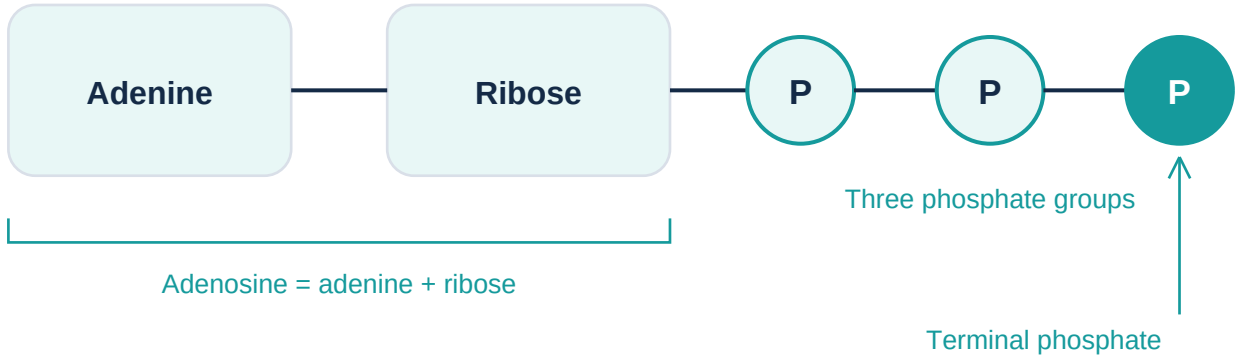
ATP: a usable energy carrier

Adenosine triphosphate transfers energy between energy-releasing reactions and processes that require energy. It is used throughout living cells.

1. THREE PARTS TO RECOGNISE



Component diagram, not a full chemical structure. The phosphate chain is attached to ribose, not directly to adenine. Each P circle represents a phosphate group.

2. A PHOSPHORYLATED NUCLEOTIDE

ATP contains the base adenine, the five-carbon sugar ribose and three phosphate groups. ADP is adenosine diphosphate, with two phosphate groups. ATP contains ribose, not deoxyribose.

3. WHY CELLS USE ATP

ATP is small and soluble, so it can move within the cell. Enzyme-controlled reactions make its energy rapidly available in manageable transfers. It is continually recycled rather than accumulated as a large, long-term energy reserve.

Currency is an analogy: ATP transfers energy; it does not create energy.

ATP components and hydrolysis: OpenStax, Biology 2e 6.4.
ATP as an energy carrier: Cooper, The Cell, Metabolic Energy.

Scope: Cambridge Biology 9700, section 12.1, outcomes 1-3, p. 32.

Hydrolysis and regeneration

Follow both matter and energy. Hydrolysis uses water; ATP formation from ADP and inorganic phosphate requires an energy input.

1. ATP HYDROLYSIS

$$ATP + H_2O \longrightarrow ADP + P_i$$

P_i = inorganic phosphate. ATPase enzymes catalyse ATP hydrolysis. The terminal phosphate is removed, leaving ADP. The overall reaction releases free energy that can be coupled to cellular work.

2. REGENERATE ATP

$$ADP + P_i \longrightarrow ATP + H_2O$$

Adding phosphate to ADP is phosphorylation. Energy must be supplied to regenerate ATP, for example from respiration. These are simplified net equations; charges and proton balance are omitted.

3. AVOID THE BOND-BREAKING TRAP

Breaking a chemical bond requires energy. ATP hydrolysis releases energy overall because the products are more stable and have lower free energy than the reactants. Do not say that breaking the phosphate bond alone releases energy.

Hydrolysis, phosphorylation and simplified net equations: OpenStax, Biology 2e 6.4.
Reaction energetics and coupling: Cooper, The Cell, Metabolic Energy.

Scope: Cambridge Biology 9700, section 12.1, outcomes 1-3, p. 32.

Link ATP to cellular work

Energy coupling links an energy-releasing reaction to an energy-requiring process. Enzymes coordinate the link; simply releasing heat nearby is not enough.

1. THREE USES OF ENERGY

ACTIVE TRANSPORT	ATP-driven pumps move ions against their electrochemical gradients. Phosphorylation can change a pump protein's shape.
MOVEMENT	ATP supports cycles of motor-protein shape changes, including muscle contraction and movement of cilia.
ANABOLIC REACTIONS	Energy is required to build complex molecules. Examples include processes involved in protein synthesis and DNA replication.

2. PHOSPHATE TRANSFER CAN COUPLE REACTIONS

An enzyme can transfer ATP's terminal phosphate to a substrate or protein. This can produce a more reactive intermediate or alter protein activity, linking ATP use directly to the next step. ATP becomes ADP.

3. TWO WAYS TO MAKE MORE ATP

Substrate-linked phosphorylation transfers phosphate directly from a phosphorylated substrate to ADP. In chemiosmosis, a proton gradient drives ATP synthase: across the inner mitochondrial membrane during respiration, or the thylakoid membrane in chloroplasts during photosynthesis.

ATP cycles rapidly between use and regeneration. Energy enters the cycle; some is transferred to work and some dissipates as heat.

Coupled biosynthesis, transport and movement: Alberts et al., Molecular Biology of the Cell.
Substrate-linked phosphorylation and chemiosmosis: OpenStax, Biology 2e 7.1.

Scope: Cambridge Biology 9700, section 12.1, outcomes 1-3, p. 32.