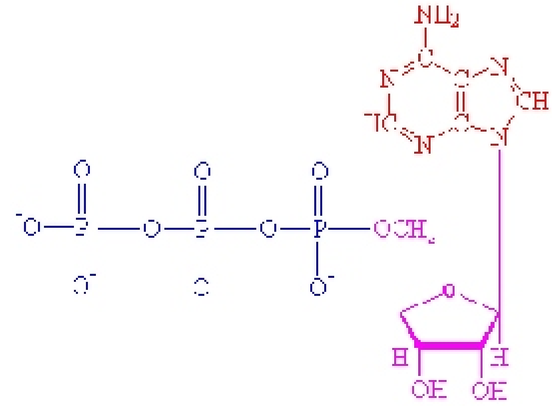
ENERGY IN BIOLOGICAL BONDS, ATP

10/30/91, rvsd 11/3/93, 11/4/96, 3 Nov 99, 1 Nov 00, 2 Nov 01, 5 Nov 03, 19Oct07, 24Oct08, 23Oct09
BRP pp. 296-307, BKH: pp. 376-383, BKH 5th: 368-378, 6th: , 7th: 221-229



All cellular chemical reactions: **metabolism**
Metabolic pathways:

- **catabolism**: produce energy-rich molecules (energy is stored in chemical bonds)
- **anabolism**: use energy-rich molecules to perform synthesis

Energy in biological systems, needed to sustain processes of life.
ATP is the **universal energy coupler**, collects energy from catabolism, used in anabolism.

Draw **Adenosine triphosphate** (p 225) explore the sources of its bond energy:

- **Phosphoester bonds** formed from alcohol and *phosphoric* acid (remember ester = alcohol + acid)
- **Phosphoanhydride** formed from condensation of two phosphoric acids (acid anhydride: any two acids)
  Phosphoanhydride bond, high energy, critical in ATP function:

Why is phosphoanhydride a high energy bond? Due to two factors: (p 226)

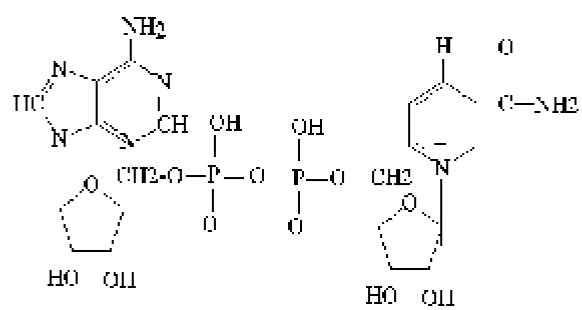
1. **charge repulsion** Negatively charged adjacent PO_4 groups repel each other
2. **resonance stabilization** Resonance hybridization leads to maximum stability
   Negative charges *delocalized* .

anhydrides prevent delocalization (the *major* contributor to bond energy)
When oxygen of PO_4 is covalently bonded in ester or anhydride, **charge delocalization** can't occur easily
Show carboxylate and phosphate with charges distributed by resonance.

Breaking anhydride or ester bonds produces more stable products, is highly **exergonic**
For **esters**, *only* PO_4 is resonance stabilized after hydrolysis, R-OH not ΔH = about -3 to -4 Kcal
for **anhydrides**, *both* products are stabilized, thus higher exergonic ΔH = -7.3 Kcal

Products of hydrolysis are stabilized by resonance...
See table 9-1, p 227 graph on 228:

Compound	**Kcal/mole of bond broken**	
Phosphoenolpyruvate:	-14.8	(anhydride ***plus*** distorted enol)
1,3 bisphosphoglyceric acid:	-11.8	(anhydride)
ATP	-7.3	
(In between energy rich sources, and phosphorylated glucose)		
Glucose-1-PO_4	-5.0	(ester)
Glucose-6-PO_4	-3.3	(ester)

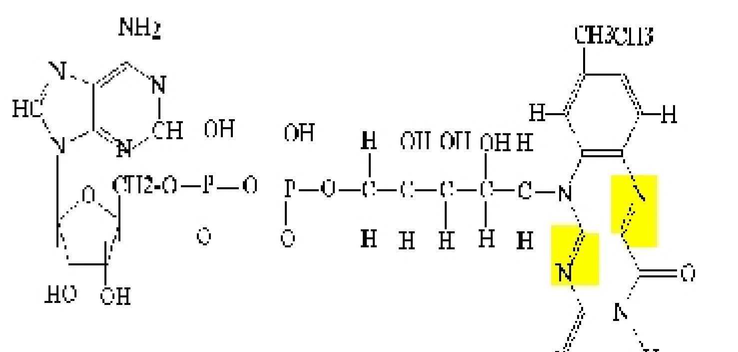


Note that ATP is central, ideal intermediate between high energy and low energy PO_4ylated compounds.

Most cells have 90% of their adenosine as ATP

HYDROGEN CARRIERS IN METABOLISM:
Nicotinamide adenine dinucleotide (NAD^+)
accepts hydrogens onto carbon (p. 230) (a coenzyme)
Two riboses in NAD linked via
#5 carbons with **pyrophosphate** linkage

Flavin adenine dinucleotide (FAD)
accepts hydrogens onto nitrogen, lower energy than NAD (p 262)



flavin adenine dinucleotide (FAD)