4]
1	oxygen debt	
2	not enough oxygen supplied (to muscles) during exercise	
3	to muscles	
4	anaerobic respiration	
5	lactic acid produced	
6	lactic acid, broken down / respired / converted to glucose / CO_2 and water / oxidized	
7	requires (extra) oxygen	
8	oxygen restored to haemoglobin	
9	AVP. e.g. restored to myoglobin (in muscles)	[max 5]

QUESTION:4

(a) Yeast cells and human muscle cells can carry out both aerobic and anaerobic respiration.

Complete Table 4.1 by writing the end products of aerobic and anaerobic respiration in these two types of cell.

Table 4.1

cell	end products of respiration	
	aerobic	anaerobic
yeast	..... + ...	..... + ...
human muscle cell	..... + ...	.....

[4]

(b) During exercise there are changes to:

- breathing rate;
- ventilation rate;
- oxygen absorption;
- heart rate;
- blood pressure.

The effect of strenuous exercise is shown in Table 4.2.

Table 4.2

	before exercise	immediately after exercise
breathing rate / breaths per minute	11	22
ventilation rate (volume of air taken into the lungs per minute) / dm^3 per minute	6	90
oxygen absorption / cm^3 per minute	250	2500
heart rate / beats per minute	65	170
blood pressure / kPa	15	25

QUESTION:4[CONTINUED]

Explain why the changes shown in Table 4.2 occur during exercise.

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..... [5]

[Total: 9]

MARKING SCHEME:4

(a)		cell: yeast — aerobic: carbon dioxide/CO_2 + water/H_2O ; anaerobic: carbon dioxide/CO_2 + alcohol/ethanol/C_2H_5OH ; cell: human muscle cell — aerobic: carbon dioxide/CO_2 + water/H_2O ; anaerobic: lactic acid lactate/ $C_3H_6O_3$/$CH_3CH(OH)COOH$ / $CH_3CH(OH)COO^-$;	[4]	***ignore*** ATP/energy
(b)	1 2 3 4 5 6 7 8 9 10 11 12 13	muscles <u>contract</u> ; need more energy ; increase in need for oxygen ; **ORA** removal of (more) carbon dioxide ; (increase in) <u>aerobic</u> respiration ; <u>anaerobic</u> respiration also occurs ; developing <u>oxygen debt</u>/oxygen not supplied fast enough ; (production of) lactate/lactic acid ; increase in stroke volume (of heart) ; increase in, blood flow/glucose/oxygen, to muscles ; blood pressure increase because heart rate/stroke volume increases ; removal of heat ; ref to adrenaline ;	[max 5]	***ignore*** 'breathing rate', 'ventilation rate', 'oxygen absorption', 'heart rate', 'blood pressure' (all are in the Table) **R** repaying oxygen debt (occurs after exercise)
			[Total: 9]	

QUESTION:5

Researchers designed an investigation to find the effect of increasing levels of exercise on two groups of people.

The first group of people were trained cyclists and the second group were untrained cyclists.

The researchers asked all the people to cycle at four levels of effort: 30%, 45%, 60% and 75% of their maximum cycle speed.

They cycled for eight minutes at each level of effort.

(a) The researchers predicted that the pulse rate of all the cyclists would increase during exercise.

Explain this prediction.

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Fig. 3.1 shows the average concentration of lactic acid in the blood of the trained cyclists and untrained cyclists in the investigation.

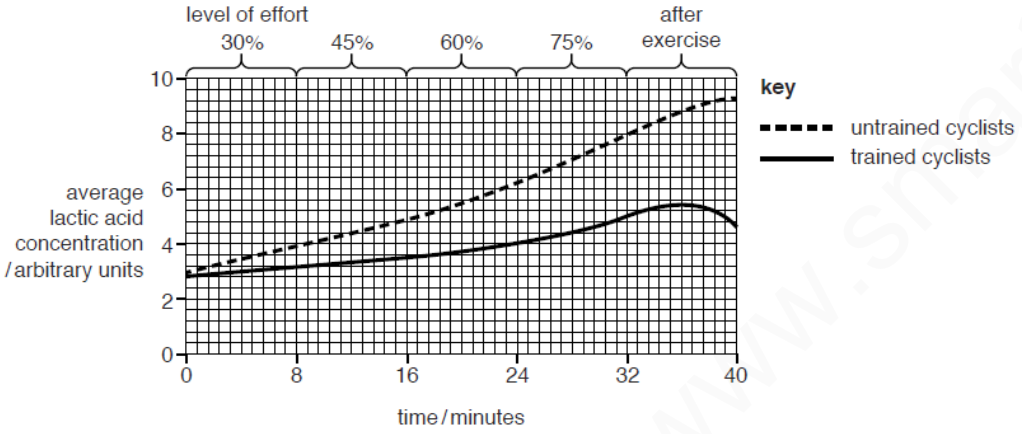

Fig. 3.1

QUESTION:5 [CONTINUED]

(b) Describe the effect of the increasing levels of effort on the average lactic acid concentration in the blood of the **untrained** cyclists.

You should use data from Fig. 3.1 in your answer.

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(c) Lactic acid is produced in the muscles during anaerobic respiration.

(i) Define the term *anaerobic respiration*.

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(ii) Describe how the lactic acid produced in muscle cells enters the blood.

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(iii) Name the component of the blood that transports lactic acid.

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QUESTION:5[CONTINUED]

(d) Explain why the lactic acid concentration in the blood in trained cyclists is different from the untrained cyclists eight minutes **after** the exercise.

You should use data from Fig. 3.1 in your answer.

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[Total: 13]

MARKING SCHEME:5

(a)	increased blood flow *or* heart, pumps / beats, faster ; more, oxygen / glucose (for muscles) / carbon dioxide removed ; more energy released by respiration ; for muscle contraction ;	max [2]	**ignore** increased, pulse rate / heart rate **R** 'energy produced' / 'energy created'
(b)	increase in, time / exercise intensity / effort, increase in lactic acid concentration ; increase is, steady / proportional ; after exercise lactic acid concentration continues to increase ; after exercise / near end of exercise, concentration levels off / AW ; appropriate use of data ;	max [3]	units must be used at least once
(c) (i)	the release of a relatively small amount of energy ; by the breakdown of glucose ; in the absence of oxygen / without oxygen ;	max [2]	**R** 'produce / AW, energy' **ignore** 'use' unqualified **ignore** air / fermentation unqualified
(ii)	(by) diffusion ;	[1]	
(iii)	(blood) plasma ;	[1]	
(d)	*in trained cyclists* lower anaerobic respiration / more aerobic respiration ; less lactic acid produced (during exercise) ; because more oxygen supplied to muscles ; less oxygen debt ; less oxygen required, to oxidise / breakdown, lactic acid ; (breakdown) to glucose / carbon dioxide and water ; quicker, removal / breakdown, of lactic acid ; appropriate comparative data quote with units ;	max [4]	
		[Total: 13]	

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