Chapter 15 Review Problems

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15.1) The terms that are listed below are used throughout chapter 15. Check your understanding of these terms by defining them.

a) metabolism

b) metabolic pathway

c) coenzyme

d) acyl group

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15.1) The terms that are listed below are used throughout chapter 15. Check your understanding of these terms by defining them.

a) metabolism

b) metabolic pathway

c) coenzyme

d) acyl group

HINT:

Review the videos that discuss these topics (or read/re-read about them in the textbook, chapter 15, section 2).

Videos links: chapter 15 part 1 and part 2

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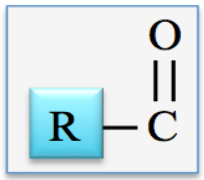
15.1) The terms that are listed below are used throughout chapter 15. Check your understanding of these terms by defining them.

a) metabolism - The entire set of life-sustaining chemical reactions that occur in organisms.
- These reactions number in the thousands and include reactions such as those responsible for getting energy from food, processing and removal of waste, building up muscles, growth, photosynthesis in plants, cell division, and reproduction.

b) metabolic pathway - sets of sequential metabolic reactions
- Many of the reactions in metabolic pathways require enzymes, therefore organisms can control (accelerate or suppress) metabolic pathways, according to their current needs, by upregulating, downregulating, inhibiting, or activating one or more of the enzymes involved in the pathway.

c) coenzyme - a species that must bind to an enzyme in order for the enzyme to function.
- In most cases, a coenzyme is actually one of the substrates (reactants) in the catalyzed reaction. The reason that certain substrates are also referred to as coenzymes is that these substrates are common substrates in many different enzymatic reactions in which they donate electrons, atoms, or groups of atoms to other substrates, or accept electrons, atoms or groups of atoms from other substrates.

d) acyl group - An acyl group consists of a carbonyl group bonded to an organic group (R), as shown below.



general form of an acyl group

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For more details: See chapter 15 part 1 and part 2 videos or chapter 15 section 2 in the textbook.

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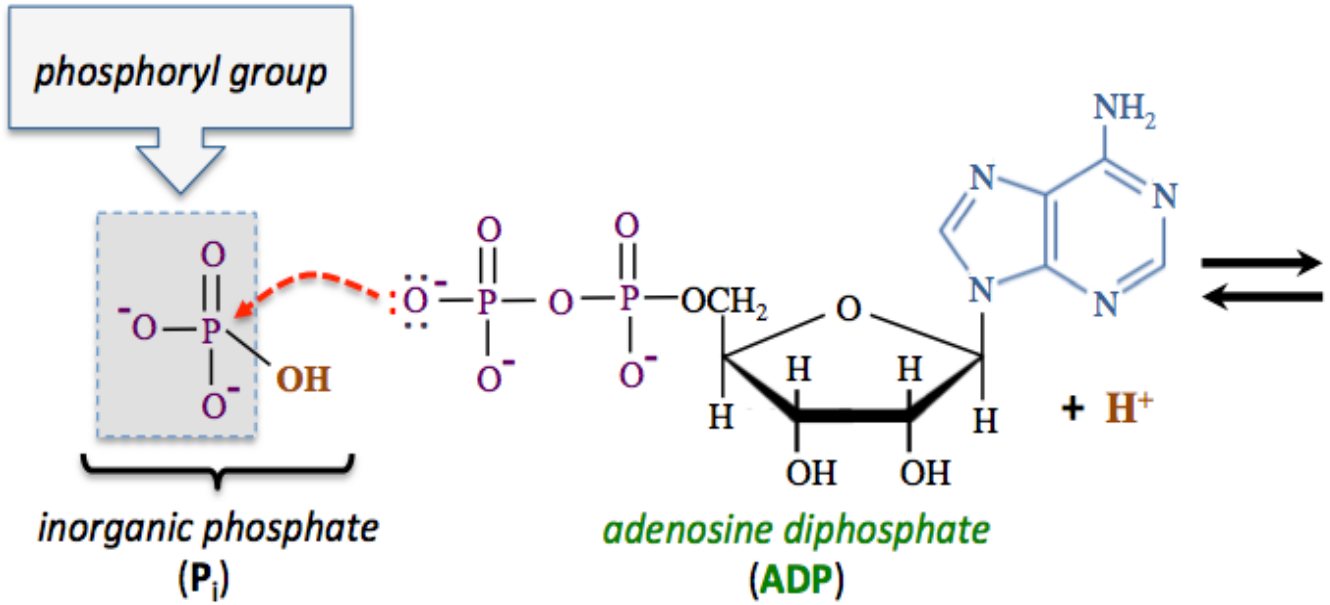
15.2) Name the **products** of the *phosphorylation* of ADP reaction shown below.

- NOTE: You do not need to draw the structural formulas of the products, just name them or use their abbreviations.



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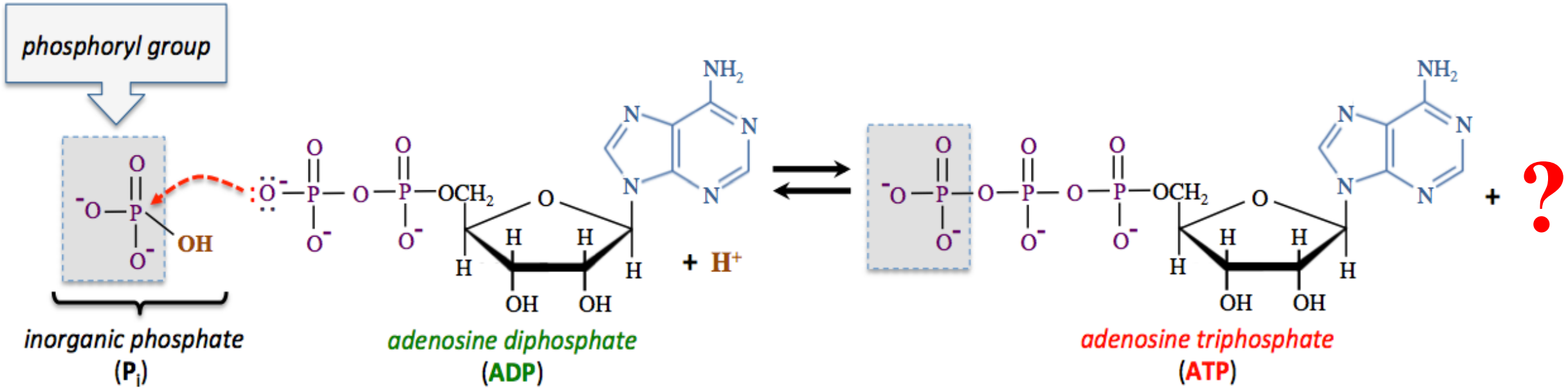
15.2) Name the **products** of the *phosphorylation* of ADP reaction shown below.

- NOTE: You do not need to draw the structural formulas of the products, just name them or use their abbreviations.

HINT: There are two products in this reaction, one of the products is ATP. What is the other product?



For more help: See chapter 15 part 1 video or chapter 15 section 2 in the textbook.

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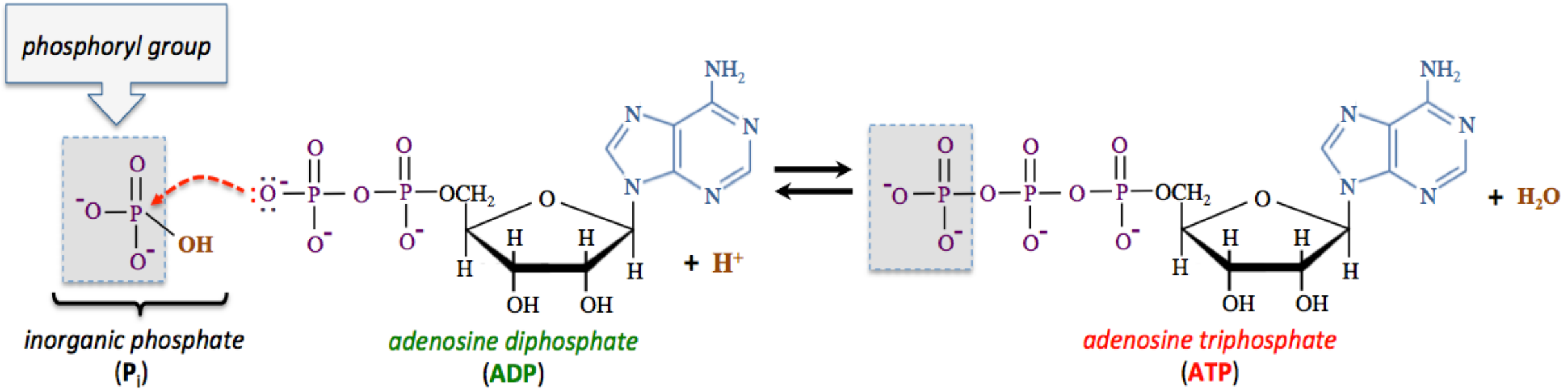
15.2) Name the **products** of the *phosphorylation* of ADP reaction shown below.

- NOTE: You do not need to draw the structural formulas of the products, just name them or use their abbreviations.

ANSWER: adenosine triphosphate (ATP) and water (H_2O)



EXPLANATION:

When a compound gains/accepts a phosphoryl group in a reaction, we say that the compound became "*phosphorylated*." The chemical equation for the transfer of a *phosphoryl group* (**PO_3**) ***from*** *inorganic phosphate* (**P_i**) ***to*** **ADP** is shown above.

For more details: See chapter 15 part 1 video or chapter 15 section 2 in the textbook.

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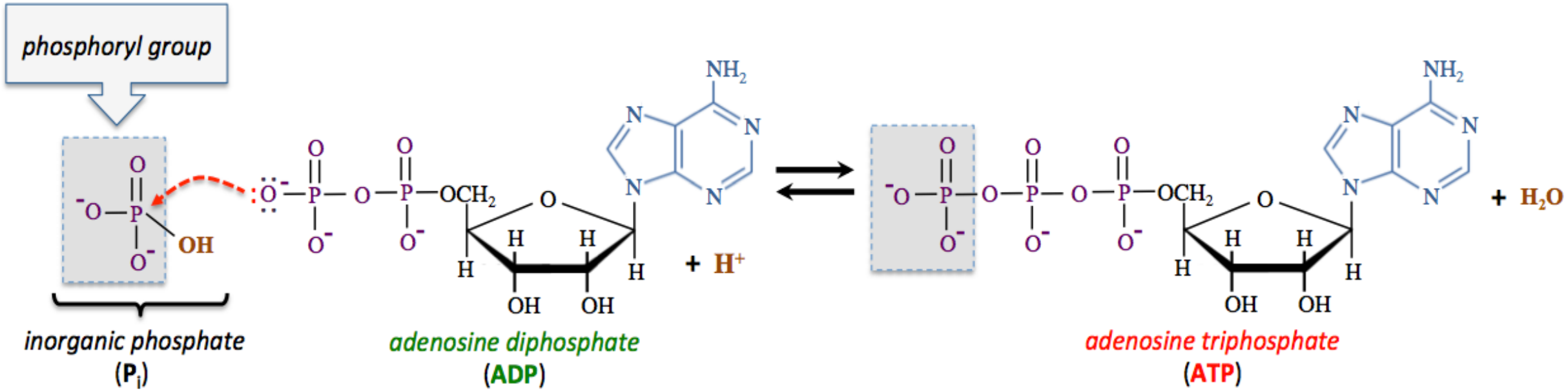
15.3) In the previous problem, you drew the products for the phosphorylation of ADP reaction (shown below). Does that reaction **require energy** or **release energy** when it occurs?



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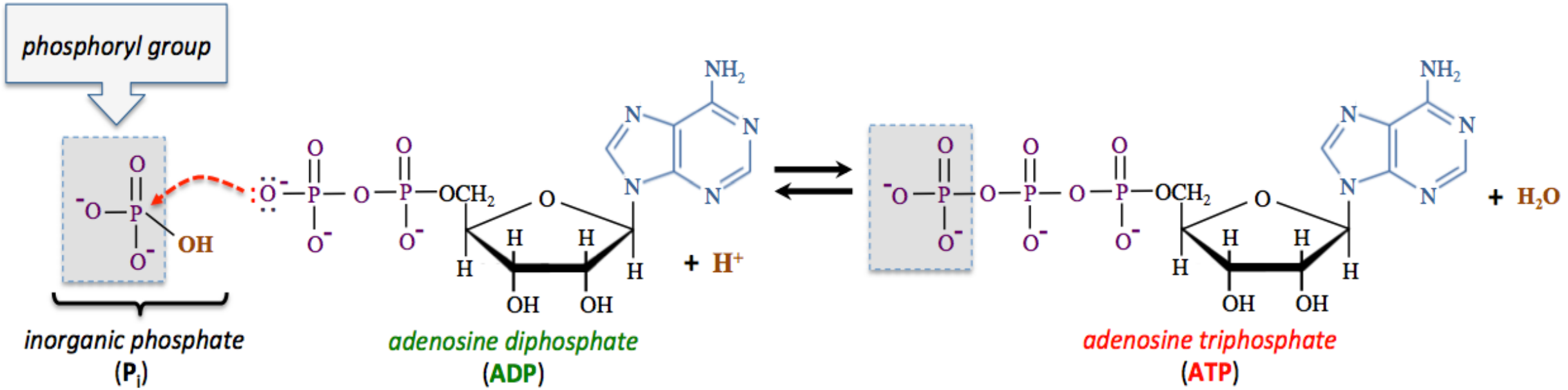
15.3) In the previous problem, you drew the products for the phosphorylation of ADP reaction (shown below). Does that reaction **require energy** or **release energy** when it occurs?

HINT: **ΔG** for this reaction is 7300 Joules per mole of ADP that reacts.



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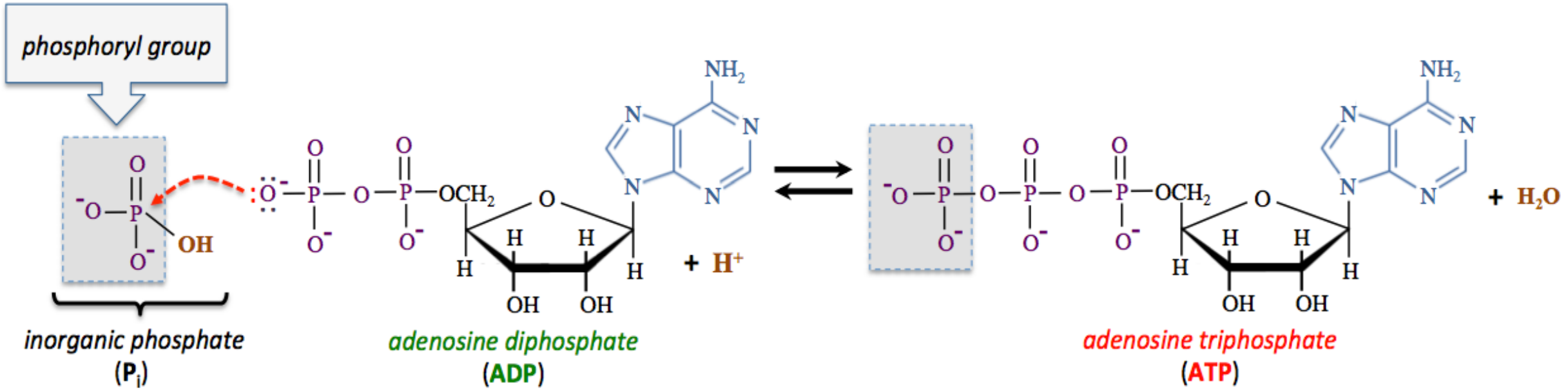
15.3) In the previous problem, you drew the products for the phosphorylation of ADP reaction (shown below). Does that reaction **require energy** or **release energy** when it occurs?

ANSWER: This reaction **requires energy** in order to occur.



EXPLANATION:

Adding a *phosphoryl group* to **ADP** in order to form **ATP** ***requires*** energy. The positive value of **ΔG** for this reaction (7300 Joules per mole of ADP) indicates that the reaction **requires energy** in order to occur. This reaction will not occur spontaneously unless external energy is provided. Catabolic metabolic pathways often use the energy contained in food to drive the transfer of *phosphoryl groups* to **ADP**, thereby forming **ATP**.

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For more details: See chapter 15 part 1 video or chapter 15 section 2 in the textbook.

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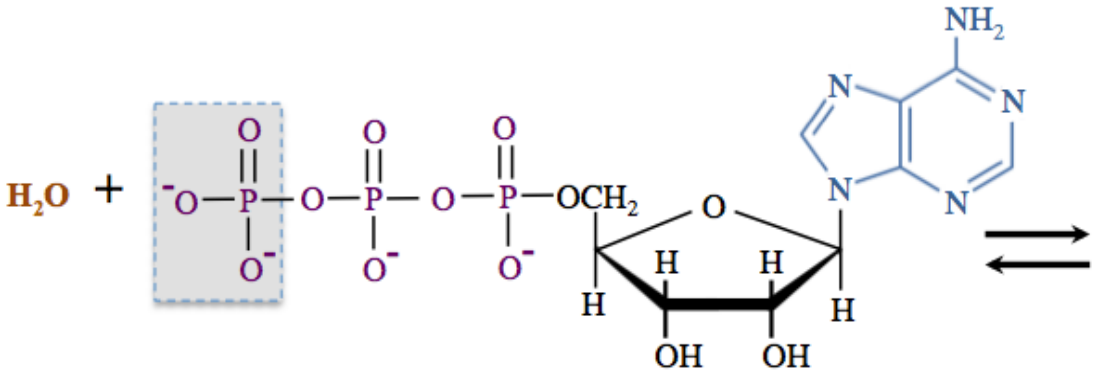
15.4)

a) Name the **products** of the ***dephosphorylation*** of ATP reaction shown below.

- NOTE: You do not need to draw the structural formulas of the products, just name them or use their abbreviations.



adenosine triphosphate
(ATP)

b) Does the ***dephosphorylation*** of ATP reaction **require energy** or **release energy**?

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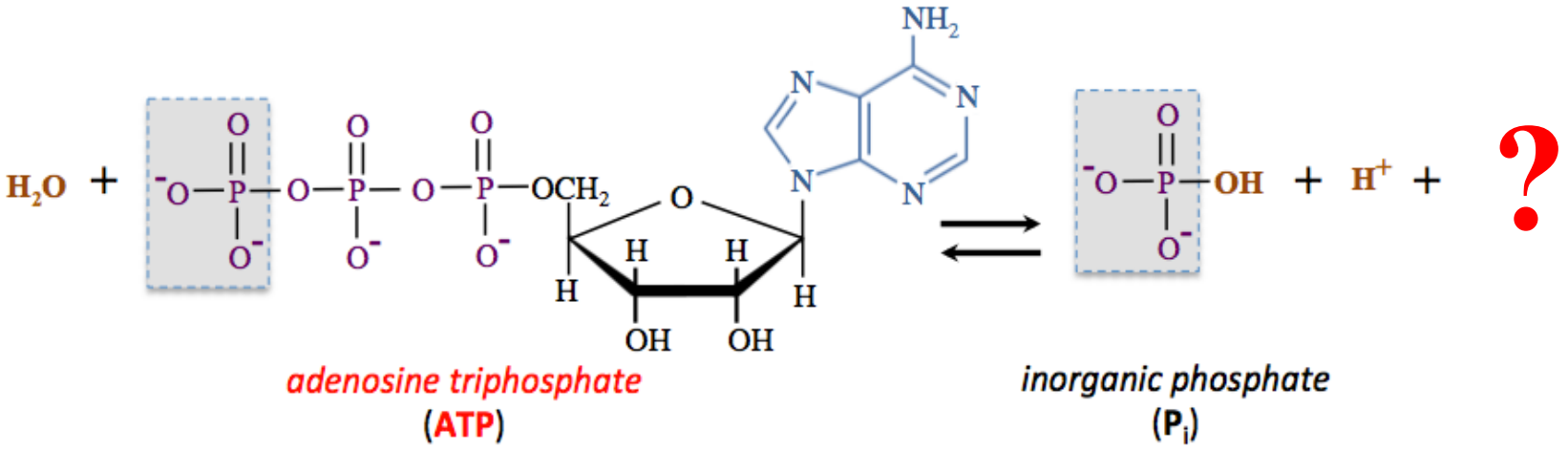
15.4)

a) Name the **products** of the ***dephosphorylation*** of ATP reaction shown below.

- NOTE: You do not need to draw the structural formulas of the products, just name them or use their abbreviations.



HINT:
There are ***three products*** in this reaction, one of the products is an inorganic phosphate (P_i), another is a hydrogen ion (H^+). What is the third product?

b) Does the ***dephosphorylation*** of ATP reaction **require energy** or **release energy**?

HINT: **ΔG** for this reaction is -7300 Joules per mole of ATP that reacts.

For more help: See chapter 15 part 1 video or chapter 15 section 2 in the textbook.

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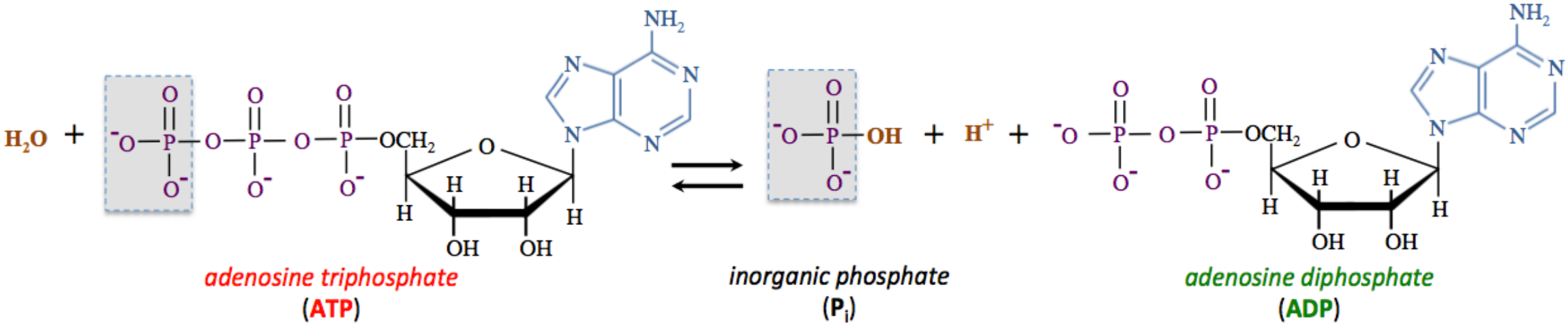
15.4)

a) Name the **products** of the ***dephosphorylation*** of ATP reaction shown below.

- NOTE: You do not need to draw the structural formulas of the products, just name them or use their abbreviations.

ANSWER: inorganic phosphate (P_i), H^+, and adenosine diphosphate (ADP)



b) Does the ***dephosphorylation*** of ATP reaction **require energy** or **release energy**?

Energy is *released* from ATP when it is converted to ADP.

- This energy is used by organisms to drive energy-requiring reactions or physical processes that would otherwise not occur spontaneously. *One* way that energy can be released from **ATP** is by reacting it with **H_2O** to ***form*** **ADP**, *inorganic phosphate*, and an **H^+** ion. Although this reaction is spontaneous (ΔG is negative), the reaction rate is quite slow, therefore organisms employ enzymes in order for the reaction to proceed at a useful rate.

For more details: See chapter 15 part 1 video or chapter 15 section 2 in the textbook.

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15.5)

i) Coenzyme A is classified as a coenzyme because it is involved in the transfer of an _____ in many different enzymatically catalyzed reactions.

a) carbonyl
b) acyl
c) hydroxyl
d) carboxyl

ii) An acyl group that is central to the metabolism of food is the _____ group.

a) hydroxyl
b) acetyl
c) carbonyl
d) carboxyl

iii) When NAD^+ accepts a hydride ion from another species, it is _____ to NADH.

a) oxidized
b) reduced

iv) $FADH_2$ is _____ to FAD by donating two electrons (and two H^+ ions) to other species.

a) oxidized
b) reduced

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15.5)

i) Coenzyme A is classified as a coenzyme because it is involved in the transfer of an _____ in many different enzymatically catalyzed reactions.

HINT:
~~a) carbonyl~~
b) acyl
~~c) hydroxyl~~
d) carboxyl

ii) An acyl group that is central to the metabolism of food is the _____ group.

HINT:
~~a) hydroxyl~~
b) acetyl
c) carbonyl
d) carboxyl

iii) When NAD^+ accepts a hydride ion from another species, it is _____ to NADH.

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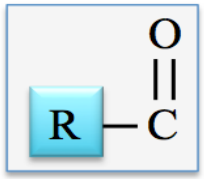
15.5)

i) Coenzyme A is classified as a coenzyme because it is involved in the transfer of an _____ in many different enzymatically catalyzed reactions.

a) carbonyl
b) acyl
c) hydroxyl
d) carboxyl



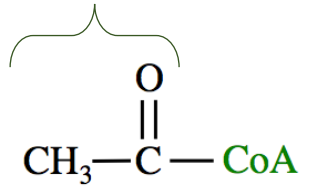
general form of an acyl group

ii) An acyl group that is central to the metabolism of food is the _____ group.

a) hydroxyl
b) acetyl
c) carbonyl
d) carboxyl

Acetyl groups are donated and accepted by *coenzyme A*. When an acetyl group is bonded to coenzyme A, the compound is referred to as acetyl-coenzyme A (acetyl-CoA). The structural formula of acetyl-coenzyme A is often abbreviated as shown on the right.

acetyl group



acetyl-coenzyme A

iii) When NAD^+ accepts a hydride ion from another species, it is _____ to NADH.

a) oxidized
b) reduced

Many oxidation-reduction reactions reactions involve the transfer of an electron by way of the hydride ion (H:-). Recall that a hydrogen atom has one electron, whereas a hydride ion has an "extra" (second) electron. A substance that *accepts* a hydride ion is reduced because of the hydride's "extra" electron.

iv) $FADH_2$ is _____ to FAD by donating two electrons (and two H^+ ions) to other species.

a) oxidized
b) reduced

A substance is *oxidized* when it *loses electrons*.

For more details: See chapter 15 part 2 video or chapter 15 section 2 in the textbook.

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15.6) Match each of the **coenzymes listed below** with the ***species that they transport***.

i) ADP

ii) Coenzyme A (CoA)

iii) FAD

iv) Coenzyme Q (CoQ)

v) NAD^+

***transported species choices*:**

a) acyl groups

b) phosphate groups

c) hydride ions ($H:^-$)/electrons

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iv) Coenzyme Q (CoQ)

v) NAD^+

***transported species choices*:**

a) acyl groups

b) phosphate groups

c) hydride ions ($H:^-$)/electrons

HINT:

A *coenzyme* is a species that must bind to an enzyme in order for the enzyme to function. In most cases, a coenzyme is actually one of the *substrates* (reactants) in the catalyzed reaction. The reason that certain *substrates* are ***also*** referred to as *coenzymes* is that these *substrates* are ***common substrates in many different enzymatic reactions*** in which they ***donate electrons, atoms, or groups of atoms*** to other substrates, ***or accept electrons, atoms or groups of atoms*** from other substrates. The five group-transfer coenzymes in this problem, that are central to the metabolization of food, along with the species each transfers *are listed in your lecture notes and the textbook.*

For more help: See chapter 15 part 1 and part 2 videos or chapter 15 section 2 in the textbook.

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15.6) Match each of the **coenzymes listed below** with the ***species that they transport***.

i) ADP **(b) phosphate groups**

ii) Coenzyme A (CoA) **(a) acyl groups**

iii) FAD **(c) hydride ions (H:$^-$) or electrons**

iv) Coenzyme Q (CoQ) **(c) hydride ions (H:$^-$)/electrons**

v) NAD^+ **(c) hydride ions (H:$^-$)/electrons**

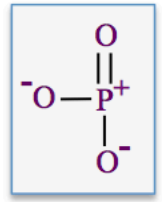
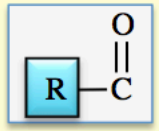
***transported species choices*:**

a) acyl groups

b) phosphate groups

c) hydride ions (H:$^-$)/electrons

EXPLANATION: A *coenzyme* is a species that must bind to an enzyme in order for the enzyme to function. In most cases, a coenzyme is actually one of the *substrates* (reactants) in the catalyzed reaction. The reason that certain *substrates* are ***also*** referred to as *coenzymes* is that these *substrates* are ***common substrates in many different enzymatic reactions*** in which they ***donate electrons, atoms, or groups of atoms*** to other substrates, ***or accept electrons***, ***atoms or groups of atoms*** from other substrates. The five group-transfer coenzymes that are central to the metabolization of food, along with the species each transfers are listed in the table on the right.

Coenzyme	Species that is Transferred
ADP/ATP	phosphoryl group = 
NAD^+/NADH	hydride ion (H:$^-$) **or** electrons
FAD/$FADH_2$	hydride ion (H:$^-$) **or** electrons
coenzyme A	acyl group = 
coenzyme Q	hydride ion (H:$^-$) **or** electrons

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For more details: See chapter 15 part 1 and part 2 videos or chapter 15 section 2 in the textbook.

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15.7) Determine whether each of the following changes is an **oxidation** or **reduction**.

a) gain of electrons

b) loss of electrons

c) Fe^{2+} to Fe^{3+}

d) NADH to NAD^+

e) FAD to $FADH_2$

f) CH_4 to CO_2

g) NAD^+ to NADH

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e) FAD to $FADH_2$

f) CH_4 to CO_2

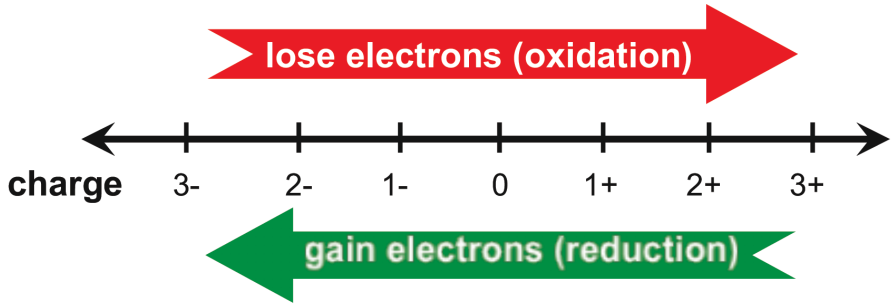
g) NAD^+ to NADH

HINT: A useful mnemonic to differentiate **oxidation** and **reduction** is the term "**OILRIG**"

(**O**xidation **i**s the **L**oss of electrons; **R**eduction **i**s the **G**ain of electrons).

It is possible to identify redox reactions for inorganic compounds by inspecting the chemical equation and determining if electrons are *transferred from one species to another*.

- If the **charge** of an atom or ion in a reactant was ***increased*** (toward positive) in the conversion of reactants to products, ***an oxidation occurred***.
- If the **charge** of an atom or ion in a reactant was ***decreased*** (toward negative) in the conversion of reactants to products, ***a reduction occurred***.



HINT: For ***covalent compounds***, such as organic and biological compounds, the gaining and losing of electrons is the result of a **gain** or **loss** of bond(s) to ***oxygen atoms*** or ***hydrogen atoms***.

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Click here to **check your answer**

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15.7) Determine whether each of the following changes is an **oxidation** or **reduction**.

a) gain of electrons **reduction**

b) loss of electrons **oxidation**

c) Fe^{2+} to Fe^{3+} **oxidation**

d) NADH to NAD^+ **oxidation**
lost bond to ***hydrogen atom***

e) FAD to $FADH_2$ **reduction**
gained bond to ***hydrogen atom***

f) CH_4 to CO_2 **oxidation**
gained bonds to ***oxygen atoms***
and **lost** bonds to ***hydrogen atoms***

g) NAD^+ to NADH **reduction**
gained bond to ***hydrogen atom***

EXPLANATION:

A useful mnemonic to differentiate **oxidation** and **reduction** is the term "**OILRIG**"
(**O**xidation **i**s the **L**oss of electrons; **R**eduction **i**s the **G**ain of electrons).

It is possible to identify redox reactions for inorganic compounds by inspecting the chemical equation and determining if electrons are *transferred from one species to another*.

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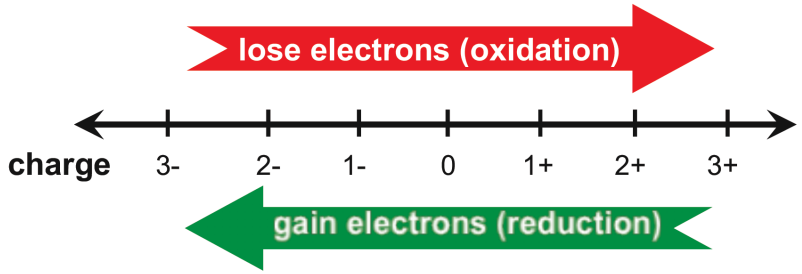

For ***covalent compounds***, such as organic and biological compounds, the gaining and losing of electrons is the result of a **gain** or **loss** of bond(s) to ***oxygen atoms*** or ***hydrogen atoms***.

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For more details on NAD^+/NADH and FAD/FADH: See chapter 15 part 2 video or chapter 15 section 2 in the textbook.

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15.8) Explain the difference between ***catabolism*** and ***anabolism***.

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15.8) Explain the difference between ***catabolism*** and ***anabolism***.

HINT:

Metabolic pathways can usually be classified as catabolic (**catabolism**) or anabolic (**anabolism**). One of these pathways involve the breakdown of larger organic compounds into smaller compounds. The other pathway involve building up of larger organic compounds from smaller ones.

For more help: See chapter 15 part 1 video or chapter 15 section 2 in the textbook.

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15.8) Explain the difference between ***catabolism*** and ***anabolism***.

YOUR ANSWER SHOULD BE SOMETHING LIKE THIS:

Metabolic pathways can usually be classified as catabolic (**catabolism**) or anabolic (**anabolism**).
Catabolic pathways involve the breakdown of larger organic compounds into smaller compounds.
Anabolic pathways involve building up of larger organic compounds from smaller ones.

For more details: See chapter 15 part 1 video or chapter 15 section 2 in the textbook.

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15.9)

i) What type of chemical bonds are broken in the digestion of starch?

a) ester bonds
b) peptide bonds
c) glycosidic bonds
d) phosphoester bonds

ii) What is the name of the monosaccharide that is produced in the digestion of starch?

iii) Why can't humans digest cellulose?

iv) Digestion is the **first stage** of carbohydrate catabolism. In **stage 2** of carbohydrate catabolism, ***glucose*** is converted into **acetyl-coenzyme A**, CO_2, and H_2O. This process begins with a *catabolic pathway* called **glycolysis**. ***Glycolysis*** is a series of ten sequential reactions. Complete the overall chemical equation (below) for glycolysis by adding the products.

NOTE: You do not need to write the structural formulas of the products; you can use their chemical formulas, names, or their abbreviations.

$$\textbf{glucose} + 2\,\textbf{ADP} + 2\textbf{P}_\textbf{i} + 2\,\textbf{NAD}^+ \rightleftarrows$$

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15.9)

i) What type of chemical bonds are broken in the digestion of starch?

HINT:
a) ester bonds
b) peptide bonds
c) glycosidic bonds
~~d) phosphoester bonds~~

ii) What is the name of the monosaccharide that is produced in the digestion of starch?

HINT: Amylose and amylopectin, the two components of starch, are homopolysaccharides. Which monosaccharide residues do they contain?

iii) Why can't humans digest cellulose?

iv) Digestion is the **first stage** of carbohydrate catabolism. In **stage 2** of carbohydrate catabolism, ***glucose*** is converted into **acetyl-coenzyme A**, CO_2, and H_2O. This process begins with a *catabolic pathway* called **glycolysis**. ***Glycolysis*** is a series of ten sequential reactions. Complete the overall chemical equation (below) for glycolysis by adding the products.

NOTE: You do not need to write the structural formulas of the products; you can use their chemical formulas, names, or their abbreviations.

glucose + 2 **ADP** + 2 $\mathbf{P_i}$ + 2 $\mathbf{NAD^+}$ $\rightleftarrows$ **HINT**: There are *five* products. One of them is NADH, another is ATP.

For more help: See chapter 15 part 3 and part 4 videos or chapter 15 section 3 in the textbook.

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15.9)

i) What type of chemical bonds are broken in the digestion of starch?

a) ester bonds
b) peptide bonds
c) glycosidic bonds
d) phosphoester bonds

ii) What is the name of the monosaccharide that is produced in the digestion of starch? **glucose**

Amylose and amylopectin, the two components of starch, are homopolysaccharides; they contain glucose residues only.

iii) Why can't humans digest cellulose? Not all dietary carbohydrates can be digested. Cellulose cannot be digested because humans do not have a dietary enzyme capable of hydrolyzing **β-(1⟶4)** glucose-glucose glycosidic bonds.

iv) Digestion is the **first stage** of carbohydrate catabolism. In **stage 2** of carbohydrate catabolism, ***glucose*** is converted into **acetyl-coenzyme A**, CO_2, and H_2O. This process begins with a *catabolic pathway* called **glycolysis**. ***Glycolysis*** is a series of ten sequential reactions. Complete the overall chemical equation (below) for glycolysis by adding the products.

NOTE: You do not need to write the structural formulas of the products; you can use their chemical formulas, names, or their abbreviations.

$$\textbf{glucose} + 2\,\textbf{ADP} + 2\textbf{P}_\textbf{i} + 2\,\textbf{NAD}^+ \rightleftarrows 2\,\textbf{pyruvate ions} + 2\,\textbf{ATP} + 2\,\textbf{NADH} + 2\,\textbf{H}_2\textbf{O} + 2\,\textbf{H}^+$$

For more help: See chapter 15 part 3 and part 4 videos or chapter 15 section 3 in the textbook.

For more details: See chapter 15 part 3 and part 4 videos or chapter 15 section 3 in the textbook.

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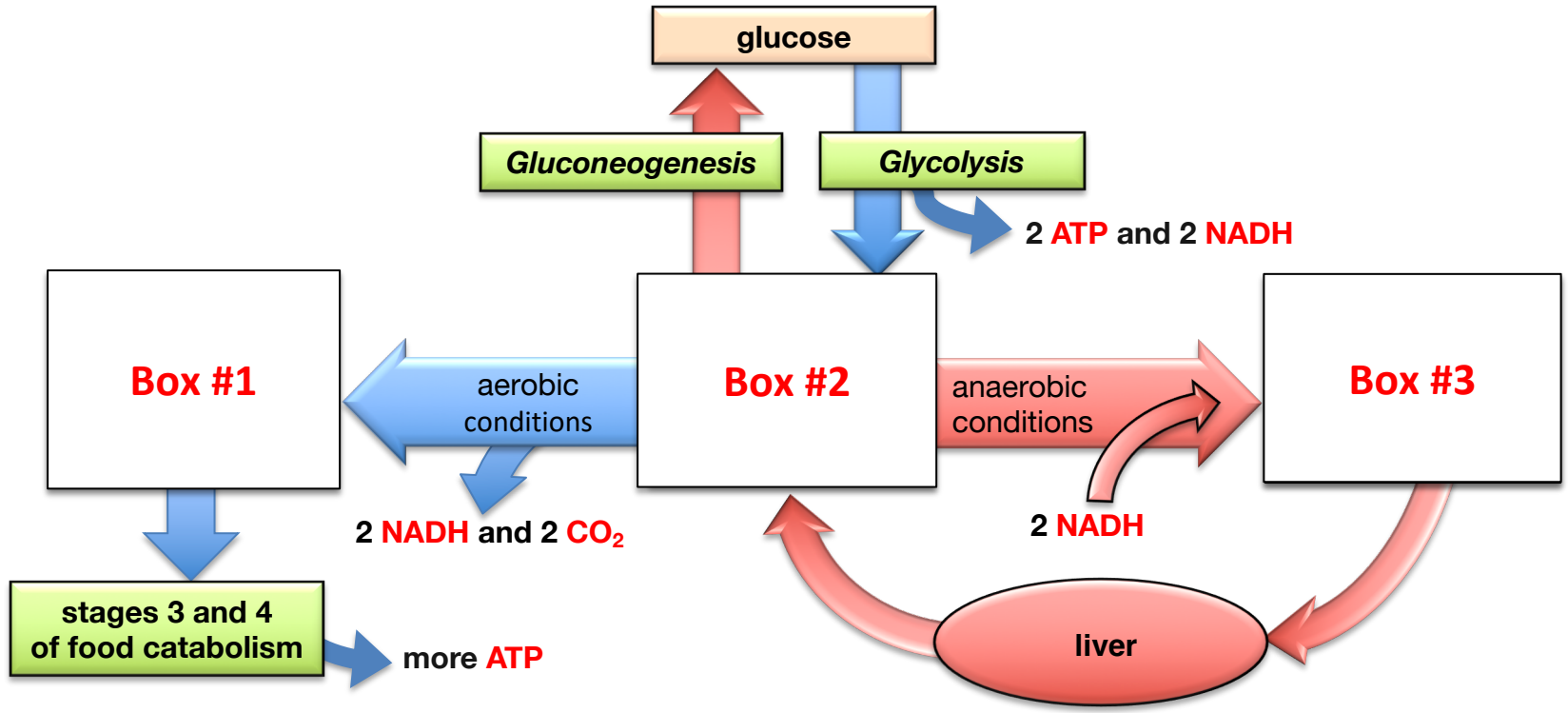
15.10) The fate of the pyruvate that is produced in glycolysis by aerobic organisms (organisms that require O_2 to grow), such as humans and most other organisms, depends on *the availability of oxygen* in cells. The term "*aerobic condition*" is used to describe a situation where a significant amount of oxygen is present. The term "*anaerobic condition*" is used to describe a situation where a significant amount of oxygen is not present.

An illustrative summary of **stage 2** of food catabolism and the fate of pyruvate is shown below. Match the **compounds listed below** with the **numbered boxes** in the illustration.

a) pyruvate

b) acetyl-coenzyme A

c) lactate



Go back

Click here for a **hint**

Click here to **check your answer**

Go to next question

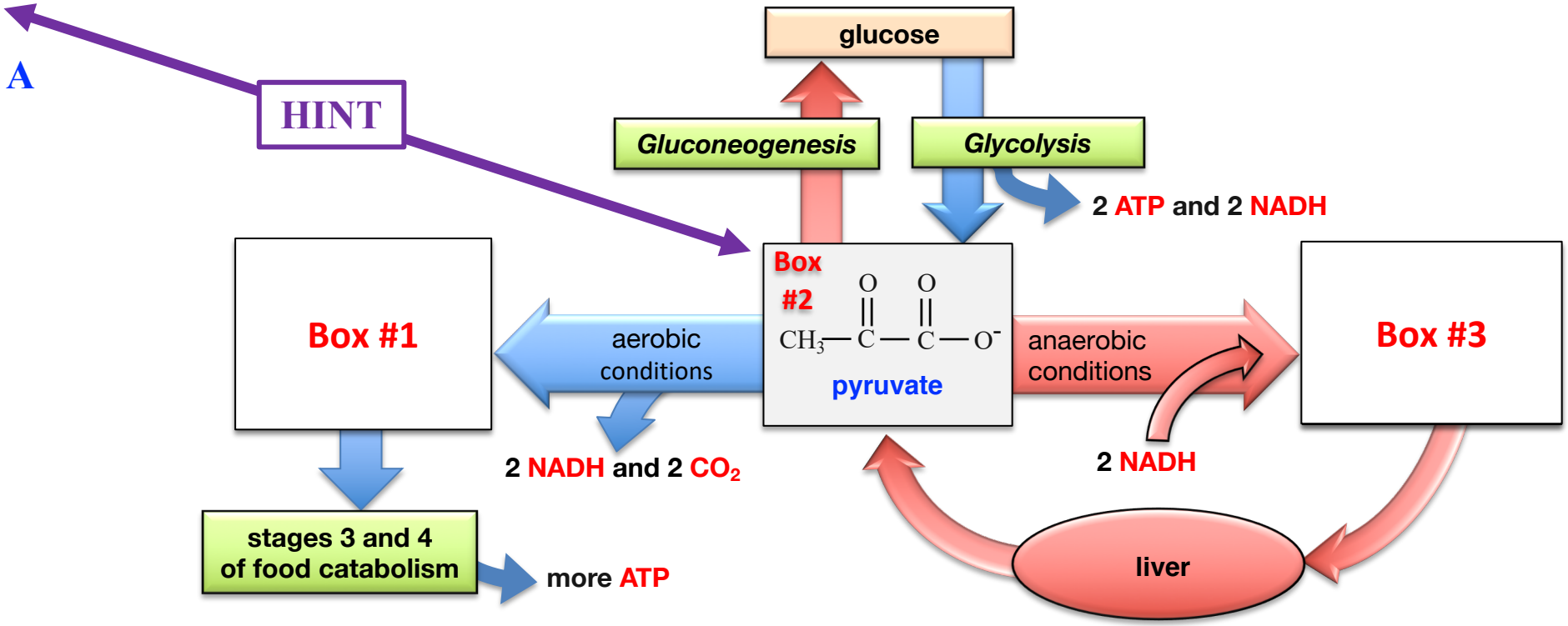
15.10) The fate of the pyruvate that is produced in glycolysis by aerobic organisms (organisms that require O_2 to grow), such as humans and most other organisms, depends on *the availability of oxygen* in cells. The term "*aerobic condition*" is used to describe a situation where a significant amount of oxygen is present. The term "*anaerobic condition*" is used to describe a situation where a significant amount of oxygen is not present.

An illustrative summary of **stage 2** of food catabolism and the fate of pyruvate is shown below. Match the **compounds listed below** with the **numbered boxes** in the illustration.

a) pyruvate Box #2

b) acetyl-coenzyme A

c) lactate



For more help: See chapter 15 part 3 and part 4 videos or chapter 15 section 3 in the textbook.

Click here to **check your answer**

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15.10) The fate of the pyruvate that is produced in glycolysis by aerobic organisms (organisms that require O_2 to grow), such as humans and most other organisms, depends on *the availability of oxygen* in cells. The term "*aerobic condition*" is used to describe a situation where a significant amount of oxygen is present. The term "*anaerobic condition*" is used to describe a situation where a significant amount of oxygen is not present.

An illustrative summary of **stage 2** of food catabolism and the fate of pyruvate is shown below. Match the **compounds listed below** with the **numbered boxes** in the illustration.

a) pyruvate **Box #2**

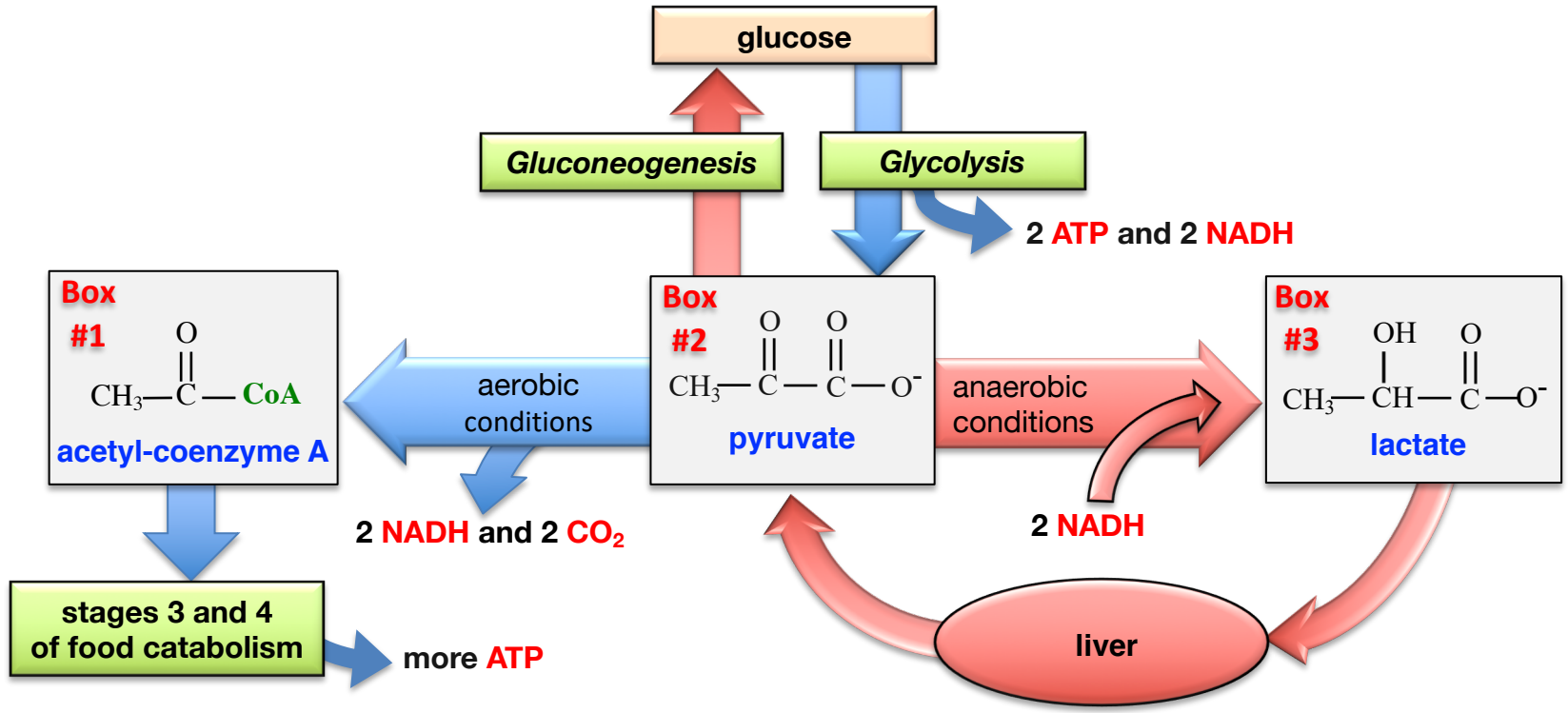
b) acetyl-coenzyme A **Box #1**

c) lactate **Box #3**

EXPLANATION:

Under *aerobic conditions*, the **pyruvate** made in glycolysis passes from the cytoplasm into the mitochondria and is then converted to **acetyl-coenzyme A** and CO_2.

Under *anaerobic conditions*, the pyruvate that is made in glycolysis remains in the cytoplasm and is converted (***reduced***) to **lactate**.



For more details: See chapter 15 part 3 and part 4 videos or chapter 15 section 3 in the textbook.

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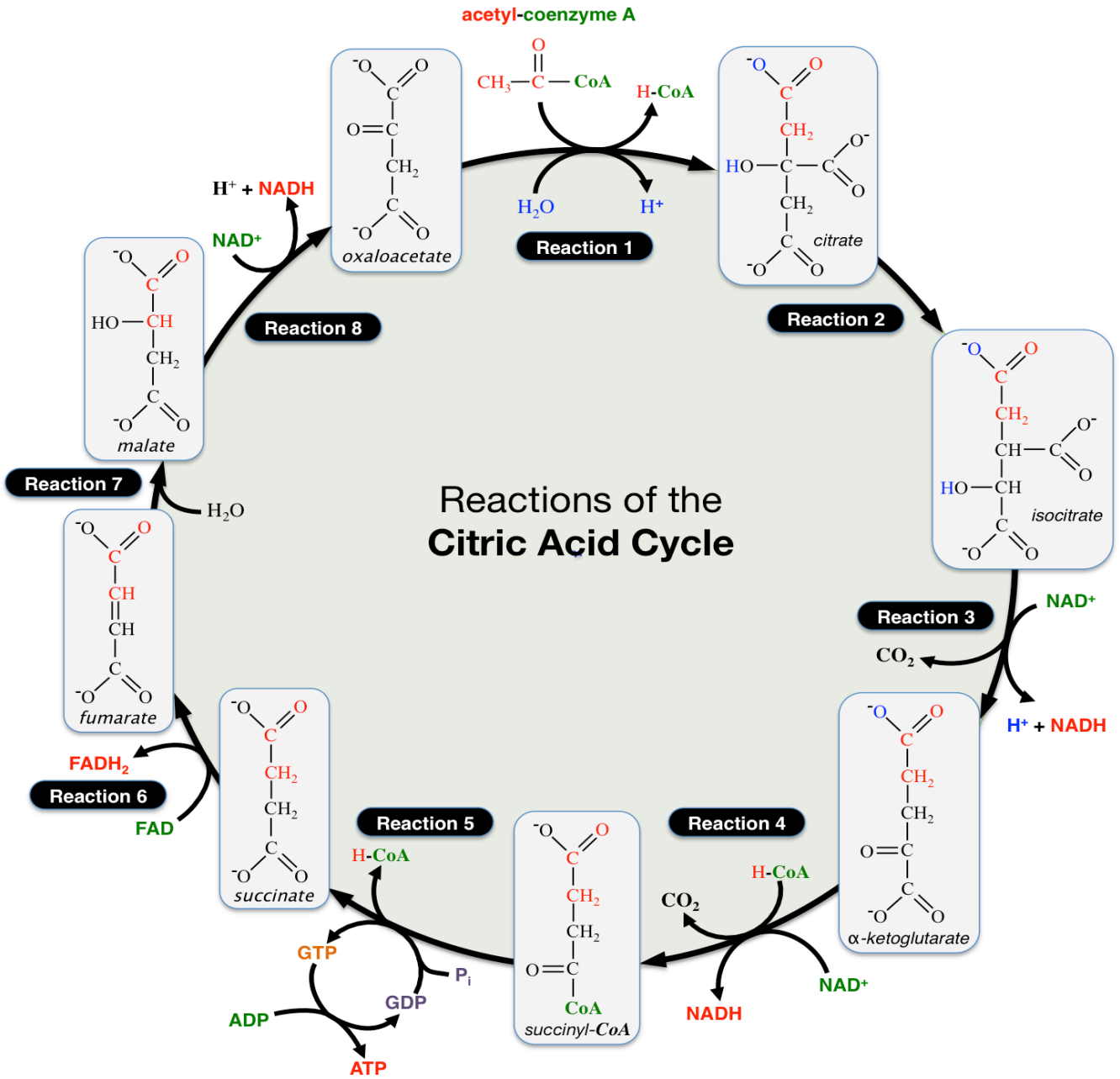
15.11) The reactions of the citric acid cycle are shown here.

When one acetyl-CoA molecule is completely processed in the citric acid cycle:

a) how many NADH molecules are produced?

b) how many $FADH_2$ molecules are produced?

c) how many ATP ions are produced?



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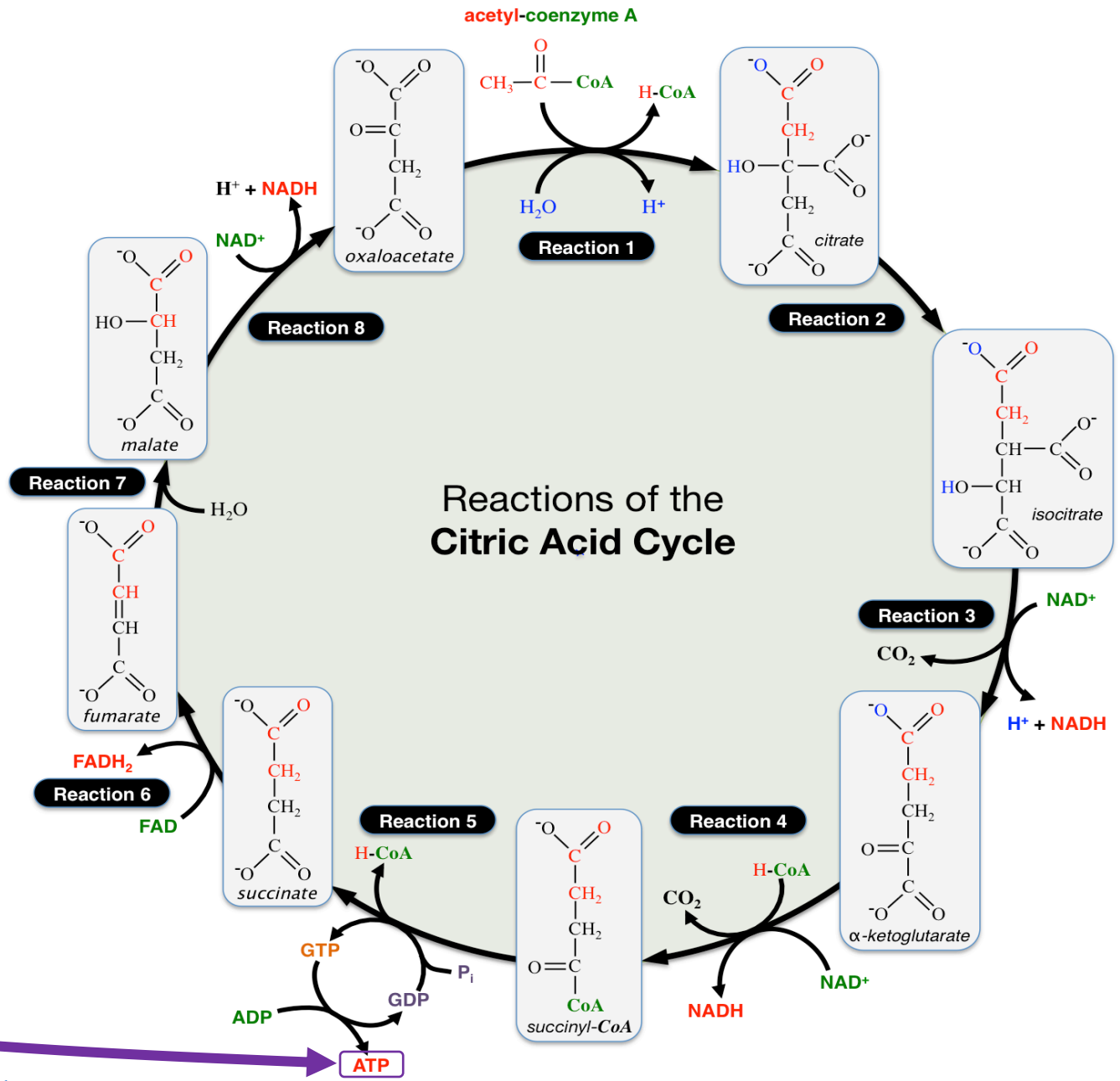
b) how many $FADH_2$ molecules are produced?

c) how many ATP ions are produced?

HINT



For more help: See chapter 15 part 5 video or chapter 15 section 3 in the textbook.

Click here to **check your answer**

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Go to next question

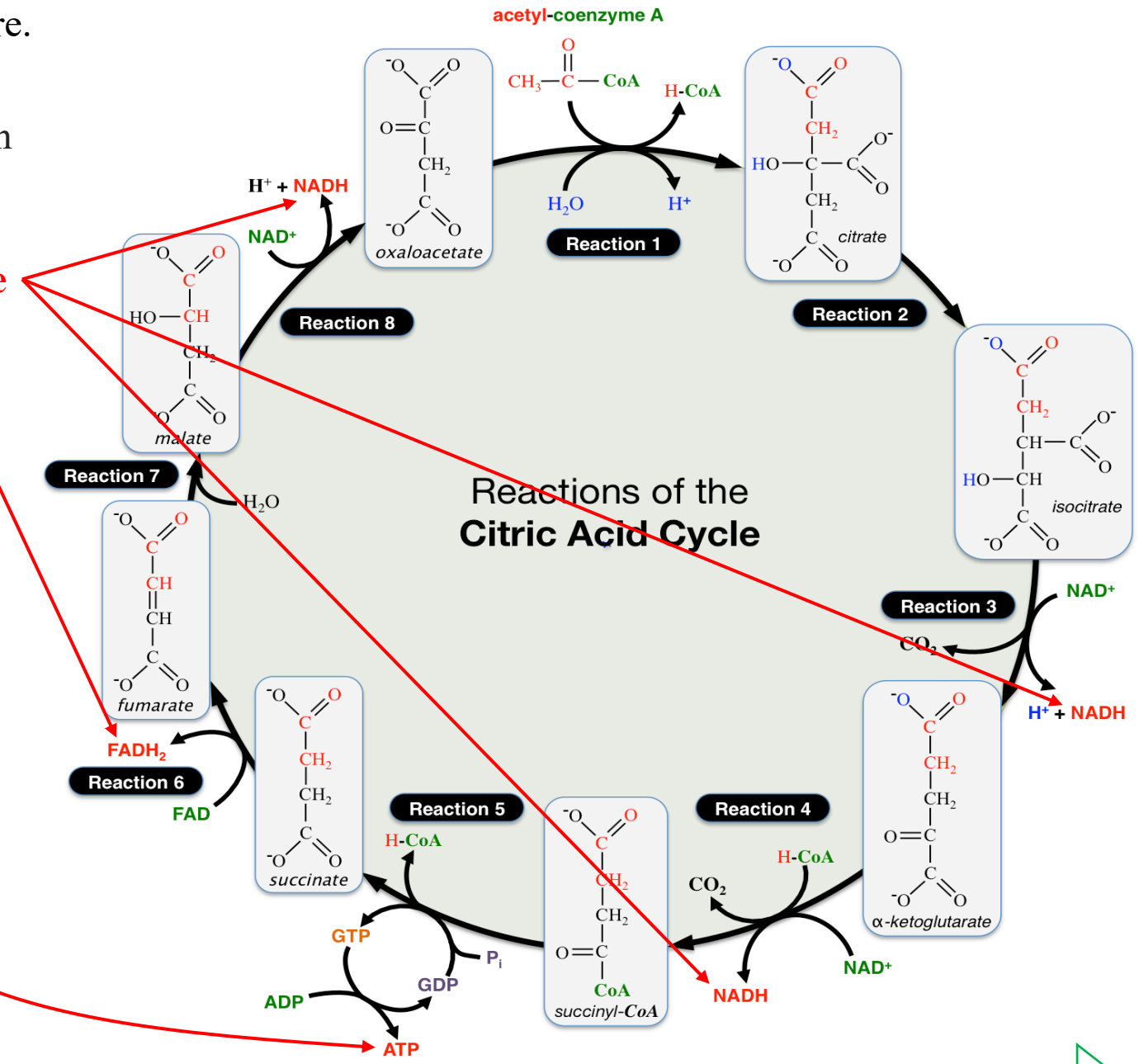
15.11) The reactions of the citric acid cycle are shown here.

When one acetyl-CoA molecule is completely processed in the citric acid cycle:

a) how many NADH molecules are produced? **three**

b) how many $FADH_2$ molecules are produced? **one**

c) how many ATP ions are produced? **one**



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For more details: See chapter 15 part 5 video or chapter 15 section 3 in the textbook.

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15.12) Determine whether each of the following metabolic processes occurs in the **cytoplasm** (outside of the mitochondria) or in the **mitochondria**.

a) glycolysis

b) citric acid cycle

c) beta oxidation

d) oxidative phosphorylation

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Go to next question

15.12) Determine whether each of the following metabolic processes occurs in the **cytoplasm** (outside of the mitochondria) or in the **mitochondria**.

a) glycolysis

b) citric acid cycle

c) beta oxidation

d) oxidative phosphorylation

HINT:

All but one of these processes occur in the mitochondria.

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Click here to **check your answer**

Go to next question

15.12) Determine whether each of the following metabolic processes occurs in the **cytoplasm** (outside of the mitochondria) or in the **mitochondria**.

a) glycolysis **cytoplasm**

b) citric acid cycle **mitochondria**

c) beta oxidation **mitochondria**

d) oxidative phosphorylation **mitochondria**

EXPLANATION:

The enzymes that catalyze the reactions of the citric acid cycle, beta-oxidation, and oxidative phosphorylation are all located in the mitochondria.

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15.13) The NADH that is produced by glycolysis is not able to pass through the inner mitochondrial membrane to enter the matrix region and undergo oxidative phosphorylation. ***Name*** the two processes in which the energy from NADH made in glycolysis can enter the mitochondrial matrix.

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Click here for a **hint**

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Go to next question

15.13) The NADH that is produced by glycolysis is not able to pass through the inner mitochondrial membrane to enter the matrix region and undergo oxidative phosphorylation. ***Name*** the two processes in which the energy from NADH made in glycolysis can enter the mitochondrial matrix.

HINT:

In order for the energy from the NADH that is produced by glycolysis to be utilized, it must be processed through "**NADH** shuttles."

What are the names of the **NADH** shuttles?

For more help: See chapter 15 part 6 video or chapter 15 section 3 in the textbook.

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Go to next question

15.13) The NADH that is produced by glycolysis is not able to pass through the inner mitochondrial membrane to enter the matrix region and undergo oxidative phosphorylation. ***Name*** the two processes in which the energy from NADH made in glycolysis can enter the mitochondrial matrix.

ANSWER:

1) **malate-aspartate shuttle**
2) **glycerol 3-phosphate shuttle**

EXPLANATION:

Oxidative phosphorylation requires that **NADH** be located ***within* the *mitochondrial matrix***. Since pyruvate oxidation/decarboxylation ***and*** the reactions of the citric acid cycle occur in the *mitochondrial matrix*, the **NADH** created in those processes can immediately undergo oxidative phosphorylation. The **NADH *that is produced by glycolysis*** is able to pass through the ***outer*** *mitochondrial membrane* and enter the *intermembrane space*; however, it is ***not*** able to pass through the ***inner*** *mitochondrial* membrane to enter the ***matrix*** region. In order for the energy from this **NADH** to be utilized, it must be processed through "**NADH** shuttles."

The two most important **NADH** shuttles are the **malate-aspartate shuttle** and the **glycerol 3-phosphate shuttle**. The **malate-aspartate shuttle** works by oxidizing the **NADH *produced by glycolysis*** to **NAD^+** in the intermembrane space, then transferring the electrons through the inner mitochondrial matrix to an **NAD^+** that ***is already inside the matrix,*** *thereby producing an* **NADH** that *can undergo oxidative phosphorylation*. In the **glycerol 3-phosphate shuttle**, **NADH *produced by glycolysis*** is oxidized in the intermembrane space by transferring electrons to an inner mitochondrial membrane-bound **FAD**, ***thereby producing an* $FADH_2$** that *can undergo oxidative phosphorylation.*

For more details: See chapter 15 part 6 video or chapter 15 section 3 in the textbook.

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15.14) The metabolic strategy of oxidative phosphorylation is to convert the chemical potential energy in reduced coenzymes, NADH and $FADH_2$ into chemical potential energy in ATP.

a) How many ATP are produced, on average, for each NADH that undergoes oxidative phosphorylation?

b) How many ATP are produced, on average, for each $FADH_2$ that undergoes oxidative phosphorylation?

Go back

Click here for a **hint**

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Go to next question

15.14) The metabolic strategy of oxidative phosphorylation is to convert the chemical potential energy in reduced coenzymes, NADH and $FADH_2$ into chemical potential energy in ATP.

HINT:

a) How many ATP are produced, on average, for each NADH that undergoes oxidative phosphorylation? **2.5 ATP**

b) How many ATP are produced, on average, for each $FADH_2$ that undergoes oxidative phosphorylation?

For more help: See chapter 15 part 7 and part 8 videos or chapter 15 section 3 in the textbook.

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Go to next question

15.14) The metabolic strategy of oxidative phosphorylation is to convert the chemical potential energy in reduced coenzymes, NADH and $FADH_2$ into chemical potential energy in ATP.

a) How many ATP are produced, on average, for each NADH that undergoes oxidative phosphorylation? **2.5 ATP**

b) How many ATP are produced, on average, for each $FADH_2$ that undergoes oxidative phosphorylation? **1.5 ATP**

EXPLANATION:

The number of ATP that can be produced from NADH or $FADH_2$ depends on the cell and its current conditions. The latest research indicates that, on average, one NADH produces about 2.5 ATP, and one $FADH_2$ produces about 1.5 ATP.

For more details: See chapter 15 part 7 and part 8 videos or chapter 15 section 3 in the textbook.

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15.15) The reduced coenzymes generated by the citric acid cycle (and beta-oxidation) donate electrons in oxidative phosphorylation. Answer each of the questions below by selecting the appropriate species from the ***list of species choices***.
NOTE: You will need to select ***more than one species*** for some of these questions.

a) Which species donate electrons to the proteins of the electron transport chain?

b) Which species is the final acceptor of electrons in oxidative phosphorylation?

c) Which species are the final products of oxidative phosphorylation?

list of species choices:

H_2O
NADH
NAD^+
ATP
ADP
O_2
$FADH_2$
FAD
Coenzyme A

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Click here for a **hint**

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Go to next question

15.15) The reduced coenzymes generated by the citric acid cycle (and beta-oxidation) donate electrons in oxidative phosphorylation. Answer each of the questions below by selecting the appropriate species from the ***list of species choices***.
NOTE: You will need to select ***more than one species*** for some of these questions.

list of species choices:

H_2O
NADH
NAD^+
ATP
ADP
O_2
$FADH_2$
FAD
Coenzyme A

a) Which species donate electrons to the proteins of the electron transport chain?
HINT: ***Two*** species donate electrons to the proteins of the electron transport chain.

b) Which species is the final acceptor of electrons in oxidative phosphorylation?

c) Which species are the final products of oxidative phosphorylation?
HINT: ***One*** of the final products of oxidative phosphorylation is **H_2O**; there are ***three*** other products.

For more help: See chapter 15 part 7 and part 8 videos or chapter 15 section 3 in the textbook.

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Click here to **check your answer**

Go to next question

15.15) The reduced coenzymes generated by the citric acid cycle (and beta-oxidation) donate electrons in oxidative phosphorylation. Answer each of the questions below by selecting the appropriate species from the ***list of species choices***.
NOTE: You will need to select ***more than one species*** for some of these questions.

a) Which species donate electrons to the proteins of the electron transport chain?
NADH and $FADH_2$

b) Which species is the final acceptor of electrons in oxidative phosphorylation?
O_2

c) Which species are the final products of oxidative phosphorylation?
H_2O, NAD^+, FAD, and ATP

list of species choices:

H_2O
NADH
NAD^+
ATP
ADP
O_2
$FADH_2$
FAD
Coenzyme A

EXPLANATION: The primary goal of food catabolism is the production of **ATP**. Before *oxidative phosphorylation*, most of the chemical potential energy extracted from food is still in the form of **reduced coenzymes** (**NADH** and **$FADH_2$**). **Oxidative phosphorylation** is the process in which electrons from **NADH** or **$FADH_2$** are transferred, through a series of electron transfer intermediates (first to the proteins of the electron transport chain) to dissolved oxygen (O_2) in order to provide the energy required to produce **ATP**. In this process, **ADP** and an inorganic phosphate (P_i) are converted to **ATP**. The formation of **ATP** from **ADP** and P_i would ***not*** occur spontaneously without the input of energy that is provided when electrons are transferred to O_2.

For more details: See chapter 15 part 7 and part 8 videos or chapter 15 section 3 in the textbook.

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15.16) Determine whether each of the statements below is **true** or **false**.

a) The pH in the mitochondrial matrix is less than the pH in the intermembrane space.

b) The energy that results from the difference in hydrogen ion concentration between the mitochondrial matrix and the cytoplasm is used to generate ATP.

c) ATP synthase provides energy in the form of ATP to actively transport H^+ into the intermembrane space.

d) Hydrogen ions enter the mitochondrial matrix via facilitated diffusion.

e) The hydrogen ion concentration is lower in the mitochondrial matrix that in the intermembrane space.

f) Oxidative phosphorylation does not happen in exactly the same way for NADH as it does for $FADH_2$.

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Click here for a **hint**

Click here to **check your answer**

Go to next question

15.16) Determine whether each of the statements below is **true** or **false**.

a) The pH in the mitochondrial matrix is less than the pH in the intermembrane space.
HINT: Review the oxidative phosphorylation images in your lecture notes or the textbook. Remember that H_3O^+ is represented by "H^+" in those images. Is the H_3O^+ concentration in the mitochondrial matrix is greater or less than the H_3O^+ concentration in the intermembrane space? As the H_3O^+ increases, the pH decreases.

b) The energy that results from the difference in hydrogen ion concentration between the mitochondrial matrix and the cytoplasm is used to generate ATP.
HINT: Does oxidative phosphorylation occur in the cytoplasm outside of the mitochondria or entirely within the mitochondria?

c) ATP synthase provides energy in the form of ATP to actively transport H^+ into the intermembrane space.
HINT: Review the role of ATP synthase.

d) Hydrogen ions enter the mitochondrial matrix via facilitated diffusion.
HINT: The diffusion of ions and polar molecules though protein channels is referred to as *facilitated diffusion*.

e) The hydrogen ion concentration is lower in the mitochondrial matrix that in the intermembrane space.
HINT: Review the oxidative phosphorylation images in your lecture notes or the textbook. Remember that H_3O^+ is represented by "H^+" in those images.

f) Oxidative phosphorylation does not happen in exactly the same way for NADH as it does for $FADH_2$.
HINT: Is the amount of ATP generated from one NADH equal to the amount of ATP generated from one $FADH_2$?

For more help: See chapter 15 part 7 and part 8 videos or chapter 15 section 3 in the textbook.

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Click here to **check your answer**

Go to next question

15.16) Determine whether each of the statements below is **true** or **false**.

a) The pH in the mitochondrial matrix is less than the pH in the intermembrane space. **false** - The H_3O^+ concentration in the mitochondrial matrix is less than the H_3O^+ concentration in the intermembrane space, therefore the pH in the mitochondrial matrix is greater than the pH in the intermembrane space. H_3O^+ is represented by "H^+" in the oxidative phosphorylation images in the lecture notes and textbook.

b) The energy that results from the difference in hydrogen ion concentration between the mitochondrial matrix and the cytoplasm is used to generate ATP. **false** - The energy that results from the difference in hydrogen ion concentration between the mitochondrial matrix and the **intermembrane space** is used to generate ATP.

c) ATP synthase provides energy in the form of ATP to actively transport H^+ into the intermembrane space. **false**
The transfer of electrons through the electron transport chain provides energy to actively transport H^+ into the intermembrane space.

d) Hydrogen ions enter the mitochondrial matrix via facilitated diffusion. **true** - Hydrogen spontaneously diffuse from the intermembrane space (higher concentration) to the matrix region (lower concentration). The only path between these regions in which hydrogen ions can passively diffuse is through the ATP synthase enzyme (facilitated diffusion).

e) The hydrogen ion concentration is lower in the mitochondrial matrix that in the intermembrane space. **true**

f) Oxidative phosphorylation does not happen in exactly the same way for NADH as it does for $FADH_2$. **true**
Because this statement is true, one NADH produces about 2.5 ATP, whereas one $FADH_2$ produces about 1.5 ATP.

For more details: See chapter 15 part 7 and part 8 videos or chapter 15 section 3 in the textbook.

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Go to next question

15.17) How many ATP can be produced from the catabolism of **one glucose molecule** when the two NADH from glycolysis use the glycerol 3-phosphate shuttle? For this calculation, assume that each NADH that undergoes oxidative phosphorylation produces 2.5 ATP, and each $FADH_2$ produces 1.5 ATP.

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Click here for a **hint**

Click here to **check your answer**

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HINT:

In the **glycerol 3-phosphate shuttle**, **NADH** produced by glycolysis is oxidized in the intermembrane space by transferring electrons to an inner mitochondrial membrane-bound **FAD**, ***thereby producing an*** **$FADH_2$** that *can undergo oxidative phosphorylation.*

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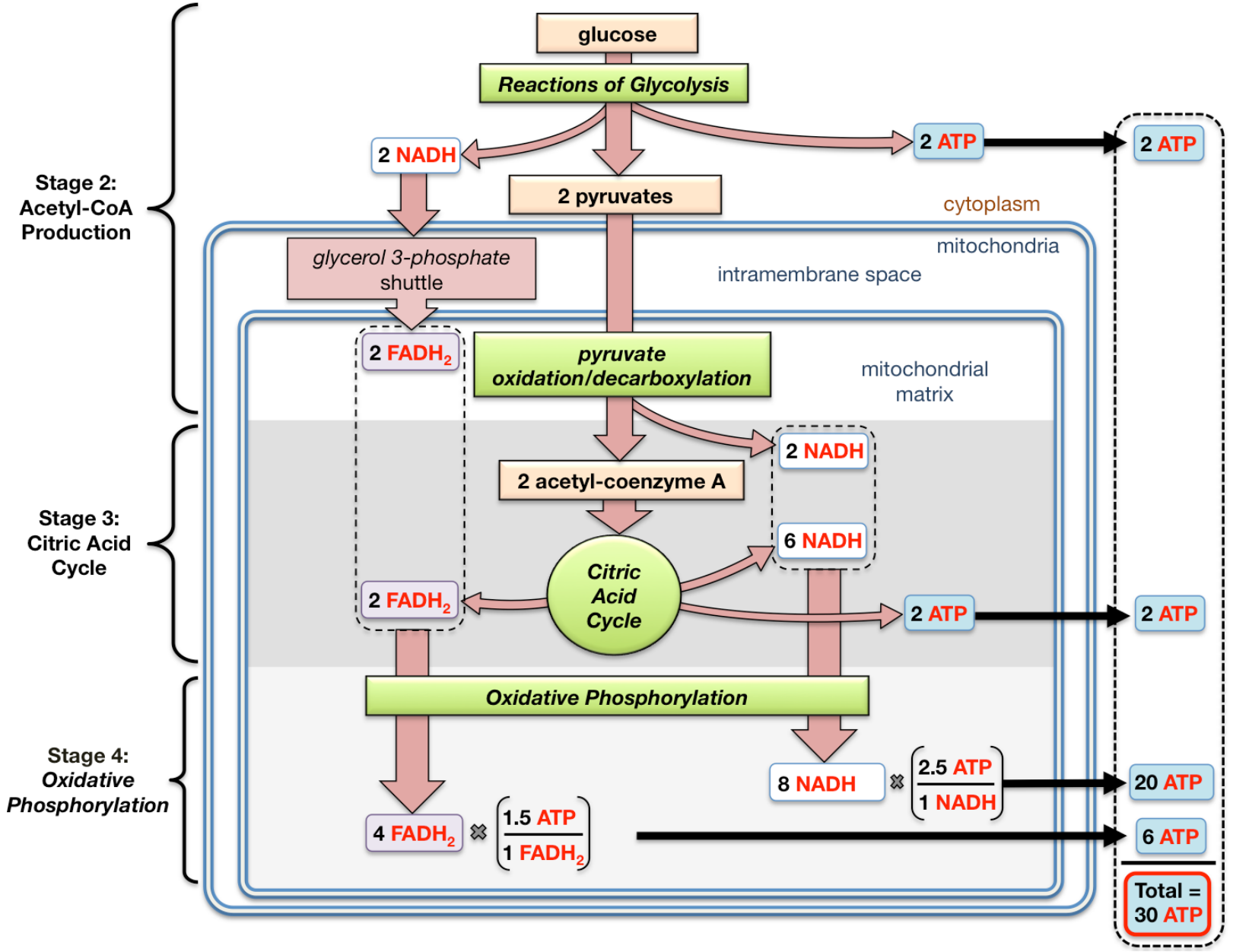

ANSWER: 30 ATP

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15.18) Determine whether the following statements describe **insulin**, **glucagon**, or **both insulin *and* glucagon**.

a) secreted by pancreas

b) released when blood glucose concentration is high

c) released when blood glucose concentration is low

d) *immediately* increases the amount of glucose entering cells

e) is a hormone

f) lowers blood glucose concentration

g) not enough is produced by individuals with type-1 diabetes

h) stimulates glycogen breakdown (glycogenolysis)

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Click here for a **hint**

Click here to **check your answer**

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HINT:

When **insulin** binds to liver and muscle cell receptors, it triggers a series of events that result in the activation of an enzyme in the glycogenesis pathway and the inhibition of an enzyme in the glycogenolysis pathway.

Glucagon has the ***opposite effect*** of insulin on liver cells; it accelerates glycogenolysis and suppresses glycogenesis.

For more help: See chapter 15 part 9 video or chapter 15 section 3 in the textbook.

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Click here to **check your answer**

Go to next question

15.18) Determine whether the following statements describe **insulin**, **glucagon**, or **both insulin *and* glucagon**.

a) secreted by pancreas
both insulin *and* glucagon

b) released when blood glucose concentration is high
insulin

c) released when blood glucose concentration is low
glucagon

d) *immediately* increases the amount of glucose entering cells
insulin

e) is a hormone
both insulin *and* glucagon

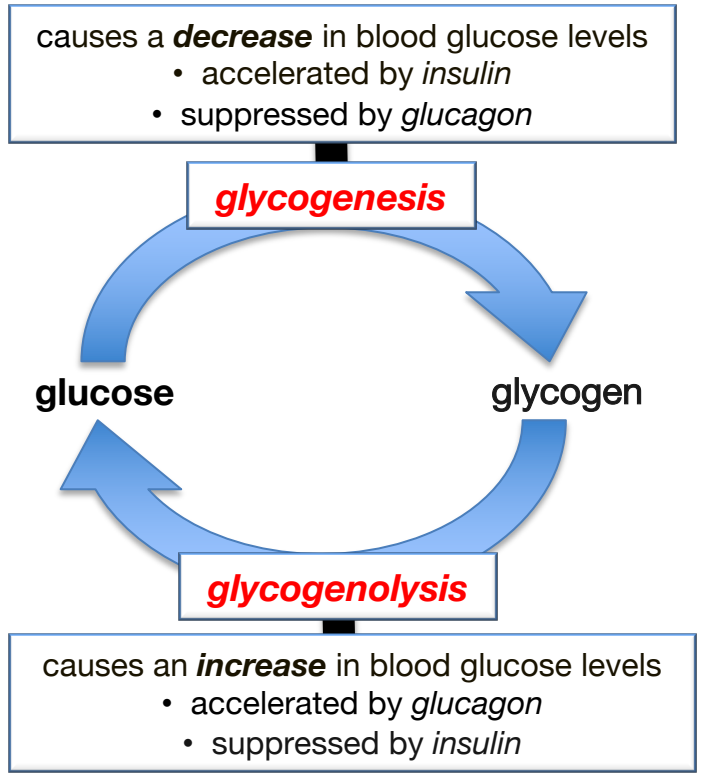
f) lowers blood glucose concentration
insulin

g) not enough is produced by individuals with type-1 diabetes
insulin

h) stimulates glycogen breakdown (glycogenolysis)
glucagon

EXPLANATION: When **insulin** binds to liver and muscle cell receptors, it triggers a series of events that result in the activation of an enzyme in the glycogenesis pathway and the inhibition of an enzyme in the glycogenolysis pathway.

Glucagon has the ***opposite effect*** of insulin on liver cells; it accelerates glycogenolysis and suppresses glycogenesis



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For more details: See chapter 15 part 9 video or chapter 15 section 3 in the textbook.

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15.19) Diabetes is a metabolic disease in which the body does not appropriately process glucose. If not treated, it results in dangerously high blood glucose concentration. Determine whether the following statements describe **type I**, **type II**, or **both type I *and* type II diabetes**.

a) also known as adult onset diabetes

b) also known as juvenile diabetes

c) also known as insulin-resistant diabetes

d) results from lack of insulin production

e) the most common type of diabetes

f) leads to hyperglycemia if untreated

g) can be treated with insulin injections

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d) results from lack of insulin production

e) the most common type of diabetes

f) leads to hyperglycemia if untreated

g) can be treated with insulin injections

HINT:

In diabetes type I, also called insulin dependent diabetes, the pancreas produces too little insulin. This can be a result of genetic disease, viral infection, or damage to the pancreas. Diabetes type I can be treated with insulin injections. Individuals must use a glucometer to frequently measure the concentration of glucose in their blood, and then inject insulin when elevated glucose levels are observed. Because diabetes type I often begins in childhood, it is sometimes referred to as juvenile diabetes.

Diabetes type II, also called insulin-resistant diabetes, occurs when sufficient insulin is produced, however the insulin receptors are unable to respond appropriately. About 90% of diabetes cases are type II. This type of diabetes can be even more difficult to manage than type I diabetes because it does not respond to insulin injections. Diabetes type II occurs after childhood and is therefore sometimes referred to as adult-onset diabetes.

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For more help: See chapter 15 part 9 video or chapter 15 section 3 in the textbook.

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Go to next question

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type II

b) also known as juvenile diabetes
type I

c) also known as insulin-resistant diabetes
type II

d) results from lack of insulin production
type I

e) the most common type of diabetes
type II

f) leads to hyperglycemia if untreated
both type I *and* type II

g) can be treated with insulin injections
type I

EXPLANATION:

In diabetes type I, also called insulin dependent diabetes, the pancreas produces too little insulin. This can be a result of genetic disease, viral infection, or damage to the pancreas. Diabetes type I can be treated with insulin injections. Individuals must use a glucometer to frequently measure the concentration of glucose in their blood, and then inject insulin when elevated glucose levels are observed. Because diabetes type I often begins in childhood, it is sometimes referred to as juvenile diabetes.

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For more details: See chapter 15 part 9 video or chapter 15 section 3 in the textbook.

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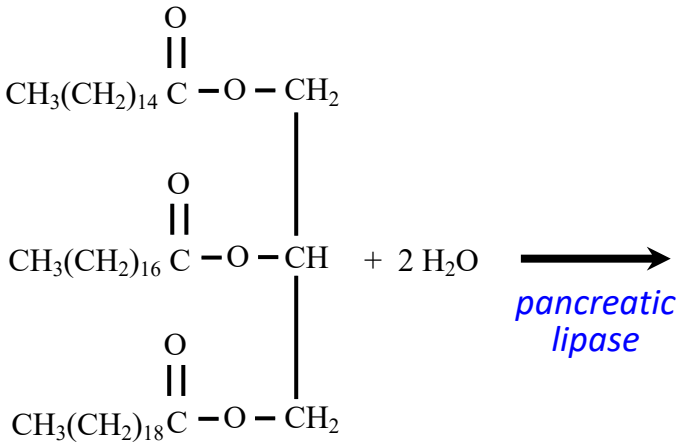
15.20) In the digestion of triglycerides, pancreatic lipase enzymes catalyze the hydrolysis of emulsified triglycerides. Note that these enzymes only lyse (break) **two** of the three ester bonds. The enzymes will specifically lyse the top and bottom ester bonds, leaving the ester bond to the middle carbon on the glycerol backbone unchanged. Draw the **products** for the pancreatic lipase catalyzed hydrolysis of the triglyceride shown below.



a ***tri***glyceride

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Click here for a **hint**

Click here to **check your answer**

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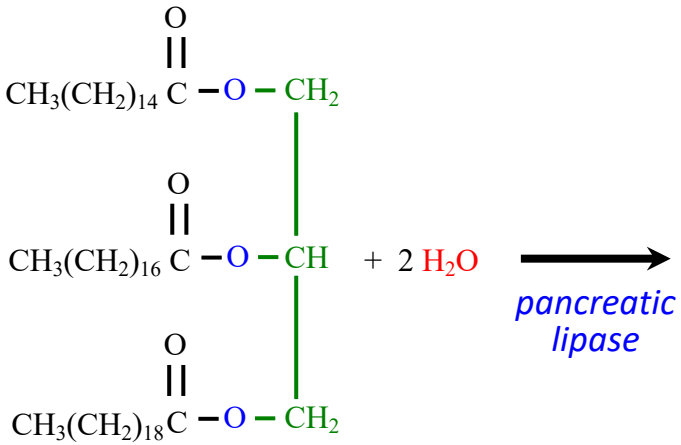
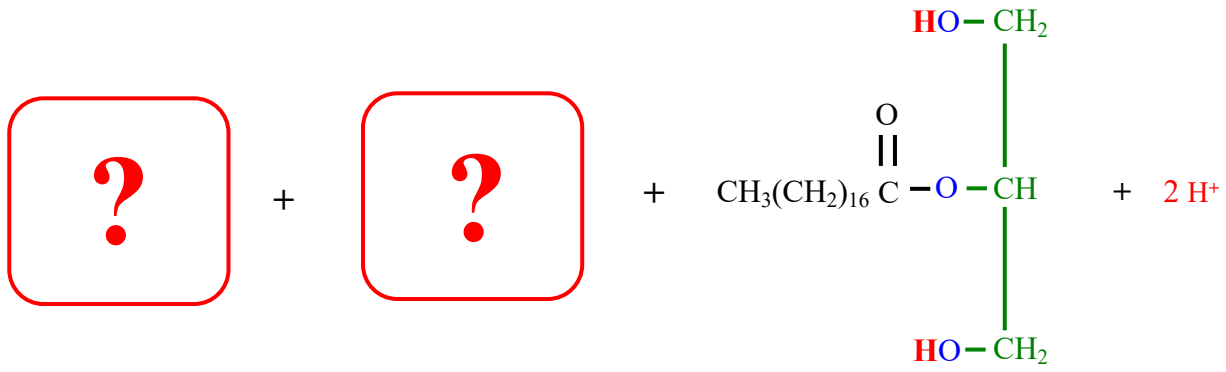


a ***tri***glyceride

pancreatic lipase

HINT:



a ***mono***glyceride

There are **two more** products to add, what are they?

For more help: See chapter 15 part 10 video or chapter 15 section 4 in the textbook.

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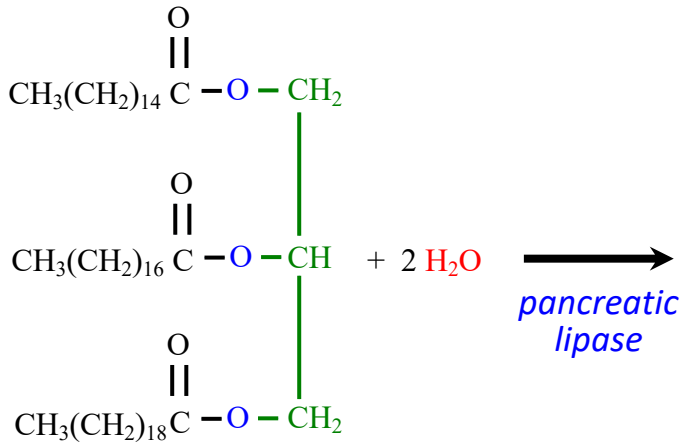
Click here to **check your answer**

Go to next question

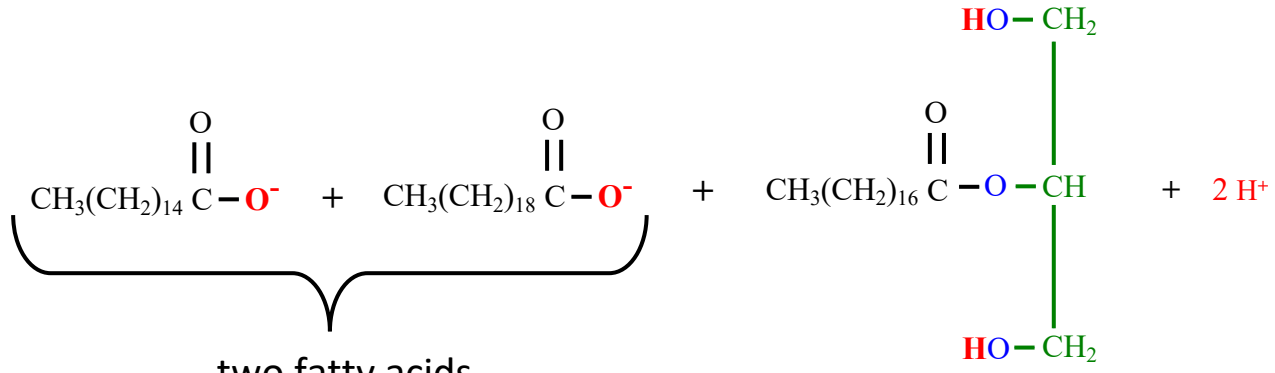
15.20) In the digestion of triglycerides, pancreatic lipase enzymes catalyze the hydrolysis of emulsified triglycerides. Note that these enzymes only lyse (break) **two** of the three ester bonds. The enzymes will specifically lyse the top and bottom ester bonds, leaving the ester bond to the middle carbon on the glycerol backbone unchanged. Draw the **products** for the pancreatic lipase catalyzed hydrolysis of the triglyceride shown below.



a ***tri***glyceride

pancreatic lipase

ANSWER:

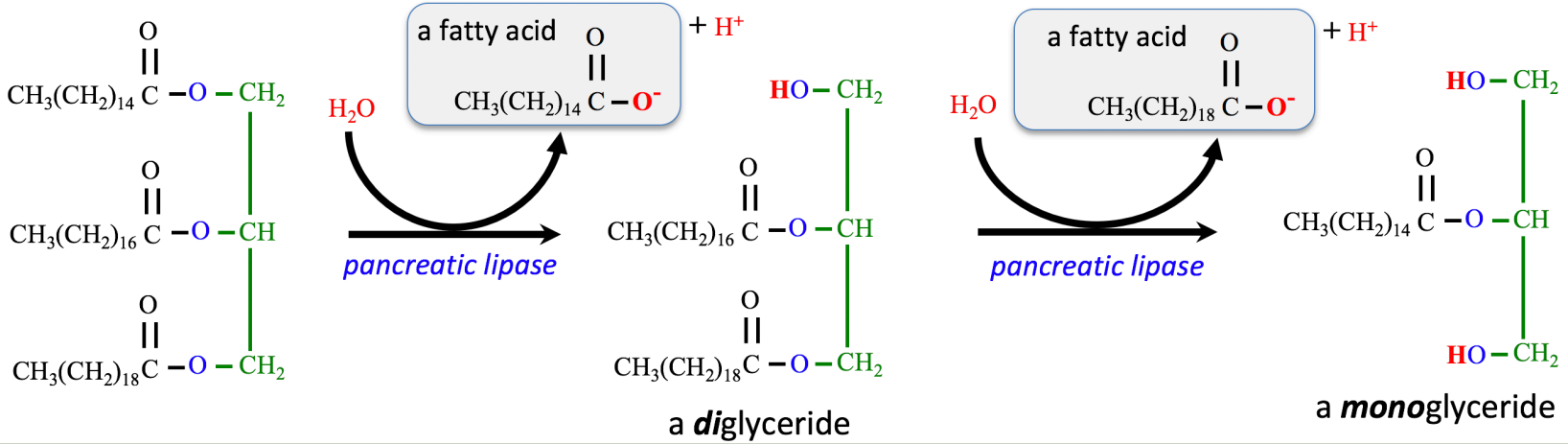


two fatty acids (base forms)

a ***mono***glyceride

EXPLANATION:

Triglycerides are first hydrolyzed to diglycerides, and then to monoglycerides. Each one of these reactions produces a fatty acid, as shown on the right.



a ***di***glyceride

a ***mono***glyceride

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For more details: See chapter 15 part 10 video or chapter 15 section 4 in the textbook.

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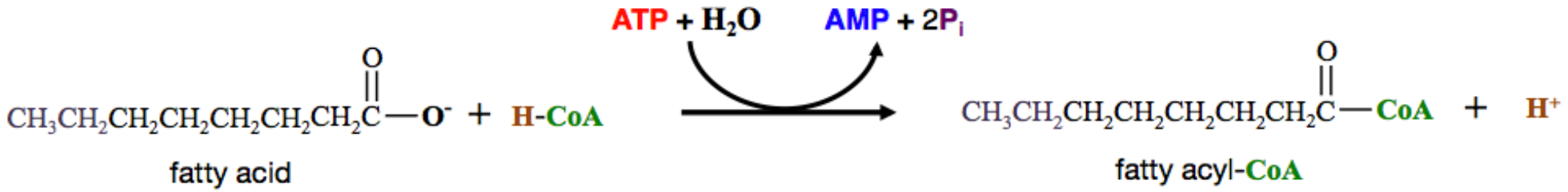
15.21) The first reaction in the catabolism of fatty acids is called ***activation***. In this reaction, the acyl group of a fatty acid is transferred to coenzyme A. The fatty acid is converted to a fatty acyl-coenzyme A. The reaction is shown below using a fatty acid that contains only eight carbons (for simplicity); in biological systems fatty acids typically contain twelve to twenty carbons.



When fatty acyl-CoA enters the mitochondrial matrix, it undergoes a catabolic pathway called ***beta-oxidation*** (***β***-oxidation). In ***β***-oxidation, a fatty acyl-CoA, goes through a repeated series of ***four reactions***, each time losing two of its carbons. Explain why the term "***β*-oxidation**" is used for this pathway.

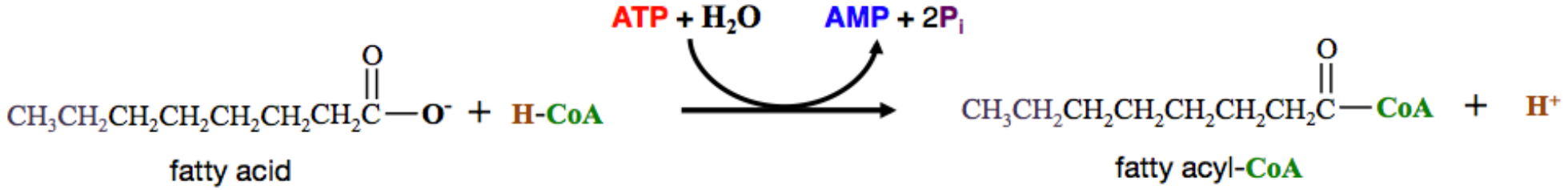
Go back

Click here for a **hint**

Click here to **check your answer**

Go to next question

15.21) The first reaction in the catabolism of fatty acids is called ***activation***. In this reaction, the acyl group of a fatty acid is transferred to coenzyme A. The fatty acid is converted to a fatty acyl-coenzyme A. The reaction is shown below using a fatty acid that contains only eight carbons (for simplicity); in biological systems fatty acids typically contain twelve to twenty carbons.

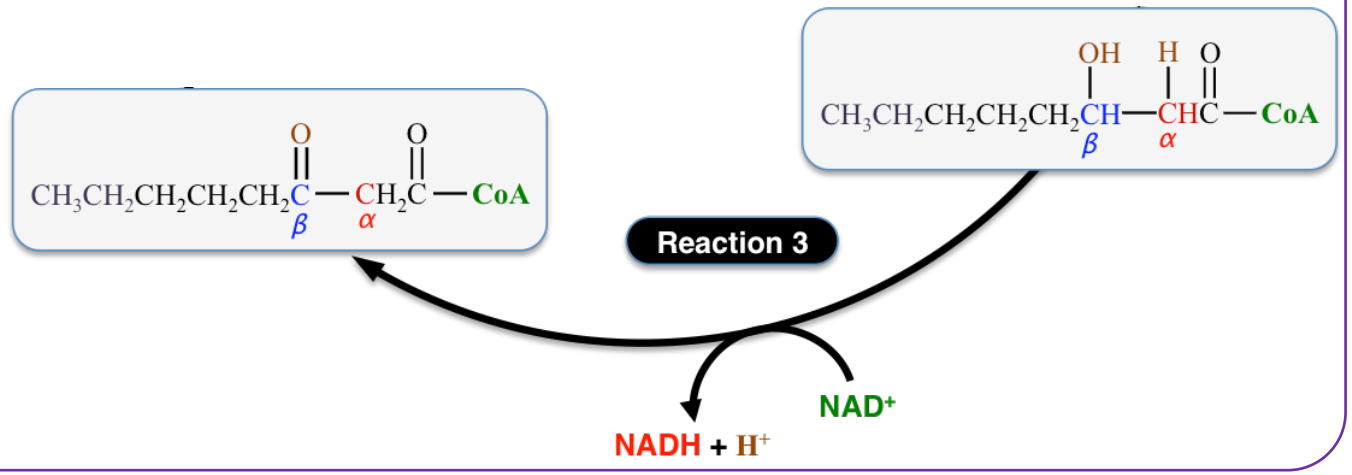


When fatty acyl-CoA enters the mitochondrial matrix, it undergoes a catabolic pathway called ***beta-oxidation*** (***β***-oxidation). In ***β***-oxidation, a fatty acyl-CoA, goes through a repeated series of ***four reactions***, each time losing two of its carbons. Explain why the term "***β*-oxidation**" is used for this pathway.

HINT:

The carbon that is next to a fatty acyl's carbonyl group is designated as the "***α***-carbon," and the carbon that is two carbons away from the carbonyl group is designated as the "***β***-carbon."

Consider what occurs in Reaction 3 of ***β*-oxidation** (shown on the right).



For more help: See chapter 15 part 11 video or chapter 15 section 4 in the textbook.

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Click here to **check your answer**

Go to next question

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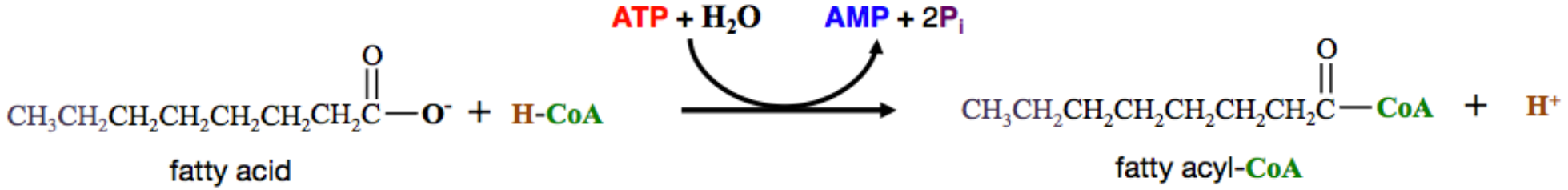
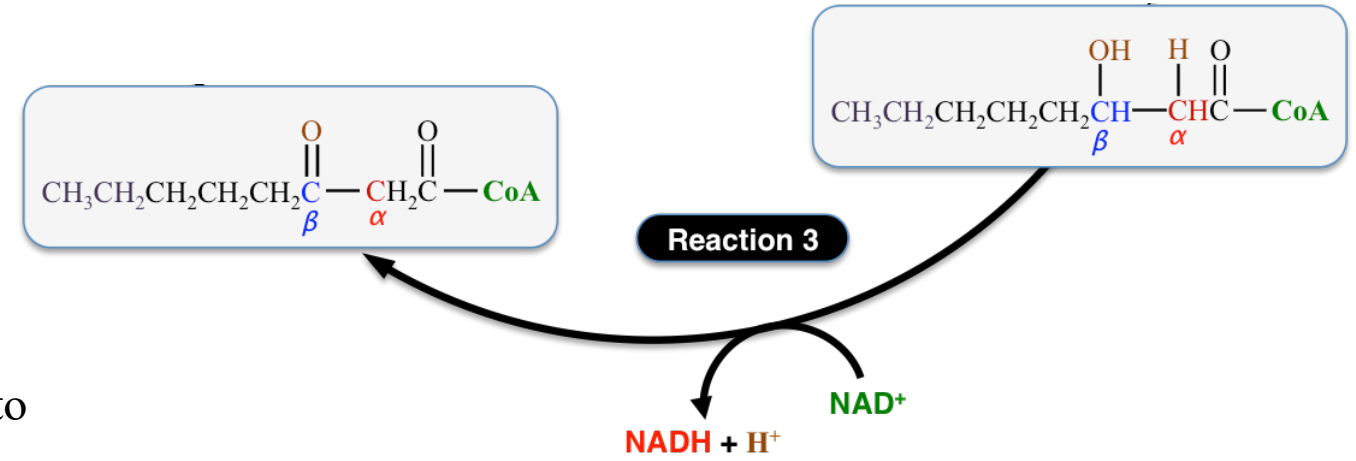


When fatty acyl-CoA enters the mitochondrial matrix, it undergoes a catabolic pathway called ***beta-oxidation*** (***β***-oxidation). In ***β***-oxidation, a fatty acyl-CoA, goes through a repeated series of ***four reactions***, each time losing two of its carbons. Explain why the term "***β*-oxidation**" is used for this pathway.

YOUR ANSWER SHOULD BE SOMETHING LIKE THIS:

The carbon that is next to a fatty acyl's carbonyl group is designated as the "***α***-carbon," and the carbon that is two carbons away from the carbonyl group is designated as the "***β***-carbon." In **reaction 3** of ***β***-oxidation (shown on the right), the ***β***-carbon is ***oxidized***. It is for this reason that the reaction pathway is called ***β***-oxidation. In this oxidation, a hydrogen and electron are transferred to **NAD+**, reducing it to **NADH**.



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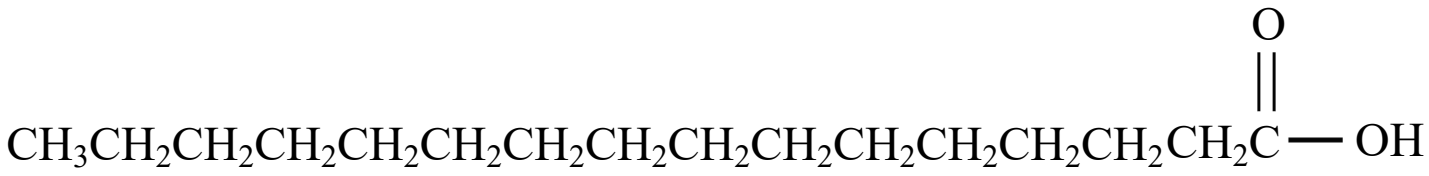
For more details: See chapter 15 part 11 video or chapter 15 section 4 in the textbook.

Go to next question

15.22) What is the net gain in ATP for β-oxidation of *palmitic acid* (a ***sixteen-carbon*** fatty acid)?



palmitic acid
(a ***sixteen-carbon*** fatty acid)

NOTES:

- Assume that oxidative phosphorylation produces, on average, 2.5 ATP per NADH and 1.5 ATP per $FADH_2$.
- Because we are using average values for the calculation of ATP from oxidative phosphorylation, you will come up with fractional ATP subtotals; that is not a problem because you're calculating average ATP production. For example, you will calculate that, on average, 16.5 ATP are produced from the $FADH_2$ in this problem.
- Remember to subtract one ATP to account for the ATP that was consumed in the *activation* step.

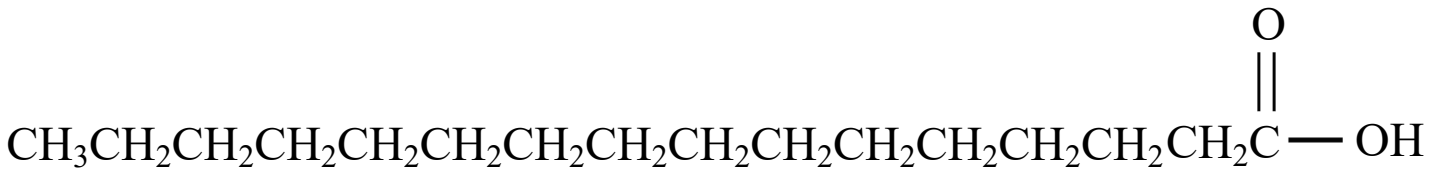
Go back

Click here for a **hint**

Click here to **check your answer**

Go to next question

15.22) What is the net gain in ATP for β-oxidation of *palmitic acid* (a ***sixteen-carbon*** fatty acid)?



palmitic acid
(a ***sixteen-carbon*** fatty acid)

HINT:

First, palmitic acid is activated to produce a 16-carbon fatty acyl-CoA. The activation step ***consumes*** one **ATP**. A 16-carbon fatty acyl-CoA will undergo six ***β***-oxidation spirals. Each of the first *six* cycles of the ***β***-oxidation spiral produces one acetyl-CoA, one **NADH**, and one **$FADH_2$**. The *final cycle* of the spiral produces ***two*** acetyl-CoA, one **NADH**, and one **$FADH_2$**. The acetyl-CoA are processed through the citric acid cycle, producing **ATP** and *more* reduced coenzymes. The **NADH**, and **$FADH_2$** formed in ***β***-oxidation, and the **NADH**, and **$FADH_2$** formed in the citric acid cycle undergo oxidative phosphorylation. Because one **ATP** is consumed in the activation reaction, it is subtracted when calculating the *net gain* of **ATP**.

For more help: See chapter 15 part 11 video or chapter 15 section 4 in the textbook.

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Click here to **check your answer**

Go to next question

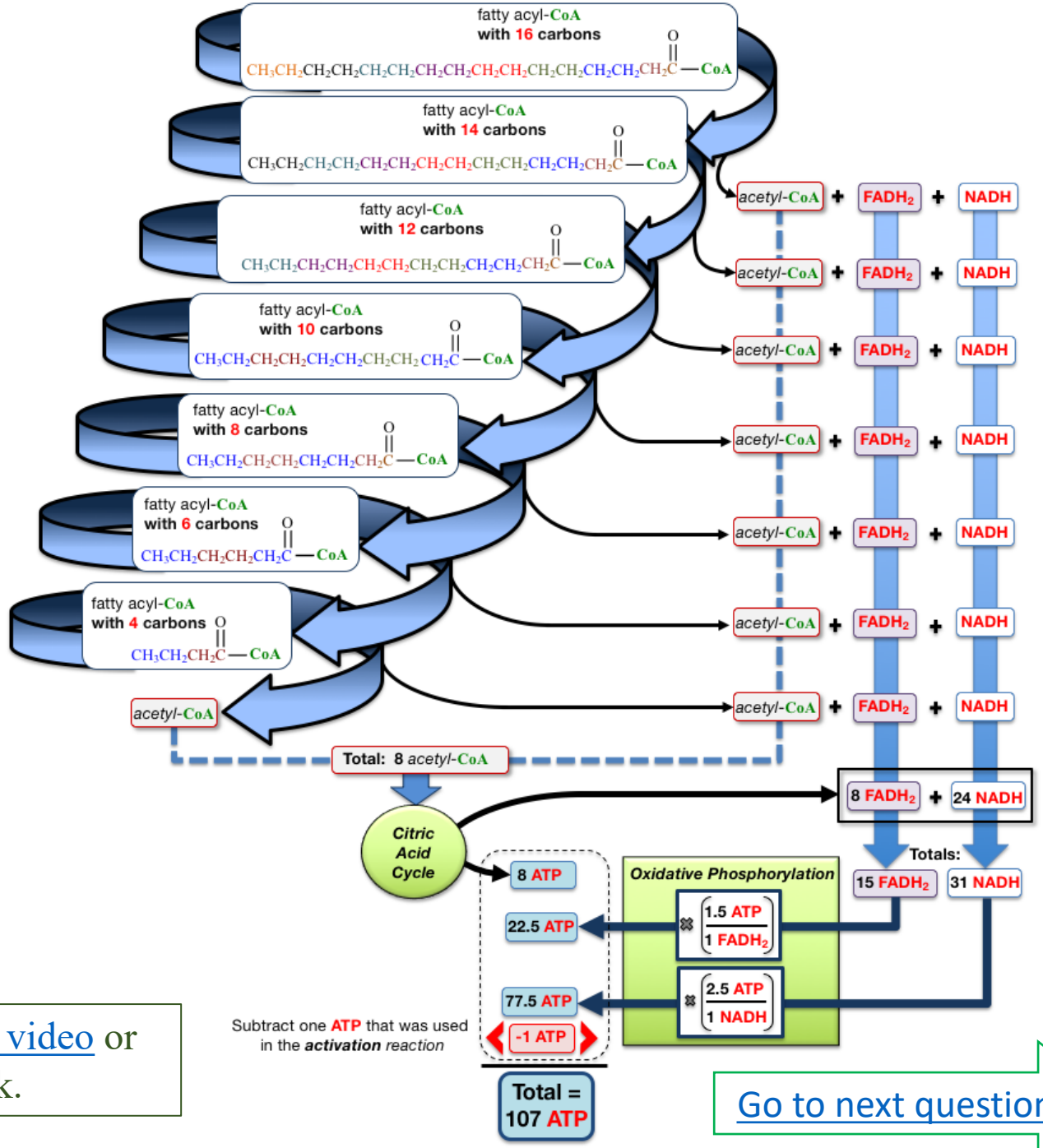
15.22) What is the net gain in ATP for ***β***-oxidation of *palmitic acid* (a ***sixteen-carbon*** fatty acid)?

ANSWER: 107 ATP

EXPLANATION:

First, palmitic acid is activated to produce a 16-carbon fatty acyl-CoA. The activation step ***consumes*** one **ATP**.

A 16-carbon fatty acyl-CoA will undergo *seven* ***β***-oxidation spirals. Each of the first *six* spirals of ***β***-oxidation produces one acetyl-CoA, one **NADH**, and one **$FADH_2$**. The *final cycle* of the spiral produces ***two*** acetyl-CoA, one **NADH**, and one **$FADH_2$**. The acetyl-CoA are processed through the citric acid cycle, producing **ATP** and *more* reduced coenzymes. The **NADH**, and **$FADH_2$** formed in ***β***-oxidation, and the **NADH**, and **$FADH_2$** formed in the citric acid cycle undergo oxidative phosphorylation. Because one **ATP** was consumed in the activation reaction, it is subtracted when calculating the *net gain* of **ATP**. ***β***-oxidation of a sixteen-carbon fatty acid, *on average*, results in a net gain of **107 ATP**.



For more details: See chapter 15 part 11 video or chapter 15 section 4 in the textbook.

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15.23) Explain the difference between ***ketogenesis*** and ***ketoacidosis***.

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Click here for a **hint**

Click here to **check your answer**

Go to next question

15.23) Explain the difference between ***ketogenesis*** and ***ketoacidosis***.

HINT:

Acetyl-CoA that is produced in excess of the amount that can be metabolized in the citric acid cycle results in a high concentration of acetyl-CoA. When this occurs, acetyl-CoA reacts with *other* acetyl-CoA to produce the three compounds that are referred to as **ketone bodies**. This process is referred to as ***ketogenesis***. When individuals diet, they begin to metabolize the triglycerides that are stored in fat cells. This leads to ***ketogenesis***. Now discuss ***ketoacidosis***....

For more help: See chapter 15 part 12 video or chapter 15 section 4 in the textbook.

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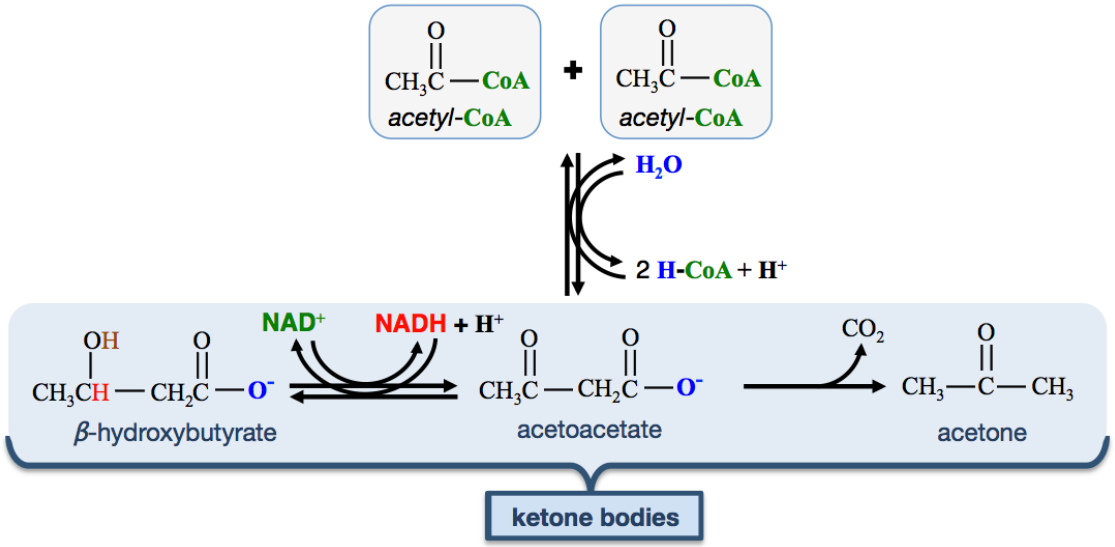
Go to next question

15.23) Explain the difference between ***ketogenesis*** and ***ketoacidosis***.

YOUR ANSWER SHOULD BE SOMETHING LIKE THIS (perhaps a bit less detailed):

Acetyl-CoA that is produced in excess of the amount that can be metabolized in the citric acid cycle results in a high concentration of acetyl-CoA. When this occurs, acetyl-CoA reacts with *other* acetyl-CoA to produce the three compounds that are referred to as **ketone bodies**. This process is referred to as ***ketogenesis***. Ketone bodies are produced as shown in the reactions below. When individuals diet, they begin to metabolize the triglycerides that are stored in fat cells. This leads to ***ketogenesis***.



In cases of starvation, poorly treated diabetes, and conditions related to alcoholic binge drinking, the cells cannot get glucose and extremely high rates of fatty acid catabolism results in dangerous, and even fatal levels of ketone bodies. β-hydroxybutyric acid and acetoacetic acid (the acid forms of β-hydroxybutyrate and acetoacetate, respectively) have significant acid strength. Their production results in a higher concentration of H_3O^+, which can overcome the blood's buffering capacity. When this occurs, the blood becomes acidic. When blood pH is less than the normal range (7.35-7.45), the condition is called **acidosis**. When acidosis is caused by excess ketone bodies, the condition is called ***ketoacidosis***.

For more details: See chapter 15 part 12 video or chapter 15 section 4 in the textbook.

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15.24) Explain how chemical potential energy that is present in the protein that we eat is metabolized to provide energy in the form of ATP.

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Go to next question

15.24) Explain how chemical potential energy that is present in the protein that we eat is metabolized to provide energy in the form of ATP.

HINT:

The protein we eat is digested to produce *amino acids*. Some of the *amino acids* produced in digestion are used for the synthesis of **proteins**, the synthesis of other **amino acids**, and the synthesis of other **nitrogen-containing compounds**.

Amino acids that are ingested in surplus of these biosynthesis needs are **catabolized** as fuel for the production of **ATP**. Summarize how this is done.

For more help: See chapter 15 part 13 video or chapter 15 section 5 in the textbook.

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Click here to **check your answer**

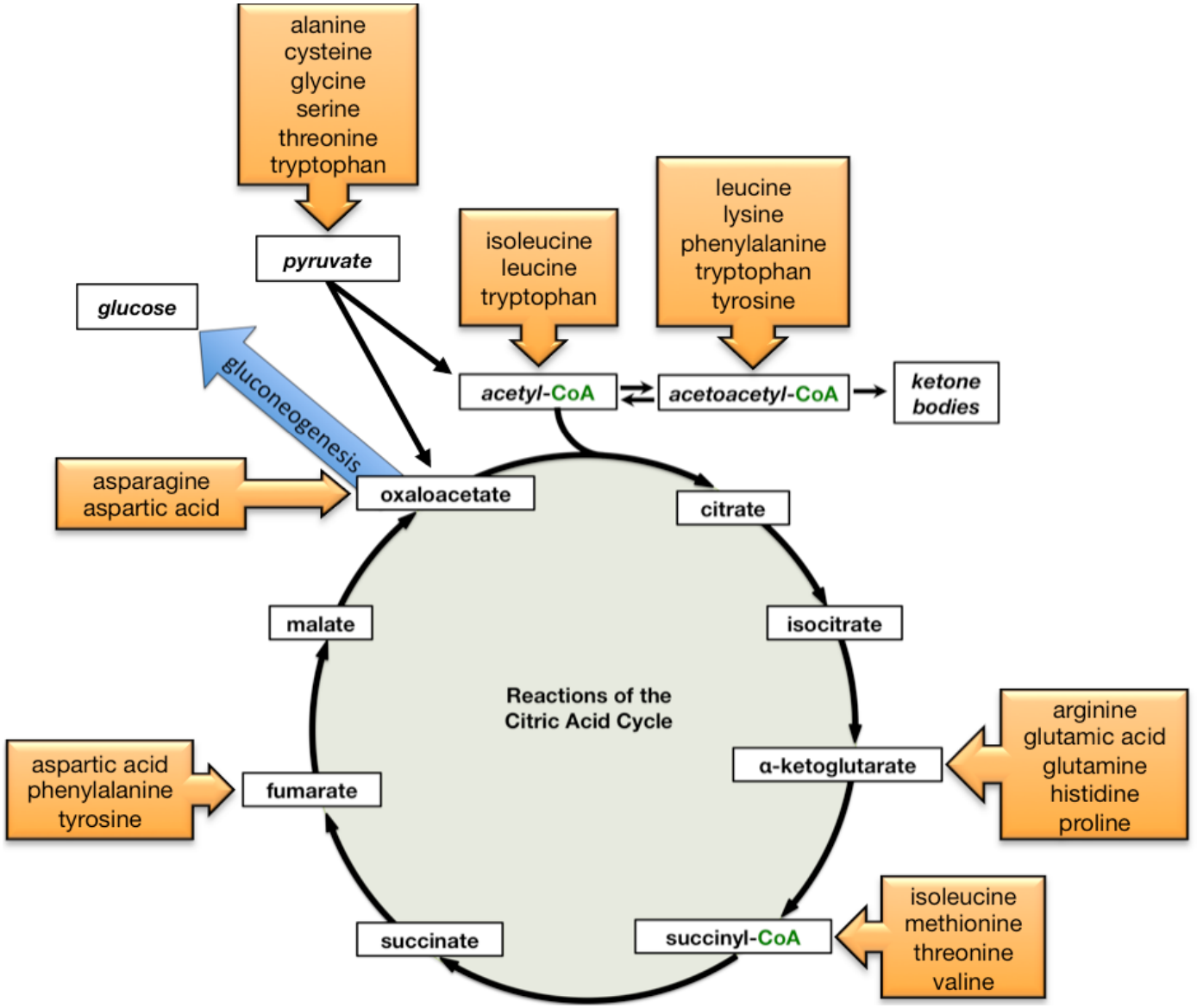
Go to next question

15.24) Explain how chemical potential energy that is present in the protein that we eat is metabolized to provide energy in the form of ATP.

YOUR ANSWER SHOULD BE SOMETHING LIKE THIS:

The protein we eat is digested to produce amino acids. Some of the amino acids produced in digestion are used for the synthesis of **proteins**, the synthesis of other **amino acids**, and the synthesis of other **nitrogen-containing compounds**. Amino acids that are ingested in surplus of these biosynthesis needs are **catabolized** as fuel for the production of **ATP**. This is done by transforming them into **intermediate metabolites** that can be converted to **glucose**, **ketone bodies**, **or** undergo the citric **acid cycle**.

For more details: See chapter 15 part 13 video or chapter 15 section 5 in the textbook.



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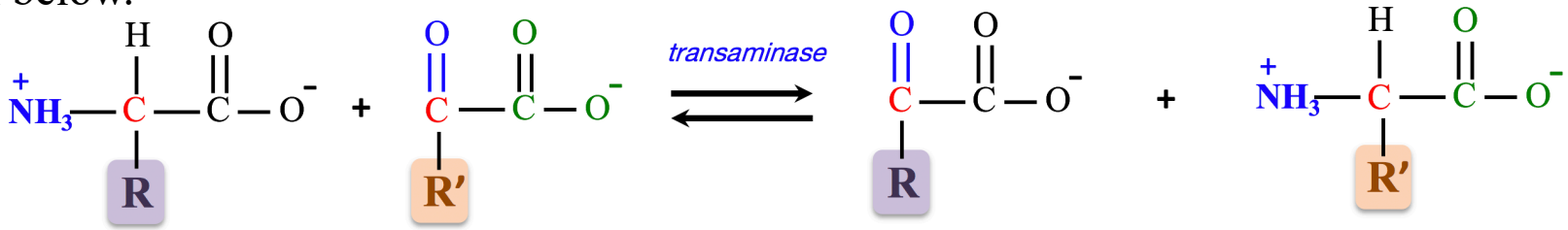
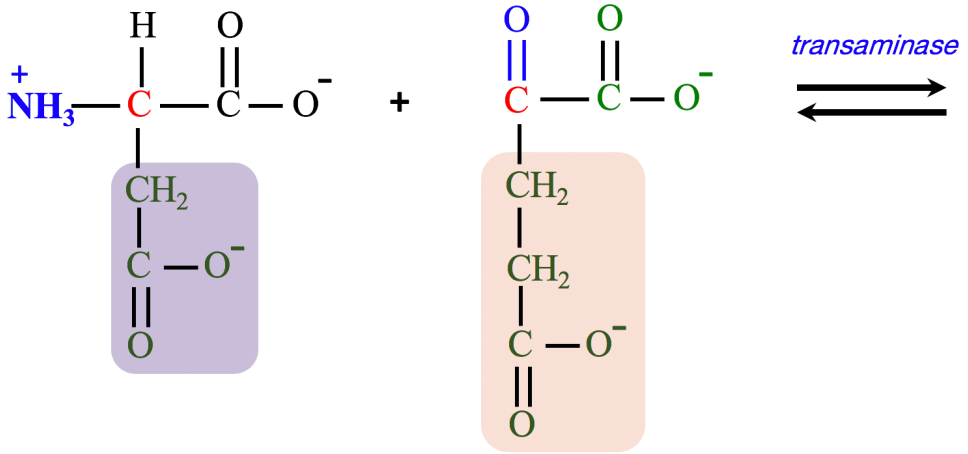
15.25) All ***twenty common amino acids*** can be converted into either pyruvate, acetyl-CoA, acetoacetyl-CoA, or a citric acid cycle intermediate. The details of *how* the ***twenty common amino acids*** are converted into the metabolic intermediates are far beyond the scope of this course. What is important to understand is that these conversions involve one or both of two important amino acid reactions: **transamination** and **oxidative deamination**. The *general form* for the transamination reaction is shown below.



In *transamination reactions*, the NH_3^+ from an amino acid is ***usually*** transferred to **α-ketoglutarate** (an α-keto acid). Draw the products for the **transamination** reaction (shown below) of aspartic acid with α-ketoglutarate.



Go back

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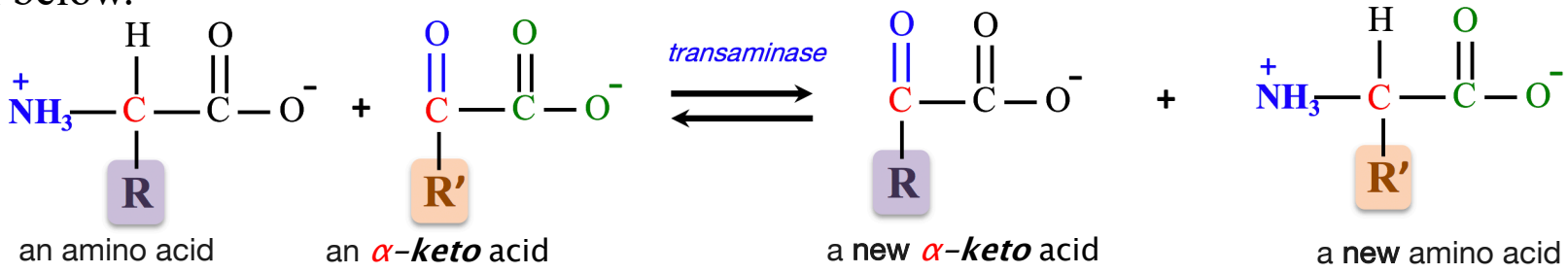

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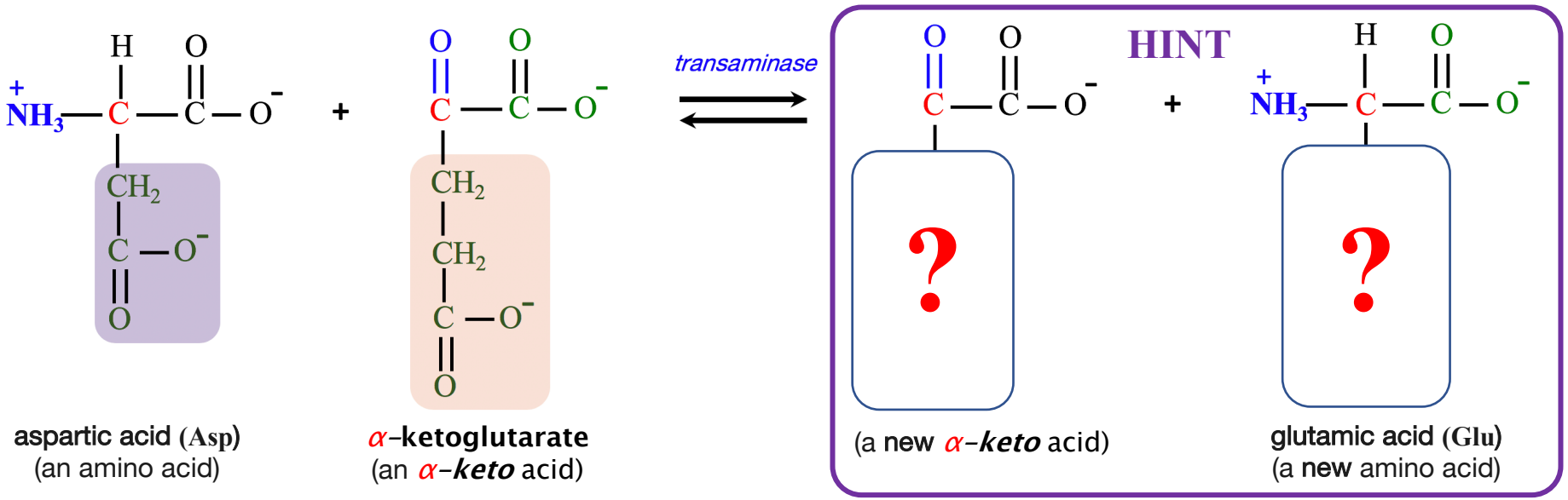

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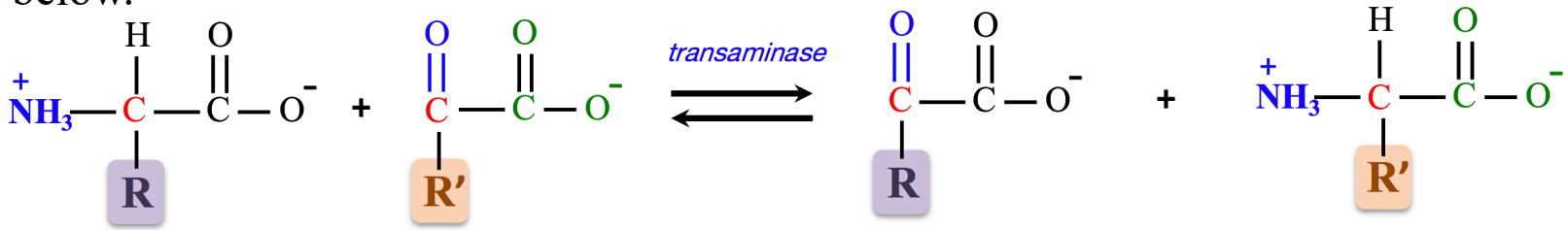

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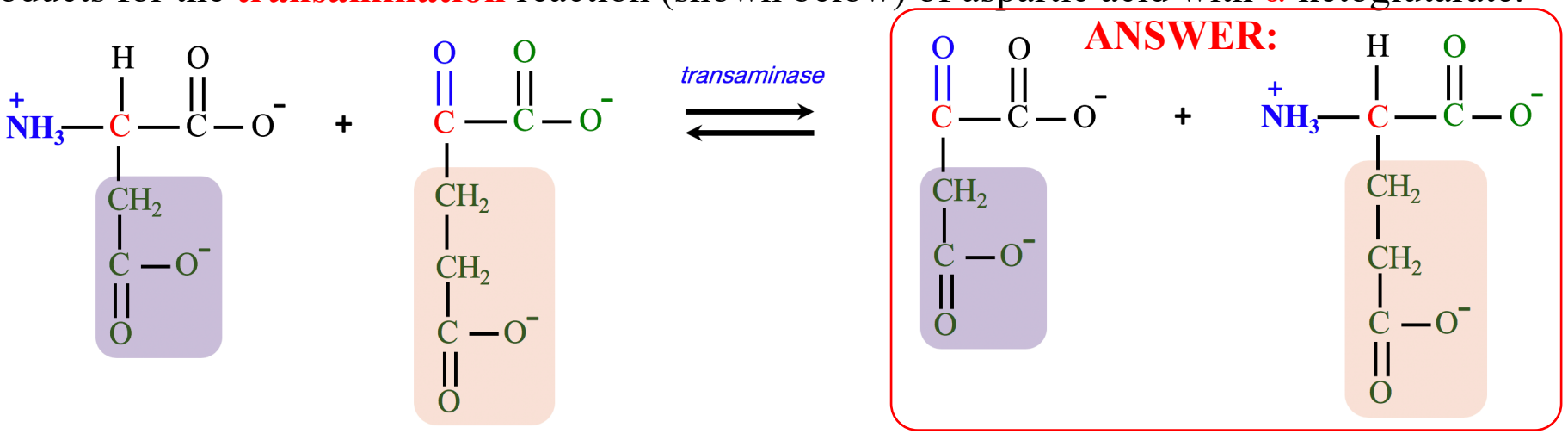

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For more details: See chapter 15 part 13 video or chapter 15 section 5 in the textbook.

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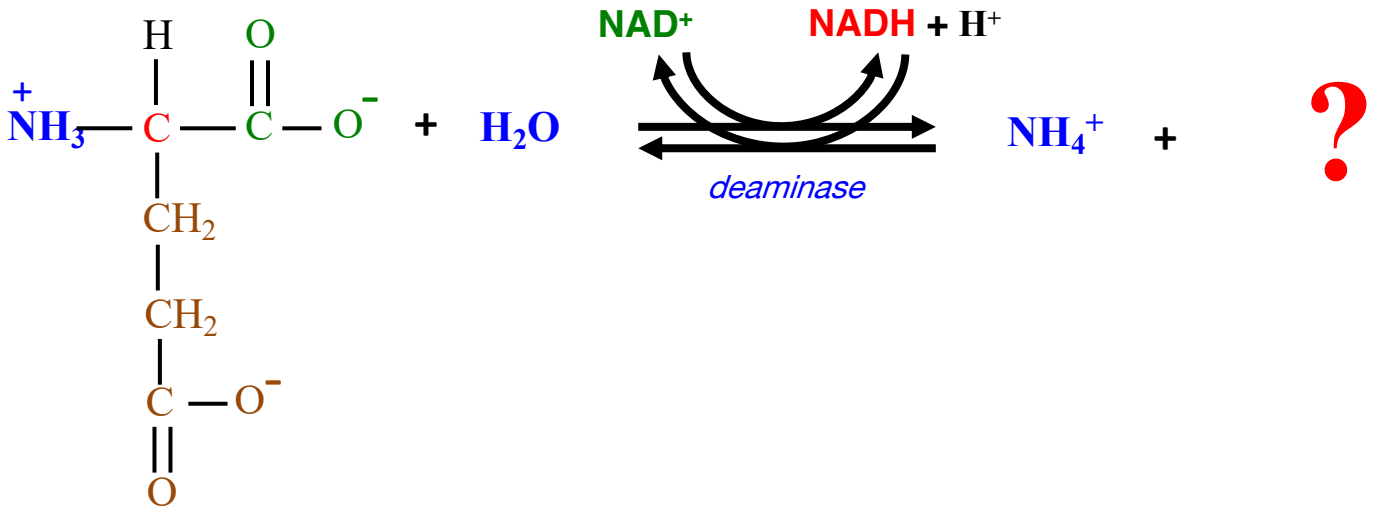
15.26) In **transamination** reactions, α-ketoglutarate is converted to glutamic acid. The other important reaction in amino acid catabolism is **oxidative deamination**. In the previous problem, and most other *transaminase reactions*, α-ketoglutarate is converted to glutamic acid (an amino acid). In oxidative deamination, a quaternary ammonium group (-NH_3^+) is removed from glutamic acid, thereby producing ammonium (NH_4^+), NADH, H^+ and one *other product*. Complete the oxidative deamination reaction below by drawing *and* naming the missing product.



glutamic acid (Glu)

Go back

Click here for a **hint**

Click here to **check your answer**

Go to next question

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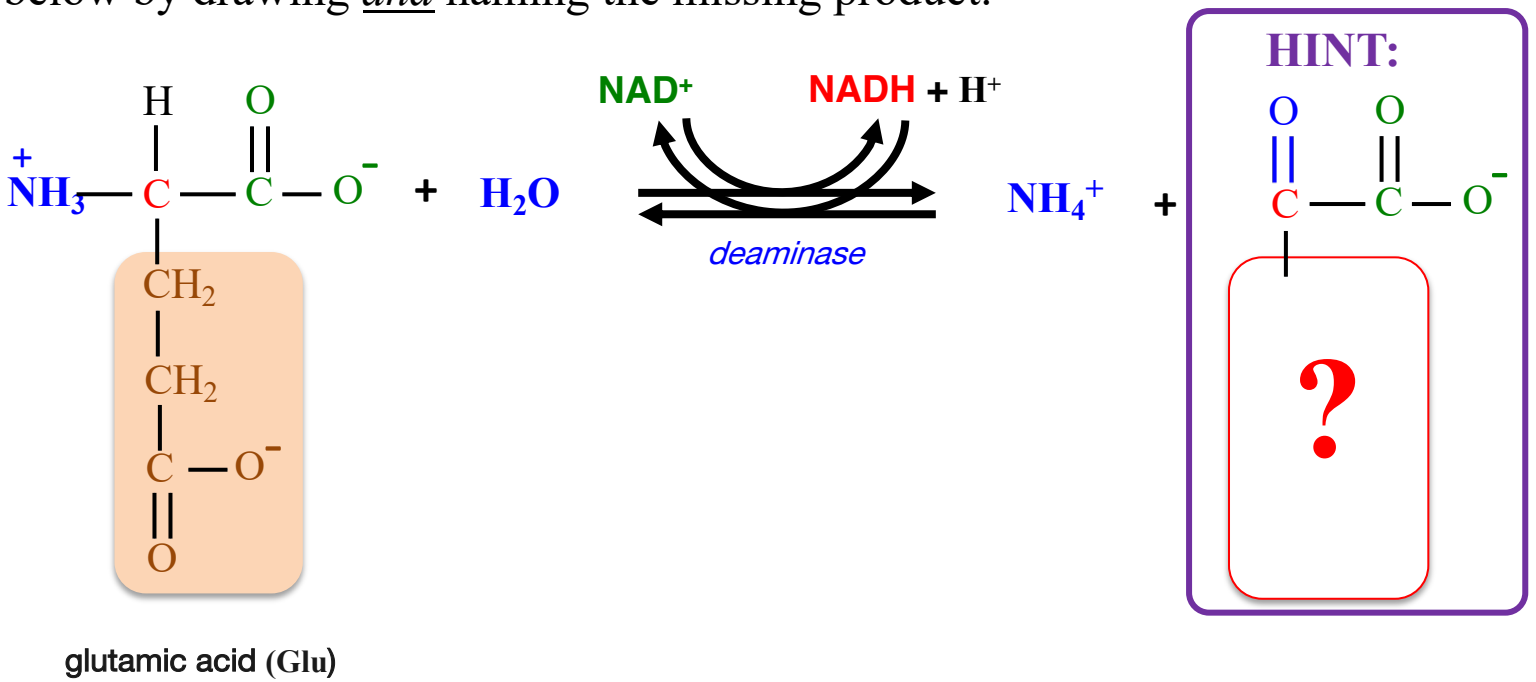

glutamic acid (Glu)

For more help: See chapter 15 part 13 video or chapter 15 section 5 in the textbook.

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Click here to **check your answer**

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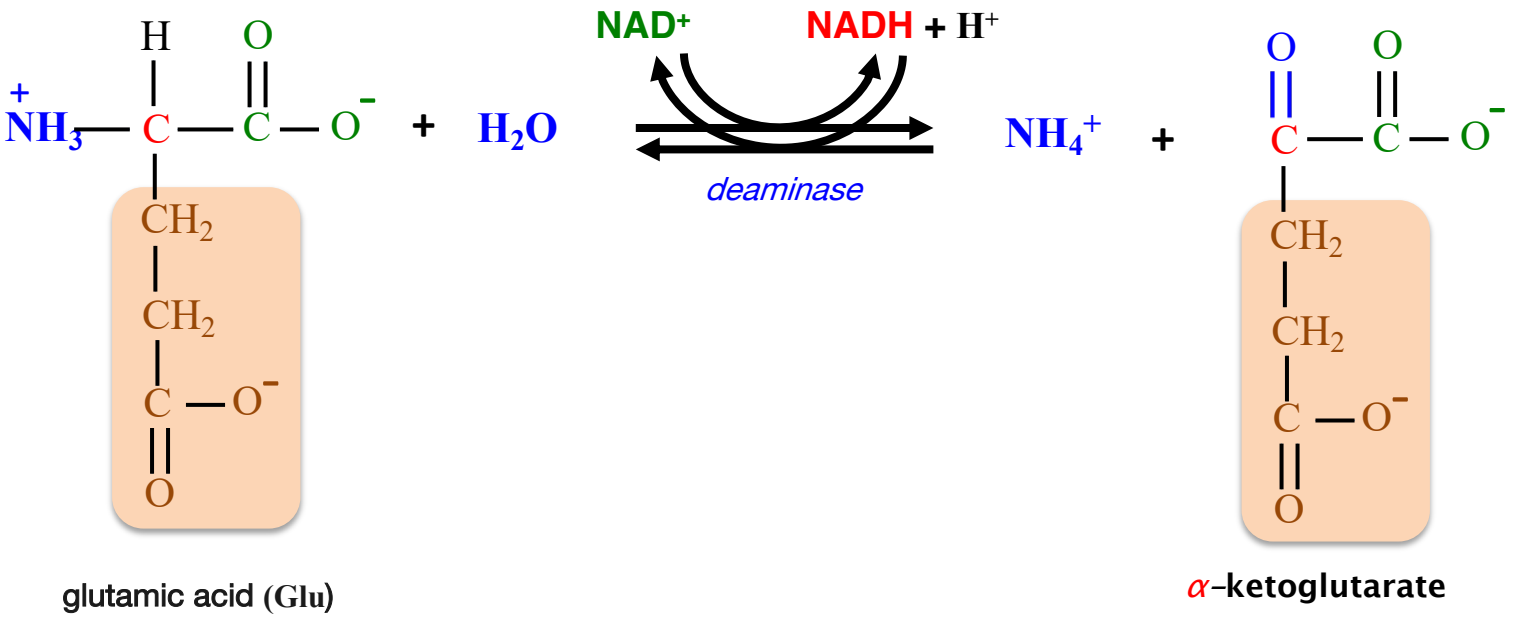
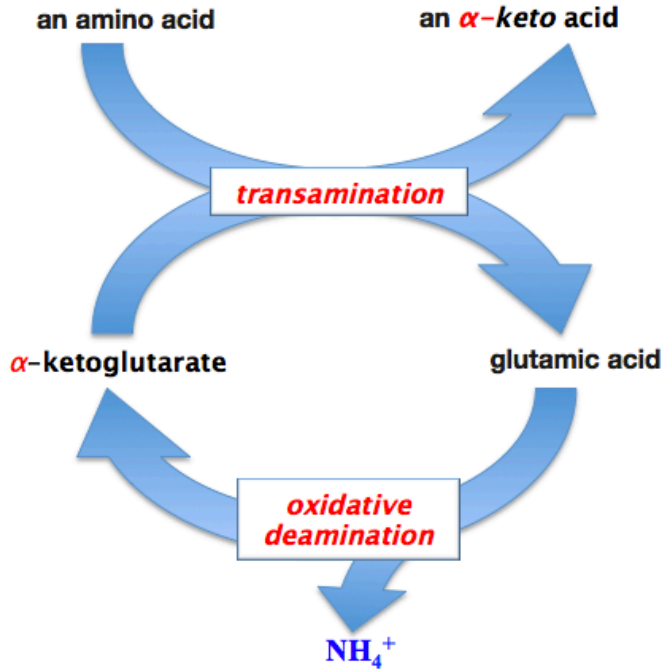


glutamic acid (Glu)

α-ketoglutarate

NOTE: The α-ketoglutarate that is produced in the reaction is now free to accept a new quaternary ammonium group from another amino acid in a transamination reaction, as illustrated below.



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For more details: See chapter 15 part 13 video or chapter 15 section 5 in the textbook.

Go to next question

15.27) Fill in the blanks in each of the statements below:

a) The free ammonium ions (NH_4^+) that are produced in oxidative deamination are toxic at elevated concentrations. Humans and most other terrestrial vertebrates are capable of converting the ammonium ions to _____.

b) Kidney disease can result in the build up of dangerous amounts of urea. The urea concentration in blood is referred to as blood urea nitrogen (BUN). In cases of endstage renal (kidney) failure, safe BUN levels are exceeded, and patients must undergo _____ treatments.

Go back

Click here for a **hint**

Click here to **check your answer**

Go to next question

15.27) Fill in the blanks in each of the statements below:

a) The free ammonium ions (NH_4^+) that are produced in oxidative deamination are toxic at elevated concentrations. Humans and most other terrestrial vertebrates are capable of converting the ammonium ions to _____.

b) Kidney disease can result in the build up of dangerous amounts of urea. The urea concentration in blood is referred to as blood urea nitrogen (BUN). In cases of endstage renal (kidney) failure, safe BUN levels are exceeded, and patients must undergo _____ treatments.

HINTS:

Part (a) choices:

aldehydes
fatty acids
ethanol
urea
carbohydrates

Part (b) choices:

blood transfusion
dialysis
chemotherapy
massage
hypnosis

For more help: See chapter 15 part 13 video or chapter 15 section 5 in the textbook.

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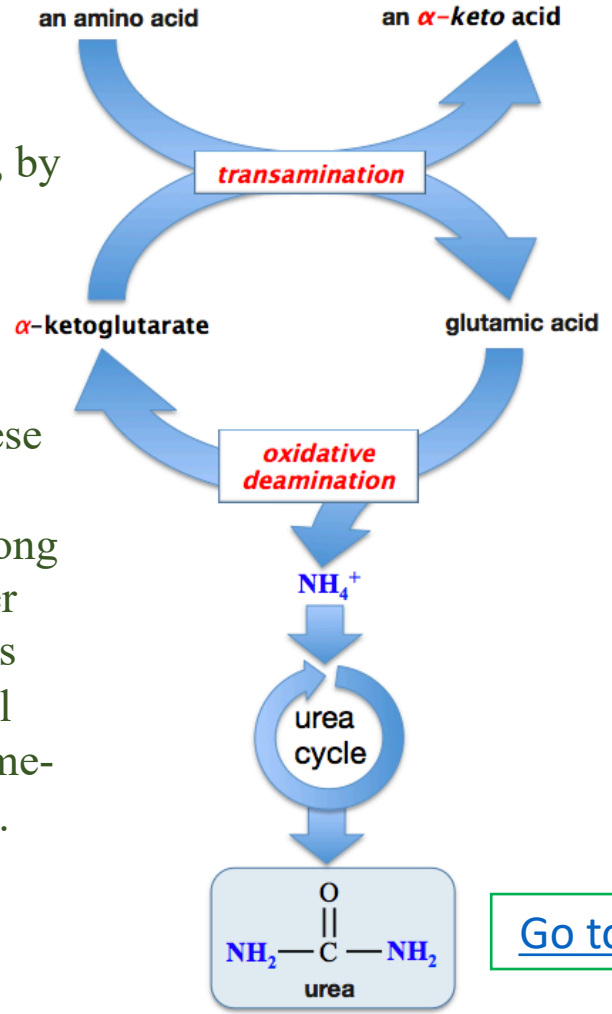
Go to next question

15.27) Fill in the blanks in each of the statements below:

a) The free ammonium ions (NH_4^+) that are produced in oxidative deamination are toxic at elevated concentrations. Humans and most other terrestrial vertebrates are capable of converting the ammonium ions to **urea**.

b) Kidney disease can result in the build up of dangerous amounts of urea. The urea concentration in blood is referred to as blood urea nitrogen (BUN). In cases of endstage renal (kidney) failure, safe BUN levels are exceeded, and patients must undergo **dialysis** treatments.

EXPLANATION: A typical adult produces about 25 to 30 grams of *urea* per day. This occurs in a series of reactions called the **urea cycle**. Urea is filtered, by the kidneys, into the urinary track and then removed from the body during urination. Kidney disease can result in the build up of dangerous amounts of urea. In cases of ***end- stage renal (kidney) failure***, safe ***blood urea nitrogen*** (**BUN**) levels are exceeded, and patients must undergo **dialysis treatments**. Dialysis involves artificial methods of urea removal. The most common of these is called **hemodialysis**. In *hemodialysis*, a patient's blood is passed along one side of a porous membrane, while a dialyzing (urea-free) solution is passed along the other. The pores allow the diffusion of urea (but not cells, proteins, or other large compounds) from the blood into the dialyzing solution. After the blood is dialyzed, it is continuously returned to the patient. Hemodialysis takes several hours and is usually done multiple times per week. This process is not only time-consuming, but far from ideal because of many complications and side effects.



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For more details: See chapter 15 part 13 video or chapter 15 section 5 in the textbook.

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15.28)

a) A *metabolic pathway* in which a series of reactions is used to repeatedly break down or build up a compound is defined as a _____ pathway.

   a) spiral
   b) walking
   c) circular
   d) linear

b) Give one example (from chapter 15), of each of the following types *metabolic pathways*:

   i) linear pathway: _____

   ii) circular pathway: _____

   iii) spiral pathway: _____

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Click here for a **hint**

Click here to **check your answer**

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15.28)

a) A *metabolic pathway* in which a series of reactions is used to repeatedly break down or build up a compound is defined as a _____ pathway.

HINT:
a) spiral
b) walking
c) circular
~~d) linear~~

b) Give one example (from chapter 15), of each of the following types *metabolic pathways*:

i) linear pathway: _____

ii) circular pathway: _____

iii) spiral pathway: _____

HINTS:

A **linear pathway** is a series of reactions that are not repeated.

A **circular pathway** is a repeating series of reactions in which the final product is ***also*** an *initial r*eactant.

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15.28)

a) A *metabolic pathway* in which a series of reactions is used to repeatedly break down or build up a compound is defined as a _____ pathway.

a) spiral
b) walking
c) circular
d) linear

b) Give one example (from chapter 15), of each of the following types *metabolic pathways*:

i) linear pathway: ***glycolysis*** (or gluconeogenesis)

ii) circular pathway: ***citric acid cycle***

iii) spiral pathway: ***β-oxidation*** (or fatty acid anabolism)

EXPLANATION:

A **linear pathway** is a series of reactions that are not repeated. *Glycolysis* is characterized as a linear pathway.

A **circular pathway** is a repeating series of reactions in which the final product is ***also*** an *initial r*eactant. The *citric acid cycle* is characterized as a circular pathway. In the citric acid cycle, *oxaloacetate* is not only a *reactant* in the first reaction, it is ***also*** the *product* of the last reaction.

A **spiral pathway** is a metabolic pathway in which a ***series of repeated reactions*** is used to break down (or build up) a compound. In a circular pathway, such as the citric acid cycle, the final product is ***exactly*** the same as *one* of the *initial* reactants. This is not the case for a *spiral* pathway. *β-oxidation* is and example of a spiral pathway.

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15.29) Fill in the blanks in each of the statements below:

a) Digestion of carbohydrates involve breaking _____ bonds; breaking these bonds produces _____.

b) Digestion of triglycerides involve breaking _____ bonds; breaking these bonds produces _____ and monoglycerides.

c) Digestion of proteins involve breaking _____ bonds; breaking these bonds produces _____.

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Click here for a **hint**

Click here to **check your answer**

Go to next question

15.29) Fill in the blanks in each of the statements below:

a) Digestion of carbohydrates involve breaking _____ bonds; breaking these bonds produces _____.

b) Digestion of triglycerides involve breaking _____ bonds; breaking these bonds produces _____ and monoglycerides.

c) Digestion of proteins involve breaking _____ bonds; breaking these bonds produces _____.

aldehydes
fatty acids
alcohols
glycosidic
ester
monosaccharides
amino acids
peptide
phosphoester
hydrogen
ether

For more help:

Review the ***digestion*** of carbohydrates, protein, and triglycerides in your lecture notes or in these videos:

digestion of carbohydrates - chapter 15 part 3 video
digestion of protein - chapter 15 part 13 video
digestion of triglycerides - chapter 15 part 10 video

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15.29) Fill in the blanks in each of the statements below:

a) Digestion of carbohydrates involve breaking **glycosidic** bonds; breaking these bonds produces **monosaccharides**.

b) Digestion of triglycerides involve breaking **ester** bonds; breaking these bonds produces **fatty acids** and monoglycerides.

c) Digestion of proteins involve breaking **peptide** bonds; breaking these bonds produces **amino acids** .

For more details:

Review the digestion of carbohydrates, protein, and triglycerides in your lecture notes or in these videos:

digestion of carbohydrates - chapter 15 part 3 video
digestion of protein - chapter 15 part 13 video
digestion of triglycerides - chapter 15 part 10 video

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Go to next question

15.30) Match each of the following **descriptions** with the appropriate **catabolic processes**.

Descriptions:

a) Carbohydrates are hydrolyzed to monosaccharides. Triglycerides are "partially" hydrolyzed to fatty acid salts and monoglyceride. Proteins are hydrolyzed to amino acids.

b) A quaternary ammonium group ($-NH_3^+$) is removed from glutamic acid, thereby producing ammonium (NH_4^+) and ***α*-ketoglutarate.**

c) Glycogen is converted to glucose.

d) A spiral metabolic pathway in which fatty acids are converted to acetyl-CoA, NADH and $FADH_2$.

e) Triglycerides that are stored primarily in adipose (fat) cells and muscle cells are broken down into fatty acids and glycerol.

f) A linear metabolic pathway in which glucose is converted into two pyruvate ions.

g) A circular metabolic pathway in which acetyl-CoA is metabolized to produce ATP, NADH, and $FADH_2$.

Catabolic Processes Choices:

Glycolysis
Glycogenolysis
Digestion
Oxidative Deamination
Citric Acid Cycle
***β*-oxidation**
Lypolysis

Go back

Click here for a **hint**

Click here to **check your answer**

Go to next question

15.30) Match each of the following **descriptions** with the appropriate **catabolic processes**.

Descriptions:

a) Carbohydrates are hydrolyzed to monosaccharides. Triglycerides are "partially" hydrolyzed to fatty acid salts and monoglyceride. Proteins are hydrolyzed to amino acids. **HINT:** The answer to part **(a)** is **Digestion**. Review the descriptions of the other processes in your lecture notes.

b) A quaternary ammonium group ($-NH_3^+$) is removed from glutamic acid, thereby producing ammonium (NH_4^+) and ***α*-ketoglutarate.**

c) Glycogen is converted to glucose.

d) A spiral metabolic pathway in which fatty acids are converted to acetyl-CoA, NADH and $FADH_2$.

e) Triglycerides that are stored primarily in adipose (fat) cells and muscle cells are broken down into fatty acids and glycerol.

f) A linear metabolic pathway in which glucose is converted into two pyruvate ions.

g) A circular metabolic pathway in which acetyl-CoA is metabolized to produce ATP, NADH, and $FADH_2$.

Catabolic Processes Choices:

Glycolysis
Glycogenolysis
Digestion
Oxidative Deamination
Citric Acid Cycle
***β*-oxidation**
Lypolysis

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For more help: See chapter 15 part 14 video or chapter 15 section 6 in the textbook.

Click here to **check your answer**

Go to next question

15.30) Match each of the following **descriptions** with the appropriate **catabolic processes**.

Descriptions:

a) Carbohydrates are hydrolyzed to monosaccharides. Triglycerides are "partially" hydrolyzed to fatty acid salts and monoglyceride. Proteins are hydrolyzed to amino acids. **Digestion**

b) A quaternary ammonium group ($-NH_3^+$) is removed from glutamic acid, thereby producing ammonium (NH_4^+) and ***α*-ketoglutarate.** **Oxidative Deamination**

c) Glycogen is converted to glucose. **Glycogenolysis**

d) A spiral metabolic pathway in which fatty acids are converted to acetyl-CoA, NADH and $FADH_2$. ***β*-oxidation**

e) Triglycerides that are stored primarily in adipose (fat) cells and muscle cells are broken down into fatty acids and glycerol. **Lypolysis**

f) A linear metabolic pathway in which glucose is converted into two pyruvate ions. **Glycolysis**

g) A circular metabolic pathway in which acetyl-CoA is metabolized to produce ATP, NADH, and $FADH_2$. **Citric Acid Cycle**

Catabolic Processes Choices:

Glycolysis
Glycogenolysis
Digestion
Oxidative Deamination
Citric Acid Cycle
***β*-oxidation**
Lypolysis

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For more details: See chapter 15 part 14 video or chapter 15 section 6 in the textbook.

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15.31) Match each of the following **descriptions** with the appropriate **anabolic processes**.

Descriptions:

a) Glucose is converted to glycogen.

b) Amino acids are converted to proteins.

c) The conversion of non-carbohydrate species into glucose. This process is similar to the reverse of glycolysis.

d) Fatty acids are produced by a spiral pathway that works in the opposite direction of β-oxidation; it builds up fatty acyl-CoA by a repeating series of reactions that add acetyl-CoA to a growing fatty acyl-CoA structure.

Anabolic Processes Choices:

Fatty Acid Synthesis
Amino Acid Synthesis
Gluconeogenesis
Fatty Acid Cycle
Protein Synthesis
Glycogenesis
Gluco-Glycosylation

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Click here for a **hint**

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This is the last question.

15.31) Match each of the following **descriptions** with the appropriate **anabolic processes**.

Descriptions:

a) Glucose is converted to glycogen.

b) Amino acids are converted to proteins.

c) The conversion of non-carbohydrate species into glucose. This process is similar to the reverse of glycolysis.

d) Fatty acids are produced by a spiral pathway that works in the opposite direction of β-oxidation; it builds up fatty acyl-CoA by a repeating series of reactions that add acetyl-CoA to a growing fatty acyl-CoA structure.

Anabolic Processes Choices:

HINT:
- **Fatty Acid Synthesis**
- ~~**Amino Acid Synthesis**~~
- **Gluconeogenesis**
- ~~**Fatty Acid Cycle**~~
- **Protein Synthesis**
- **Glycogenesis**
- ~~**Gluco-Glycosylation**~~

For more help: See chapter 15 part 14 video or chapter 15 section 6 in the textbook.

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This is the last question.

15.31) Match each of the following **descriptions** with the appropriate **anabolic processes**.

Descriptions:

a) Glucose is converted to glycogen. **Glycogenesis**

b) Amino acids are converted to proteins. **Protein Synthesis**

c) The conversion of non-carbohydrate species into glucose. This process is similar to the reverse of glycolysis. **Gluconeogenesis**

d) Fatty acids are produced by a spiral pathway that works in the opposite direction of β-oxidation; it builds up fatty acyl-CoA by a repeating series of reactions that add acetyl-CoA to a growing fatty acyl-CoA structure. **Fatty Acid Synthesis**

Anabolic Processes Choices:

Fatty Acid Synthesis
Amino Acid Synthesis
Gluconeogenesis
Fatty Acid Cycle
Protein Synthesis
Glycogenesis
Gluco-Glycosylation

For more details: See chapter 15 part 14 video or chapter 15 section 6 in the textbook.

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This is the last question.