

Students' Interdisciplinary Reasoning about “High-Energy Bonds” and ATP

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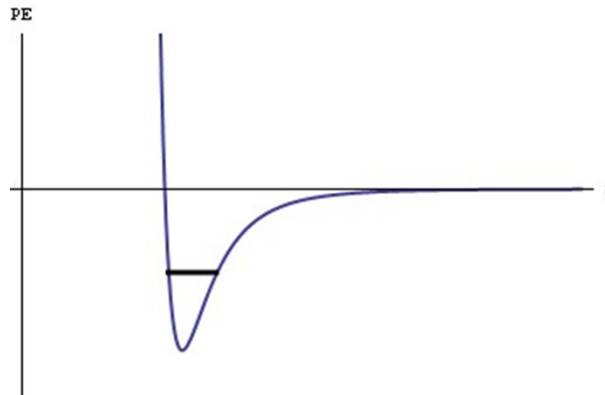
Department of Physics,
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AAPT Summer Meeting, July 31, 2012

The context: Physics for biologists

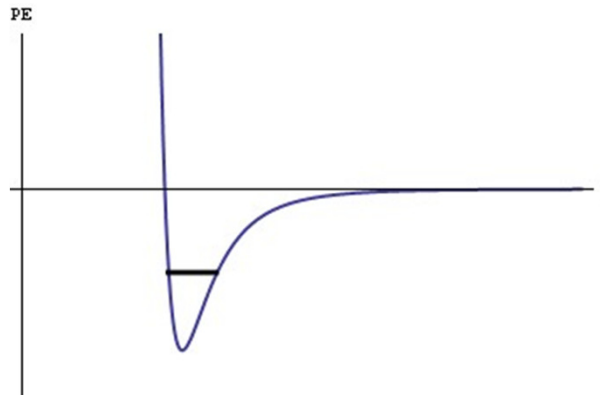
- New intro physics course for biology undergrads piloted in 2011-12
- Additional focus on energy and thermodynamics, building models that connect physics, biology, and chemistry
- Includes chemical bond energy



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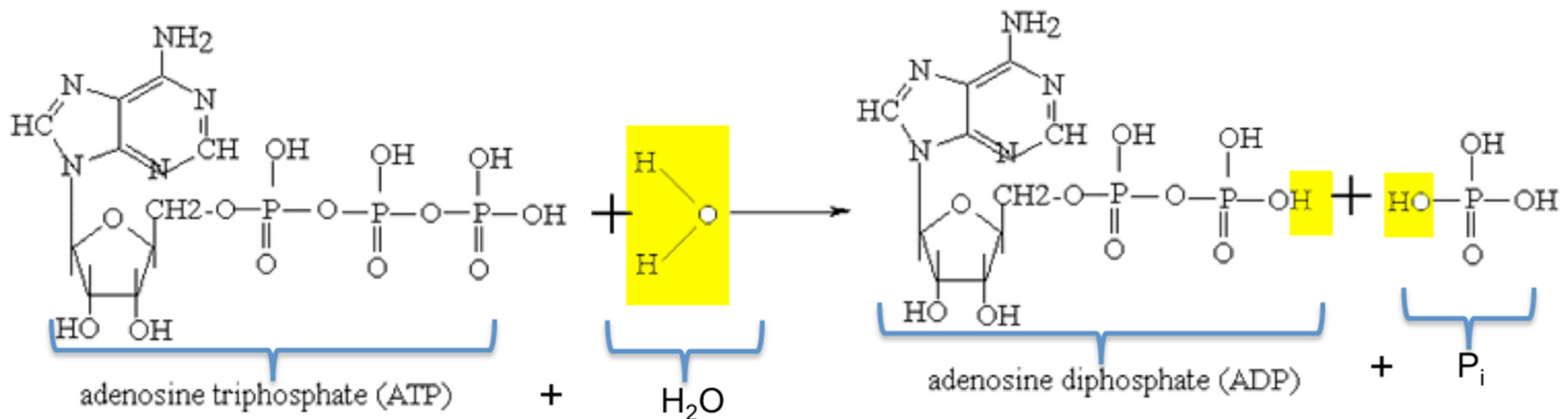
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Tonight!
Poster 2A20



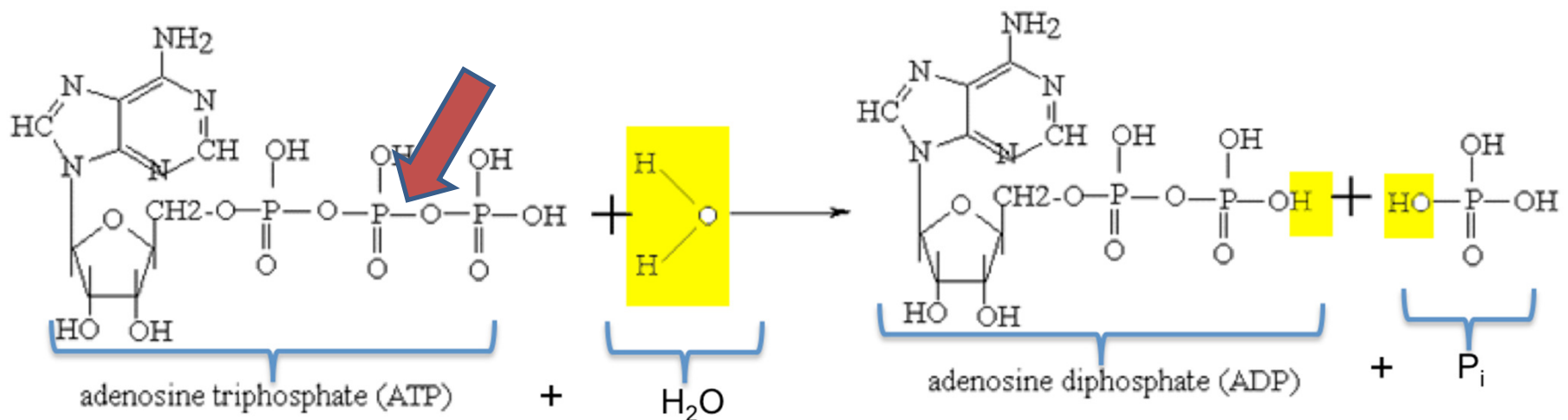
ATP: “the energy currency of the cell”

- Produced during respiration and photosynthesis.
- In ATP hydrolysis, the phosphate bond is broken, stronger bonds are formed, and the net effect is that energy is released.



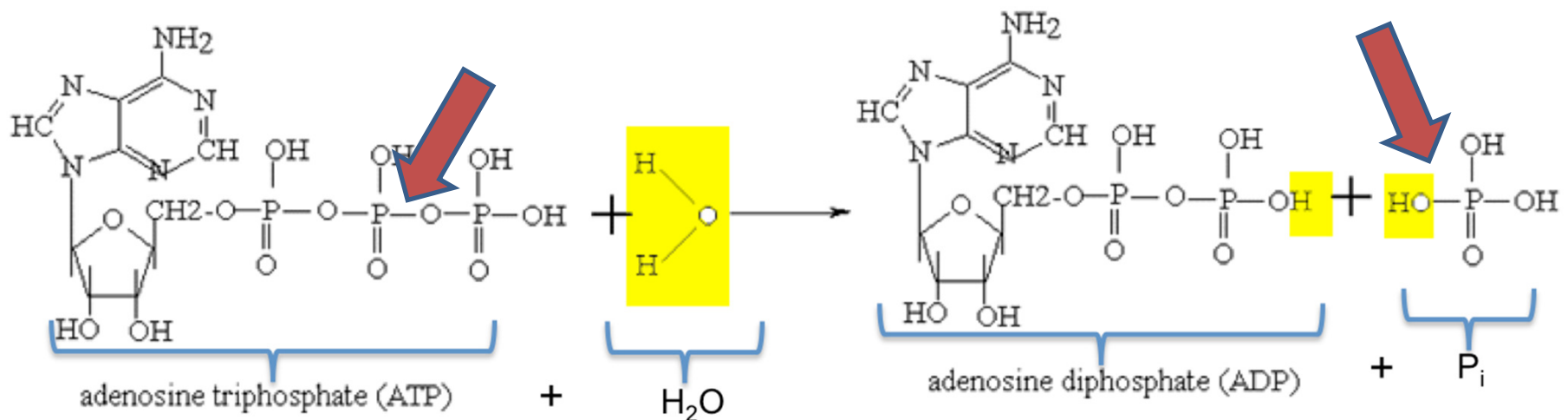
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Student “misconceptions” about ATP

- Energy is “stored” in a “high-energy bond”
- Energy is released when bonds are broken (in ATP or in general)
- Treated in the literature as a “misconception”

* Biology education: Novick 1976, Gayford 1986

** Chemistry education: Boo 1998, Teichert & Stacy 2002, Galley 2004

Quiz question

(from Galley 2004)

An O-P bond in ATP is referred to as a “high-energy phosphate bond” because

- A. The bond is a particularly stable bond.
- ✓ B. The bond is a relatively weak bond.
- C. Breaking the bond releases a significant quantity of energy.
- ✓ D. A relatively small quantity of energy is required to break the bond.

Quiz results

- 79% of our students (N=19) chose C, breaking the bond releases energy
- Comparable to Galley's result of 87%, which he calls a "persistent misconception"
- But what are these students thinking?

Interviews

- 22 semi-structured interviews with 11 students
- Two students, “Gregor” and “Wylie”, discussed the ATP quiz question
- Both Gregor and Wylie answered BCD: the “correct” answers **and** the “misconception”

What did Gregor mean?

“I put that when the bond's broken, that's energy releasing. Even though I know, if I really think about it, that obviously that's not an energy-releasing mechanism. Because like, you **can't break a bond and release energy**, like you always need to put energy in, even if it's like a really small amount of energy, to break a bond.”

Reconciling

“When I was taking the test, I guess I was thinking breaking this bond then **leads to these other reactions** inevitably. That result in an energy release. ... I don't [argue] that breaking a bond releases energy, but just like **in a larger biological context, that reaction does release energy.**”

Tagging the disciplines

“I guess that's the difference between like how **a biologist** is trained to think, in like **a larger context**, and how **physicists** just focus on sort of **one little thing.**”

How to bound the system

ATP hydrolysis:

(reaction takes place in water)

Breaking the
phosphate
bond in ATP

Formation of
new bonds

How to bound the system

ATP hydrolysis:

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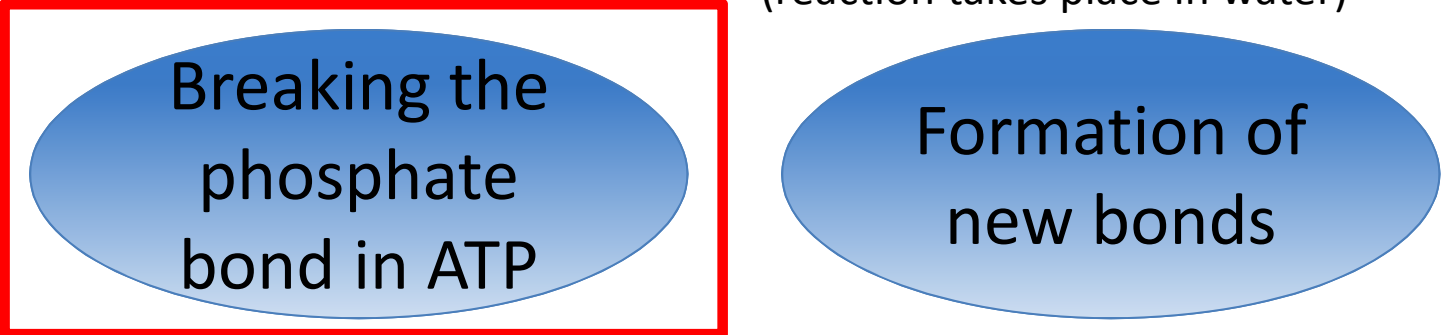
Formation of
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“Physics”?

How to bound the system

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(reaction takes place in water)



Breaking the
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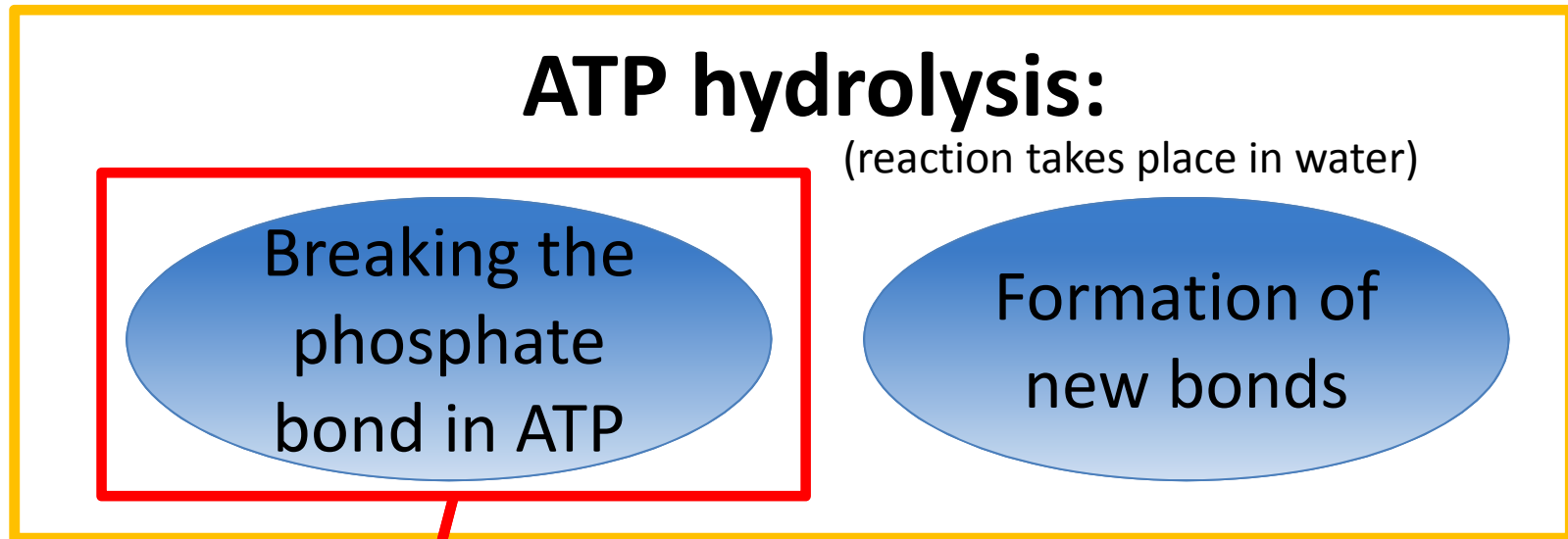
The diagram consists of two blue ovals. The left oval is enclosed in a red rectangular box. A red line extends from the bottom of this box to the text '“Physics”?' below. The right oval is not enclosed in a box.

Formation of
new bonds

“Physics”?

Breaking a bond
requires an input of
energy

How to bound the system

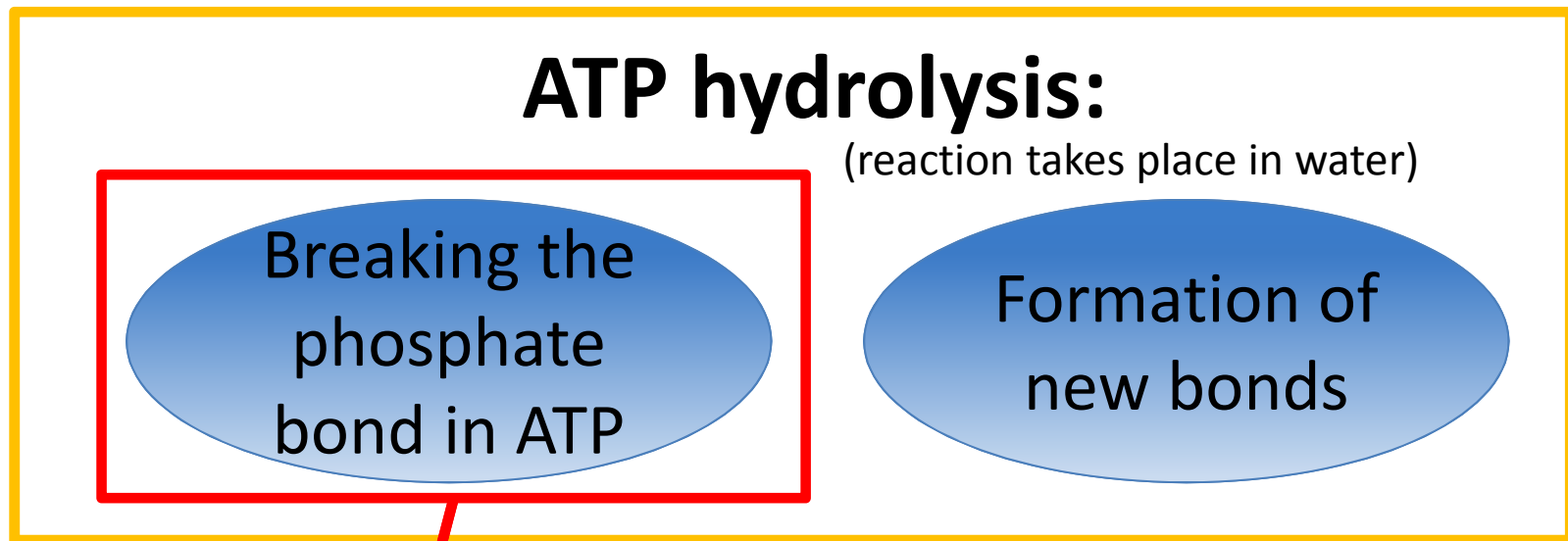


“Physics”?

“Biology”?

**Breaking a bond
requires an input of
energy**

How to bound the system



ATP hydrolysis:

(reaction takes place in water)

Breaking the
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Formation of
new bonds

“Physics”?

Breaking a bond
requires an input of
energy

“Biology”?

Breaking the
phosphate bond in ATP
releases energy

Summary

- Students may appear to have stable “misconceptions”, but Gregor is actually displaying context-dependent resources **linked to his perception of the disciplines.**
- This context-dependent reasoning may be productive!

A vision for interdisciplinary science education

- Reasoning **within** each discipline, using its own tools, in ways that are informed by and **coherent with** the other disciplines
- Making and justifying choices about how to model a phenomenon
- Flexibility in moving among models

Thank you

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Many thanks to the University of Maryland Physics Education Research Group (PERG) and Biology Education Research Group (BERG).

**Check out the poster:
Weds 9:50-10:30am FD07 (IPLS session)
Weds 8:30-10:30pm PERC**