AP BIOLOGY · UNIT 3 · TOPIC 3.5

Cellular Respiration

Learning objective 3.5.A Describe the processes of aerobic cellular respiration, and explain the role of oxygen in them.

Name: Date: Period:

Use the tool **Sugar Into ATP**. Parts 1 and 2 use **Follow the carbon**, Part 3 uses **The ATP account**, Parts 4 and 5 use **Turn off the oxygen**, and Part 6 uses **Check yourself**. Many of the questions ask where the six carbons go and where the ATP is made.

switch tab *scroll down* *predict first*

record from the tool *score yourself* *reset the tool*

The purple bar in the margin names the AP science practice a question uses.

Part 1 · Where the carbon goes

Follow the carbon | The ATP account | Turn off the oxygen | Check yourself

Use the **Follow the carbon** tab. It is the one showing when the tool opens.

Press Next stage to step through the four stages. Record the readouts after each stage.

After this stage	Where it happened	Carbon left in the pathway	CO_2 so far
Glycolysis			
Pyruvate oxidation			
Citric acid cycle			
Oxidative phosphorylation			

1. (a) Identify the four stages of aerobic respiration in order.

(b) Identify where in the cell each stage takes place.

2. Describe the path of the six carbon atoms of one glucose molecule through aerobic respiration. Include the stage at which each carbon leaves and the form in which it leaves.

Part 2 · Electron carriers and oxygen

Stay on the **Follow the carbon** tab.

Press Start again and step through the stages again. For each stage, record the NADH and $FADH_2$ it produces and the net ATP it makes directly; the stage text gives each number. Oxidative phosphorylation produces no carriers and makes no ATP directly (its ATP comes from the proton gradient), so write 0 in its row. Add each column for the TOTAL row. Then open **Why does the equation need exactly six O_2?**, which question 5 uses.

Stage	NADH	$FADH_2$	Net ATP made directly
Glycolysis			
Pyruvate oxidation			
Citric acid cycle			
Oxidative phosphorylation			
TOTAL			

3. (a) Identify the net ATP yield of glycolysis.

(b) Explain why the net yield differs from the number of ATP that glycolysis produces.

SP 1 · CONCEPT EXPLANATION

4. Describe the role of NADH and $FADH_2$ in aerobic respiration.

SP 5 · STATISTICAL TESTS AND DATA ANALYSIS

5. Using the TOTAL row of the Part 2 table and the table in "Why does the equation need exactly six O_2?", calculate the number of O_2 molecules needed to respire one molecule of glucose. Show your work.

Part 3 · The ATP account

Follow the carbon | **The ATP account** | Turn off the oxygen | Check yourself

Click **The ATP account** tab at the top of the tool.

Press each convention chip in turn and record its values. The ATP per NADH and per $FADH_2$ are shown on the chip.

Convention	ATP per NADH	ATP per $FADH_2$	Made directly	From the gradient	Total
Current estimate					
Older textbooks					

SP 4 · REPRESENTING AND DESCRIBING DATA

6. (a) Identify the quantities in the Part 3 table that changed when the convention changed.

(b) Identify the quantity in the Part 3 table that did not change.

(c) Explain what these results indicate about the source of the disagreement between textbooks.

SP 5 · STATISTICAL TESTS AND DATA ANALYSIS

7. (a) Calculate the percentage of the total ATP that comes from the proton gradient under each convention. Show your work.

(b) Describe what the two percentages have in common.

Part 4 · Take the oxygen away

Follow the carbon | The ATP account | **Turn off the oxygen** | Check yourself

Click the **Turn off the oxygen** tab at the top of the tool.

For each row, write your prediction in the predict column, then set the two switches (Oxygen available, and The cell has a fermentation pathway) as shown in the first two columns, and record the readouts. The CO_2 released readout counts only the four stages of respiration; it does not count any CO_2 that fermentation itself releases.

Oxygen	Fermentation	Stages running (predict)	Stages running (actual)	ATP per glucose	CO_2 released
Available	Yes				
None	Yes				
None	No				

SP 1 · CONCEPT EXPLANATION

8. (a) Describe the role of oxygen in aerobic respiration.

(b) Identify where in the process oxygen acts.

9. Explain why removing oxygen stops the citric acid cycle, even though the citric acid cycle does not use oxygen directly.

Part 5 · What fermentation is for

Stay on the **Turn off the oxygen** tab and scroll down to the **It makes no ATP** section.

Read **It makes no ATP** and complete the table from what you find there.

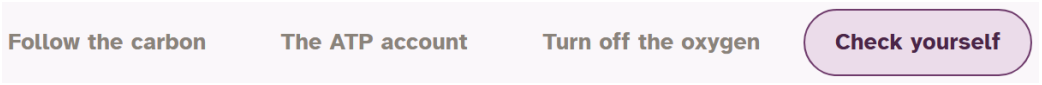
Kind of fermentation	Who does it	What happens to the pyruvate	ATP it makes
Lactic acid fermentation			
Alcoholic fermentation			

10. A student claims that fermentation is how a cell makes ATP without oxygen. Evaluate the student's claim.

11. A muscle working anaerobically nets 2 ATP per glucose.
(a) Using the tool's aerobic total of 32 ATP per glucose, calculate how many times more ATP the same glucose yields aerobically. Show your work.

(b) Explain one consequence of this difference for an athlete.

Part 6 · Learning check self-report



Click the **Check yourself** tab at the top of the tool.

The **Learning check** is at the top of that tab. Type an answer to each question, check it against the rubric, and check off the points you earned. Then record your score here and, for every point you did not earn, write what the rubric asked for that your answer left out.

Question	Points possible	Points I earned	Missed opportunities (what the rubric wanted that I left out)
1	2		
2	2		
3	2		
4	2		
5	2		
6	2		
7	2		
8	3		
Total	**17**		

What the model simplifies

The ATP total per glucose is an estimate, not a constant. It depends on which shuttle carries the electrons from the NADH made in the cytosol into the mitochondrion, and on how leaky the inner membrane happens to be. Figures between 30 and 32 are all defensible with the current per-carrier estimates, and this tool reports 32.

Individual steps, intermediates and enzyme names in glycolysis and the citric acid cycle are outside the course framework, so the tool counts carbon, electron carriers and ATP rather than naming molecules. ATP synthase is the one enzyme name the framework does expect.

The citric acid cycle is shown as making ATP directly. In most cells it makes GTP, which is then converted to ATP; the accounting is the same and the distinction is beyond the course.

Respiration is drawn here as glucose in and carbon dioxide out. Cells also respire fats and amino acids, which enter the same pathway at different points, and the reverse (using respiratory intermediates to build molecules) happens constantly.