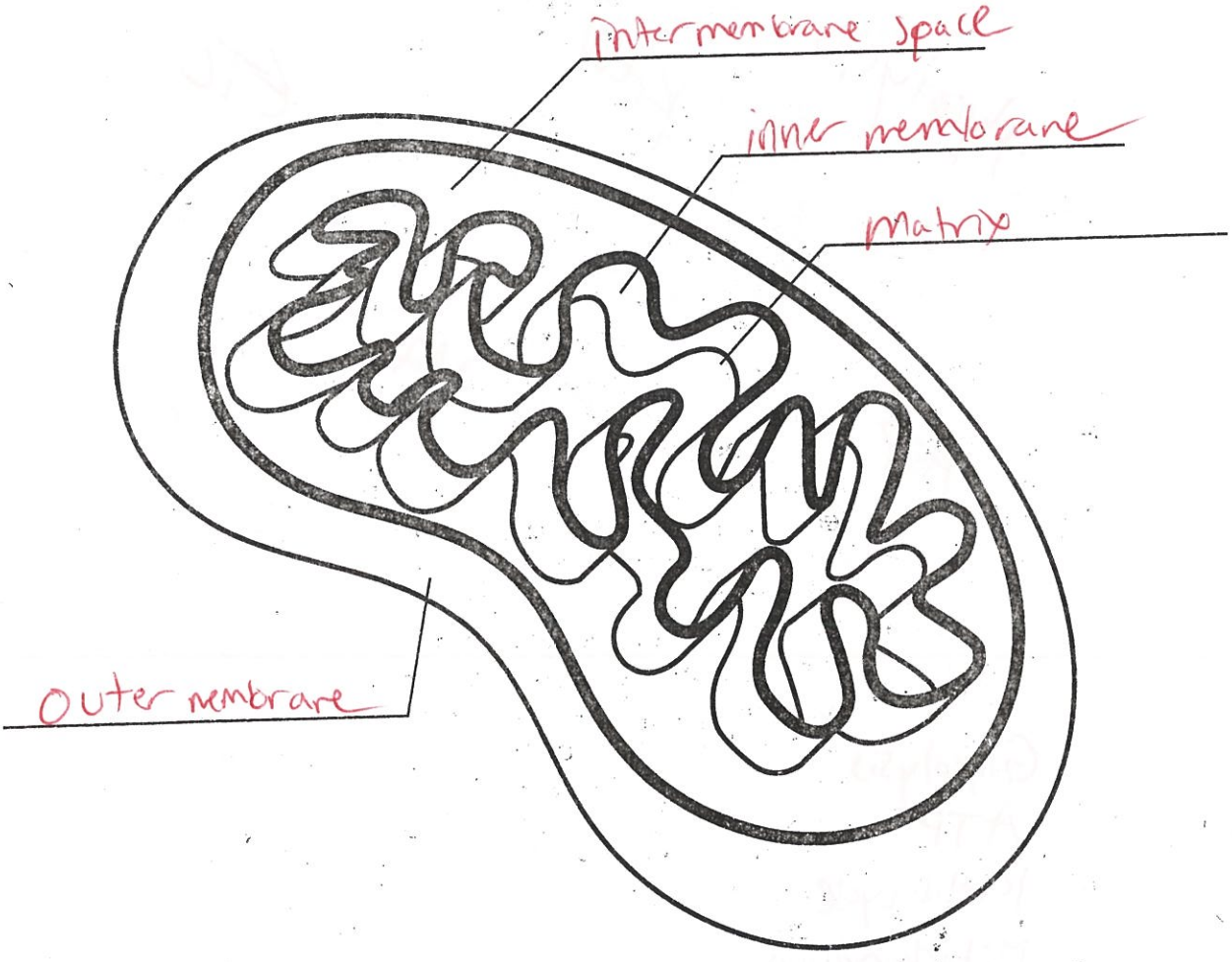
Name_____ Class_____ Date _____

The Mitochondrion

In plant and animal cells, the final stages of cellular respiration take place in mitochondria. A mitochondrion has two membranes. The inner membrane is folded up inside the outer membrane. The space between the inner and outer membranes is called the intermembrane space. The space inside the inner membrane is called the matrix.

Label the inner membrane, intermembrane space, matrix, *and* outer membrane.



Answer the questions. Circle the correct answer.

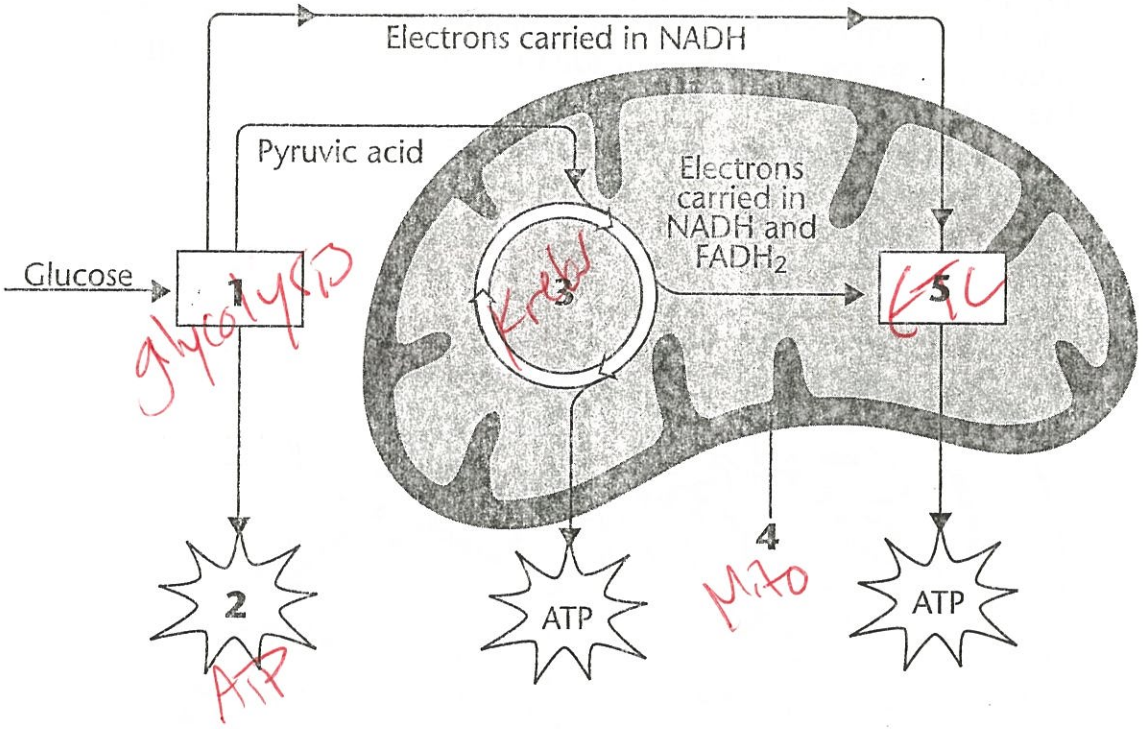
1. In which membrane is the electron transport chain located?

outer membrane inner membrane

Name_____ Class_____ Date_____

Cellular Respiration Overview

Cellular respiration is the process that releases energy from food in the presence of oxygen.



Use the words below to label the diagram of cellular respiration on the lines provided.

ATP	glycolysis	mitochondrion
electron transport chain	Krebs cycle	

1. Glycolysis
2. ATP
3. Krebs cycle
4. Mitochondrion
5. ETC

Use the diagram to answer the questions.

1. Where does glycolysis take place?

   Cytoplasm

2. Where do the Kreb cycle and electron transport chain take place?

   ~~[illegible]~~ mito

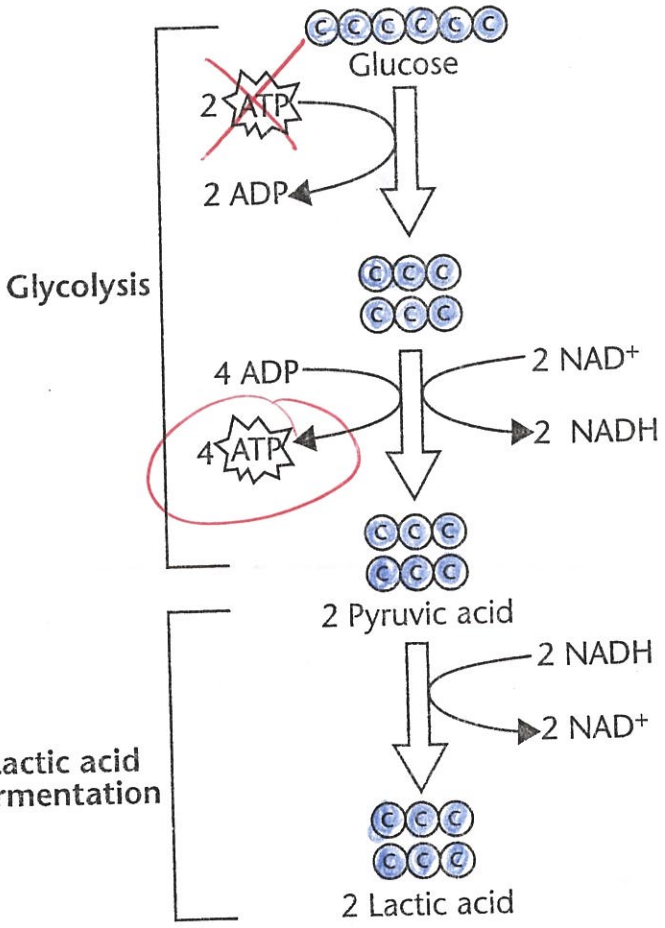
Name_____ Class_____ Date _____

Glycolysis and Fermentation

Glycolysis uses ATP to break a molecule of glucose in half, producing pyruvic acid. When oxygen is not present, glycolysis is followed by fermentation. Fermentation enables cells to produce energy in the absence of oxygen.

Follow the prompts to identify important parts of glycolysis and fermentation.

- Color the carbon atoms blue.
- Circle the place where ATP is formed.
- Mark an X on the place where ATP is used.



Answer the questions.

1. How many carbon atoms are in one molecule of glucose?

6

2. What is the product of glycolysis? 2 pyruvic acid (a 3 carbon compound)

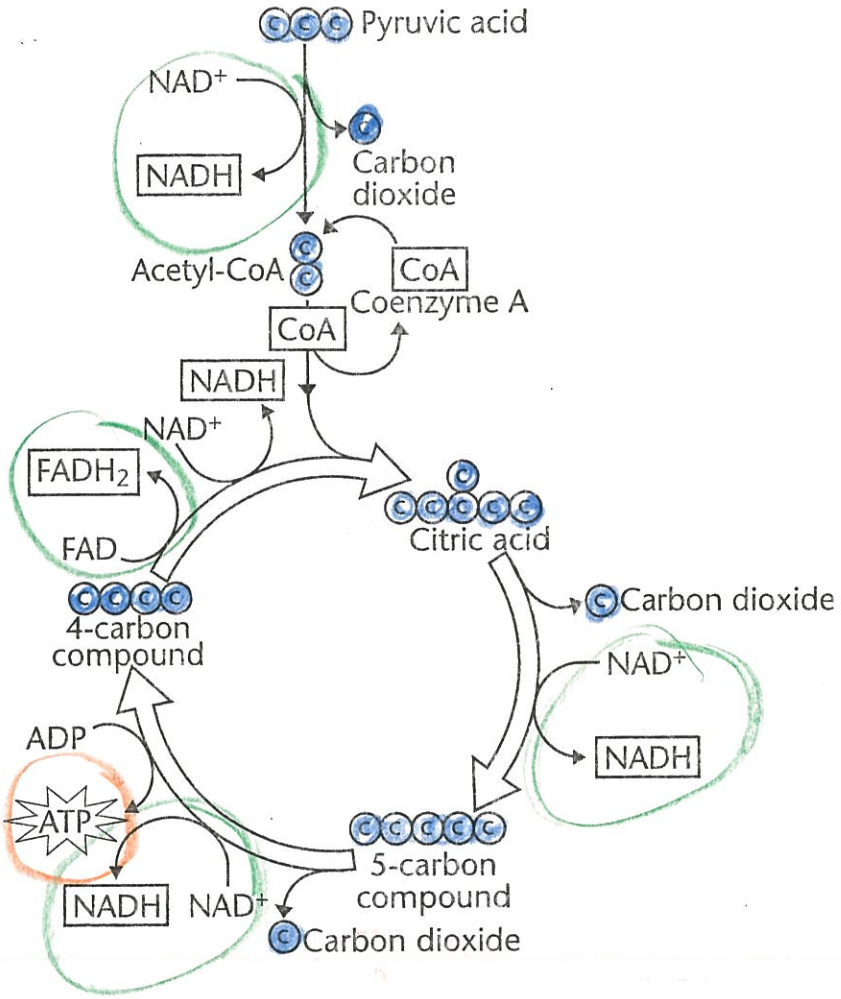
Name_____ Class_____ Date _____

The Krebs Cycle

If oxygen is present, the pyruvic acid formed during glycolysis moves into the Krebs cycle. The Krebs cycle converts pyruvic acid into carbon dioxide. As carbon dioxide is formed, high energy electrons are accepted by NAD^+ and FAD. This results in the formation of NADH and $FADH_2$. NADH and $FADH_2$ will be used later to produce ATP.

Follow the prompts to identify important parts of the Krebs cycle.

- Color the carbon atoms blue.
- Circle the electron carriers in green.
- Circle ATP in orange.



Use the diagram to answer the question. Circle the correct answer.

1. Which of the following is formed during the Krebs cycle?

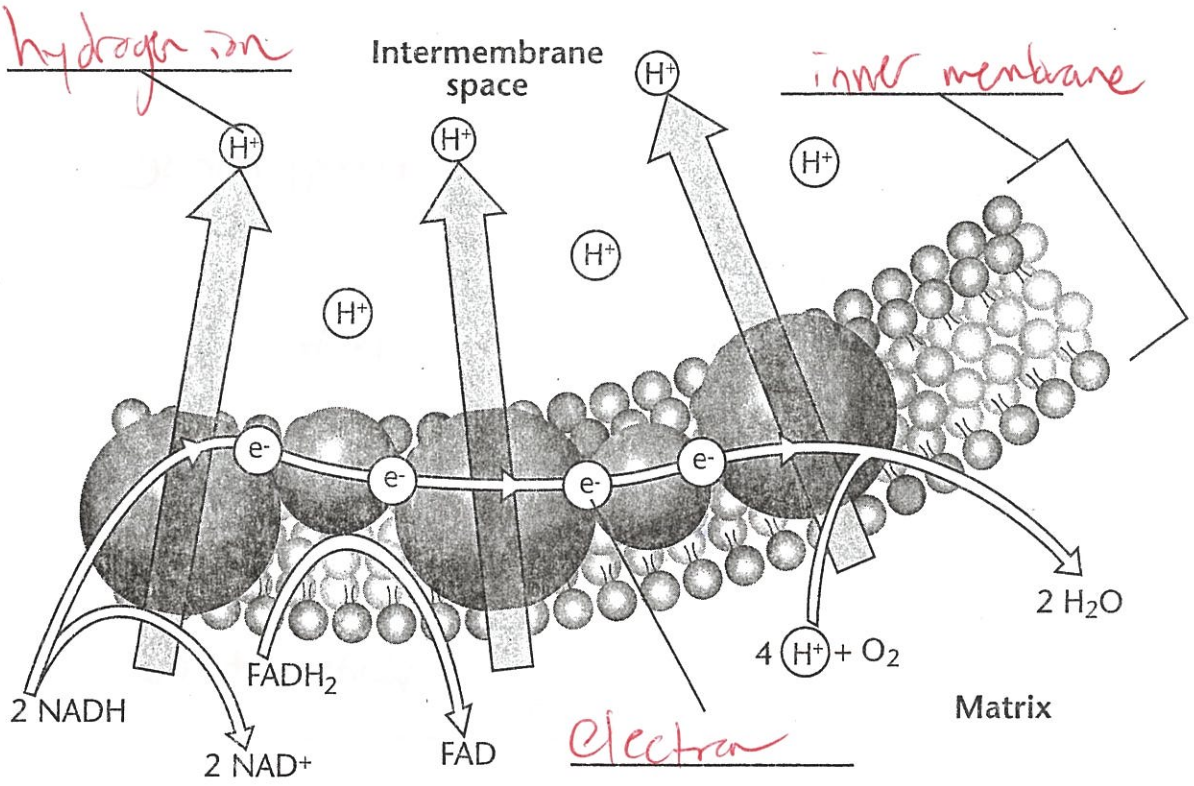
$FADH_2$ pyruvic acid

Name_____ Class_____ Date_____

Electron Transport Chain

The electron transport chain uses the high-energy electrons produced by the Krebs cycle to move hydrogen ions from one side of the inner membrane to the other.

Label the diagram with the following terms: electron, hydrogen ion, *and* inner membrane.



Use the diagram to answer the questions.

1. Where in the mitochondrion does the electron transport chain take place?

inner membrane

2. What happens to the high-energy electrons from the Krebs cycle?

The ETC uses the electrons to move H+ from one side of the inner membrane to the other

Name_____ Class_____ Date _____

Cellular Respiration and Photosynthesis

Cellular respiration and photosynthesis can be thought of as opposite processes. Energy flows in opposite directions in the two processes.

Complete the table using the words below. Some cells have been completed for you. Some words may be used more than once.

carbon dioxide	energy release	mitochondria	water

	Photosynthesis	Cellular Respiration
Function	energy capture	energy release
Location	chloroplasts	mito
Reactants	CO_2 + water	glucose; oxygen
Products	oxygen; glucose	Water + CO_2

Use the table to answer the questions.

1. Which process releases energy for the cell? Circle the correct answer.

   cellular respiration photosynthesis

2. For which reaction is $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ the correct equation? Circle the correct answer.

   cellular respiration photosynthesis

3. How do the products of photosynthesis compare to the reactants of cellular respiration?

   Same

Name _____ Class _____ Date _____

Chapter 9 Cellular Respiration

Vocabulary Review

Matching *In the space provided, write the letter of the definition that best matches each term.*

C 1. anaerobic
D 2. aerobic
B 3. calorie
A 4. cellular respiration

a. process that releases energy by breaking down food in the presence of oxygen
b. amount of energy needed to raise the temperature of 1 g of water 1°C
c. chemical process that does not require oxygen
d. chemical process that requires oxygen

Matching *In the space provided, write the letter of the definition that best matches each term.*

B 5. fermentation
D 6. glycolysis
C 7. Krebs cycle
A 8. NAD^+

a. electron carrier of glycolysis
b. process that releases energy from food molecules when no oxygen is present
c. stage of cellular respiration in which pyruvic acid is broken down into carbon dioxide in a series of energy-extracting reactions
d. process in which glucose is broken down into two molecules of pyruvic acid

Name _____ Class _____ Date _____

Section 9–1 Chemical Pathways (pages 221–225)

Key Concepts

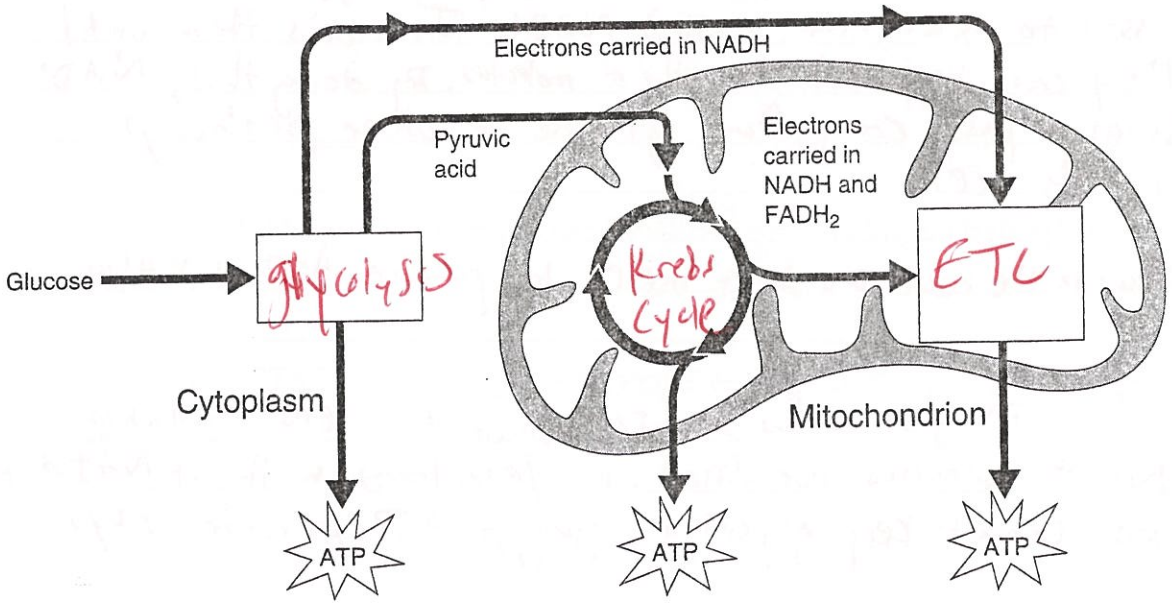
- What is cellular respiration?
- What happens during the process of glycolysis?
- What are the two main types of fermentation?

Chemical Energy and Food (page 221)

1. What is a calorie? the amount of energy needed to raise the temp. of 1 gram of water 1° C.
2. How many calories make up 1 Calorie? 1000
3. Cellular respiration begins with a pathway called glycolysis.
4. Is the following sentence true or false? Glycolysis releases a great amount of energy.
   false

Overview of Cellular Respiration (page 222)

5. What is cellular respiration? process that releases energy by breaking down glucose + other food molecules in the presence of O_2
6. What is the equation for cellular respiration, using chemical formulas?
   $6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + \text{energy}$
7. Label the three main stages of cellular respiration on the illustration of the complete process.



Name_____ Class_____ Date_____

8. What would be the problem if cellular respiration took place in just one step?
Then all of the energy from glucose would be released at once, & most of it would be lost as light & heat.

9. Where does glycolysis take place? Cytoplasm

10. Where do the Krebs cycle and electron transport take place? mitochondria

Glycolysis (page 223)

11. What is glycolysis? process in which 1 molecule of glucose is broken in half, producing 2 molecules of pyruvic acid.

12. How does the cell get glycolysis going? Puts 2 ATP into the reaction

13. If the cell uses 2 ATP molecules at the beginning of glycolysis, how does it end up with a net gain of 2 ATP molecules? 4 ATP molecules are produced

14. What is NAD^+? An electron carrier

15. What is the function of NAD^+ in glycolysis? 4 high energy electrons are passed to a carrier called NAD^+. It holds them until they can be passed to other molecules. By doing this, NAD^+ helps to pass energy from glucose to other pathways in the cell.

16. Why can glycolysis supply energy to cells when oxygen is not available?
Because the reactions don't use O_2 to produce ATP & NADH

17. What problem does a cell have when it generates large amounts of ATP from glycolysis? In just a few seconds, all of the cells available NAD^+ molecules are filled up w/ electrons. Without NAD^+, the cell cannot keep glycolysis going, & ATP production stops.

Name_____ Class_____ Date _____

Fermentation (pages 224–225)

18. What is fermentation? When O_2 is not present, glycolysis is followed by a diff. pathway. The combined process of this pathway + glycolysis is called fermentation.

19. How does fermentation allow glycolysis to continue? Cells convert NADH to NAD^+ by passing high energy e⁻ back to pyruvic acid. = NADH → NAD^+ + glycolysis can continue

20. Because fermentation does not require oxygen, it is said to be anaerobic.

21. What are the two main types of fermentation?
    a. Alcoholic
    b. Lactic Acid

22. What organisms use alcoholic fermentation? yeast + a few other organisms

23. What is the equation for alcoholic fermentation after glycolysis?
pyruvic acid + NADH → alcohol + CO_2 + NAD^+

24. What happens to the small amount of alcohol produced in alcoholic fermentation during the baking of bread? evaporates

25. What does lactic acid fermentation convert into lactic acid? pyruvic acid

26. What is the equation for lactic acid fermentation after glycolysis?
pyruvic acid + NADH → lactic acid + NAD^+

27. During rapid exercise, how do your muscle cells produce ATP? Lactic acid fermentation b/c not enough O_2 in muscles

Reading Skill Practice

When you read about complex topics, writing an outline can help you organize and understand the material. Outline Section 9–1 by using the headings and subheadings as topics and subtopics and then writing the most important details under each topic. Do your work on a separate sheet of paper.

Name_____ Class_____ Date _____

Section 9–2 The Krebs Cycle and Electron Transport (pages 226–232)

Key Concepts

- What happens during the Krebs cycle?
- How are high-energy electrons used by the electron transport chain?

Introduction (page 226)

1. At the end of glycolysis, how much of the chemical energy in glucose is still unused?
   90% locked in e⁻ of pyruvic acid
2. Because the final stages of cellular respiration require oxygen, they are said to be aerobic.

The Krebs Cycle (pages 226–227)

3. In the presence of oxygen, how is the pyruvic acid produced in glycolysis used?
   passes to the second stage of cellular respiration (Krebs).
4. What happens to pyruvic acid during the Krebs cycle? PA is broken down into carbon dioxide in a series of energy-extraction reactions.
5. Why is the Krebs cycle also known as the citric acid cycle? Citric acid is the first compound formed in this series of reactions.
6. When does the Krebs cycle begin? when pyruvic acid produced by glycolysis enters the mitochondrion.
7. What happens to each of the 3 carbon atoms in pyruvic acid when it is broken down?
   One carbon atom from pyruvic acid becomes part of CO_2 + the other 2 are joined to a compound called Coenzyme A to form acetyl-CoA.
8. What happens to the carbon dioxide produced in breaking down pyruvic acid?
   released into the air
9. How is citric acid produced? Acetyl-CoA then adds the 2 carbon acetyl group to a 4-carbon molecule producing a 6 carbon molecule called citric acid.
10. During the energy extraction part of the Krebs cycle, how many molecules of CO_2 are released? 2
11. What is the energy tally from 1 molecule of pyruvic acid during the Krebs cycle?
    4 NADH, 1 $FADH_2$ + 1 ATP

Name _____ Class _____ Date _____

12. When electrons join NAD^+ and FAD during the Krebs cycle, what do they form?
NADH + $FADH_2$

13. Why is the 4-carbon compound generated in the breakdown of citric acid the only permanent compound in the Krebs cycle? it is regenerated at the end of each complete turn of the cycle

Electron Transport (pages 228–229)

14. What is the electron transport chain? a series of proteins in the inner membrane of the mito. It uses high energy e⁻ from Krebs to ADP→ATP

15. What does the electron transport chain use the high-energy electrons from the Krebs cycle for? ADP → ATP conversion

16. How does the location of the electron transport chain differ in eukaryotes and prokaryotes? E - the chain is composed of a series of proteins in the inner membrane of mito. P - chain is in cell membrane.

17. Where does the electron transport chain get the high-energy electrons that are passed down the chain? from NADH + $FADH_2$ in Krebs

18. Is the following sentence true or false? Hydrogen serves as the final electron acceptor of the electron transport chain. false

19. What is the energy of the high-energy electrons used for every time 2 high-energy electrons move down the electron transport chain? to transport H^+ across the membrane

20. What causes the H^+ ions in the intermembrane space to move through the channels in the membrane and out into the matrix? During e⁻ transport, H^+ ions build up in the intermembrane space, making it positively charged. The other side of the membrane, from which those H^+ ions have been taken, is now neg.

21. On average, how many ATP molecules are produced as each pair of high-energy electrons moves down the electron transport chain? 3 ATP

Name_____ Class_____ Date_____

22. Complete the flowchart about electron transport. (Review Figure 9–7 on page 228 of your textbook.)

High-energy electrons from NADH and $FADH_2$ are passed into and along the ETC.

↓

The energy from the electrons moving down the chain is used to move H^+ ions across the inner membrane.

↓

H^+ ions build up in the inter membrane space, making it positively charged and making the matrix negatively charged.

↓

H^+ ions move through channels of ATP synthase in the inner membrane.

↓

The ATP synthase uses the energy from the moving ions to combine ADP and phosphate, forming high-energy ATP.

The Totals (page 229)

23. How many ATP molecules are formed during cellular respiration? 36

24. Why is more ATP generated from glucose in the presence of oxygen?
When no O_2, Krebs & ETC can't proceed → glycolysis produces just 2 ATP molecules per glucose molecule. Under aerobic conditions, the Krebs & ETC enable the cell to produce 34 more ATP per glucose

25. What happens to the energy of glucose that is not used to make ATP molecules?
it is released as heat

26. What are the final waste products of cellular respiration? H_2O + CO_2

Name_____ Class_____ Date _____

Energy and Exercise (pages 230-231)

27. What are three sources of ATP a human body uses at the beginning of a race?
ATP already in muscles, new ATP by lactic acid fermentation, + cellular resp.

28. When a runner needs quick energy for a short race, what source can supply enough ATP for about 90 seconds? ATP from glycolysis + cell. resp. + lactic acid ferm.

29. Why does a sprinter have an oxygen debt to repay after the race is over?
lactic acid is a byproduct of lactic acid ferm. Needs extra O_2 to get rid of it

30. A runner needs more energy for a longer race. How does the body generate the necessary ATP? Cell. resp. is only way to generate a continuous supply of ATP

31. Why are aerobic forms of exercise so beneficial for weight control? Stores of glycogen used in cellular resp. usually lasts 15-20 min. After that, fats.

Comparing Photosynthesis and Cellular Respiration (page 232)

32. If photosynthesis is the process that "deposits" energy in a "savings account," then what is cellular respiration? withdraws energy

33. How are photosynthesis and cellular respiration opposite in terms of carbon dioxide?
PSS removes CO_2 + CR puts it back

34. How are photosynthesis and cellular respiration opposite in terms of oxygen?
PSS releases O_2 + CR uses it to release energy from food.

Name _____ Class _____ Date _____

Vocabulary Review

Matching *In the space provided, write the letter of the definition that best matches each term.*

F 1. calorie
D 2. glycolysis
C or G 3. cellular respiration
A 4. NAD^+
E or B 5. fermentation
E 6. anaerobic
C 7. aerobic

a. electron carrier
b. pathway that releases energy from food in the absence of oxygen
c. requires oxygen
d. process in which one molecule of glucose is broken in half, producing two molecules of pyruvic acid
e. does not require oxygen
f. amount of energy needed to raise 1 gram of water 1 degree Celsius
g. process that releases energy by breaking down food molecules in the presence of oxygen

Answering Questions *In the space provided, write an answer to each question.*

8. What is the first stage of cellular respiration? Glycolysis

9. What is the second stage of cellular respiration? Krebs cycle

10. What is the third stage of cellular respiration? ET

11. How many ATP molecules can the cell produce from a single molecule of glucose through glycolysis? 2

12. How many ATP molecules can the cell produce from a single molecule of glucose through the complete process of cellular respiration? 36

Completion *Write an equation for each of the pathways below.*

13. lactic acid fermentation after glycolysis pyruvic acid + NADH → lactic acid + NAD

14. alcoholic fermentation after glycolysis pyruvic acid + NADH → alcohol + CO + NAD

15. cellular respiration Oxygen + glucose → $CO_2 + H_2O$ + Energy

Name _____ Class _____ Date _____

Reviewing Key Concepts

Completion *On the lines provided, complete the following sentences.*

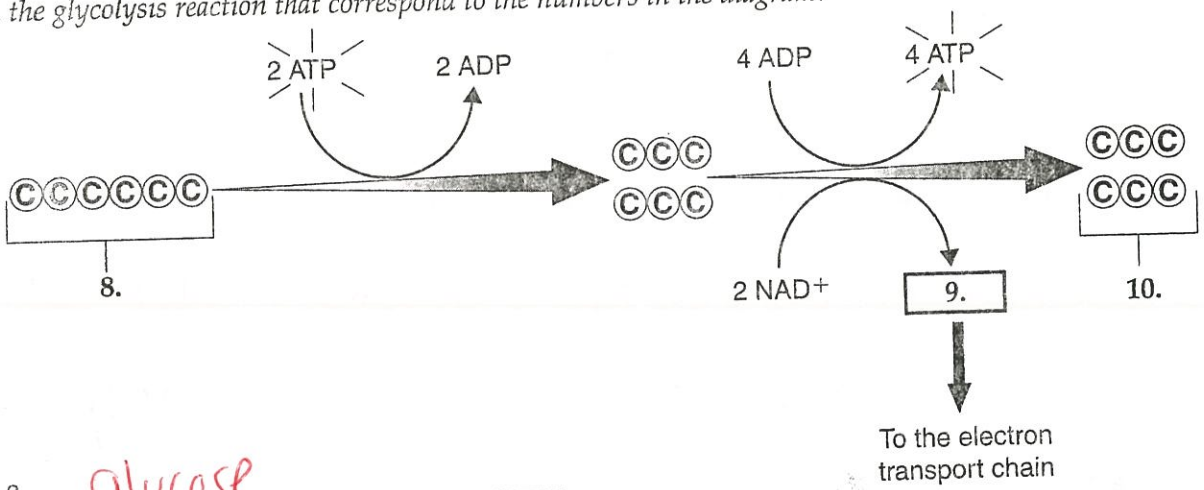
1. The process that releases energy by breaking down glucose and other food molecules in the presence of oxygen is called Cellular resp.
2. During glycolysis, one molecule of glucose is broken in half.
3. During glycolysis, NAD^+ is converted to NADH.
4. Glycolysis produces a net gain of 2 ATP molecules for each reaction.
5. The products of alcoholic fermentation are alcohol, CO_2, and NAD^+.

Short Answer *On the lines provided, answer the following questions.*

6. Why is fermentation considered an anaerobic process?
the process of fermentation doesn't require O_2
7. How does fermentation allow the production of ATP to continue?
ferm. continues to produce NADH w/o O_2. This process allows glycolysis to continue to produce ATP

Reviewing Key Skills

Labeling Diagrams *On the lines provided below, write the names of the substances in the glycolysis reaction that correspond to the numbers in the diagram.*



8. glucose
9. 2 NADH
10. 2 molecules of pyruvic acid

Name _____ Class _____ Date _____

Reviewing Key Concepts

Short Answer *On the lines provided, answer the following questions.*

1. How is pyruvic acid used in the Krebs cycle?
PA is the product of glycolysis & becomes a reactant of Krebs. Broken down into CO_2 to produce ATP.

2. How are glycolysis and cellular respiration related?
G & CR are related b/c G is the first step in CR. The pyruvic acid produced during glycolysis is broken down in the presence of O_2 during Krebs.

3. What role do high-energy electrons play in the electron transport chain?
from Krebs & glycolysis are used to convert ADP to ATP in ETC.

4. What are the reactants in cellular respiration? What are the products?
$C_6H_{12}O_6 + 6O_2 \longrightarrow 6H_2O + 6CO_2 + \text{energy (ATP)}$

Reviewing Key Skills

Identification *On the lines provided, identify which phrase describes the following processes:* cellular respiration *or* photosynthesis.

P 5. reactants are CO_2 and H_2O

P 6. occurs only in plants, algae, and some microorganisms

CR 7. $6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$

CR 8. uses oxygen to release energy from food

9. **Comparing** How many ATP molecules are produced in glycolysis? In cellular respiration?
Only 2 ATP from glycolysis - 36 From CR

10. **Applying Concepts** Would a baseball player running to first base and a cross-country skier use the same or different pathways to release energy? Explain your answer.
BB = lactic acid ferm. (quick energy & an ATP supply for short time)
CC = CR b/c needs a continuing supply of ATP for long time

Name _____ Class _____ Date _____

Defining Terms *On the lines provided, write a definition for each of the following terms.*

1. calorie the amount of energy needed to raise the temp of 1g of water 1°C
2. glycolysis 1 molecule of glucose is broken in half, producing 2 molecules of pyruvic acid, a 3-carbon compound.
3. cellular respiration releases energy by breaking down glucose & other food molecules in the presence of O_2
4. NAD^+ an electron carrier that helps pass energy from glucose to other pathways in the cell during glycolysis
5. fermentation releases energy from food molecules by producing ATP without O_2
6. anaerobic not in air
7. aerobic in air
8. Krebs cycle pyruvic acid is broken down into CO_2 in a series of energy extracting reactions.
9. electron transport chain uses high energy electrons from Krebs to convert ADP to ATP.

Identification *On the lines provided, identify which phrase describes the following processes:* cellular respiration, glycolysis, lactic acid fermentation, *or* alcoholic fermentation.

10. important in baking bread alcoholic ferm
11. builds up in muscles after a few seconds of intense activity lactic acid ferm
12. requires oxygen and glucose CR
13. produces 2 ATP molecules and pyruvic acid glycolysis
14. almost the opposite process of photosynthesis CR
15. the reason why runners breathe heavily after a race lactic acid ferm

Name_____ Class_____ Date _____

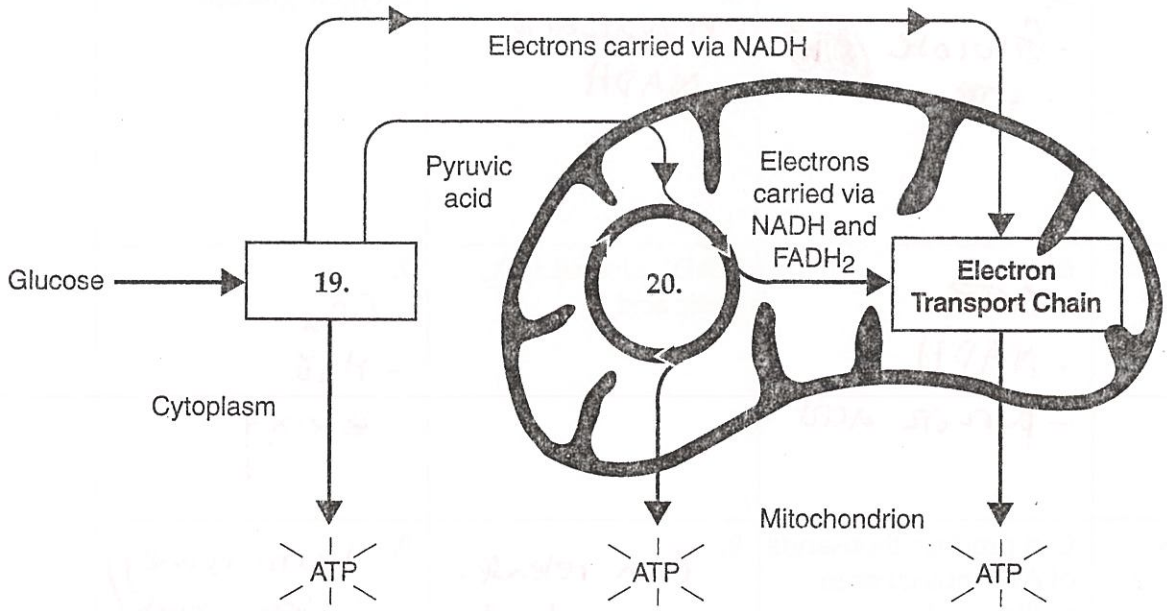
Multiple Choice *On the lines provided, write the letter that best answers the question.*

B 16. What is the net energy gain in glycolysis?
- a. 4 molecules of ATP
- b. 2 molecules of ATP
- c. 36 molecules of ATP
- d. 38 molecules of ATP

D 17. Which of the following causes a painful, burning sensation in muscles after vigorous exercise?
- a. alcohol
- b. glycolysis
- c. pyruvic acid
- d. lactic acid

C 18. What is another name for the Krebs cycle?
- a. the glycolysis cycle
- b. alcoholic fermentation
- c. the citric acid cycle
- d. the respiration cycle

Interpreting Diagrams *On the lines below, write the name of the stage of cellular respiration that corresponds with the numbers in the diagram.*



19. glycolysis

20. Krebs cycle

Name_____ Class_____ Date _____

Compare/Contrast Table

Compare glycolysis, fermentation, and cellular respiration by filling in the missing information in the compare/contrast table below. If there is not enough room in the table to write your answers, write them on a separate piece of paper.

	Glycolysis	Fermentation	Cellular Respiration
Function	1. Quick production of ATP + NADH for cellular energy	2. Release of energy w/o O_2	3. Long term - Slow production of ATP for cellular energy
Reactants	4. - Glucose - ATP	5. - Pyruvic acid - NADH	Oxygen, glucose
Products	6. - ATP - NADH - pyruvic acid	NAD^+, alcohol, CO_2, lactic acid	7. - CO_2 - H_2O - energy
Advantages	Can produce thousands of ATP molecules in milliseconds	8. Can release energy w/o O_2	9. Sustains energy production much longer than glycolysis + ferm.
Disadvantages	10. Quickly fills all available NAD+ molecules w/ electrons + process stops	Produces ATP for only 20 or 30 seconds, lactic acid causes painful side effects	11. much slower than glycolysis + ferm.