AP BIOLOGY · UNIT 3 · TOPIC 3.3

Cellular Energy

Learning objective 3.3.A Explain how cells use ATP.

Name: Date: Period:

Use the tool **Charging and Spending**. Parts 1 to 3 use the **Pay for the job** tab, Parts 4 and 5 use **The pool never gets big**, and Part 6 uses **Check yourself**. Watch two readouts closely: the **ΔG of the job**, which never changes, and **ATP + ADP**, which never changes either.

switch tab *scroll down* *record from the tool*

score yourself

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

Part 1 · What one ATP buys

Pay for the job | The pool never gets big | Where it comes from | Check yourself

Use the **Pay for the job** tab. It is the one showing when the tool opens.

Select each job in turn and set **ATP coupled** to 0, then to 1. Record the ΔG of the job, the net ΔG of the pair with 0 ATP and with 1 ATP, and whether the pair runs.

Cellular job	**ΔG of the job**	**Net ΔG with 0 ATP**	**Net ΔG with 1 ATP**	**Runs with 1 ATP?** *circle one*
Phosphorylate glucose				yes / no
Build glutamine				yes / no
Build sucrose				yes / no
Run the sodium-potassium pump				yes / no
Pull one myosin cross-bridge				yes / no
Hold body temperature steady				yes / no

1. (a) Describe what the six jobs in the Part 1 table have in common before any ATP is coupled to them.

(b) Explain what this shared feature shows about whether the jobs happen on their own.

2. With 1 ATP coupled, the ΔG from the ATP readout shows the free energy change of ATP hydrolysis.
(a) Identify the sign of ΔG for ATP hydrolysis.

(b) Describe what this sign indicates about ATP hydrolysis.

Part 2 · The readout that does not move

Stay on the **Pay for the job** tab.

Select **Build sucrose** and set the ATP coupled slider to 0, 1, 2 and 3 in turn. Record the readouts each time.

ATP coupled	ΔG of the job	ΔG from the ATP	Net ΔG of the pair	Runs? *circle one*
0				yes / no
1				yes / no
2				yes / no
3				yes / no

3. One column of the Part 2 table has the same value in all four rows.
(a) Identify the column.

(b) Explain what this result shows about how coupling to ATP allows the job to run.

4. A student claims that coupling an endergonic reaction to ATP hydrolysis makes the reaction exergonic. Evaluate the student's claim.

Part 3 · Where the rest of the energy goes

Stay on the **Pay for the job** tab and scroll down to the **Why a second ATP is not better** section.

Open **Why a second ATP is not better** and copy the three rows of its table that are listed below. Questions 5 and 6 use these numbers.

Job	ΔG of the job	Released by 1 ATP	Share reaching the job	Lost as heat
Run the sodium-potassium pump				
Build sucrose				
Phosphorylate glucose				

SP 1 · CONCEPT EXPLANATION

5. (a) Explain why the share of the energy released by one ATP that reaches the job is always less than 100%.

(b) Identify where the rest of the energy goes.

SP 4 · REPRESENTING AND DESCRIBING DATA

6. Select Run the sodium-potassium pump and set the ATP coupled slider to 3.
(a) Describe the effect of coupling 3 ATP instead of 1 ATP on the net ΔG of the pair.

(b) Describe the effect of coupling 3 ATP instead of 1 ATP on the job itself.

(c) Explain why spending the extra ATP is not an improvement.

SP 1 · CONCEPT EXPLANATION

7. Cells use ATP for four kinds of work.
(a) Identify the four kinds of work.

(b) For each kind of work, identify one example from the tool.

Part 4 · The pool that never changes



Click **The pool never gets big** tab at the top of the tool.

Leave the Pool size slider at 60. For each row, set the Jobs demanded / tick and Recharged / tick sliders as shown, press **Run 200 ticks**, and record the four readouts when the run ends.

Demand	Recharge	ATP at the end	ADP at the end	ATP + ADP	Jobs done
8	8				
40	8				
40	32				

8. (a) Identify the readout in the Part 4 table that has the same value in every row.

(b) Explain why this value cannot change.

9. From row 1 to row 2 of the Part 4 table the demand increased, and from row 2 to row 3 the recharge rate increased.
(a) Identify the change that greatly increased the number of jobs done.

(b) Explain why this change, and not the increase in demand, greatly increased the number of jobs done.

Part 5 · Cut the supply

Stay on **The pool never gets big** tab.

Set Jobs demanded / tick to 40 and Recharged / tick to 8. For each pool size below, set the Pool size slider, press Run 200 ticks and record Jobs done in total. Then press **Cut the energy supply**, which cuts the supply at tick 40, and run each pool size again. Record Jobs done in total, and use the graph to judge whether the work went on for many ticks after the cut or stopped almost at once.

Pool	Jobs done, supply on	Jobs done, supply cut at tick 40	Ticks of work after the cut
10			
60			
500			

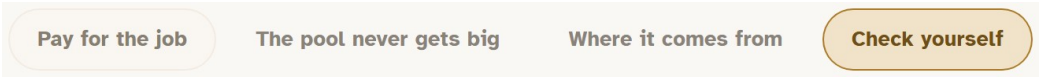
10. (a) Describe the effect of a fifty-fold larger pool (500 instead of 10) on how long the cell keeps working after the supply is cut.

(b) Explain this result.

11. Explain why a cell holds only a small quantity of ATP even though it uses enormous amounts of it.

12. Explain why living systems require a constant input of free energy rather than a single input. In your answer, refer to heat.

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		
Total	**12**		

What the model simplifies

Free energy changes are standard-condition values in kilocalories per mole, which is how they appear in most AP-level material. Inside a living cell the concentrations of ATP, ADP and Pi are far from standard, and ATP hydrolysis there releases closer to −13 kcal/mol. The argument is unaffected: the sign is the same and the sum is what matters.

The cell in the second tab counts adenine nucleotides in arbitrary units and time in arbitrary ticks. A real human cell holds on the order of a billion ATP molecules and turns the whole pool over in a minute or two; the model is scaled down so the numbers can be read on a graph.

Jobs are shown as costing whole ATP. Some cellular processes are driven by GTP instead, some by the proton gradient directly rather than by ATP at all, and protein synthesis costs several high-energy phosphates per amino acid rather than one.

The energy released by ATP that does not go into the job is shown simply as heat. In a real cell some of it appears as heat and some raises the concentration of products above what the job strictly required.