Bioenergetics – Staying Alive

Teaching of Cell Respiration and Photosynthesis does not have to be difficult

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Difficulty with Teaching Bioenergetics.

It is Abstract

It is Highly Detailed

It is Hard to Understand

It is Boring Material

It's not relevant

Research Based Educational Practices to help students learn Bioenergetics

A. It is relevant
   A. Begin with examples of relevance
B. Teach overarching principles
   Understand concepts then provide labels
C. Give Broad Overviews of the topic
D. Use visualizations, metaphors or analogies to highlight difficult abstract concepts.
E. Metacognitive Exercises & Modeling

Background Context

- Simple Chemistry (Bio)
- Principles of Cell
- Cell Structure
- Organelle Functions
- Osmosis / Diffusion / Active Transport

Research Based Educational Practices A

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Relevance of Bioenergetics

- Diets
- Athletes
- Medical Issues
- Food production
- Gardening

Physiology of Learning

Eric R. Kandel M.D., Noble Prize Physiology of Medicine

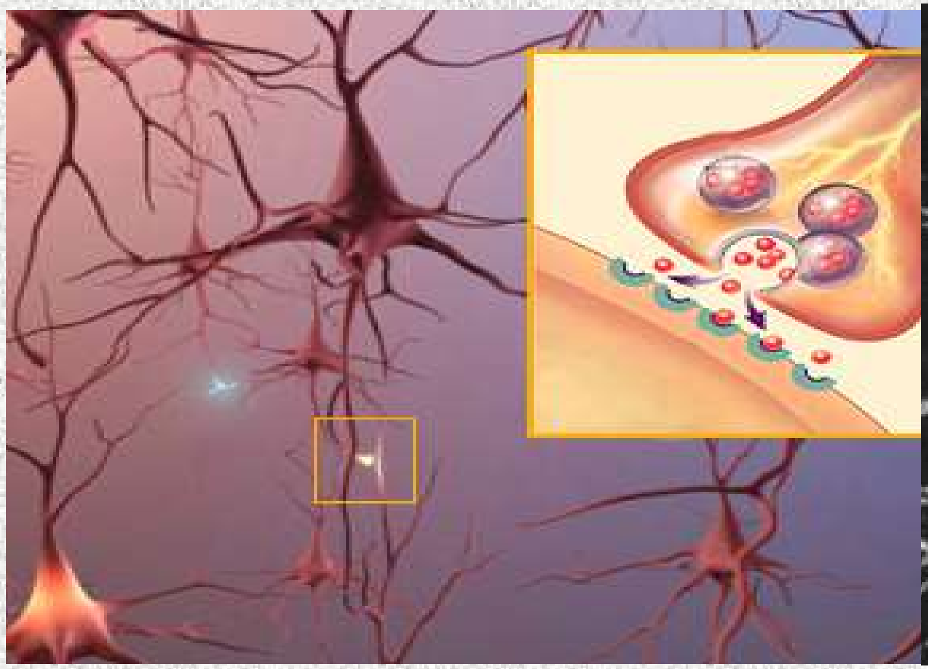
- Nerve growth requires the expression of Genes.
  - Modulated by attention
    - <u>Must be of interest to you/Value/Meaningful</u>
  - Genes are activated
  - Video of Eric Kandel and Modulatory Learning HHMI

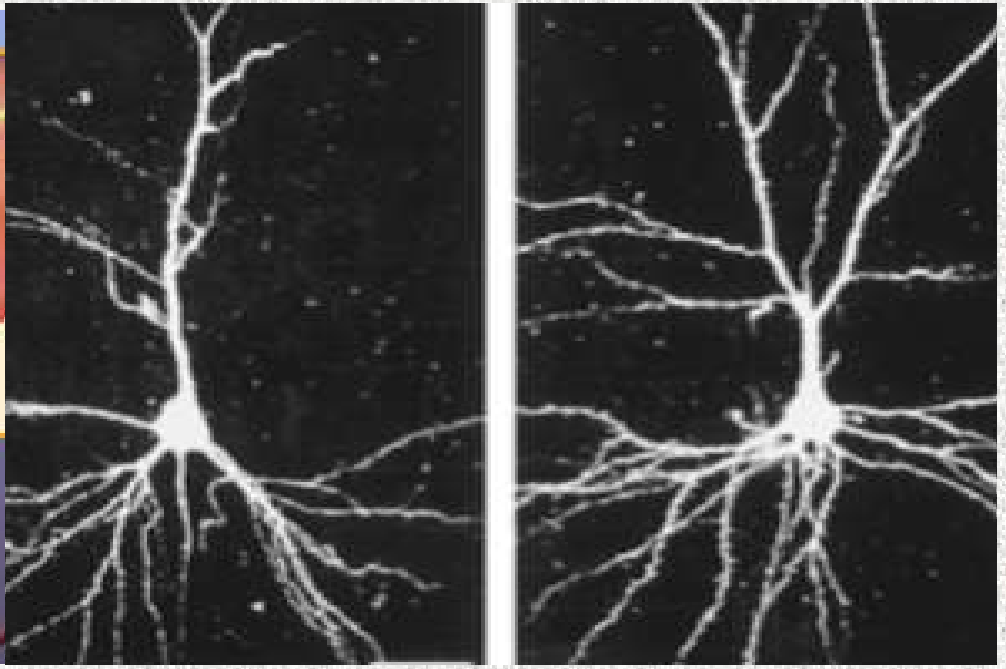
Physiological Development of Learning

Requires the growth of synapses

- Multiple stimulus causes dopamine recruitment
- Dopamine release Stimulates Genes for Synaptic Growth
- LTM has multiple synapse development

Synapses





Video to Engage Students

Research Based Educational Practices B

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E. Metacognitive Exercises & Modeling

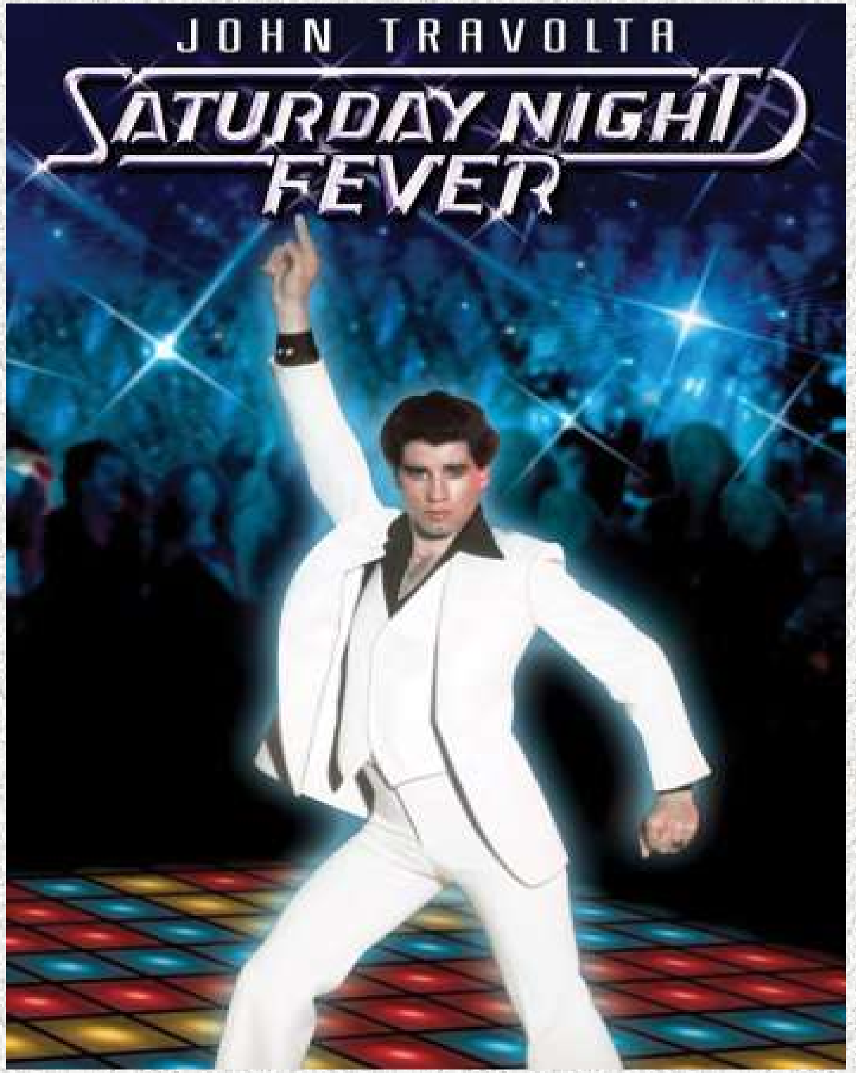
Overarching Principle: Problems with Energy Transfers in a Living Organism

1. How do we activate the energy compounds without producing a thermodynamically unstable molecule
2. How do we regulate the reactions without releasing the energy at a rate that makes the reaction thermodynamically unstable
3. When energy is released, how is it moved or stored so that the loss of energy is lessened.

Overarching Principle: Cells have a Solutions to the Problems

- Solved by 3 Principles and 3 compounds
  - Metastable Compounds & Enzymes
  - Small Energy steps & Enzymes
  - Coupled Reactions & Energy Carrying Molecules
- Having a Theme or Focus doesn't hurt

Staying Alive!



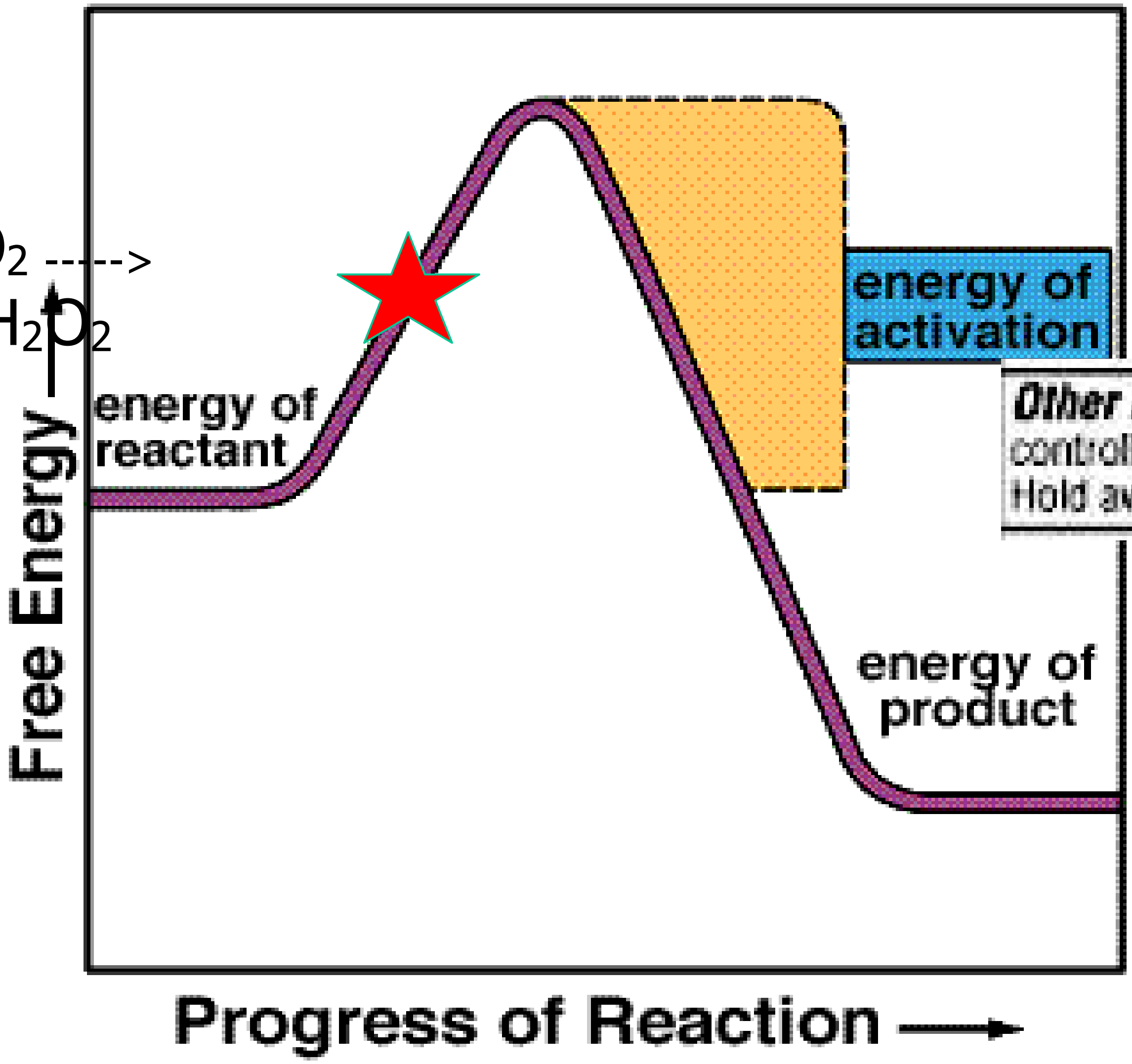
Principle 1

- How do we activate the energy compounds without producing a thermodynamically unstable molecule

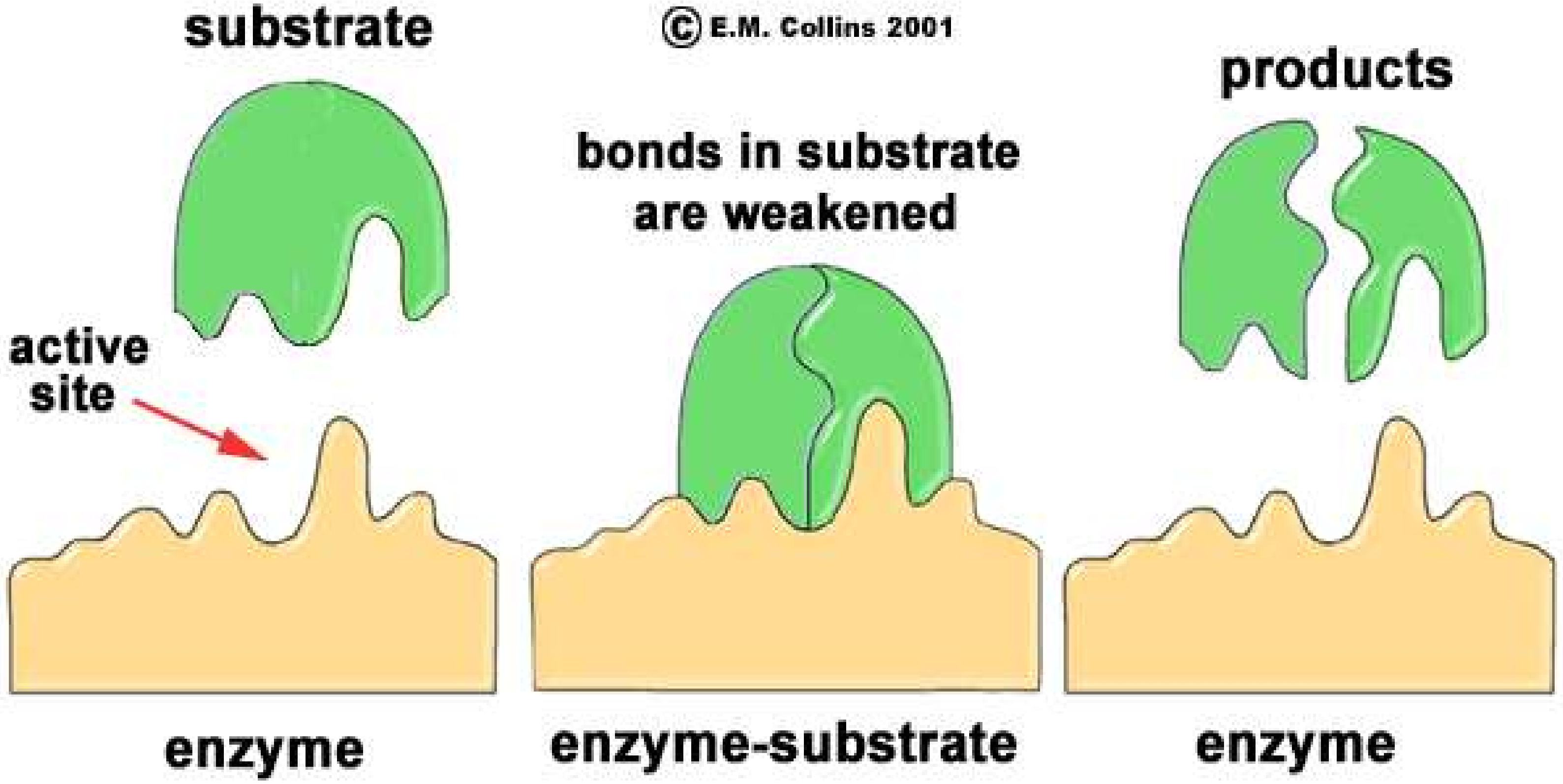
- Partially activate a compound to a level that requires only the presence of enzymes for reactions (Metastability)
    - e.g., H_2O_2
    - Kinetically Stable
    - Thermodynamically Unstable
    - $H_2O + 1/2\ O_2 \text{------------>}\ H_2O_2$

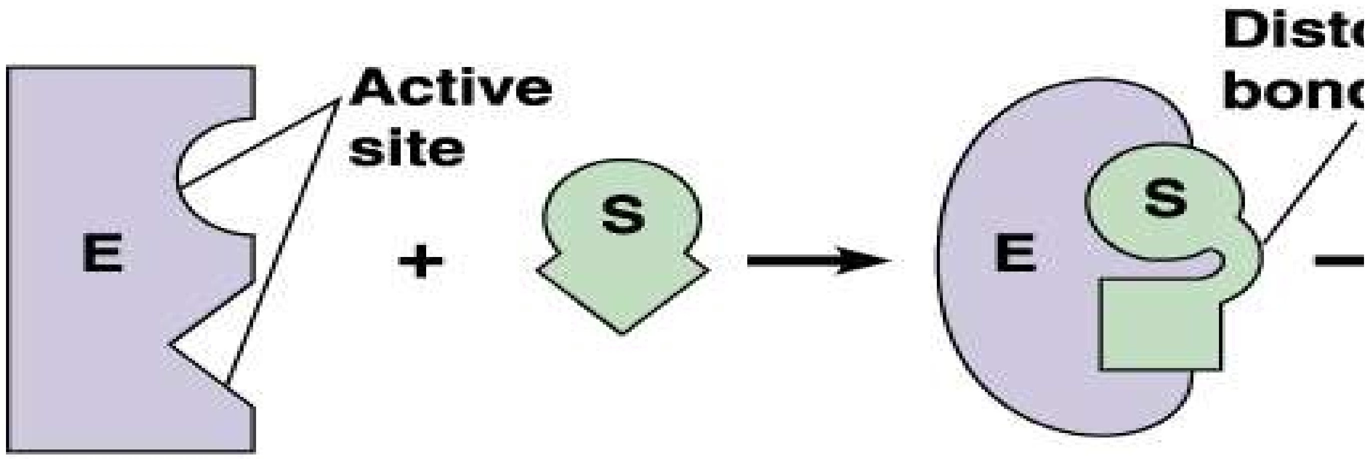
Energy of Activation (E_a)

$H_2O + 1/2\ O_2$ -----> H_2O_2

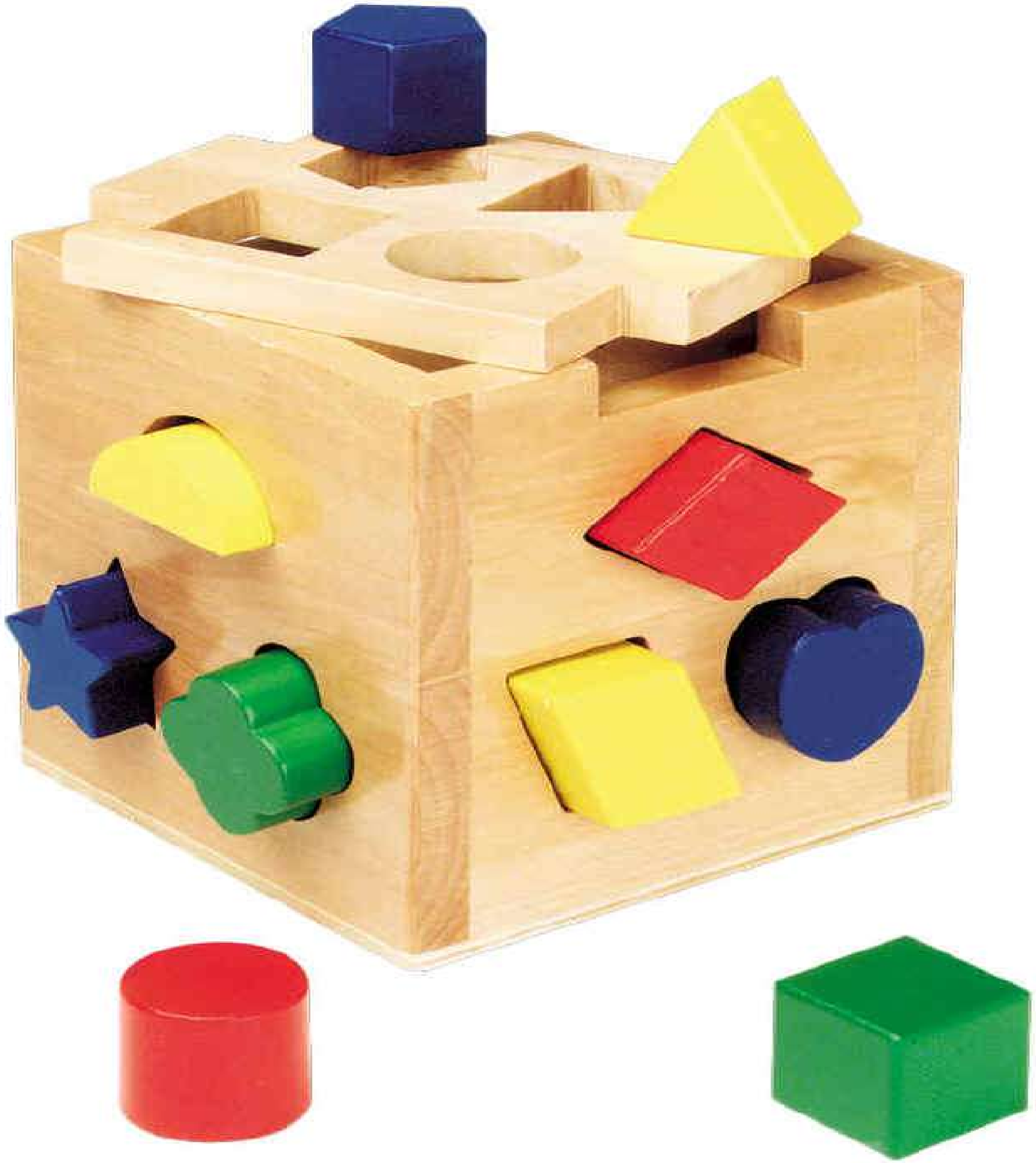


Enzyme Models

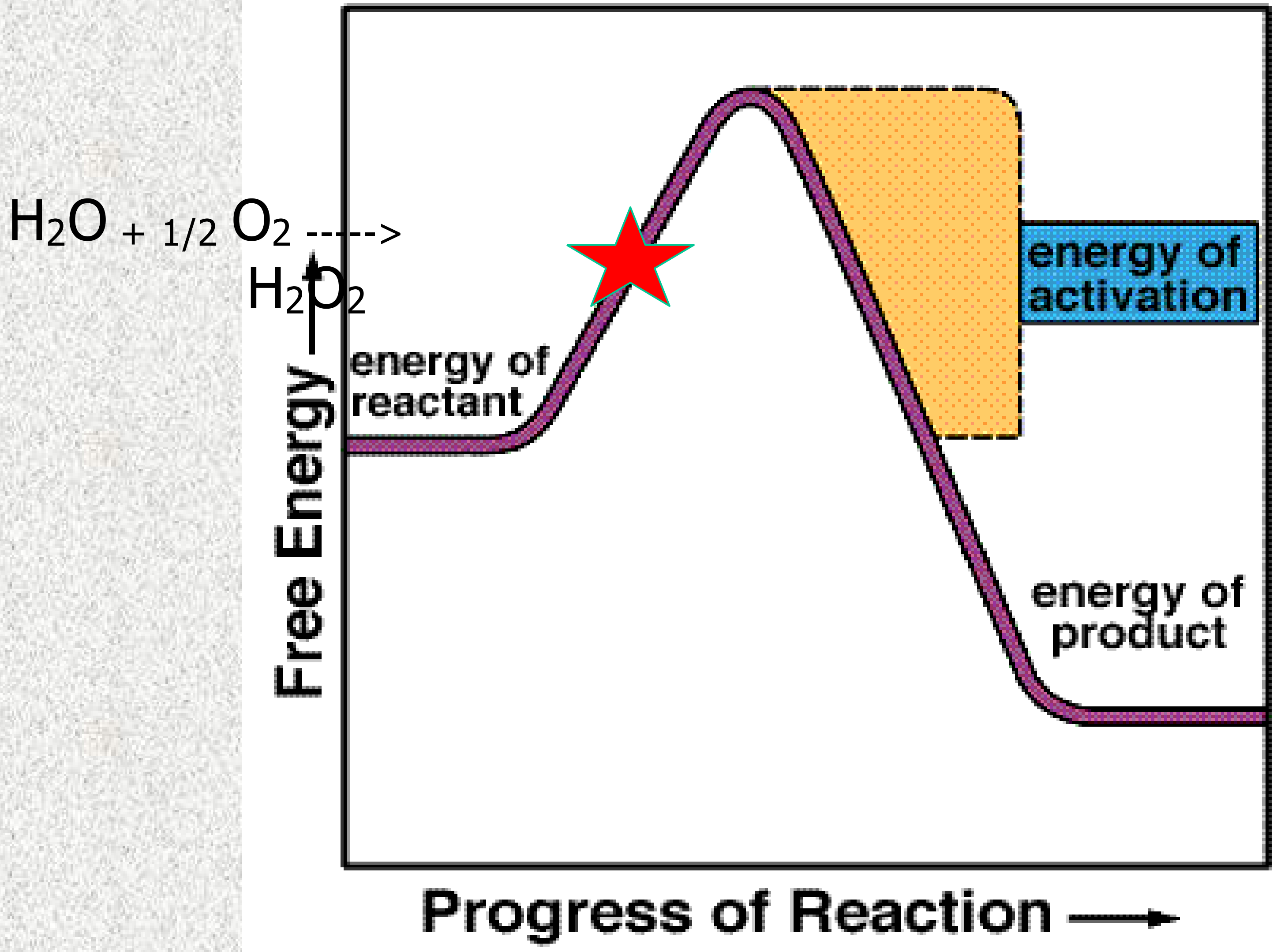




(b) Induced fit model



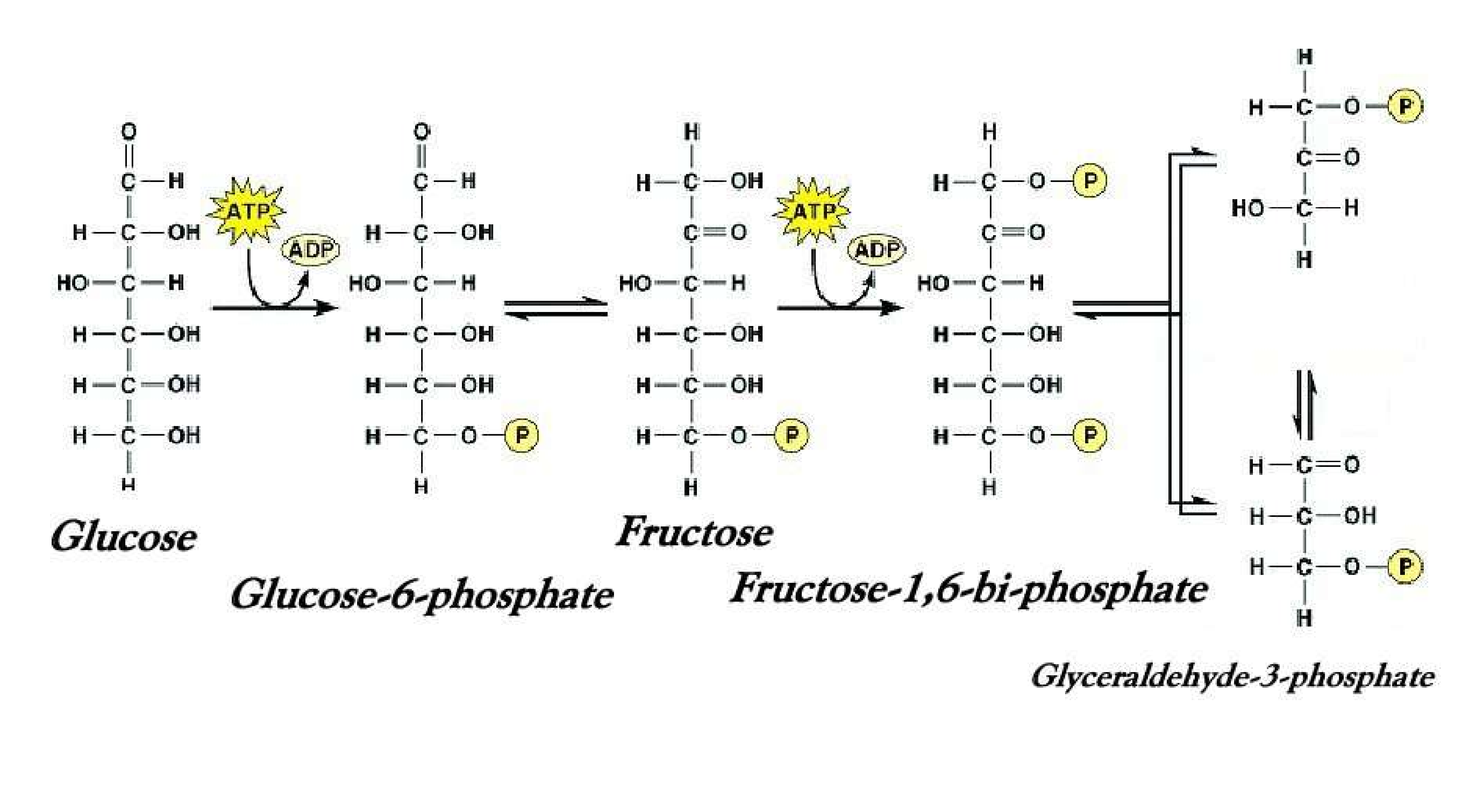
Energy of Activation (E_a)



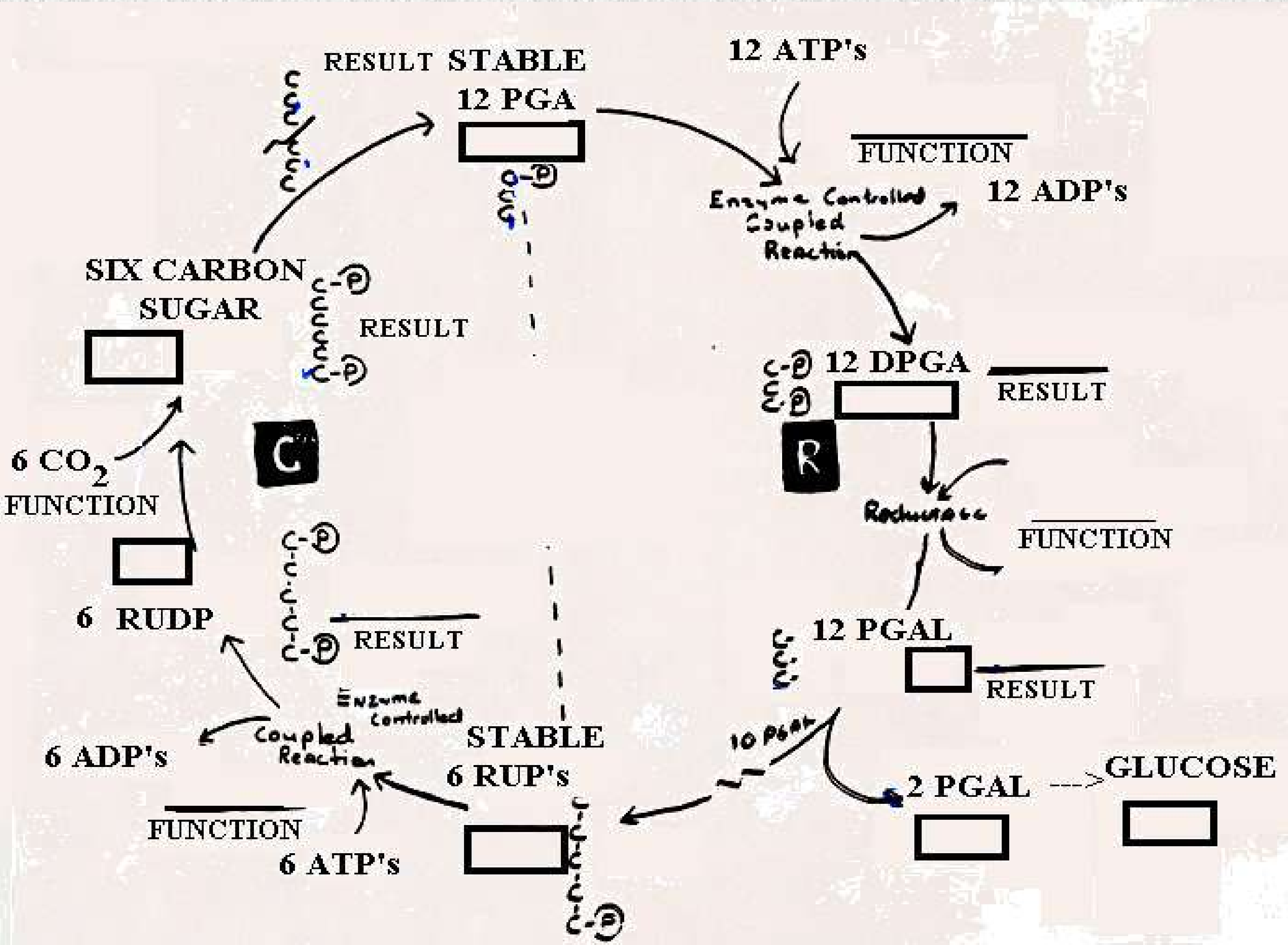
Question

- Where in the next two slides do you see the process developing metastability?

Glycolysis


ATP
ADP
ATP
ADP
Glucose
Glucose-6-phosphate
Fructose
Fructose-1,6-bi-phosphate
Glyceraldehyde-3-phosphate

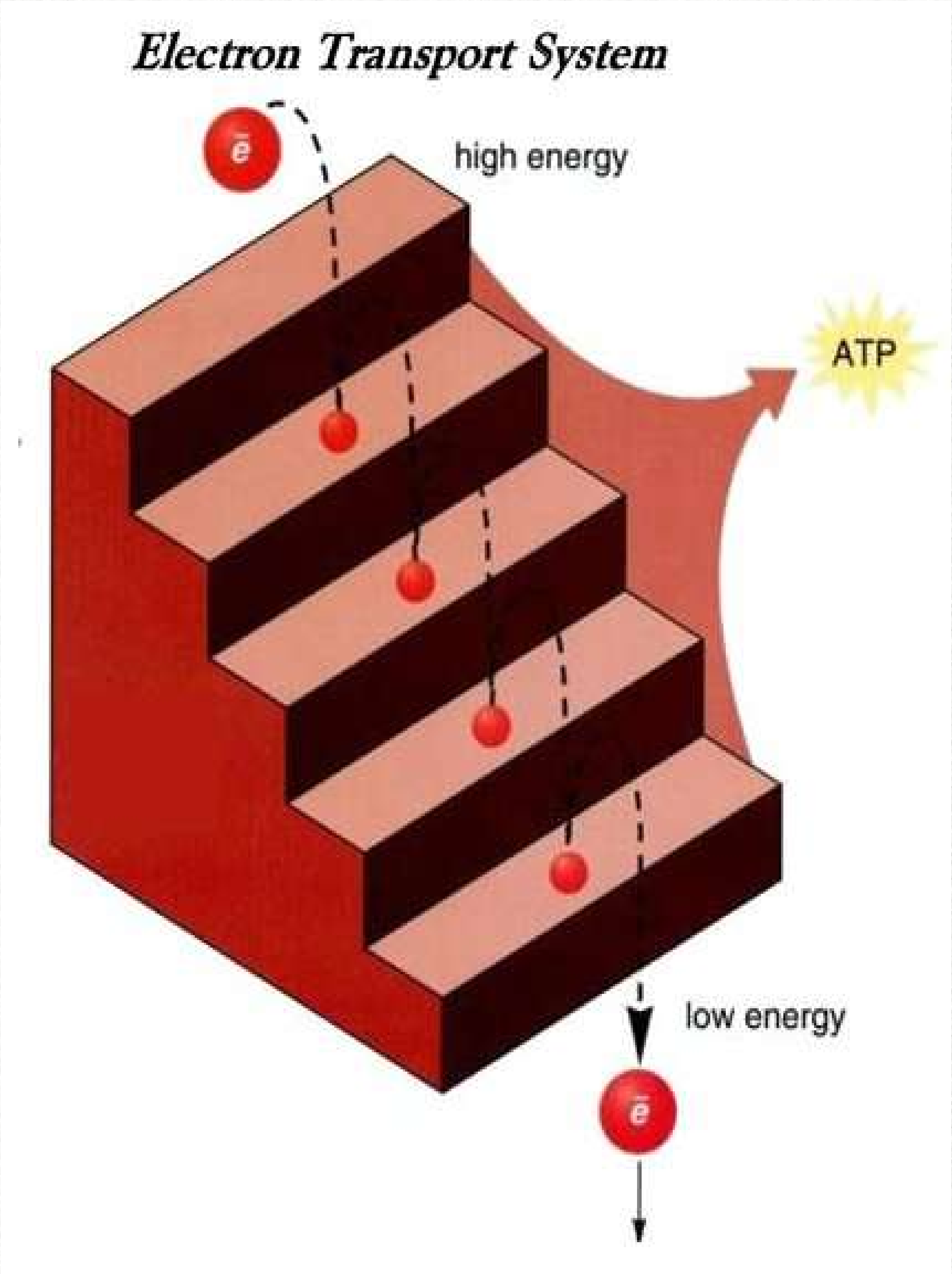
Calvin Cycle



Principle 2

How do we regulate the reactions without releasing the energy at a rate that makes the reaction thermodynamically unstable

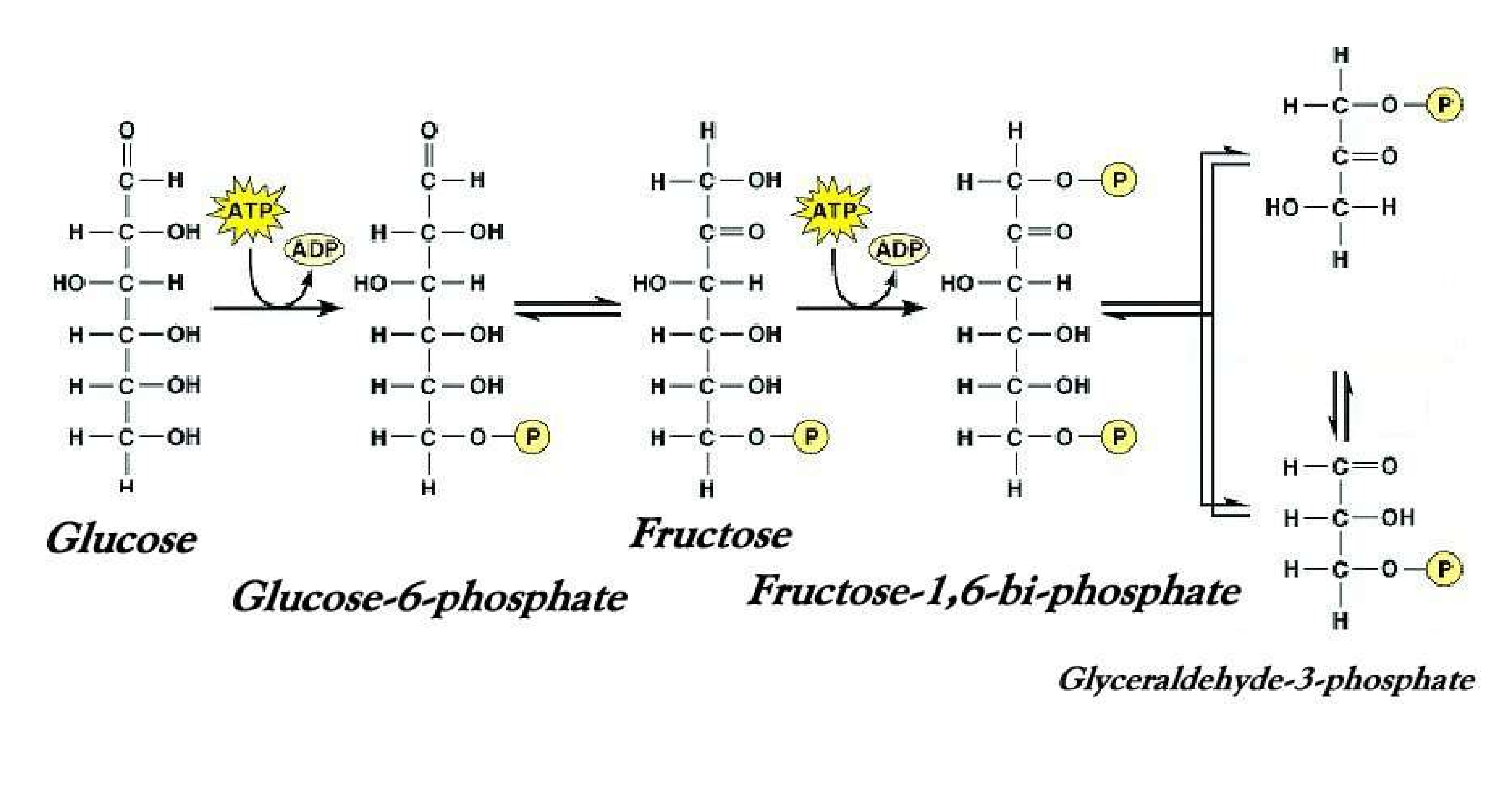
- The rate of the chemical reaction must be controlled.
- Use small steps where energy is released in small steps.

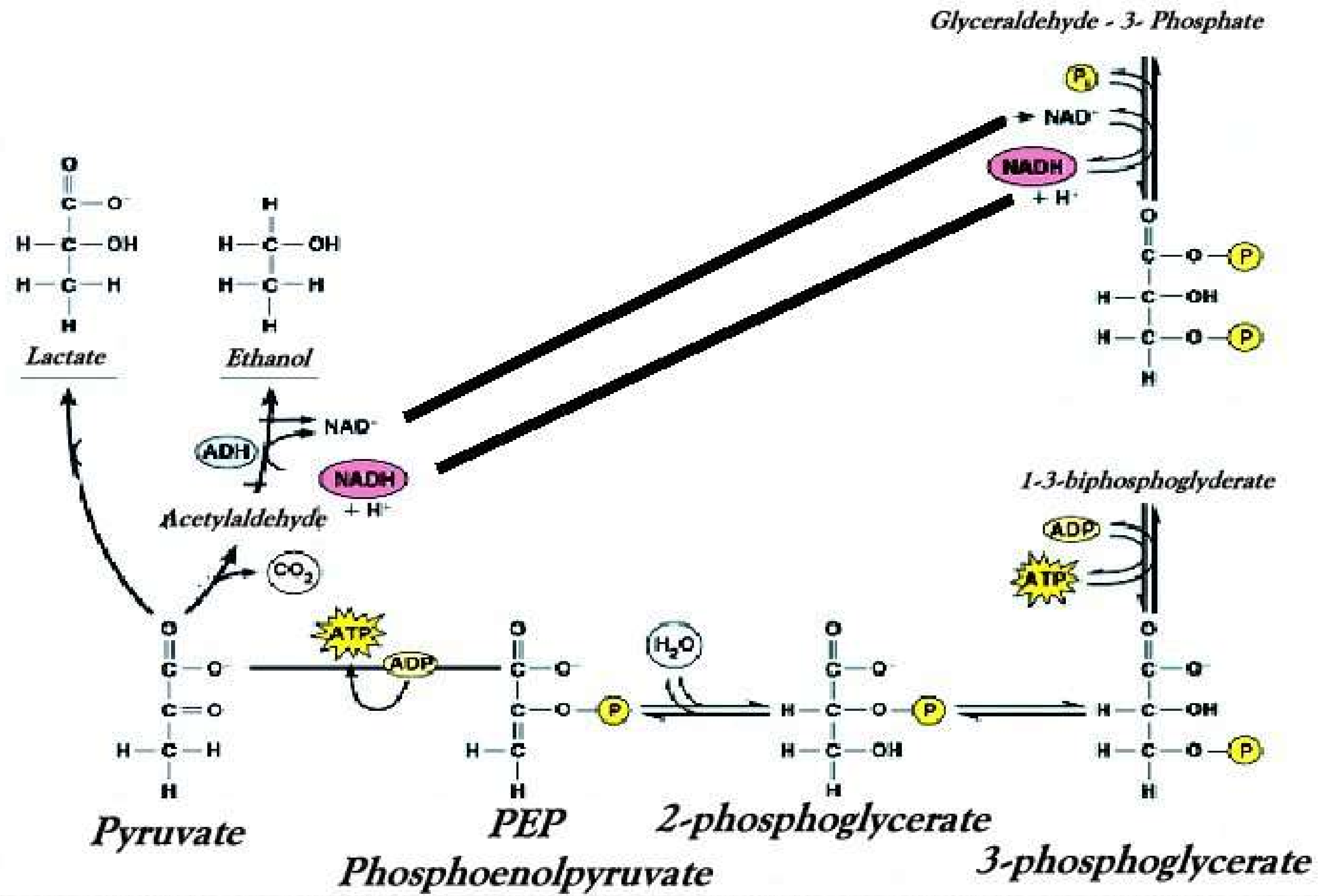



GUINNESS

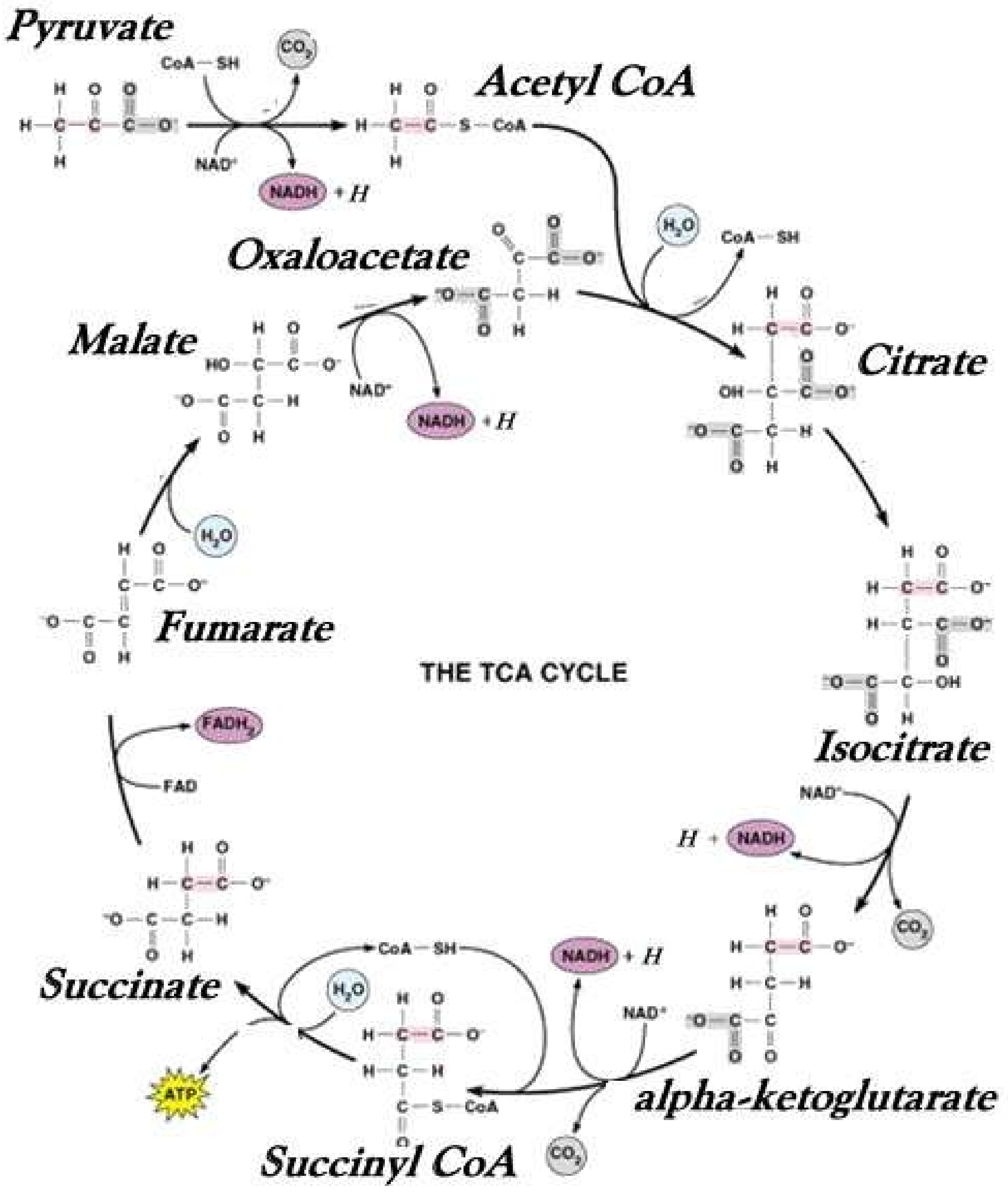
Identify Principle 2

- Where in the next slides do you see the principle being enacted?


ATP
ADP
ATP
ADP
Glucose
Glucose-6-phosphate
Fructose
Fructose-1,6-bi-phosphate
Glyceraldehyde-3-phosphate



Glyceraldehyde - 3- Phosphate
NAD+
NADH
+ H+
1-3-biphosphoglyderate
ADP
ATP
Lactate
Ethanol
ADH
NAD+
NADH
+ H+
Acetylaldehyde
CO2
ATP
ADP
H2O
Pyruvate
PEP
Phosphoenolpyruvate
2-phosphoglycerate
3-phosphoglycerate



For each Pyruvate the following are generated:

- 3 CO_2's
- 1 ATP
- 4 NADH + H
- 1 $FADH_2$

METABOLIC PATHWAYS:

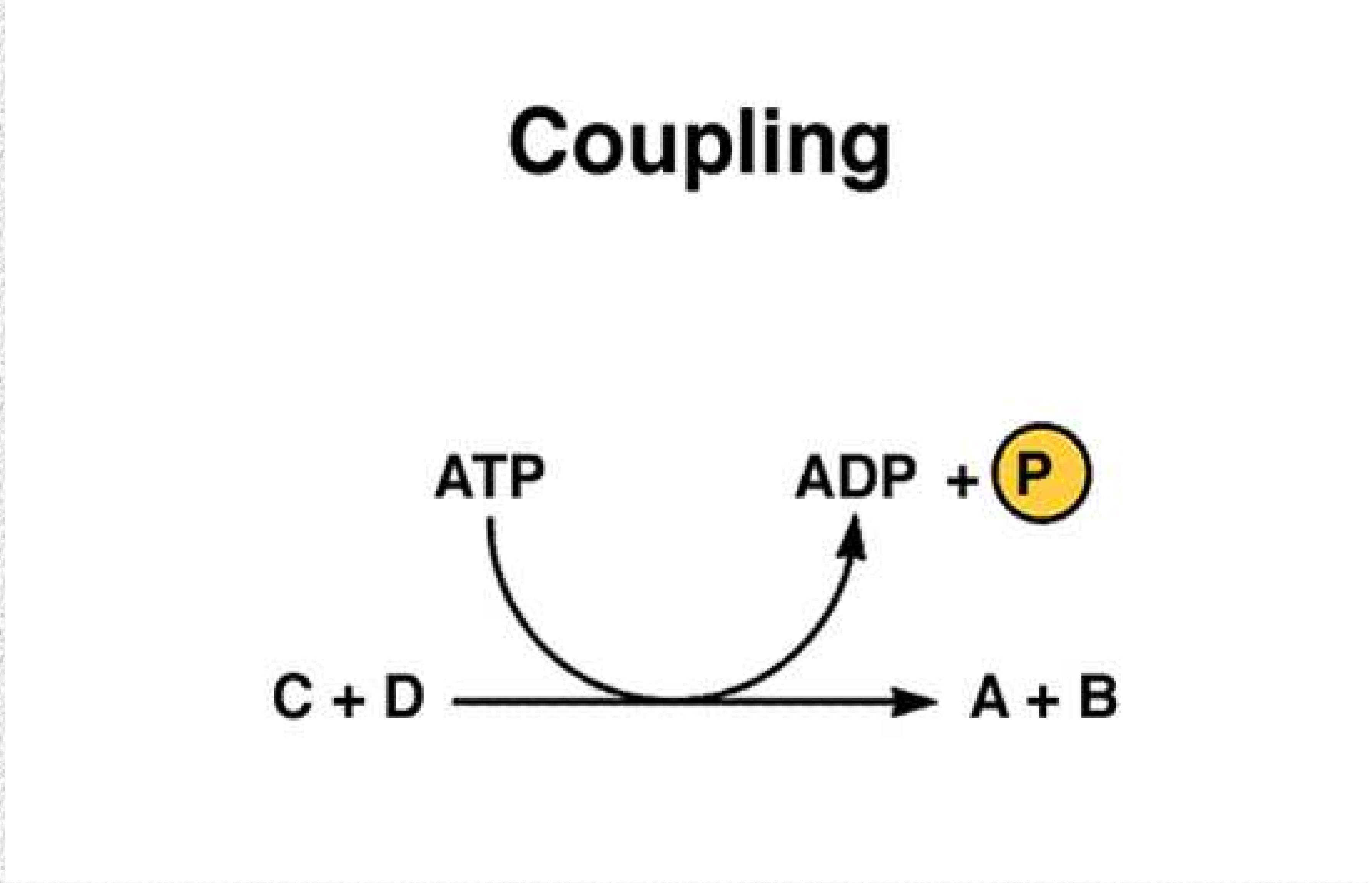
- Sequence of reactions controlled by enzymes.
- TYPES:
  - Catabolic-breakdown of large molecules release of energy.
  - Anabolic-building of large molecules and the storage of energy.

Principle 3

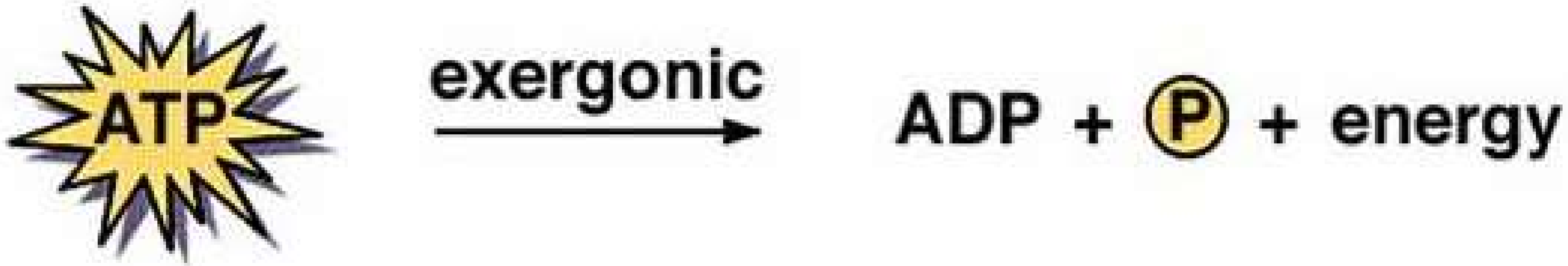
When energy is released, how is it moved or stored so that the loss of energy is lessened.

- Energy transforming reactions are coupled in biological systems
  - Catabolic versus Anabolic
  - Oxidation versus Reduction
  - Exergonic versus Endergonic
  - Phosphorylating versus Dephosphorylating
- Energy Molecule to pick up and transfer energy bonds
  - ATP and Coenzymes

As reaction c+d goes to A + B, energy is dropped off by the ATP as it becomes ADP + P

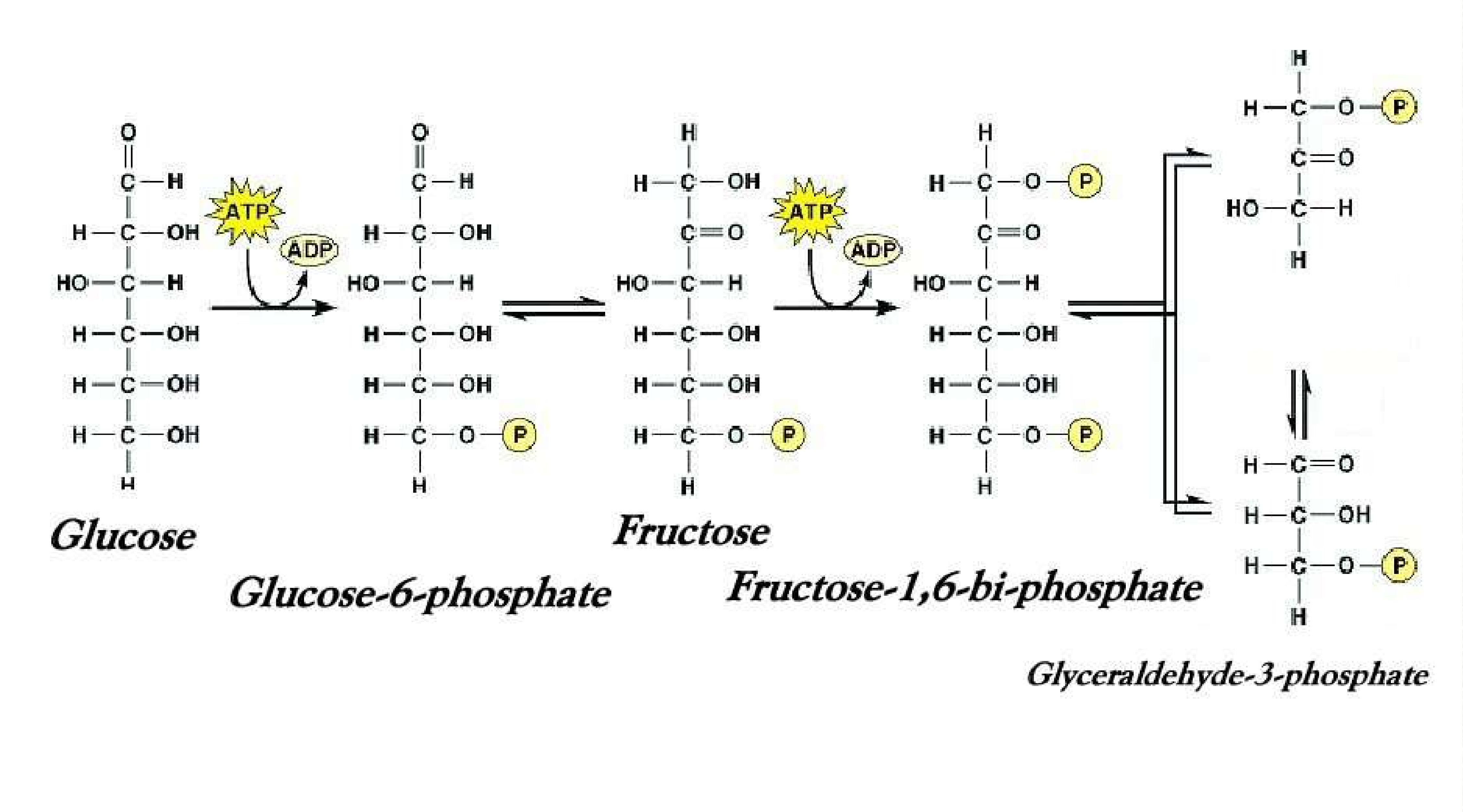


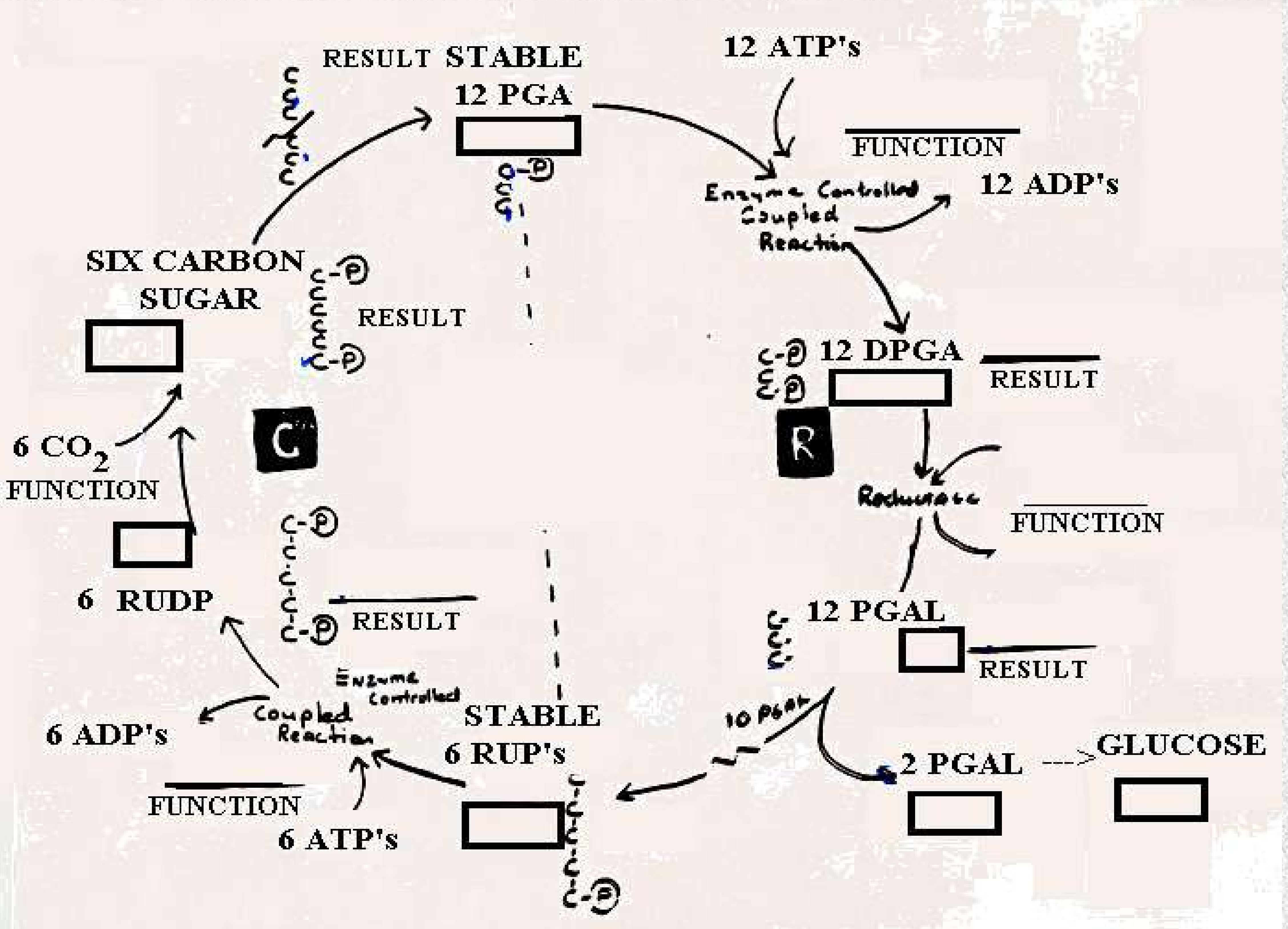
Exergonic Reaction



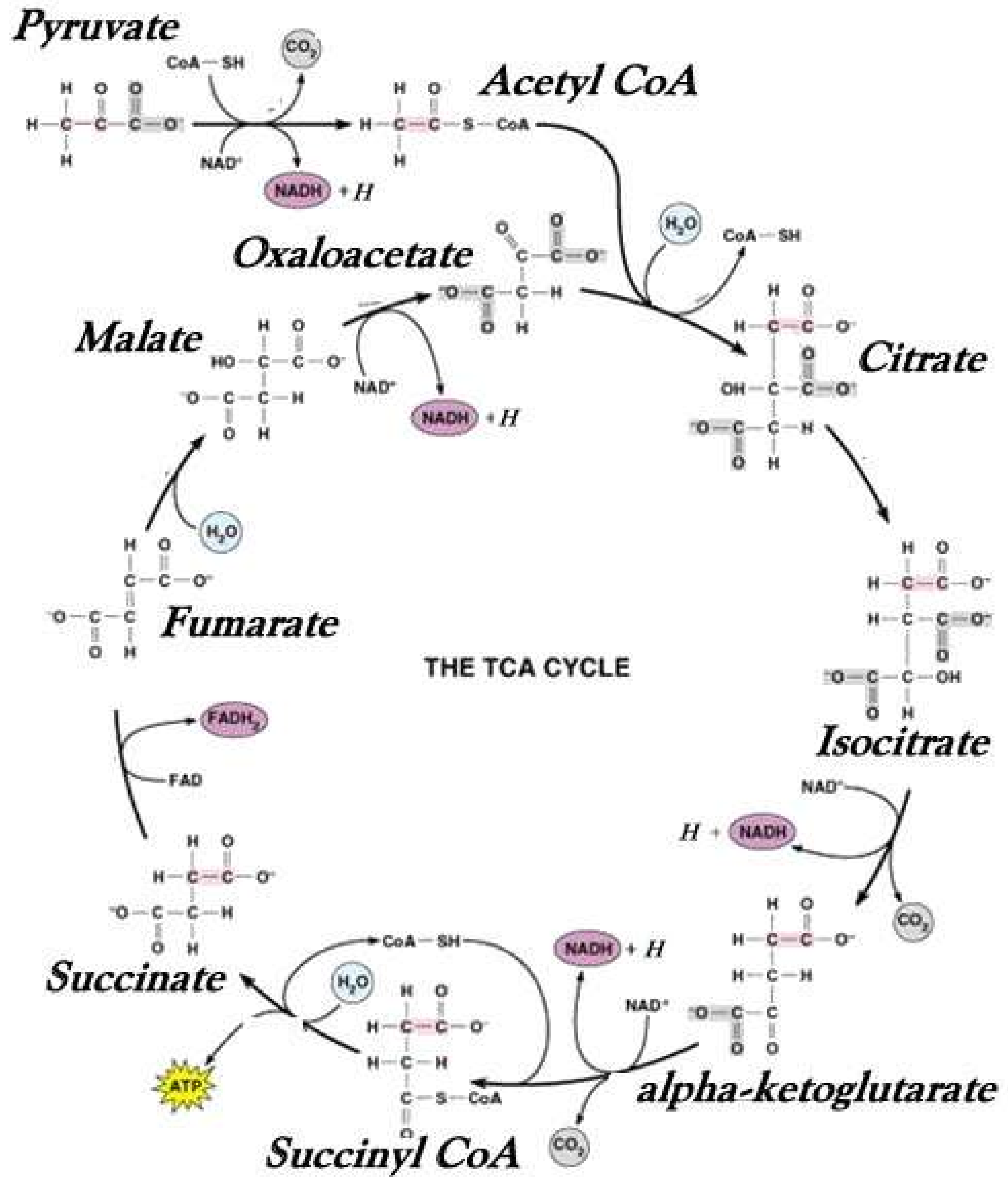
Identify the coupled reactions in the next two slides?

Cleavage Preparation





RESULT
STABLE
12 PGA
12 ATP's
FUNCTION
Enzyme Controlled
Coupled
Reaction
12 ADP's
SIX CARBON
SUGAR
RESULT
12 DPGA
RESULT
C
R
6 CO_2
FUNCTION
Reductase
FUNCTION
6 RUDP
RESULT
12 PGAL
RESULT
10 PGAL
2 PGAL ---> GLUCOSE
Enzyme
controlled
Coupled
Reaction
STABLE
6 RUP's
6 ADP's
FUNCTION
6 ATP's



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Research Based Educational Practices C, D, E

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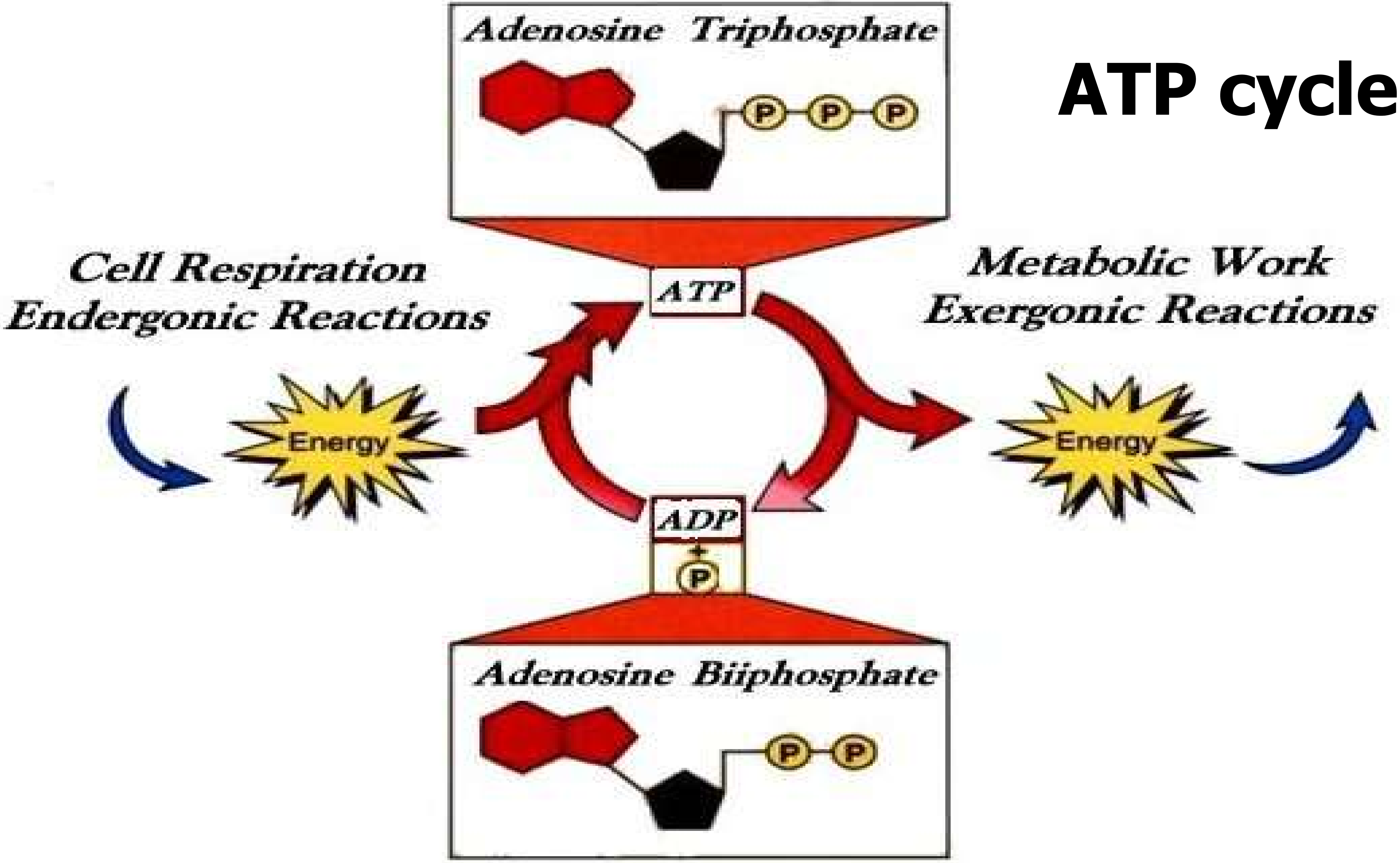
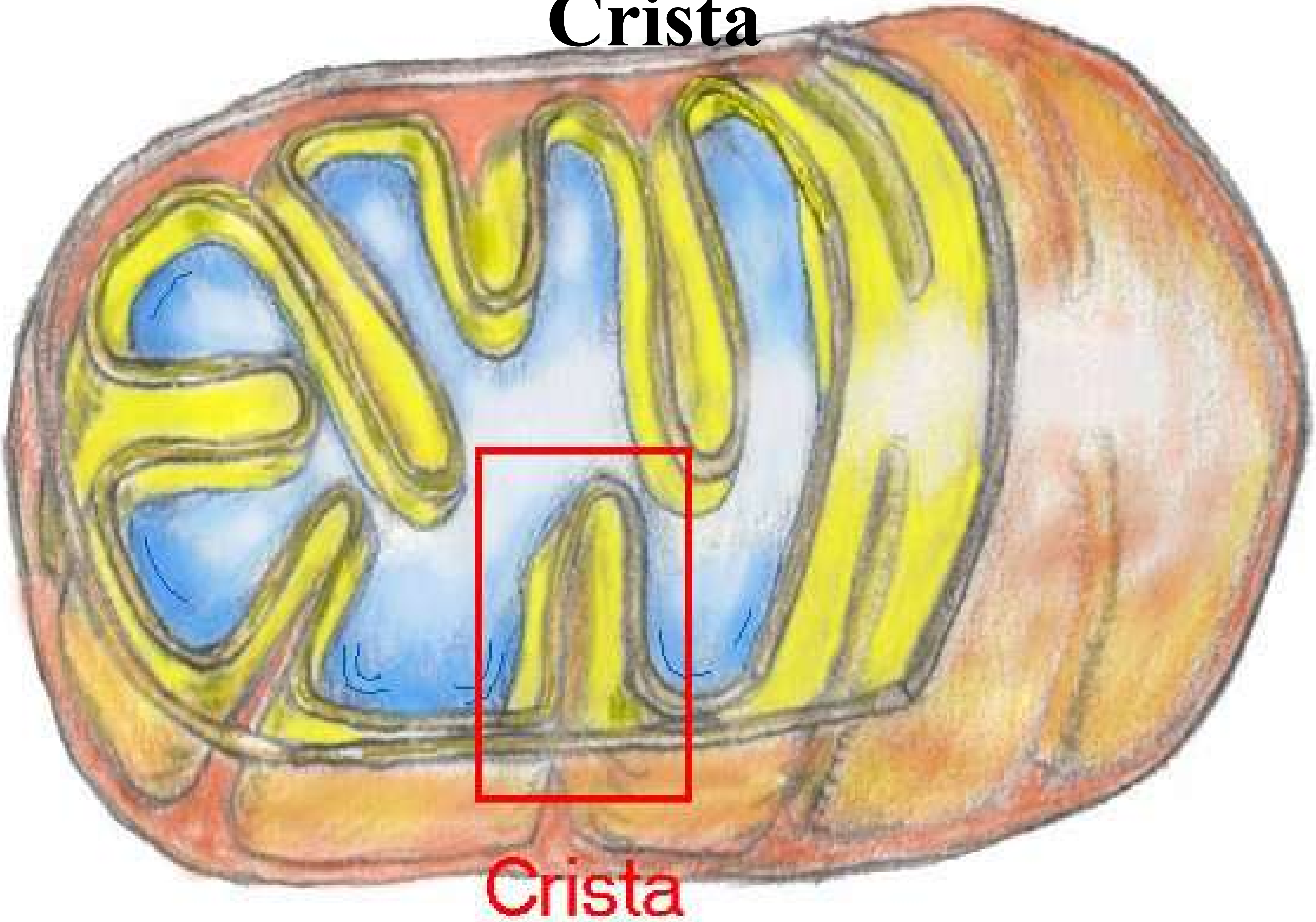
ATP cycle



Adenosine Triphosphate
P
P
P
Cell Respiration
Endergonic Reactions
ATP
Metabolic Work
Exergonic Reactions
Energy
Energy
ADP
+
P
Adenosine Biiphosphate
P
P

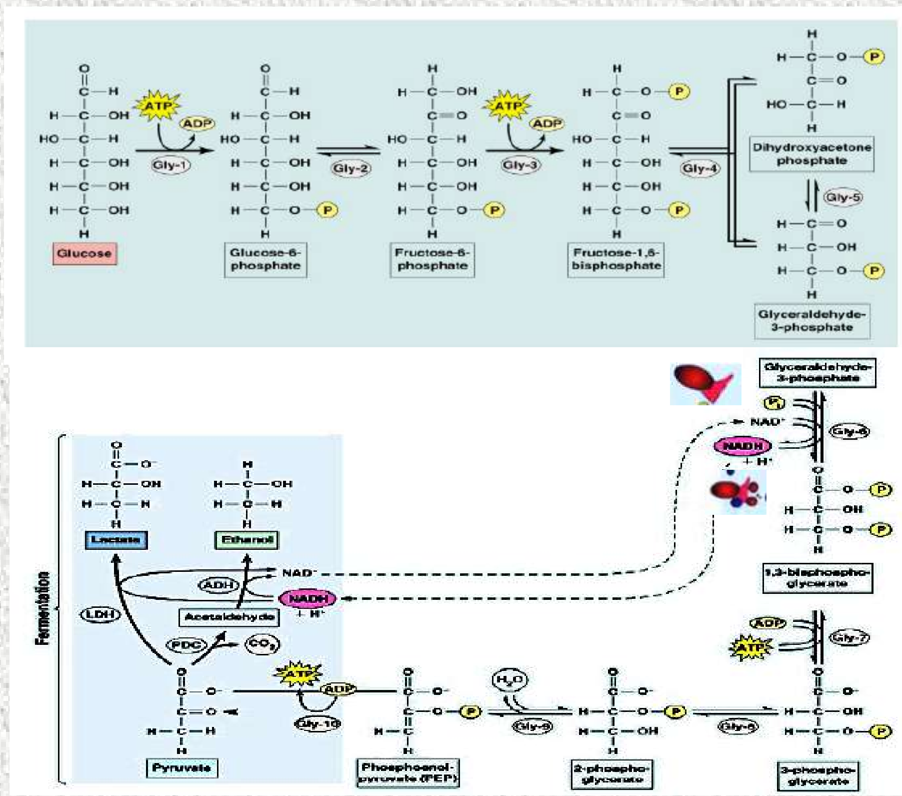
Mitochondrion

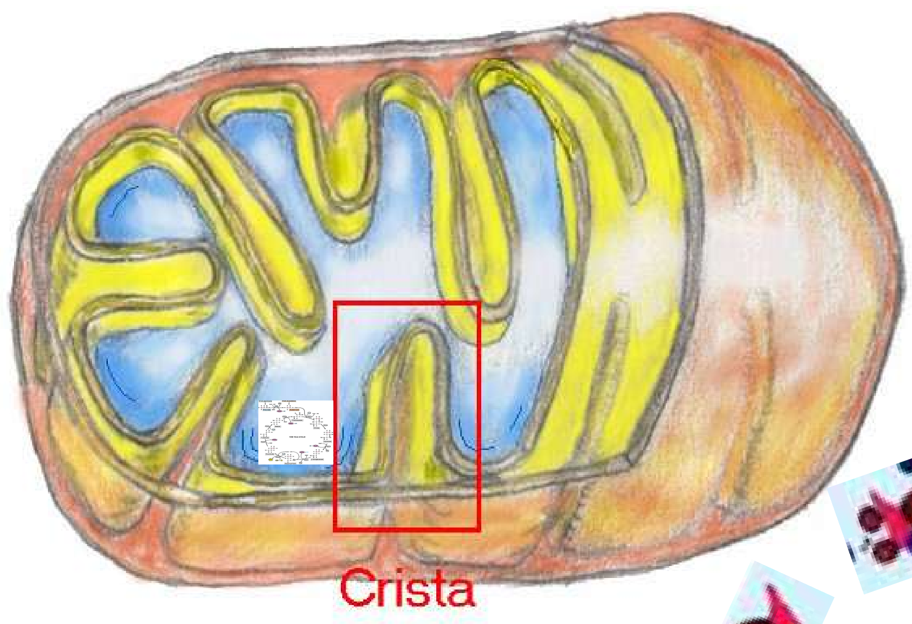
Crista

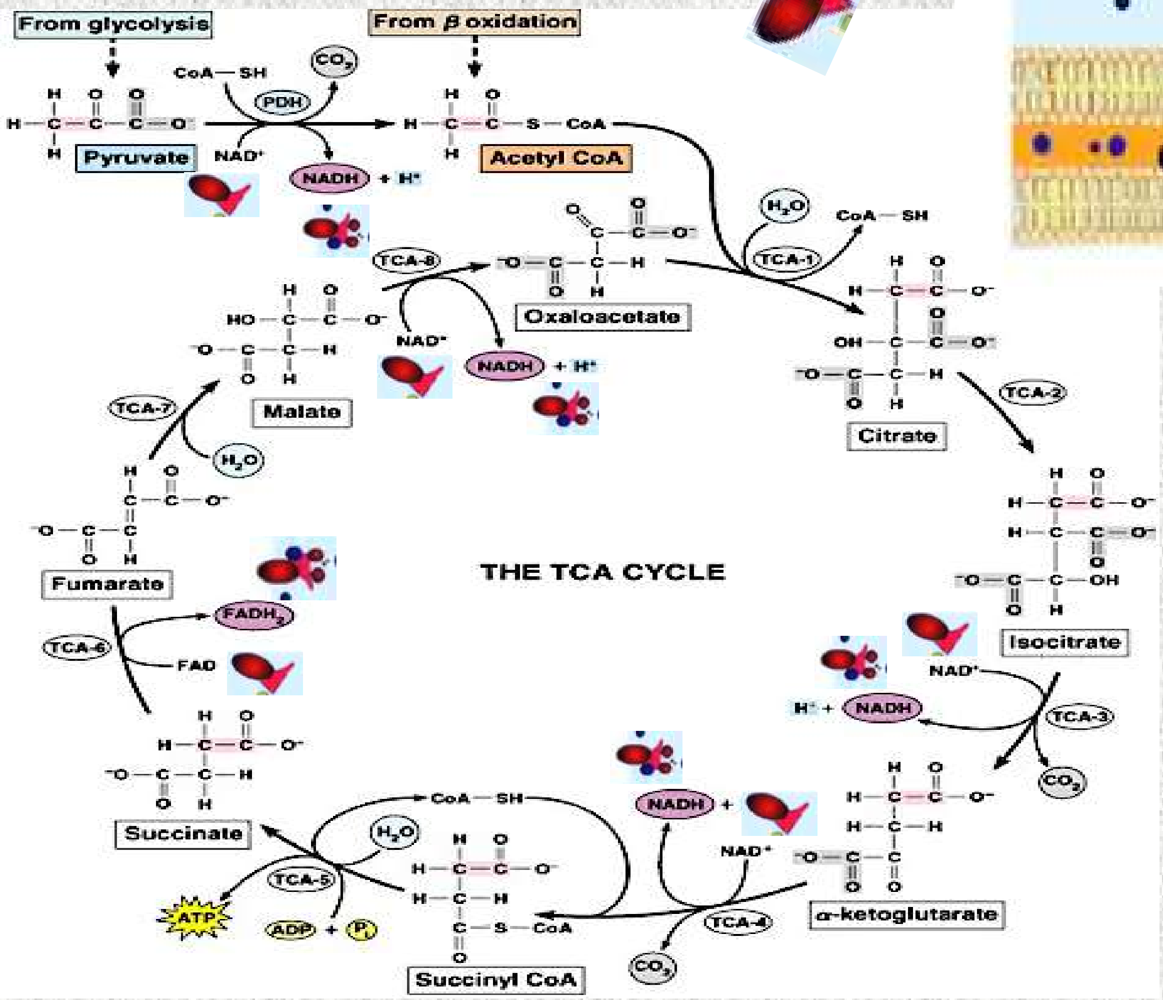


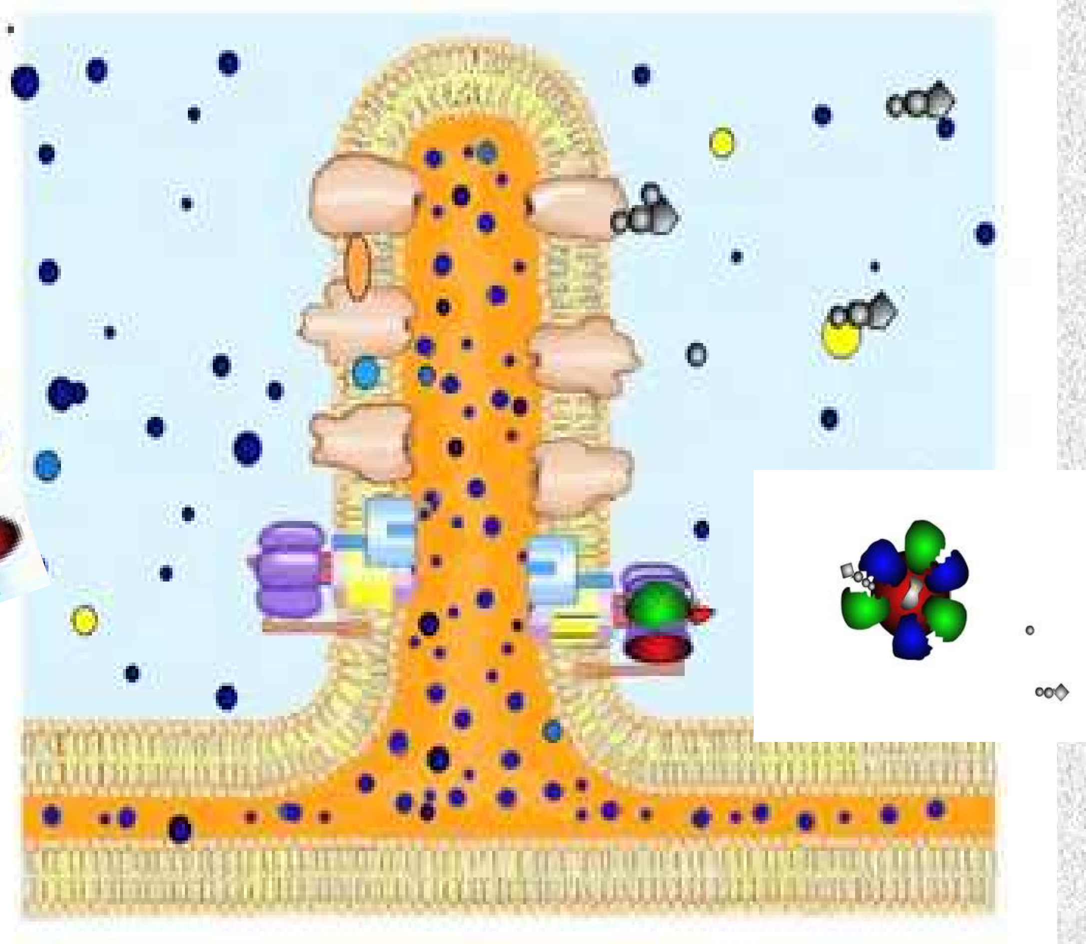
3 Problems Solved by 3 Principles and 3 compounds

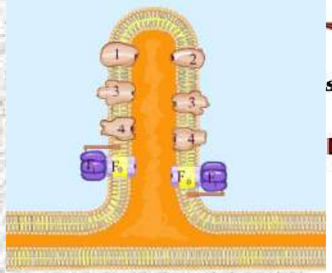
1. Partial Activation & Metastable Compounds
2. Small Energy steps & Enzymes
3. Coupled Reactions & Energy Carrying Molecules

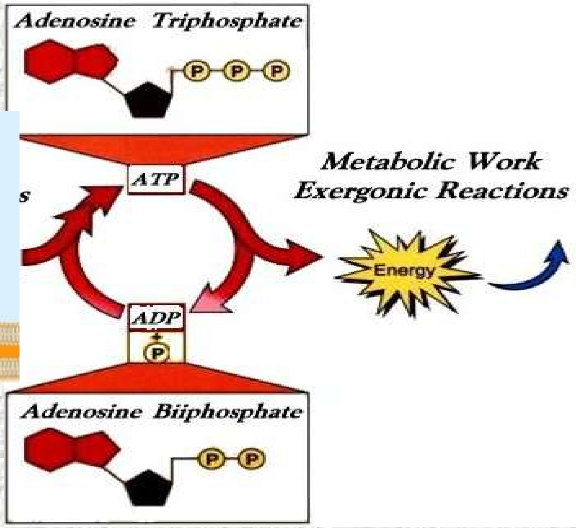




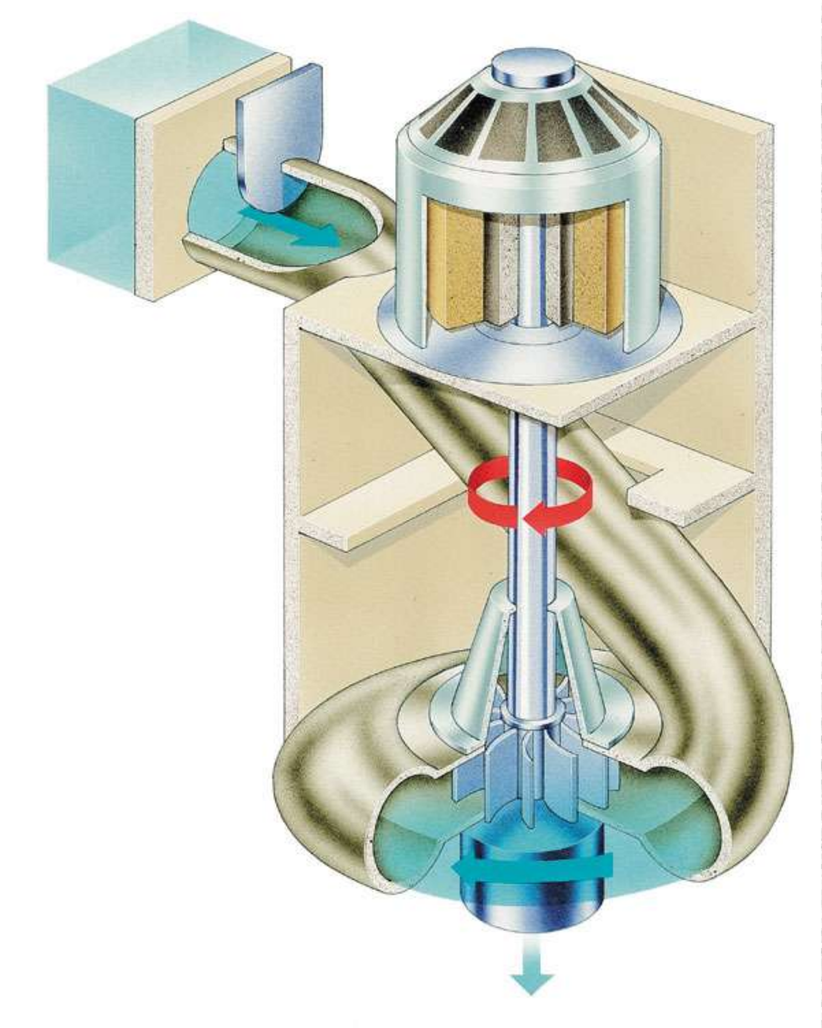




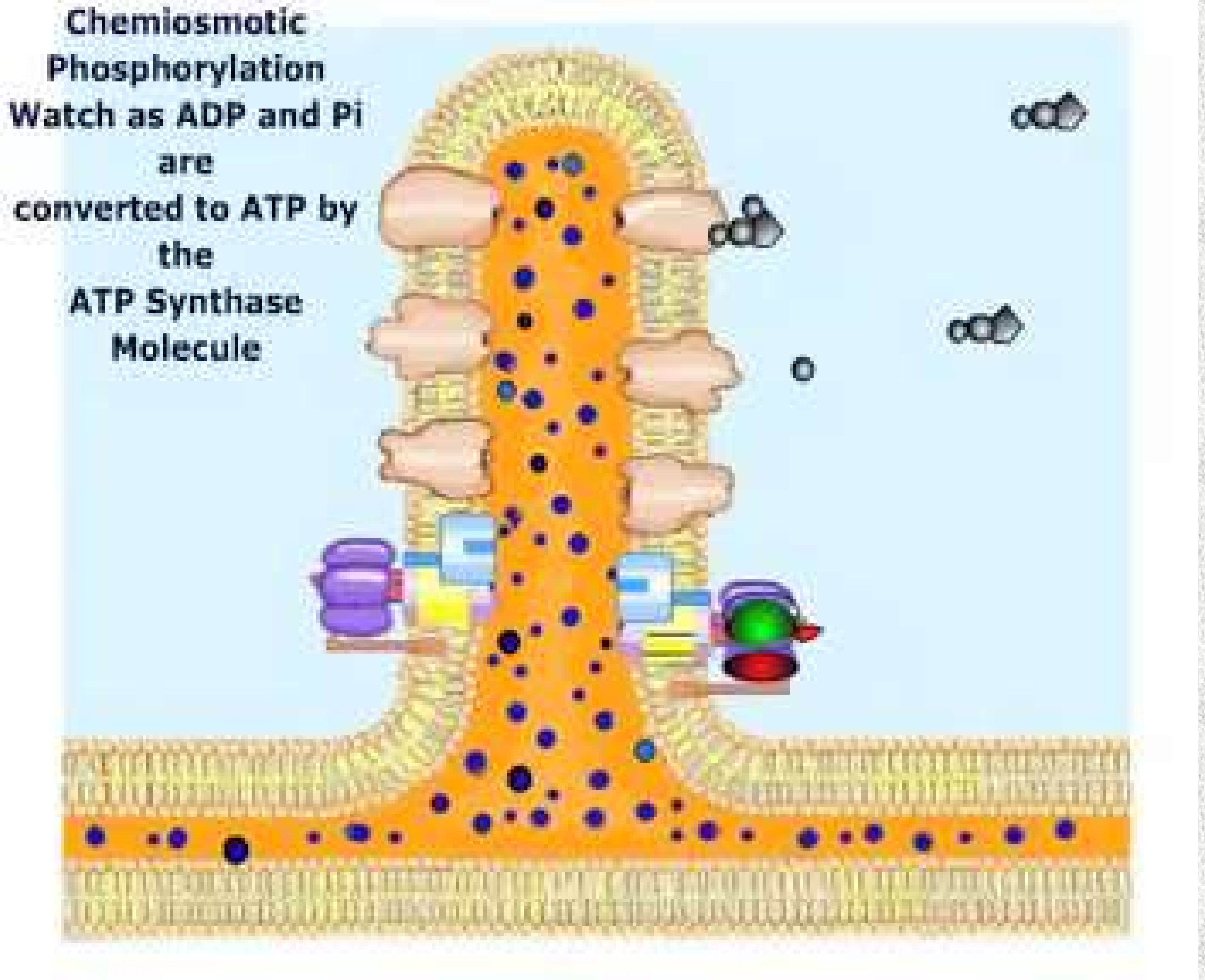




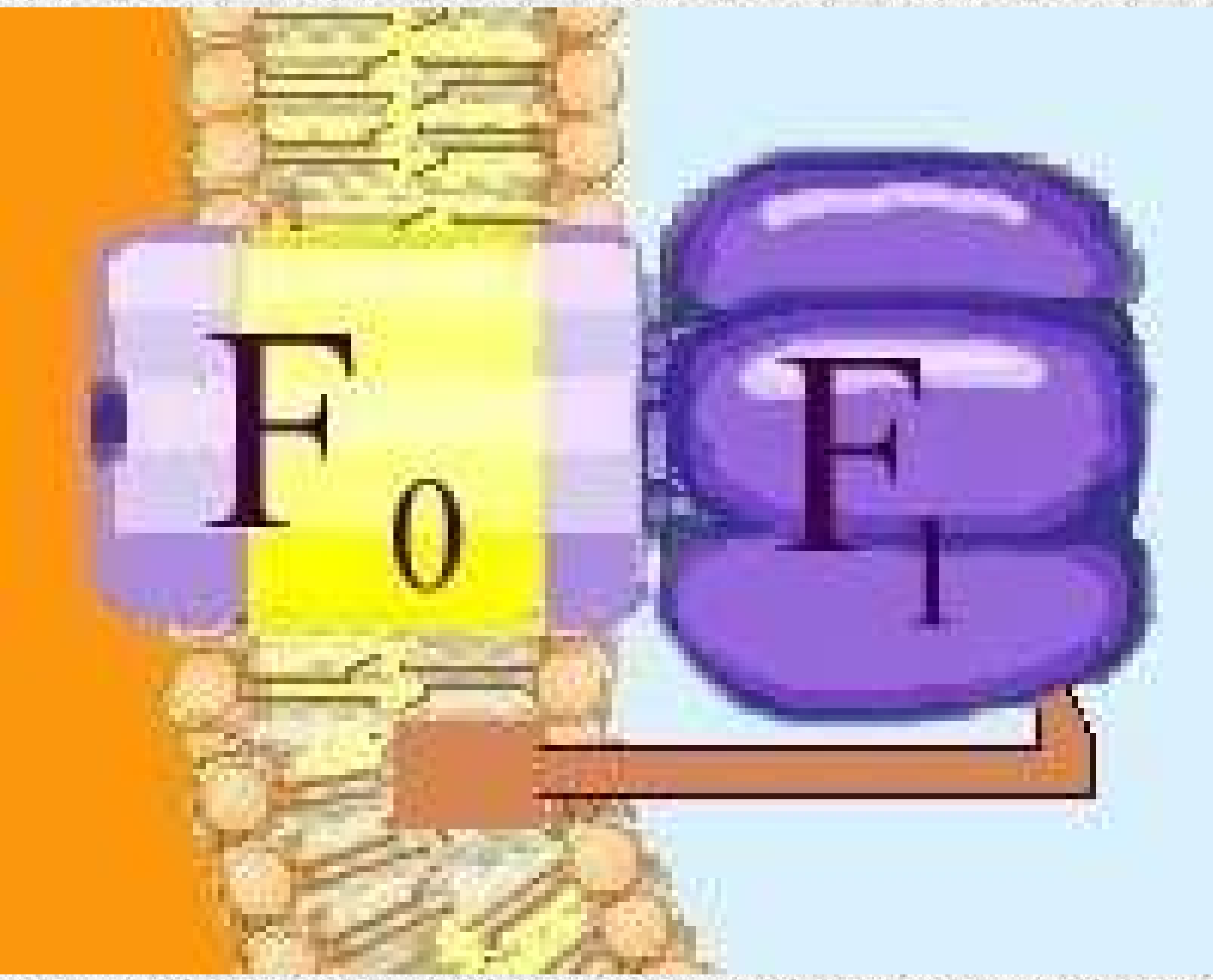
Make Analogies

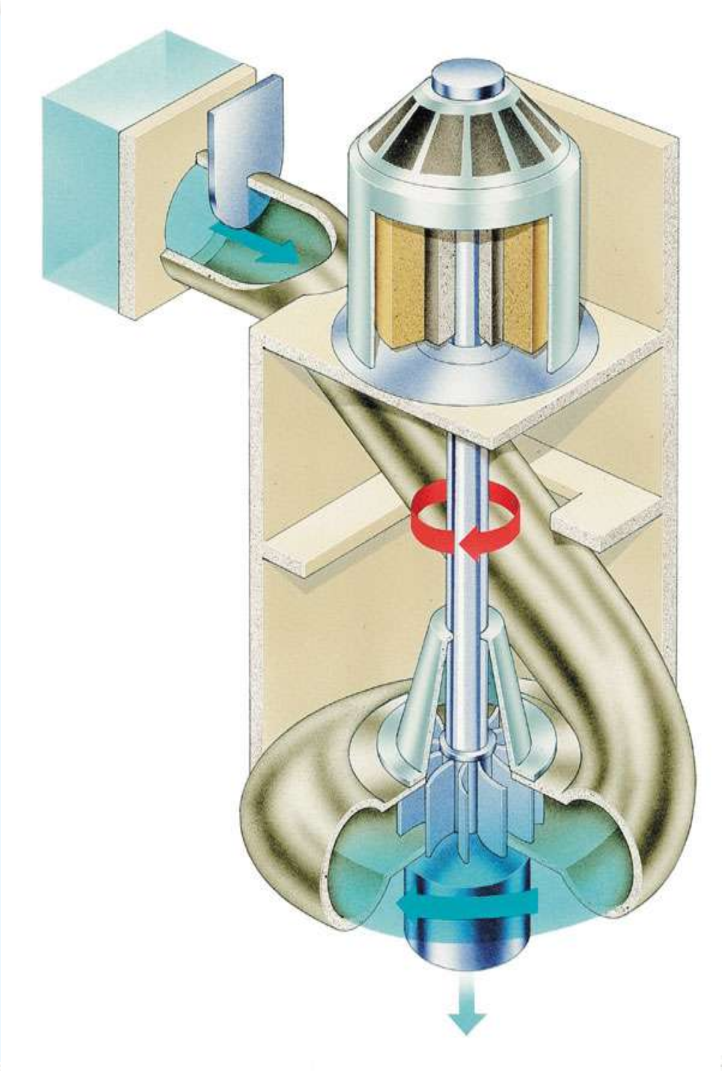


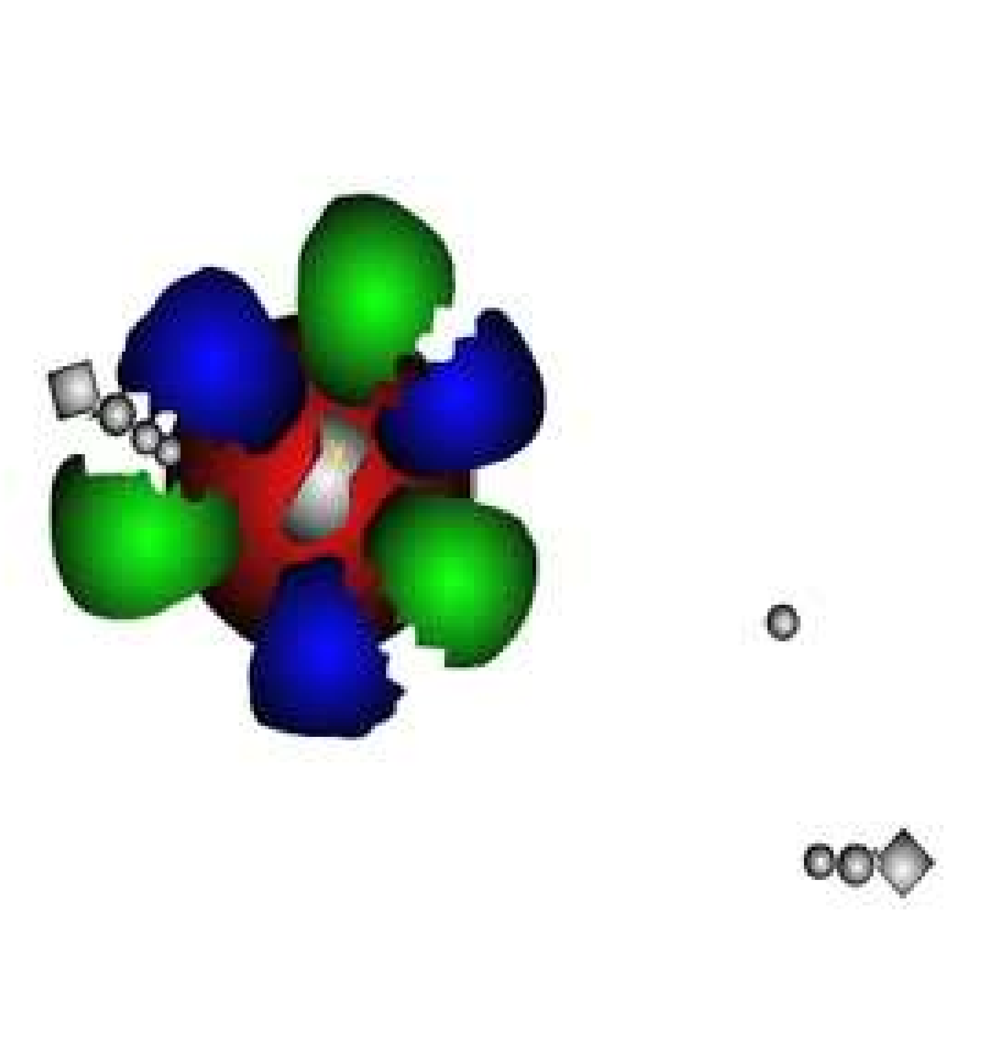
Chemiosmotic Phosphorylation



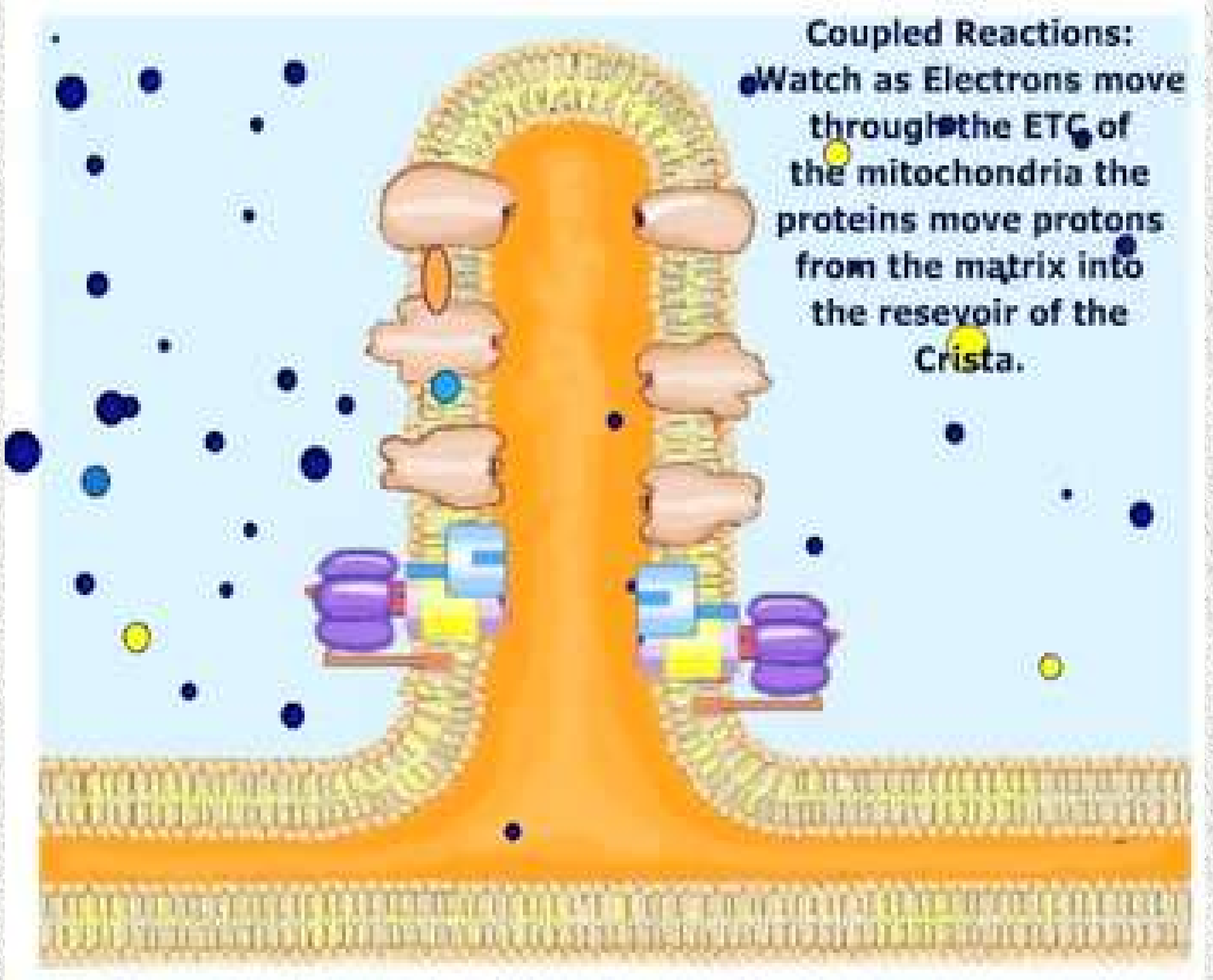
ATP Synthase

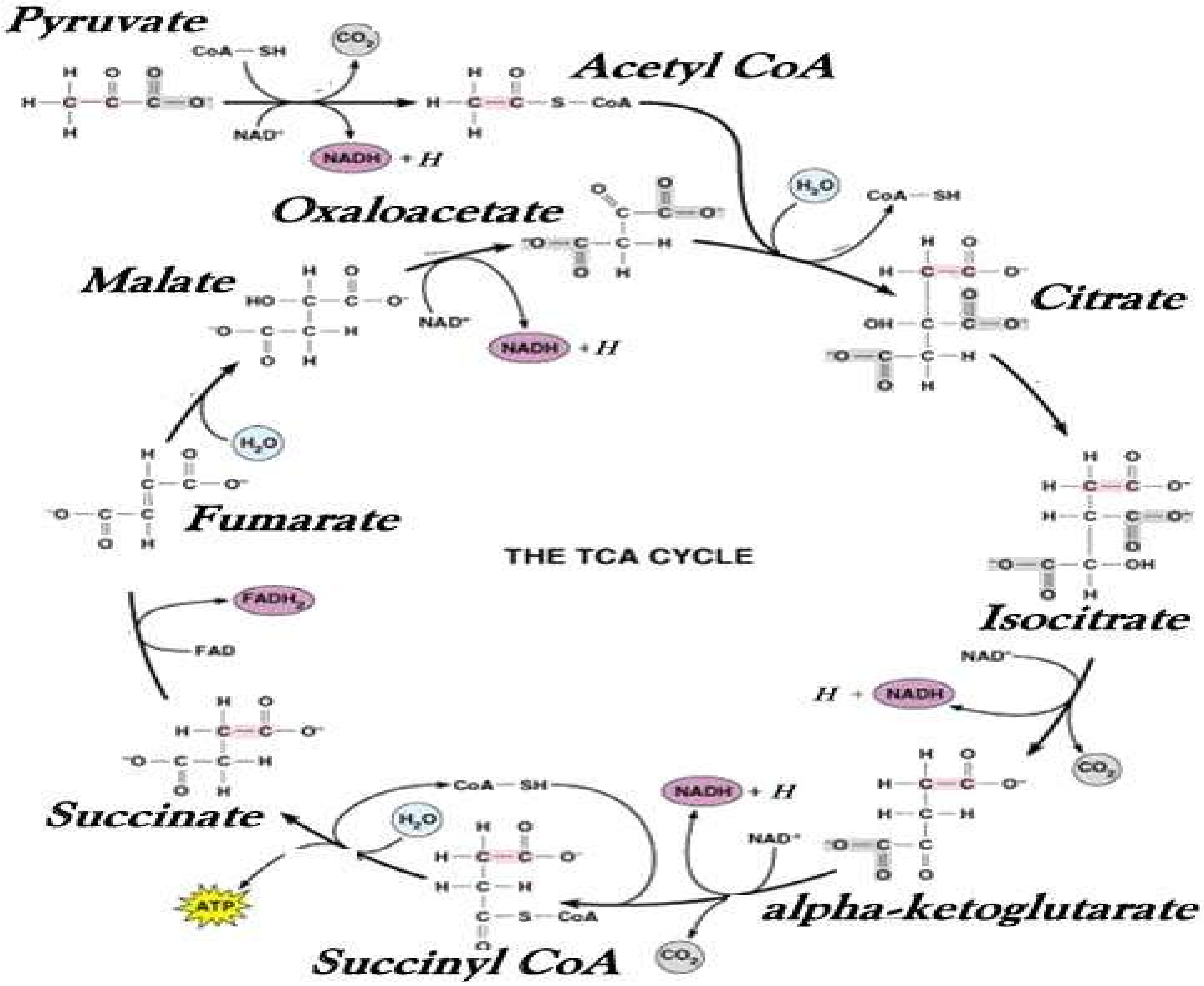


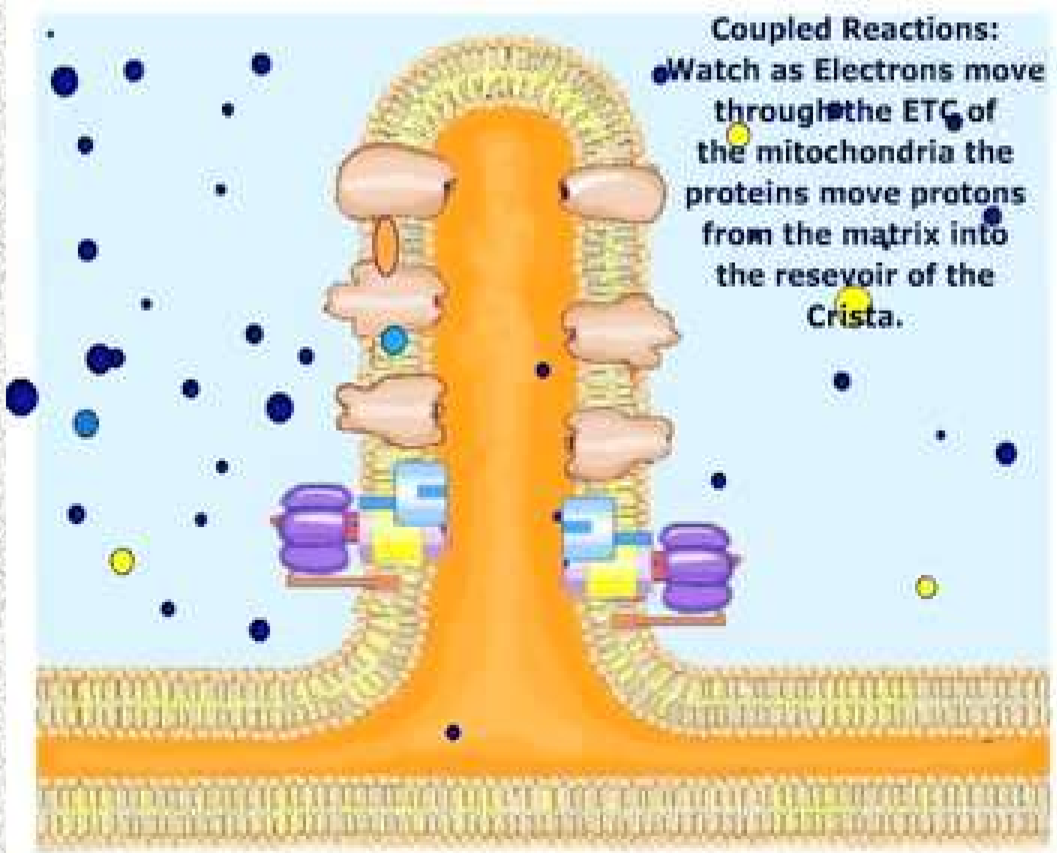


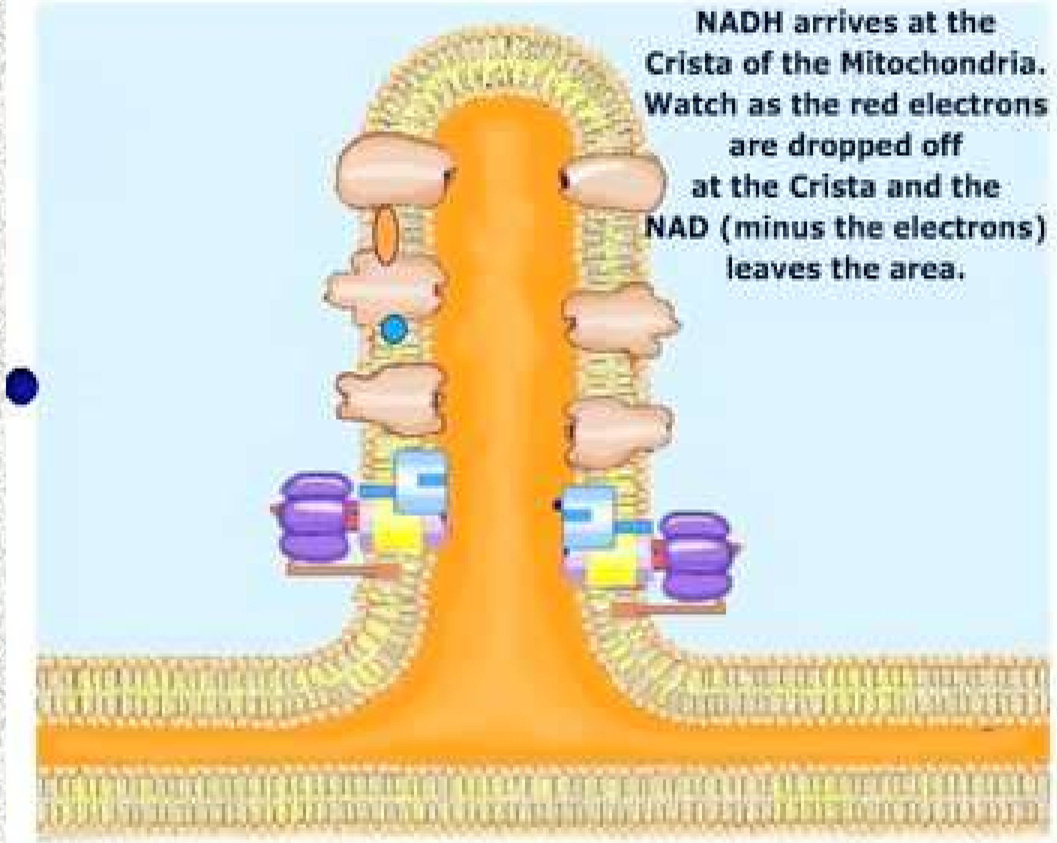


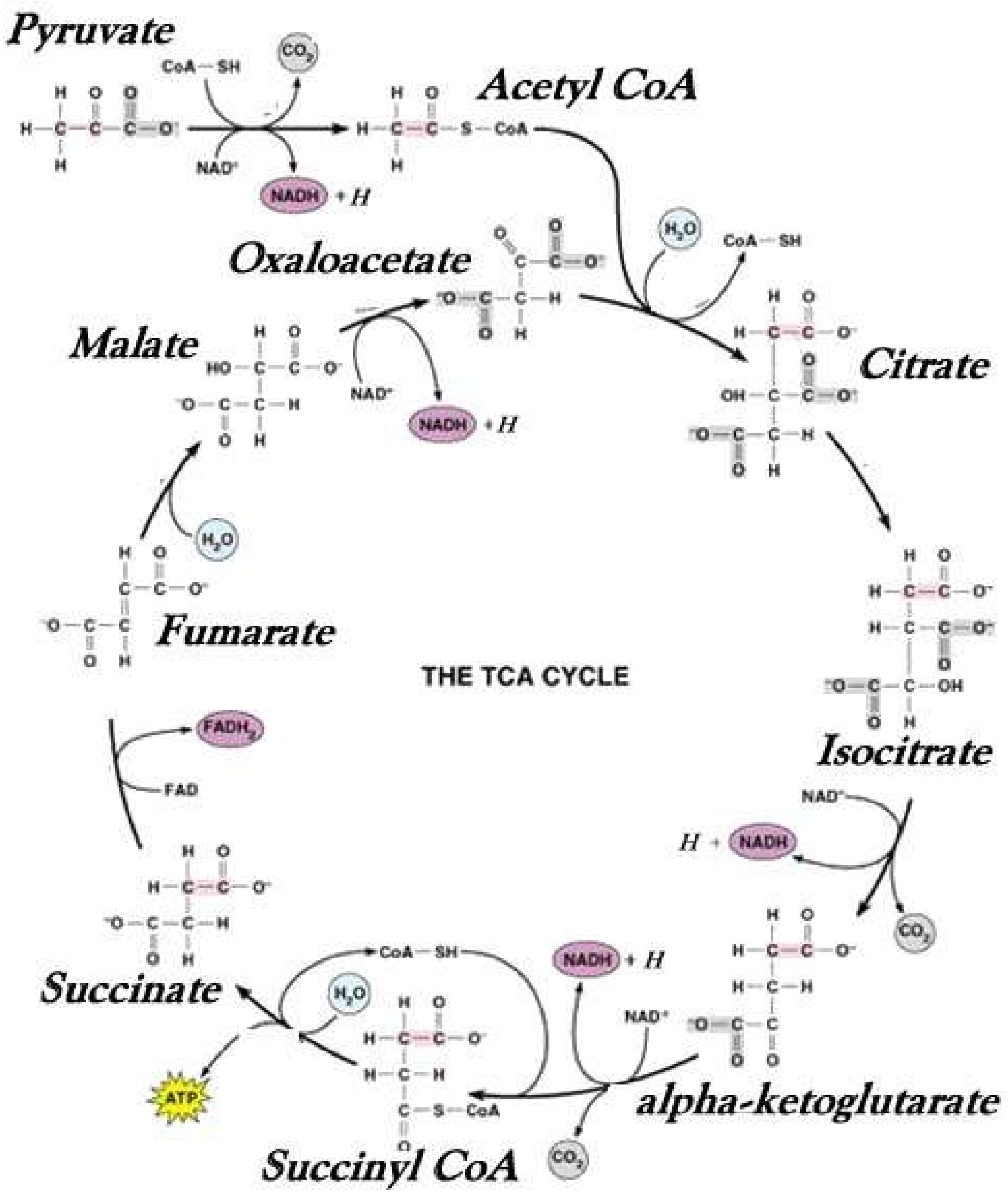
Electron Transport
Coupled Reactions

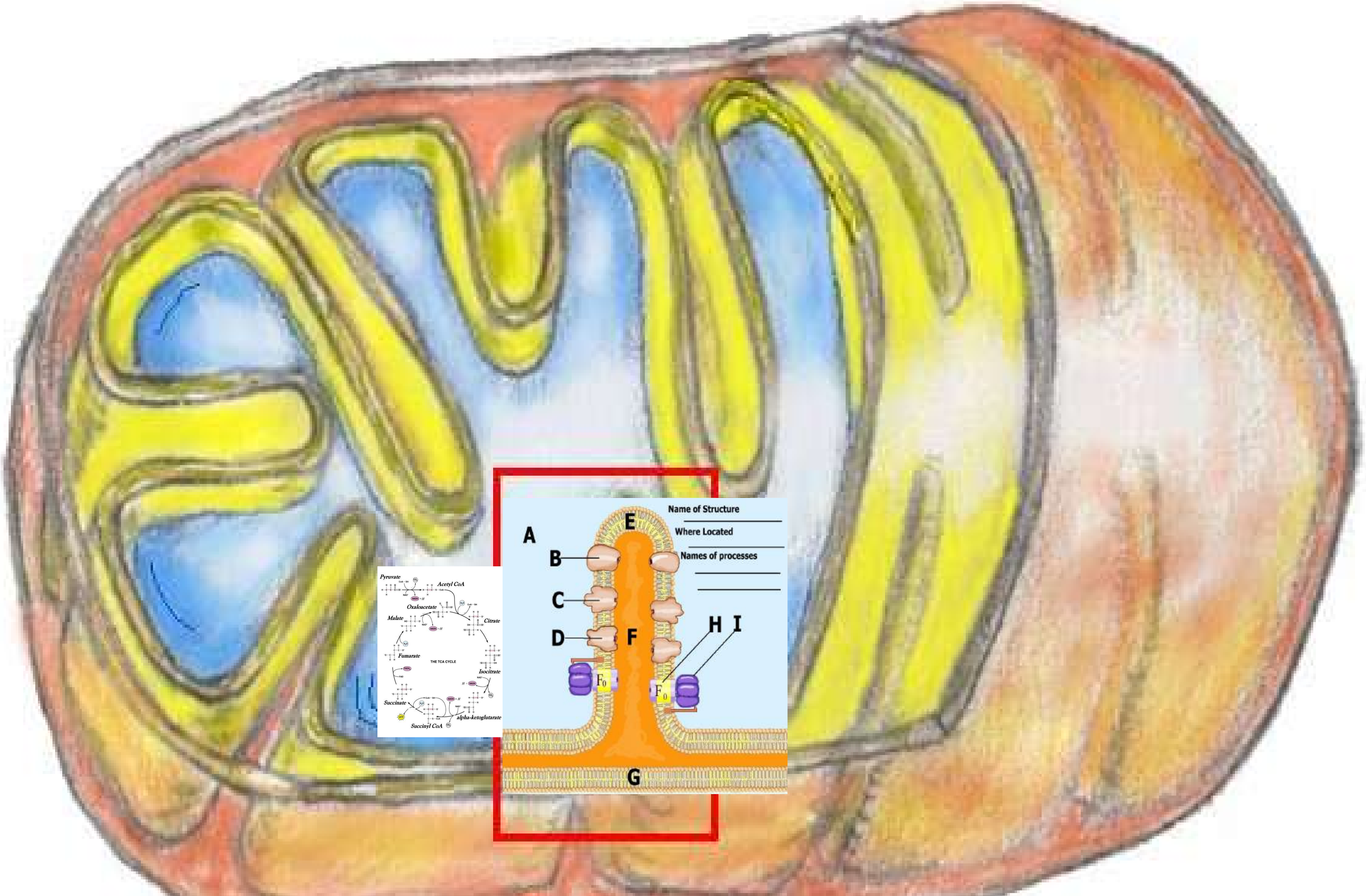



Pyruvate
CoA — SH
CO2
NAD+
NADH + H
Acetyl CoA
H2O
CoA — SH
Oxaloacetate
Malate
NAD+
NADH + H
Citrate
Isocitrate
NAD+
H + NADH
CO2
Fumarate
H2O
THE TCA CYCLE
FADH2
FAD
Succinate
H2O
CoA — SH
ATP
NADH + H
NAD+
alpha-ketoglutarate
Succinyl CoA
CO2


Coupled Reactions:
Watch as Electrons move
through the ETC of
the mitochondria the
proteins move protons
from the matrix into
the resevoir of the
Crista.


NADH arrives at the
Crista of the Mitochondria.
Watch as the red electrons
are dropped off
at the Crista and the
NAD (minus the electrons)
leaves the area.


Pyruvate
Acetyl CoA
Oxaloacetate
Citrate
Malate
Isocitrate
Fumarate
THE TCA CYCLE
alpha-ketoglutarate
Succinate
Succinyl CoA
CoA — SH
NAD+
NADH + H
CO2
H2O
FADH2
FAD
ATP

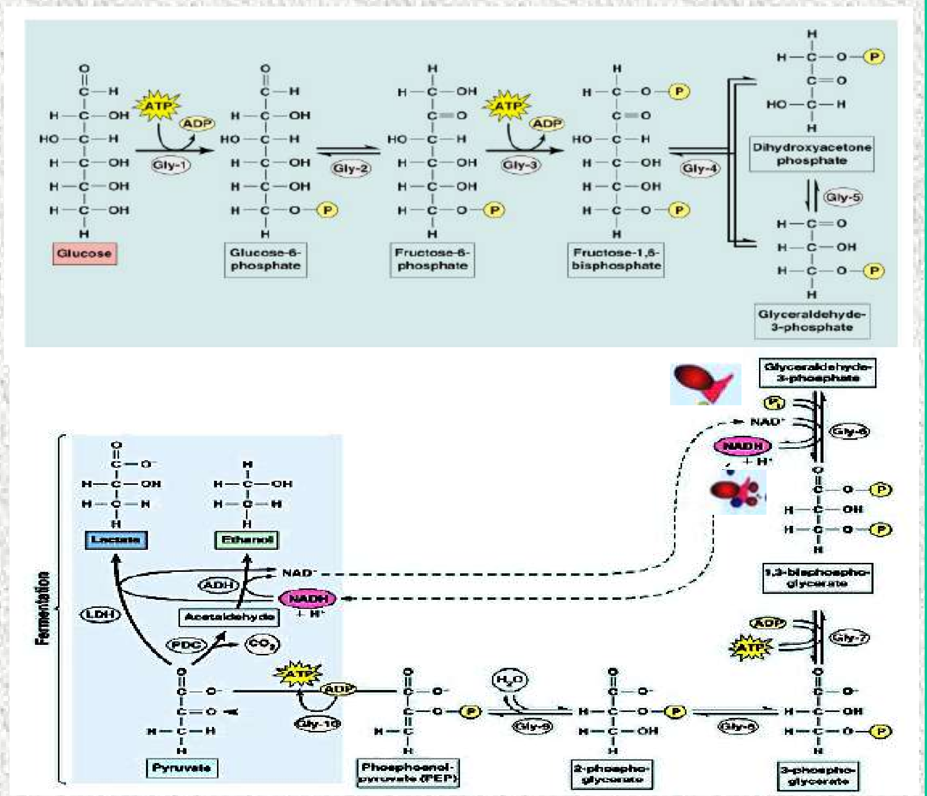


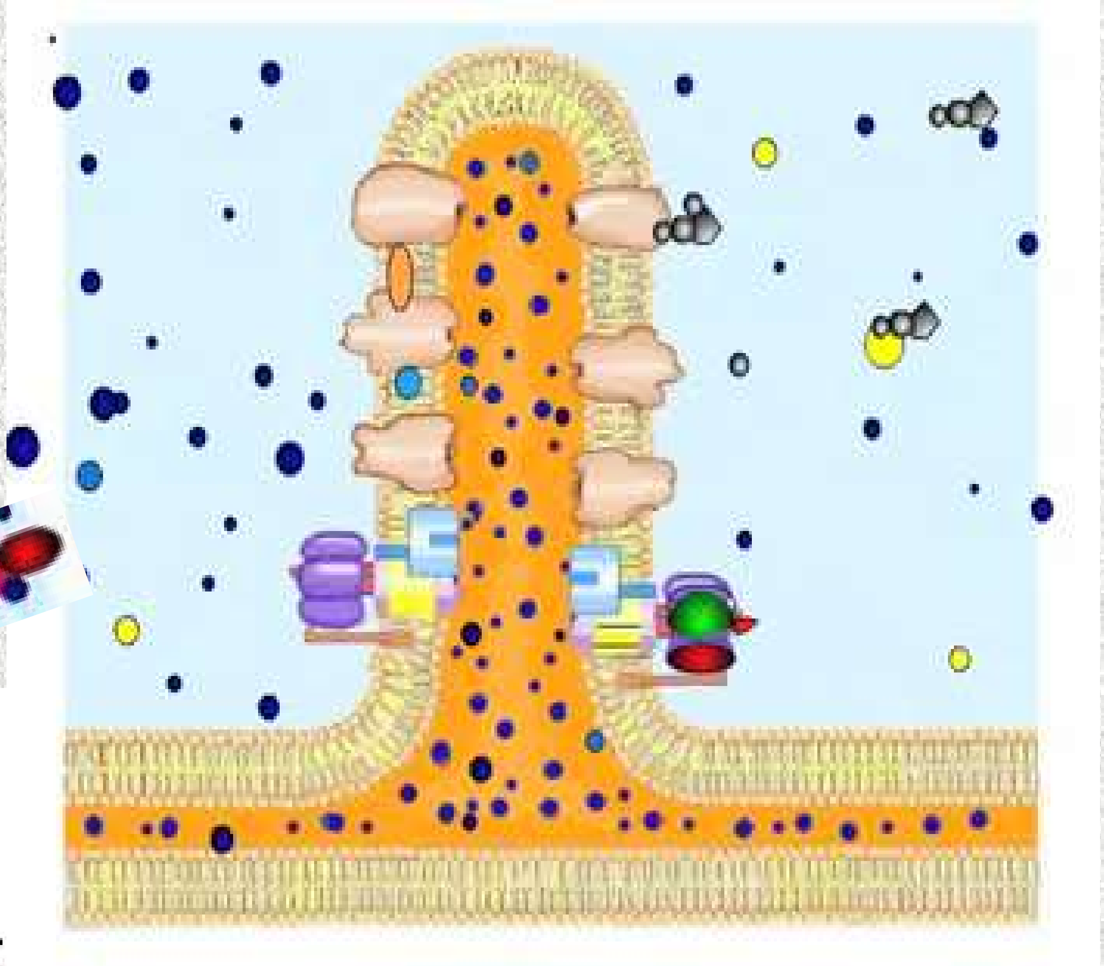
Pyruvate
Acetyl CoA
Oxaloacetate
Malate
Citrate
Fumarate
THE TCA CYCLE
Isocitrate
Succinate
alpha-ketoglutarate
Succinyl CoA
A
B
C
D
E
F
G
H
I
Name of Structure
Where Located
Names of processes

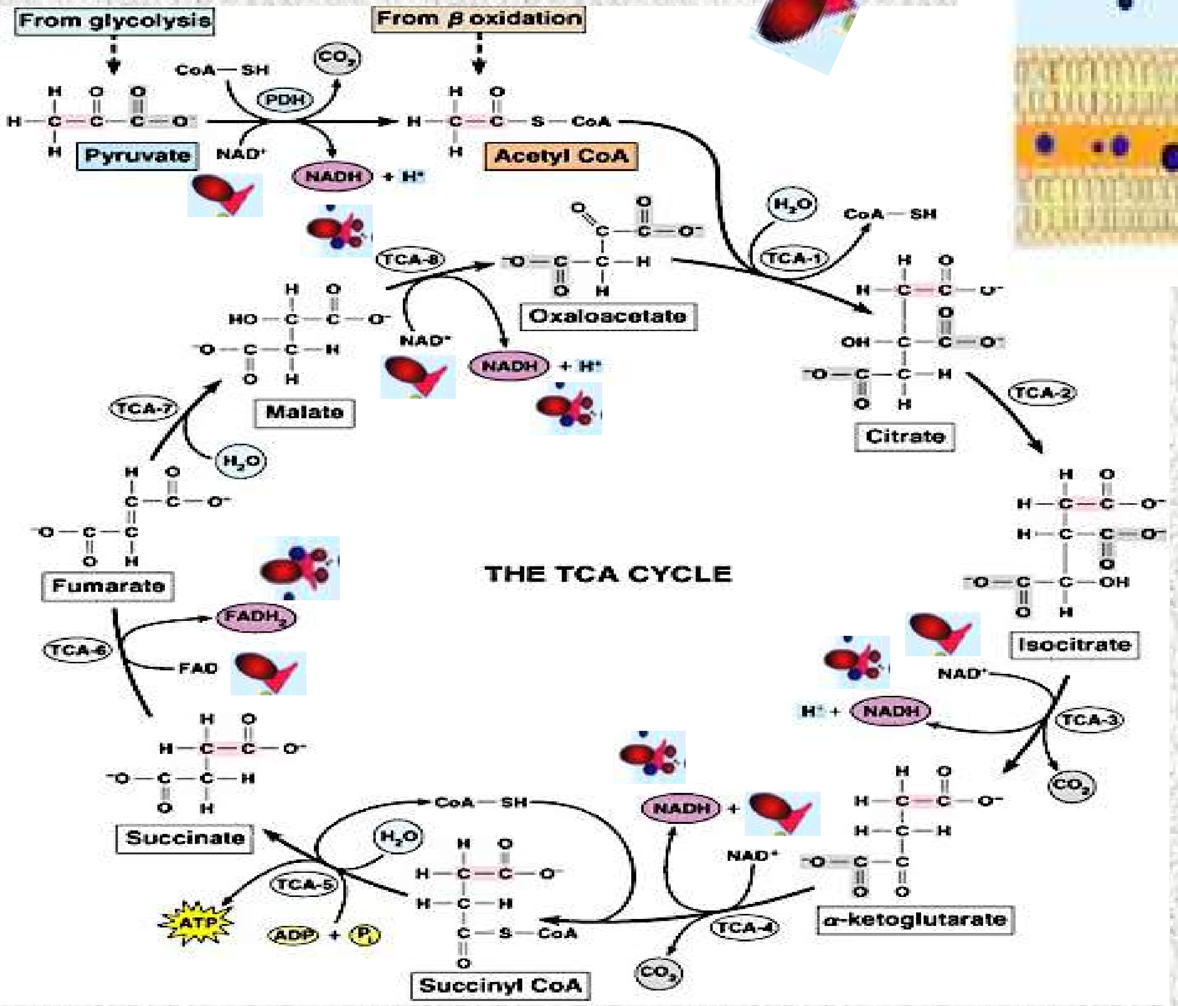
Crista

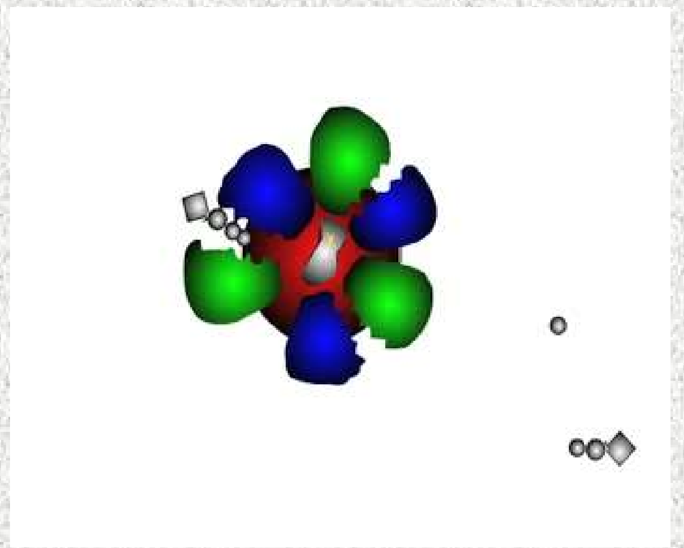
3 Problems Solved by 3 Principles and 3 compounds

1. Partial Activation & Metastable Compounds
2. Small Energy steps & Enzymes
3. Coupled Reactions & Energy Carrying Molecules

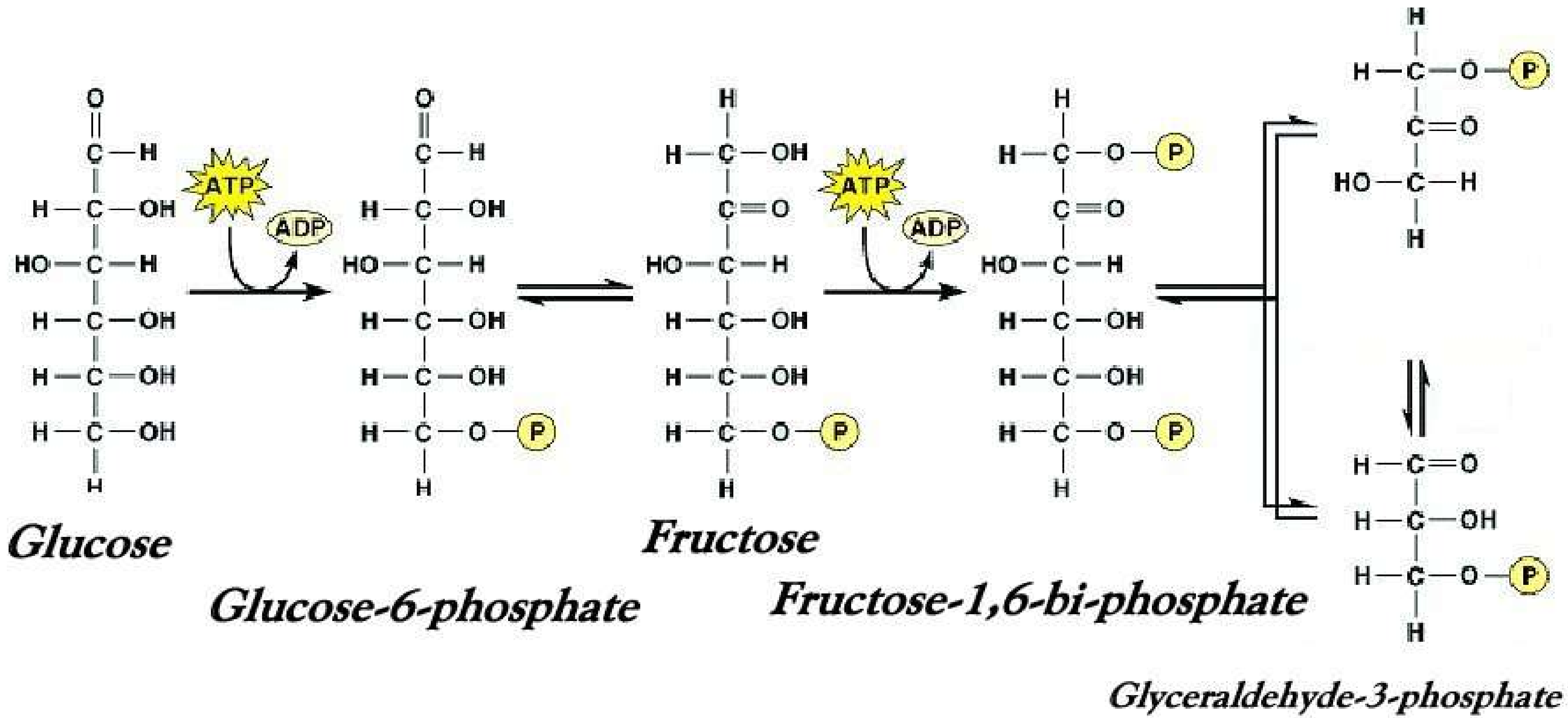


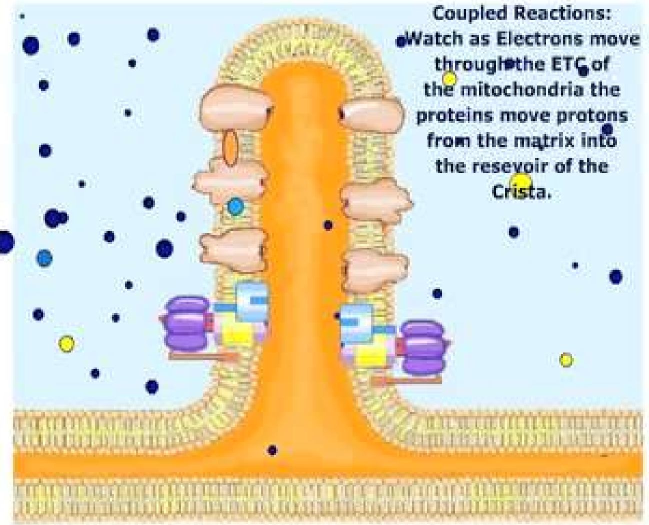




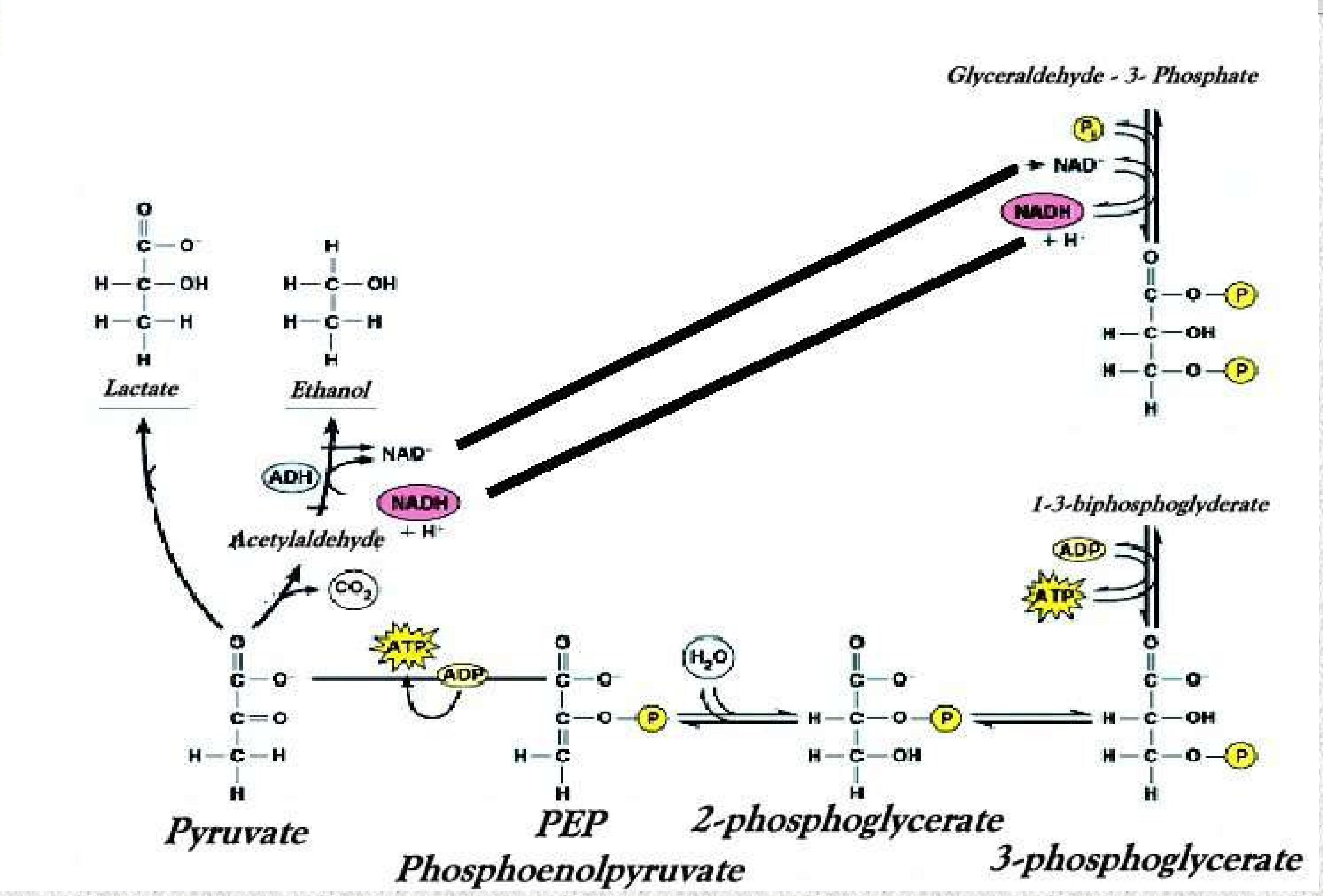


Cleavage Preparation

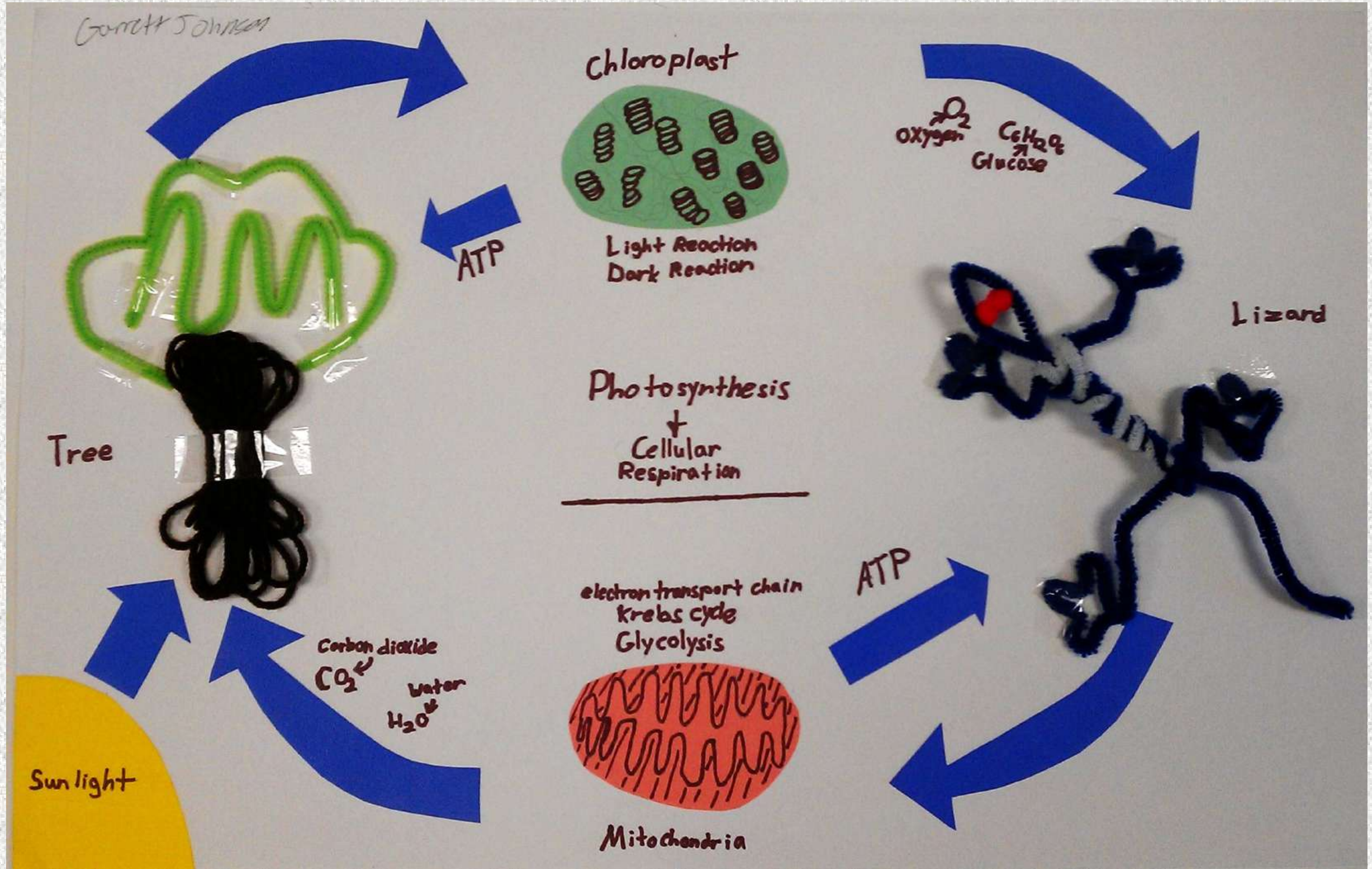




ATP Generation
Oxidation
Substrate-level Phosphorylation
&
Anaerobic Respiration



Model – Tell a Story



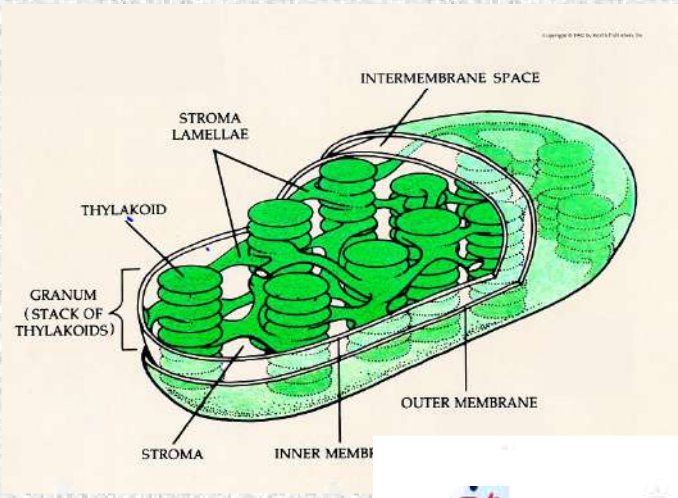
What is Next?
Where are we going both in structure and in process?
Why?
How will your students know?
What should they now know?

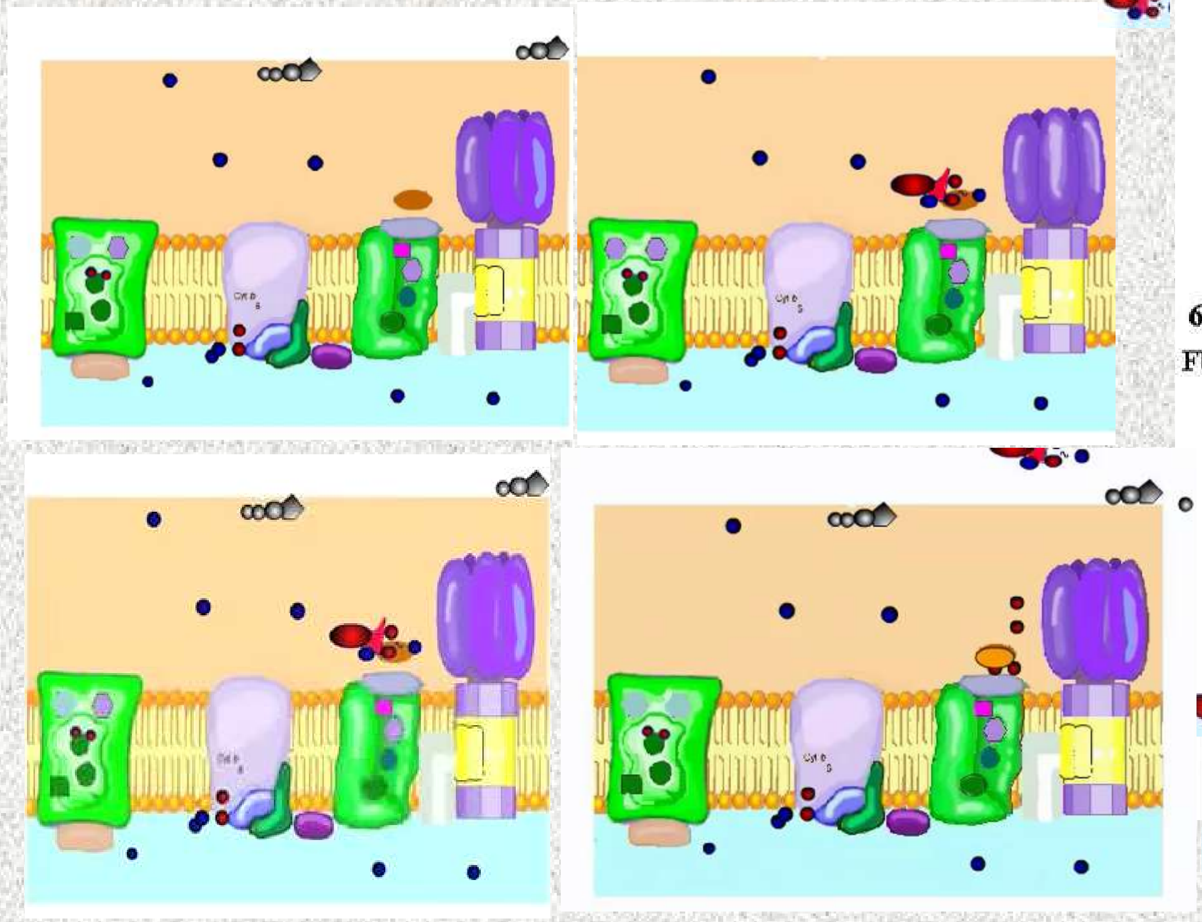
PHOTOSYNTHETIC PROCESS

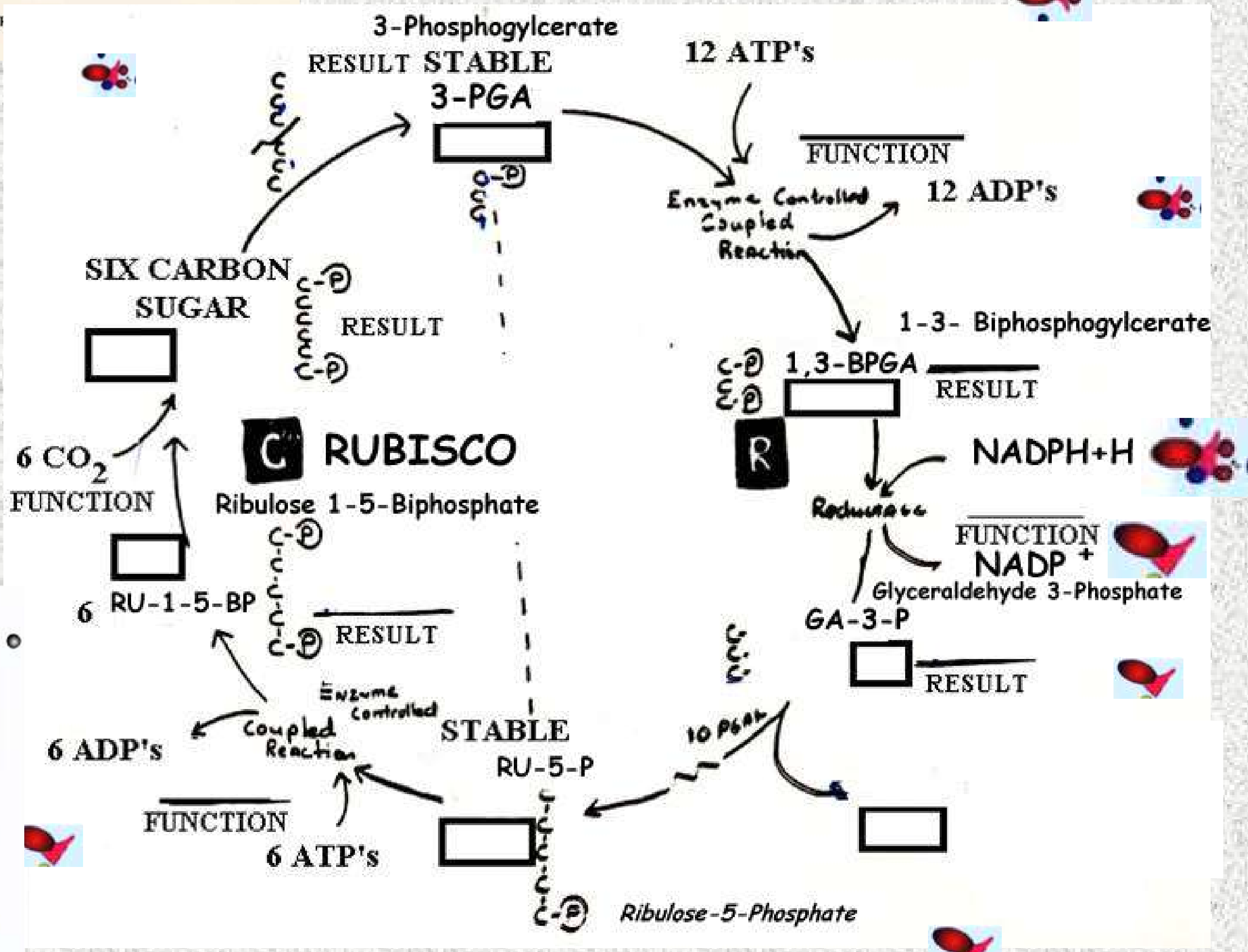
- Photosynthesis takes place in a two step reaction.
- The two reactions perform different energy conversions.
- **TWO PROCESSES**
    - Light Reaction
    - Dark Reaction

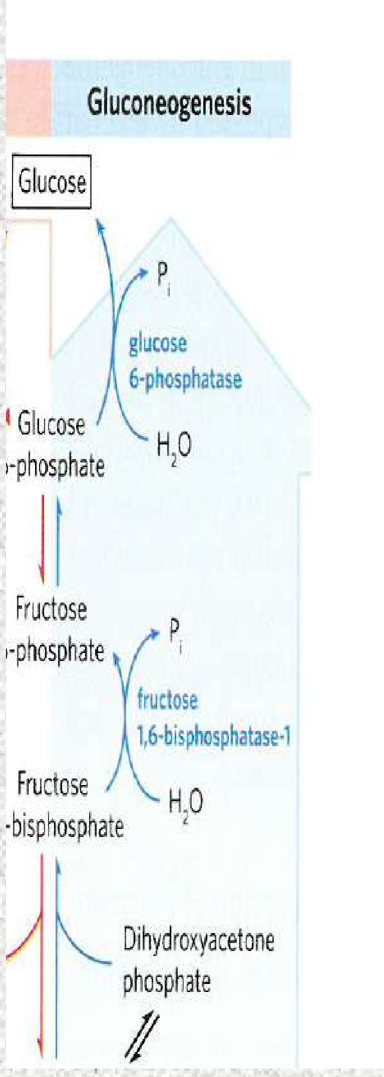
3 Problems Solved by 3 Principles and 3 compounds

1. Partial Activation & Metastable Compounds
2. Small Energy steps & Enzymes
3. Coupled Reactions & Energy Carrying Molecules

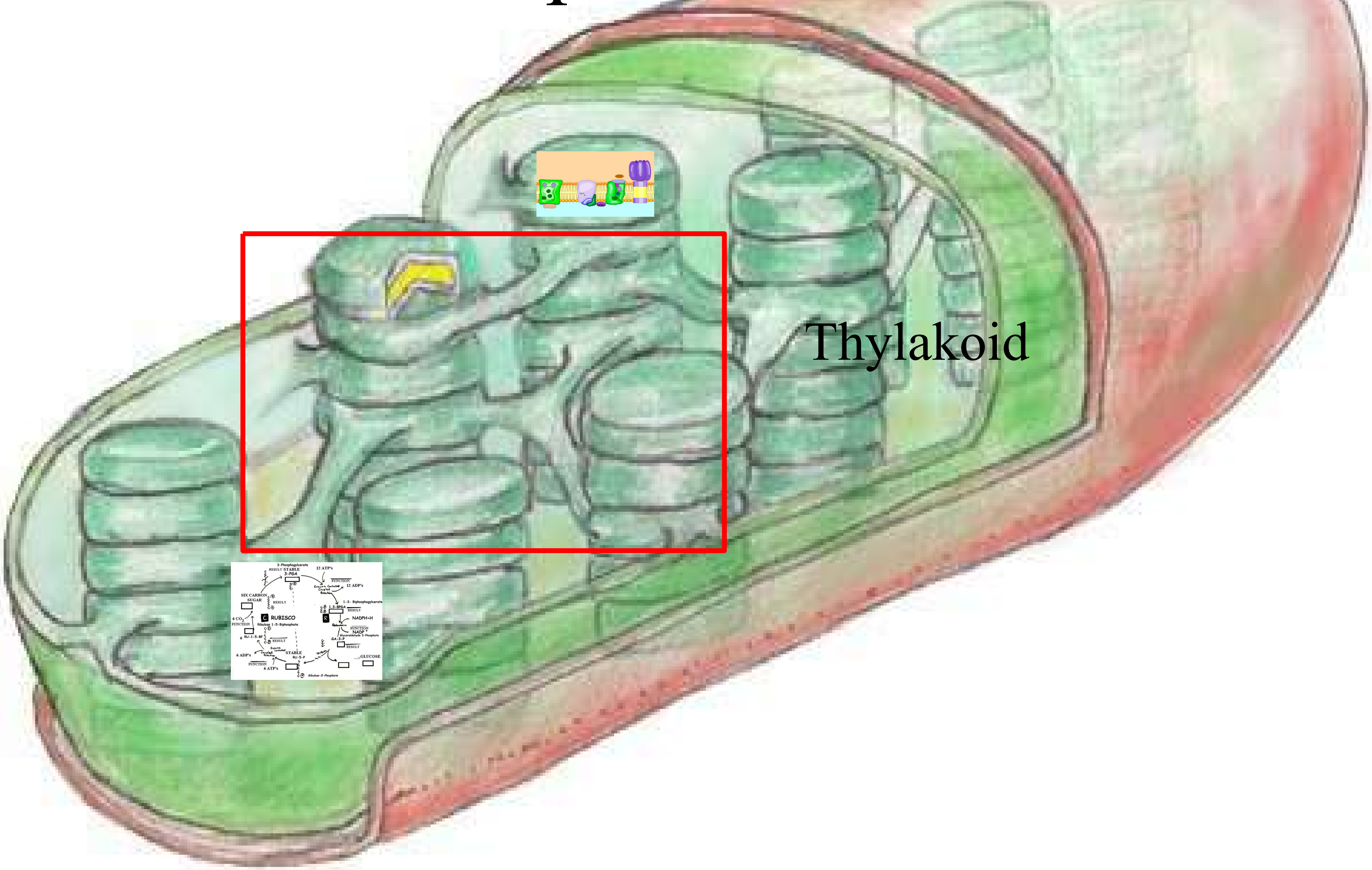


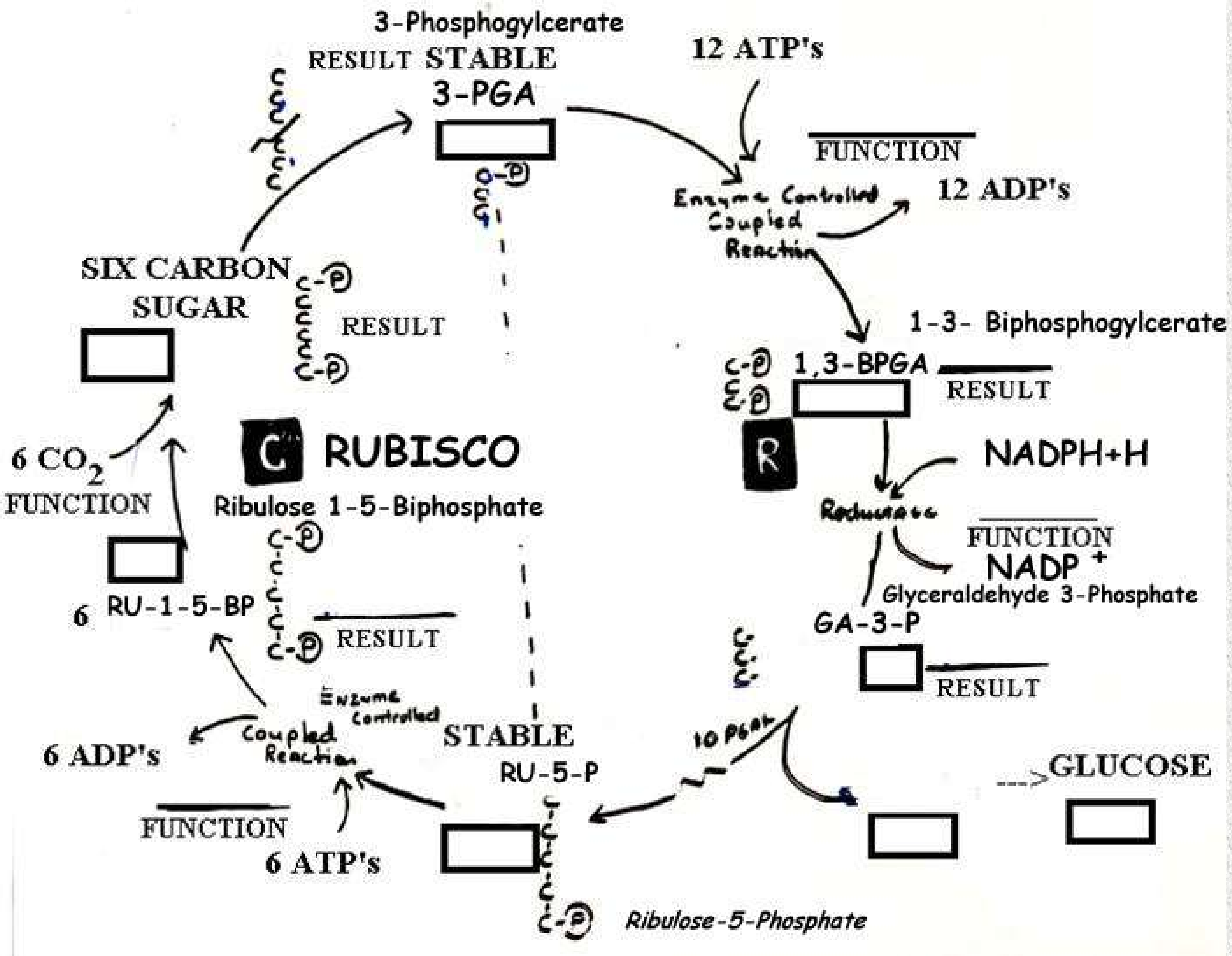




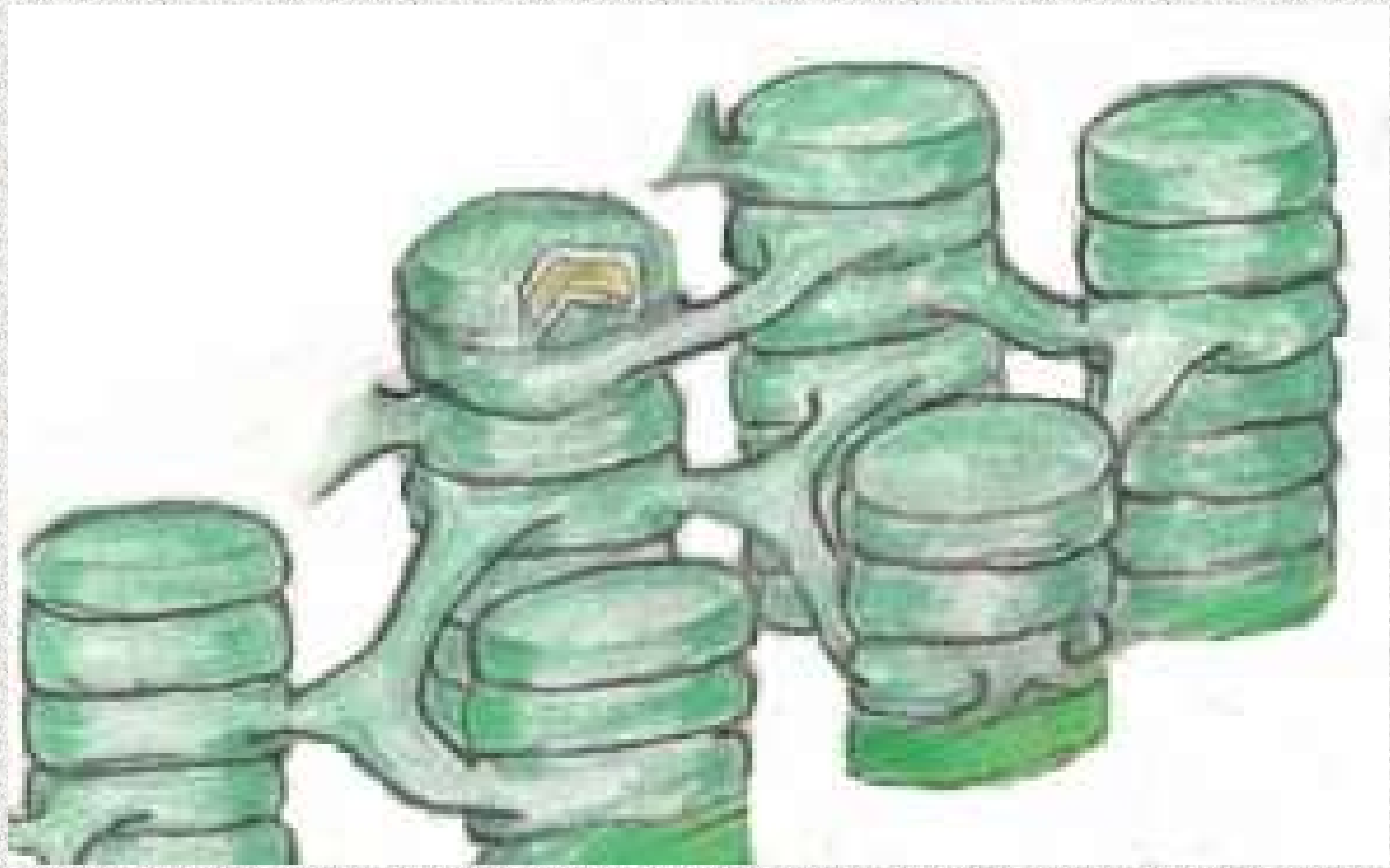


Chloroplast Structure

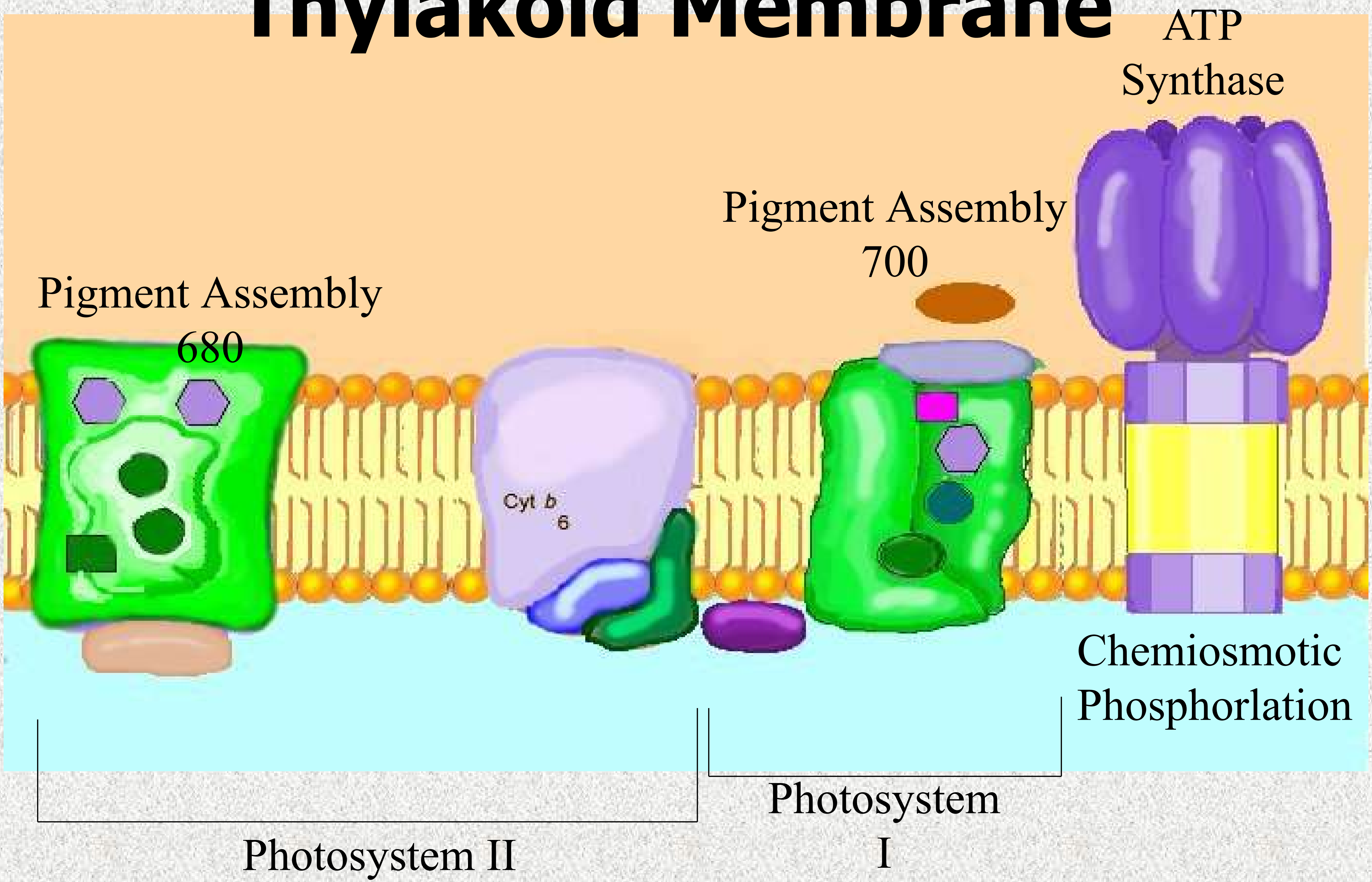


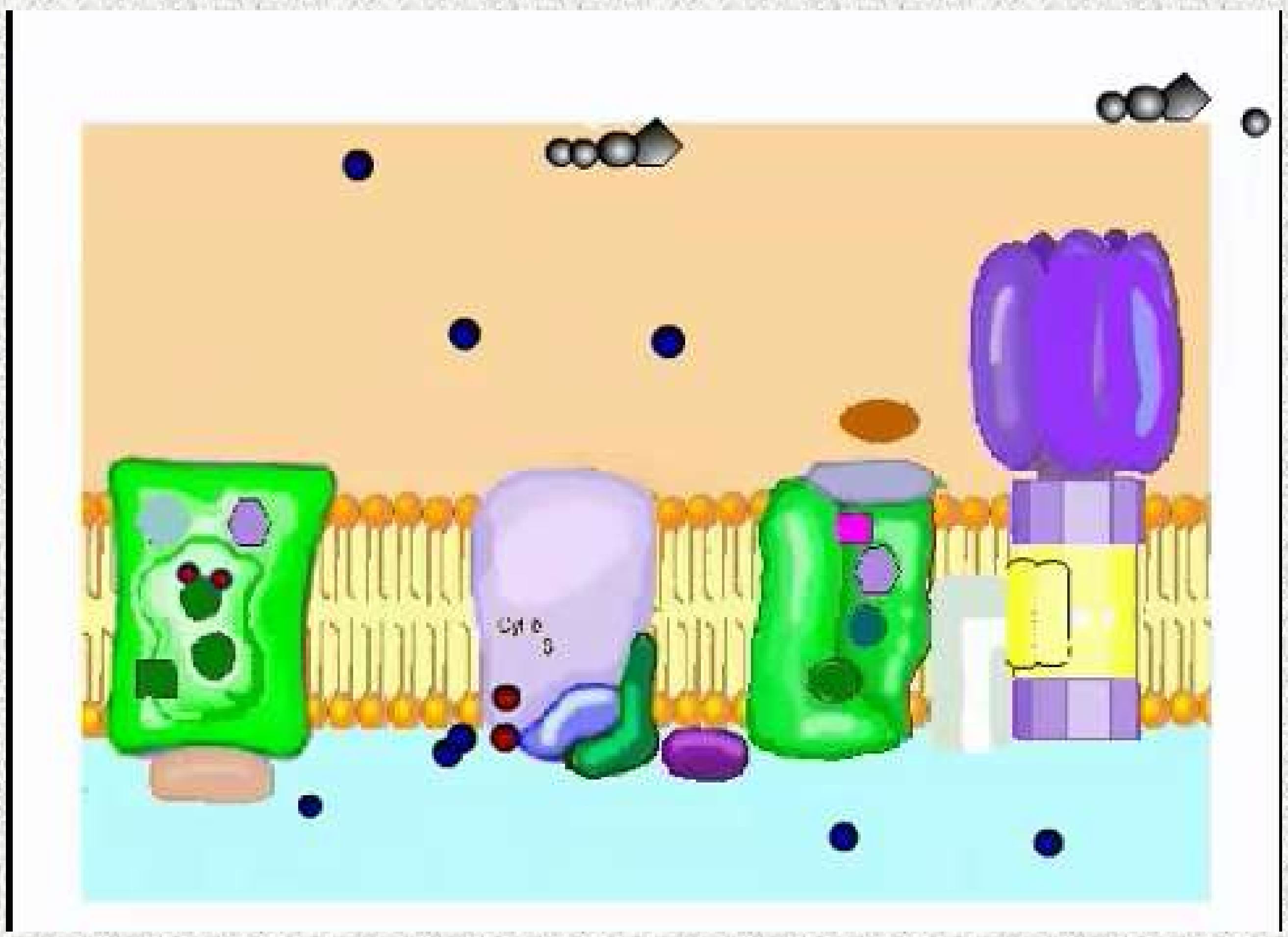

3-Phosphogylcerate
RESULT STABLE
3-PGA
12 ATP's
FUNCTION
12 ADP's
Enzyme Controlled
Coupled
Reaction
SIX CARBON
SUGAR
RESULT
1-3- Biphosphogylcerate
1,3-BPGA
RESULT
RUBISCO
NADPH+H
6 CO_2
FUNCTION
Ribulose 1-5-Biphosphate
Reductase
FUNCTION
NADP +
Glyceraldehyde 3-Phosphate
6 RU-1-5-BP
GA-3-P
RESULT
RESULT
Enzyme
Controlled
Coupled
Reaction
STABLE
RU-5-P
10 PGAL
6 ADP's
---> GLUCOSE
FUNCTION
6 ATP's
Ribulose-5-Phosphate

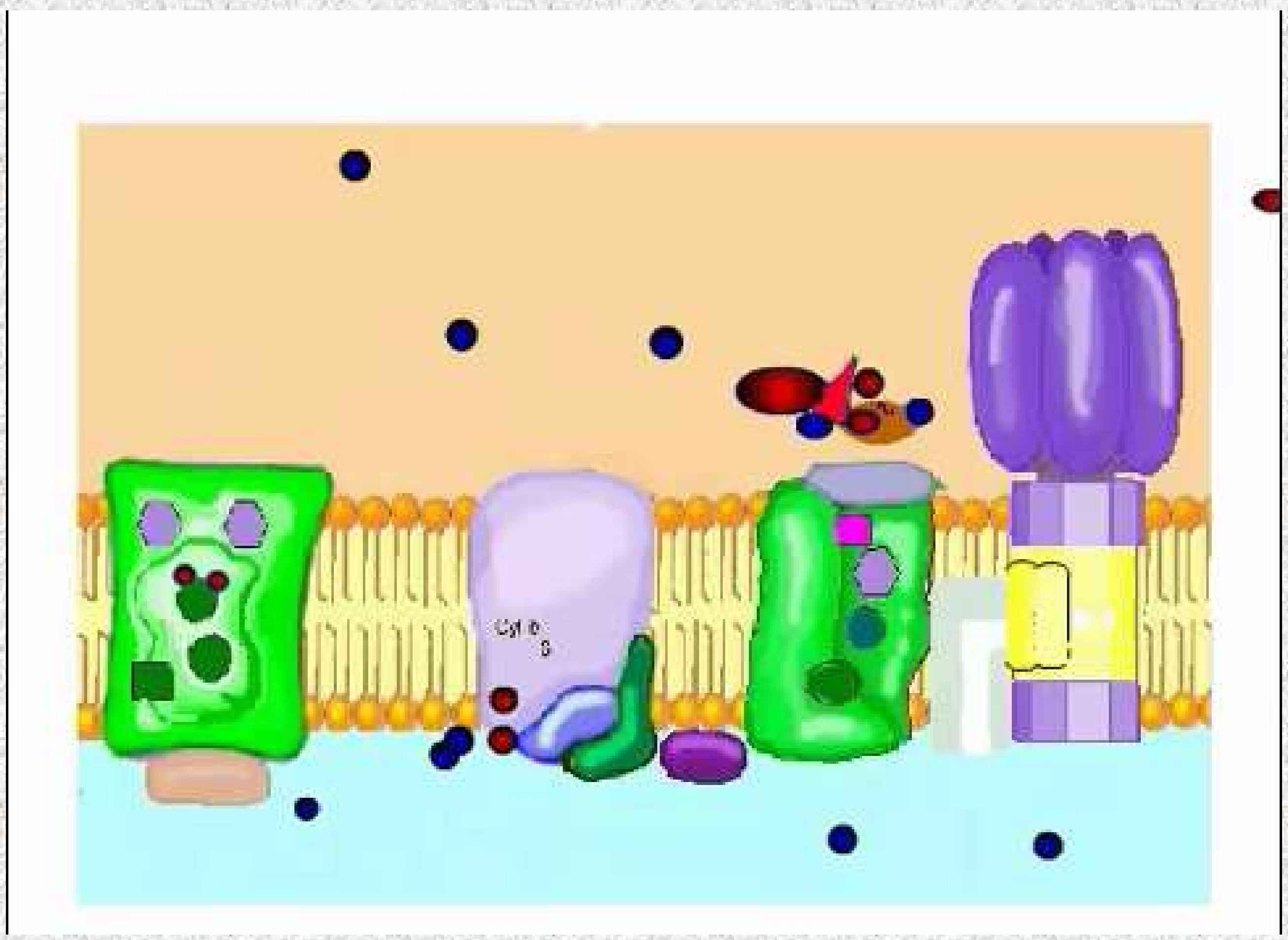
Thylakoid Structure

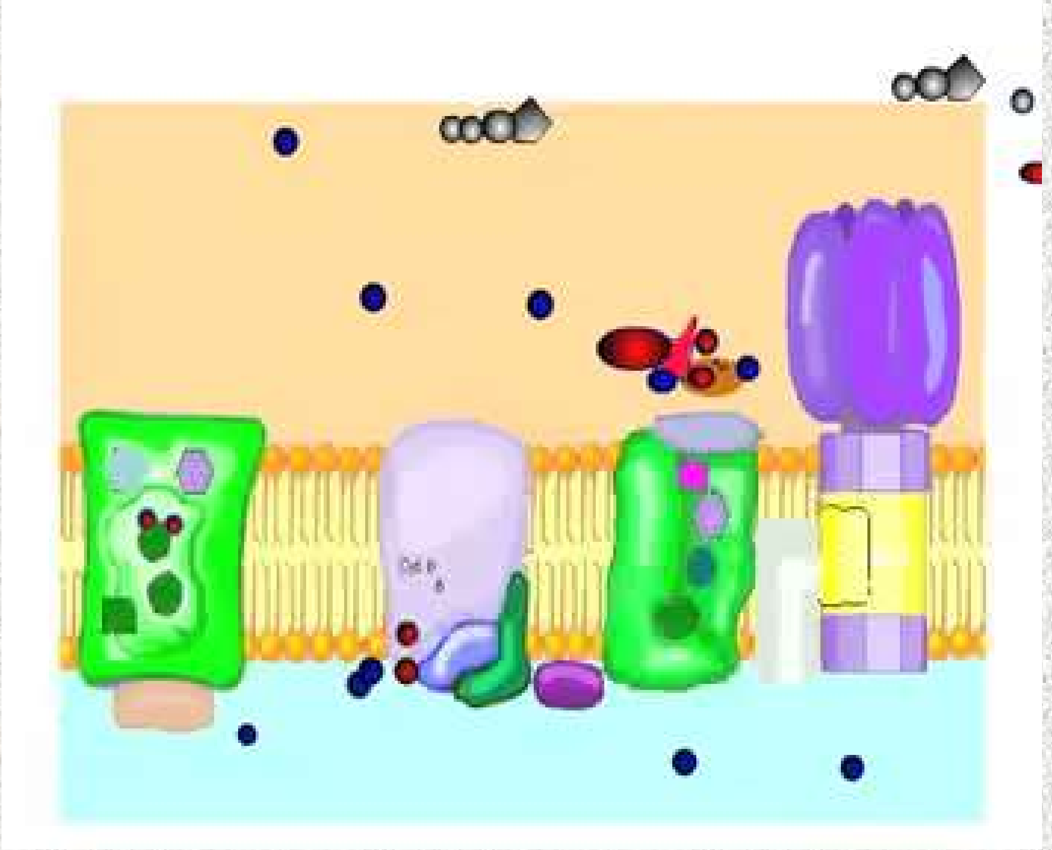


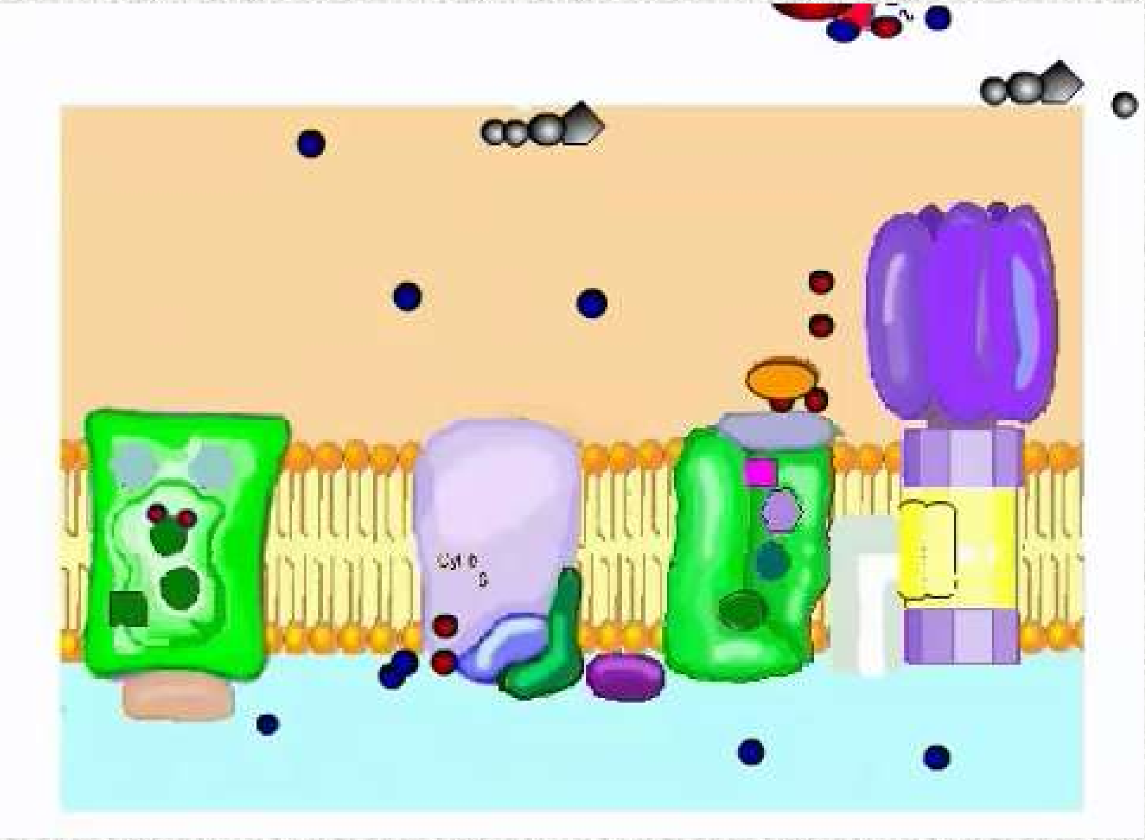
Thylakoid Membrane



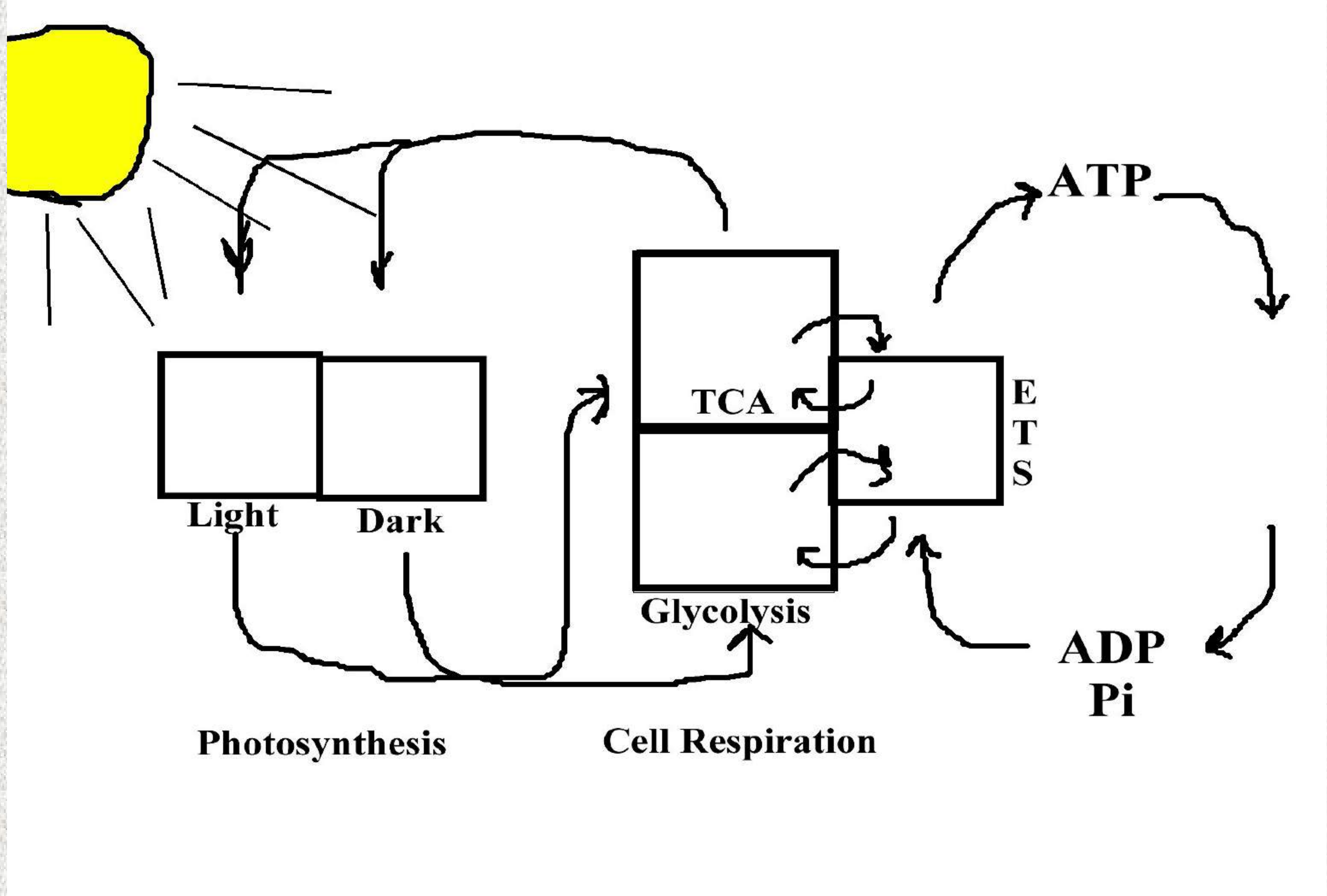








Students can develop their own Flow of Energy through the Ecosystem



Have the Models Tell Stories

- Beginning-

1. Catch the reader's attention
2. • Make the opening dramatic
3. • Make the reader want to read on
4. • Take the reader straight into the story

- Middle

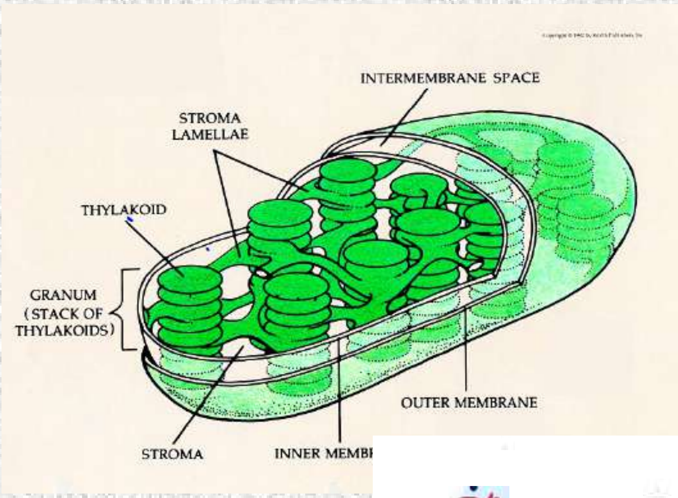
5. Keep the action going, develop the characters and story line.

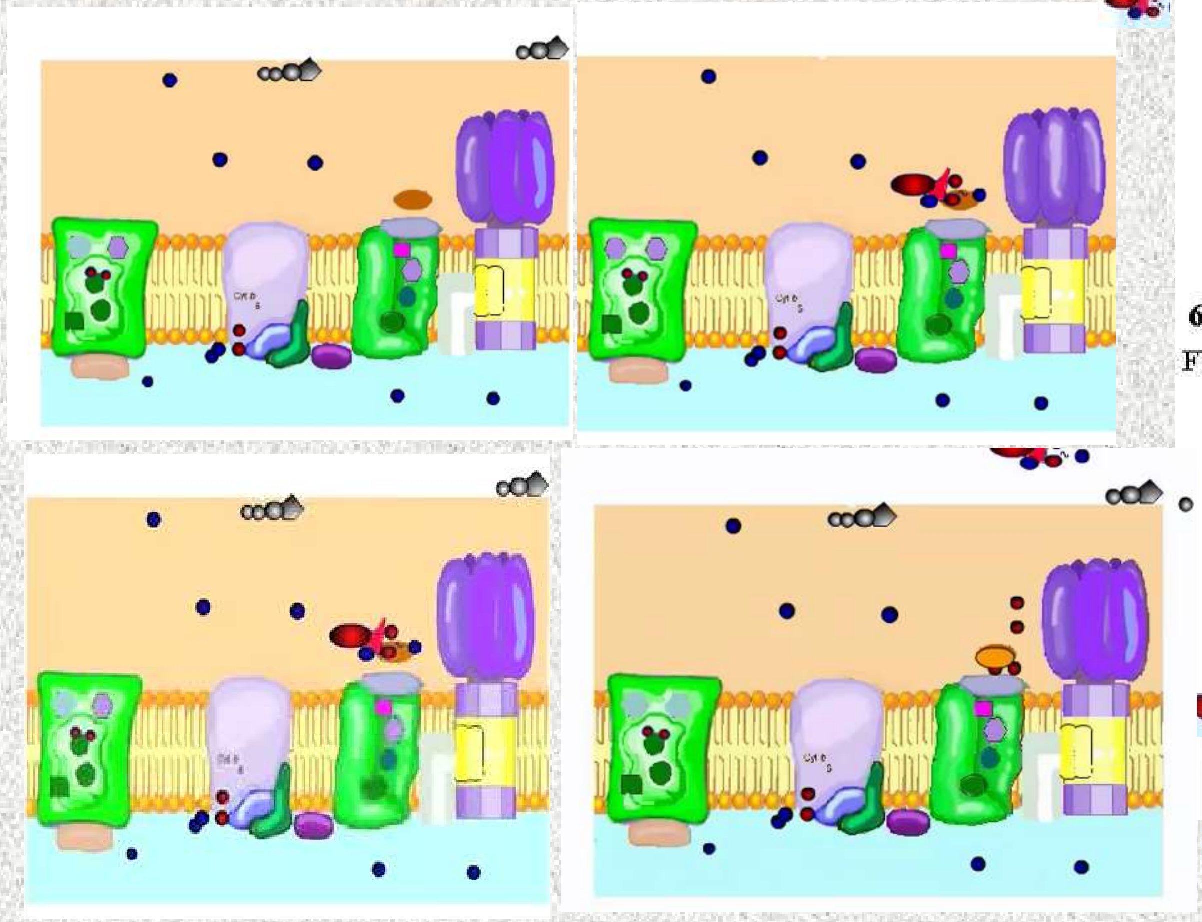
- **End-**

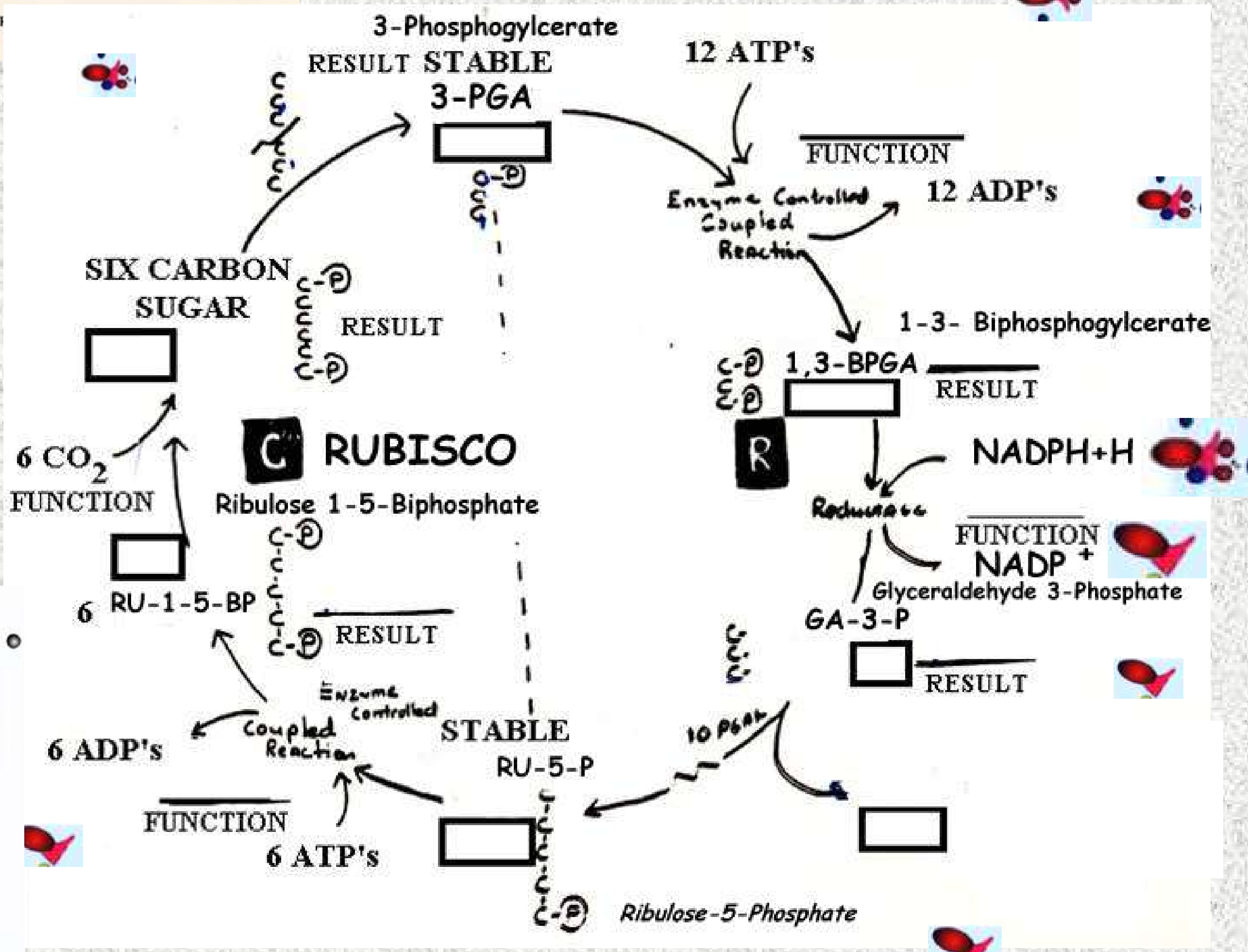
6. **Draws all the threads of the story together**
7. **Resolves any conflict within the story**
8. **Completes the telling of events**

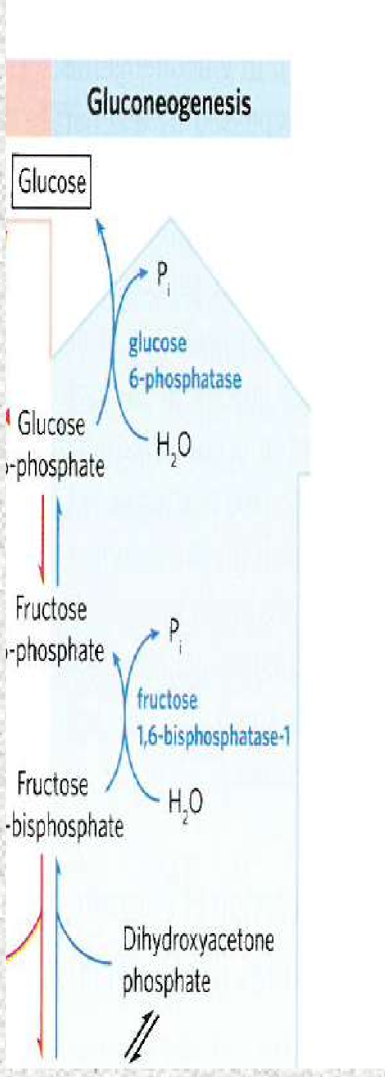
3 Problems Solved by 3 Principles and 3 compounds

1. Partial Activation & Metastable Compounds
2. Small Energy steps & Enzymes
3. Coupled Reactions & Energy Carrying Molecules









3 Problems Solved by 3 Principles and 3 compounds

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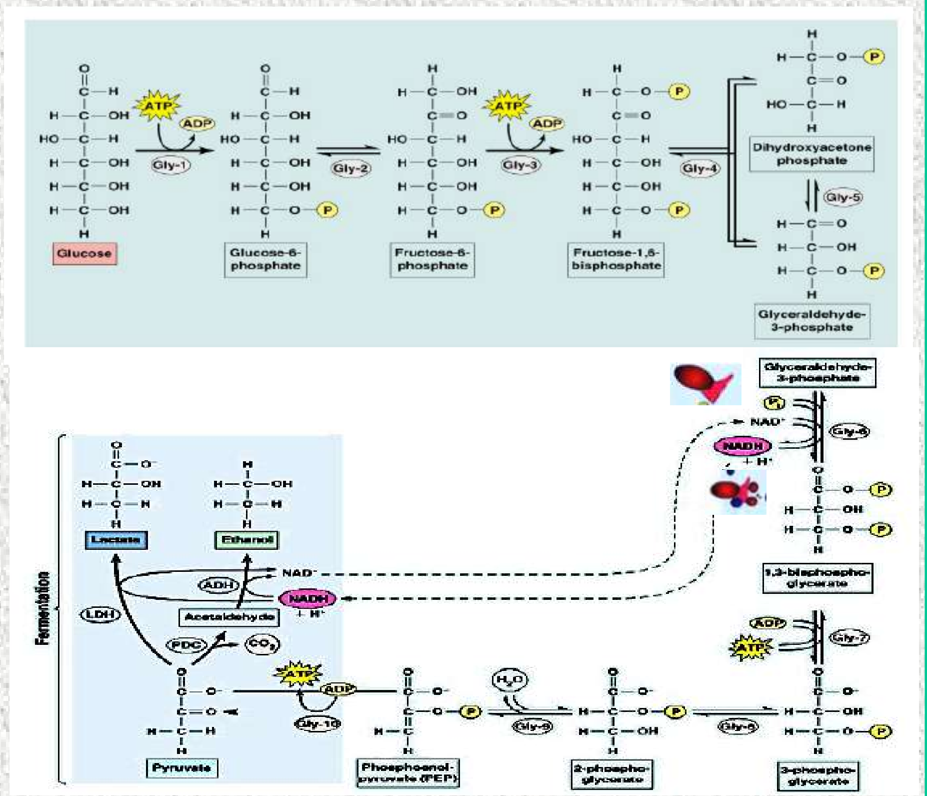

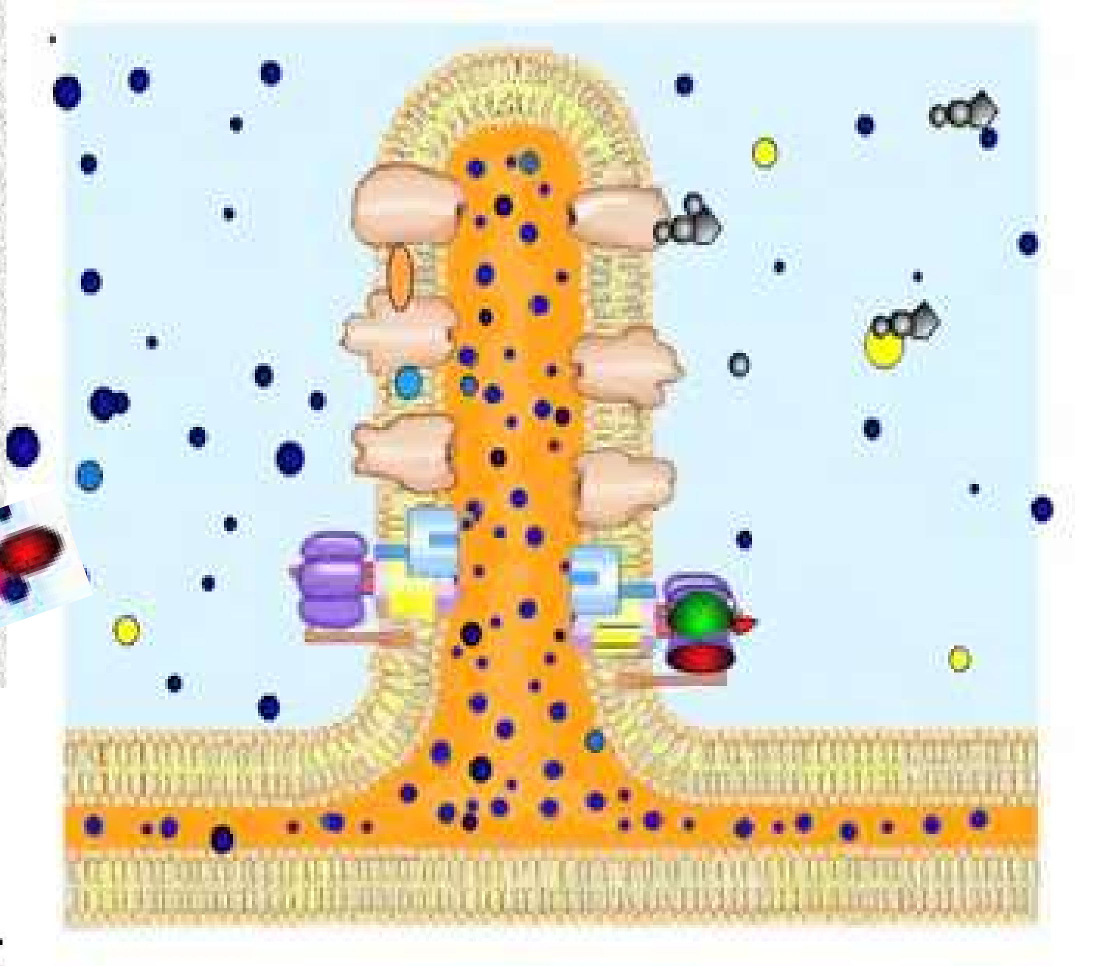

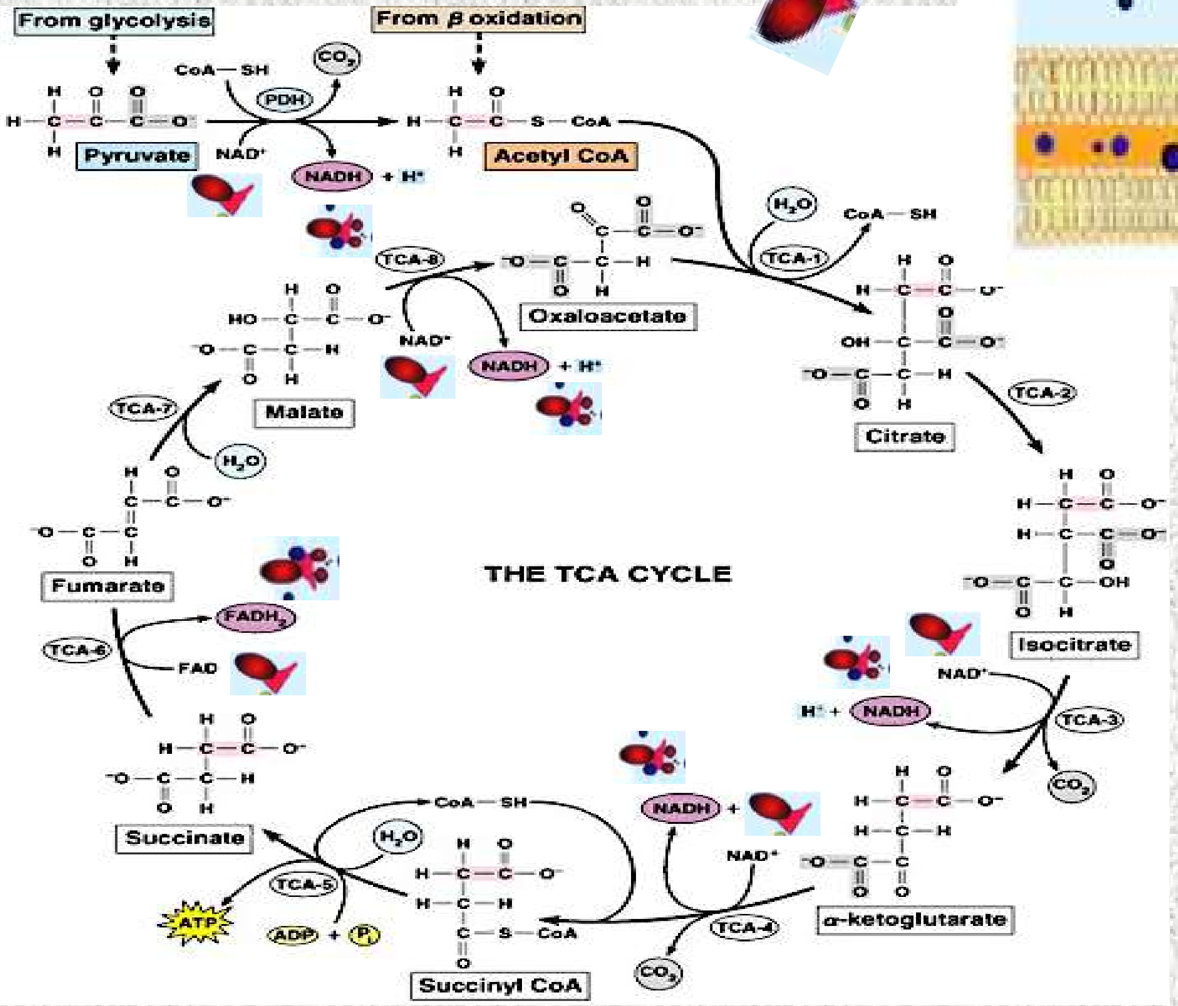

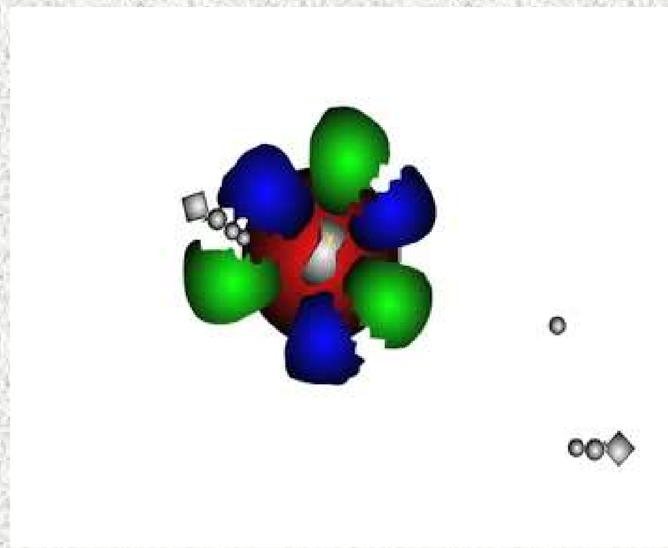

Thank You for Attending

Teaching of Cell Respiration and Photosynthesis does not have to be difficult

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