

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 and Parts 4 and 5 use **The pool never gets big**. Two readouts do the teaching here: the **ΔG of the job**, which never moves, and **ATP + ADP**, which never moves either. Watch both.

Part 1 • What one ATP buys

Select each job in turn and set **ATP coupled** to 0, then to 1. Record both net values.

Job	ΔG of the job	Net ΔG with 0 ATP	Net ΔG with 1 ATP	Runs?
Phosphorylate glucose				
Build glutamine				
Build sucrose				
Run the sodium-potassium pump				
Pull one myosin cross-bridge				
Hold body temperature steady				

1. State what all six of these jobs have in common before any ATP is coupled to them, and what that tells you about whether they happen on their own.

2. Write the sign of ΔG for ATP hydrolysis and state what that sign means.

Part 2 · The readout that does not move

Select **Build sucrose** and step the ATP slider from 0 to 3, recording all three readouts each time.

ATP coupled	ΔG of the job	ΔG from the ATP	Net ΔG of the pair	Runs?
0				
1				
2				
3				

3. One column of your table is identical on all four rows. Name it, and explain what its being identical tells you about what coupling does.

4. A student says that coupling to ATP makes an endergonic reaction exergonic. Evaluate that statement.

Part 3 · Where the rest of the energy goes

Open **Why a second ATP is not better** and read the table there. Then answer using the numbers in it.

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				

5. Explain why the share of the ATP's energy that reaches the job is never 100%, and state where the rest of it goes.

6. With the sodium-potassium pump selected, set the ATP slider to 3. State what happened to the net ΔG , state what happened to the job, and explain why spending extra ATP is not an improvement.

7. Give one example from the tool for each of the four things a cell uses ATP for.

Part 4 · The pool that never changes

Switch to **The pool never gets big**. Leave the pool at 60. Set the demand and recharge as shown, press **Run 200 ticks**, and record the four readouts at the end.

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

8. One column is the same on every row you ran. Name it and explain why it cannot change.

9. Compare rows 2 and 3. State which change raised the number of jobs done, and explain why that change and not the other one.

Part 5 · Cut the supply

Set the demand to 40 and the recharge to 8. Run the three pool sizes below. Then press **Cut the energy supply** and run each one again, recording how soon the work stops.

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

10. Describe the effect of a fifty-fold larger pool on how long the cell keeps working after the supply is cut, and explain the 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 one. Refer to heat in your answer.

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.