



#الامتحان_بالجيب

Protein Activity & Regulation

BMS 23110B

Ready for the First Quiz?



Question Bank

the **MOST EXPECTED**
and **PREVIOUS QUESTIONS**



Video Explanation

key points and
step-by-step solutions

Chapters 1 & 2

متوفر شرح شباطر الكويز الأول مجاني للجميع مع الأوراق على المنصة ويوجد في هذا
الملف أسئلة امتحانات سابقة



CHAPTER 1

Protein Activity & Regulation — Introduction to Metabolism

Part A — Multiple Choice Questions

1. ★ Which statement best explains why conserved metabolic pathways are useful for understanding diverse organisms?

A	Cell types are structurally identical in all organisms
B	Every species uses exactly the same specialized tissues
C	Cell biochemistry and metabolic routes are broadly similar
D	All organisms contain the same number of metabolites

2. Bioenergetics is best defined as the study of:

A	energy changes during metabolic reactions
B	gene expression during cell division
C	protein structure in cellular membranes
D	ion transport across epithelial tissues

3. ★ Which relationship between thermodynamics and bioenergetics is correct?

A	Thermodynamics is part of bioenergetics
B	The two fields study unrelated processes
C	Bioenergetics excludes energy transformations
D	Bioenergetics is part of thermodynamics

4. ★ DR. WAEL SPECIAL For $A + B \rightleftharpoons C + D$, if [A] doubles while [B] is halved and k is unchanged, what happens to the forward rate $k[A][B]$?

A	It becomes twice as large
B	It remains unchanged
C	It becomes four times larger
D	It becomes half as large

5. ★ DR. WAEL SPECIAL For the reversible reaction $A + B \rightleftharpoons C + D$, the reverse reaction rate primarily depends on:

A	[A], [B], and the forward rate constant
B	[A] alone and the equilibrium constant
C	[C], [D], and the reverse rate constant
D	[B] alone and the forward rate constant

6. ★ DR. WAEL SPECIAL Which expression correctly defines the equilibrium constant for $A + B \rightleftharpoons C + D$?

A	$K_{eq} = [C][D]/[A][B]$
B	$K_{eq} = [A][B]/[C][D]$
C	$K_{eq} = k_{-1}/k_1$
D	$K_{eq} = [A][D]/[B][C]$

7. ★ DR. WAEL SPECIAL If $k_1 = 6 \text{ s}^{-1}$ and $k_{-1} = 2 \text{ s}^{-1}$ for a simplified reversible reaction, what is K_{eq} ?

A	0.33
B	2
C	12
D	3

8. ★ DR. WAEL SPECIAL A reaction has $K_{eq} = 10^3$. Which outcome is expected?

A	Reactants predominate at equilibrium
B	Products predominate at equilibrium
C	Reactants and products are equal
D	The reaction cannot reach equilibrium

9. ★ Which description correctly distinguishes catabolic from anabolic reactions?

A	Catabolism degrades; anabolism synthesizes
B	Catabolism synthesizes; anabolism degrades
C	Both only degrade large molecules
D	Both only synthesize cellular polymers

10. ★ An amphibolic pathway is one that:

A	functions only in energy-consuming synthesis
B	functions only in energy-releasing degradation
C	participates in both catabolic and anabolic processes
D	operates only outside living cells

11. Which process is an example of cellular turnover?

A	Permanent storage of all cell components
B	Complete cessation of enzyme synthesis
C	Irreversible loss of all metabolites
D	Continuous synthesis and degradation of cell components

12. ★ Which pairing of pathway form and example is correct?

A	Linear — citric acid cycle
B	Cyclic — citric acid cycle
C	Spiral — serine biosynthesis
D	Cyclic — fatty acid biosynthesis

13. ★ Why do multistep catabolic pathways release energy in discrete steps?

A	To prevent enzymes from binding substrates
B	To eliminate the need for energy carriers
C	To provide smaller usable amounts of energy
D	To make all steps metabolically irreversible

14. ★ Metabolic flux is best described as:

A	the flow of material through a metabolic pathway
B	the total number of enzymes in a pathway
C	the energy stored only in ATP molecules
D	the transport of ions across a membrane

15. ★ Which combination directly influences metabolic flux?

A	Cell shape, genome size, and tissue color
B	Water intake, body temperature, and cell age
C	Membrane thickness, pH only, and gene number

D	Substrate supply, product removal, and enzyme activity
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16. ★ In feedback inhibition, the end product most commonly inhibits:

A	the final product after it leaves the pathway
B	an early step, usually the first committed step
C	every enzyme in the pathway equally
D	a reaction in an unrelated pathway

17. ★ Feed-forward activation occurs when:

A	an end product blocks the first committed step
B	a phosphatase adds phosphate to an enzyme
C	an early metabolite activates a later pathway enzyme
D	a substrate removes a product from the cell

18. ★ Which enzyme class adds phosphoryl groups during rapid covalent regulation?

A	Protein kinases
B	Protein phosphatases
C	Aldolases
D	Isomerases

19. ★ Which statement about phosphorylation of interconvertible enzymes is correct?

A	It always activates every regulated enzyme
B	It may activate one enzyme but deactivate another
C	It always deactivates every regulated enzyme
D	It cannot be reversed once it occurs

20. ★ Which compound is specifically identified as a high-energy thioester with a central role in metabolism?

A	Phosphocreatine
B	Glucose 6-phosphate
C	Adenosine monophosphate
D	Acetyl CoA

21. ★ Which example best illustrates metabolic compartmentation?

A	Fatty acid synthesis in cytosol and breakdown in mitochondria
B	Both fatty acid pathways occurring only in cytosol
C	Both fatty acid pathways occurring only in nucleus
D	Protein synthesis and DNA replication in one compartment

22. ★ Which factor contributes to the large free energy released by ATP hydrolysis?

A	Greater electrostatic repulsion after hydrolysis
B	Poorer solvation of ADP and phosphate
C	Greater resonance stabilization of hydrolysis products
D	Loss of all resonance in the products

23. ★ A phosphorylated compound with transfer potential lower than ATP is best described as:

A	an excellent ATP-forming phosphoryl donor
B	a relatively poor phosphoryl-group donor
C	a compound that always hydrolyzes irreversibly
D	a molecule with higher energy than PEP

24. ★ Which pair is specifically identified as having higher phosphoryl-group transfer potential than ATP?

A	Glucose and fructose
B	ADP and AMP
C	Citrate and pyruvate
D	PEP and 1,3-bisphosphoglycerate

25. ★ Which statement about phosphocreatine in resting muscle is correct?

A	Its concentration is about fivefold higher than ATP
B	Its concentration is about equal to ATP
C	Its concentration is about half that of ATP
D	It is absent until ATP levels fall

Part B — True / False

- ★ **DR. WAEL SPECIAL** At chemical equilibrium, the concentrations of reactants and products must be equal. [T / F]
- ★ Feed-forward activation uses an early pathway metabolite to activate an enzyme further downstream. [T / F]
- ★ Protein phosphatases add phosphoryl groups to regulated enzymes. [T / F]

4. ★ Fatty acid synthesis and fatty acid breakdown can be separated into cytosol and mitochondria, respectively. [T / F]
5. In vitro reaction conditions are always identical to the conditions inside an intact cell. [T / F]

Part C — Written Questions

1. ★ DR. WAEL SPECIAL — Reaction rate and equilibrium

For $A + B \rightleftharpoons C + D$: (a) write the forward-rate expression; (b) define K_{eq} using concentrations; (c) state the relationship between K_{eq} and k_1/k_{-1} ; (d) explain what $K_{eq} = 10^3$ predicts about the equilibrium mixture.

2. Catabolic, anabolic, and amphibolic reactions

Differentiate the three classes and give the functional role of each in metabolism.

3. Forms of metabolic pathways

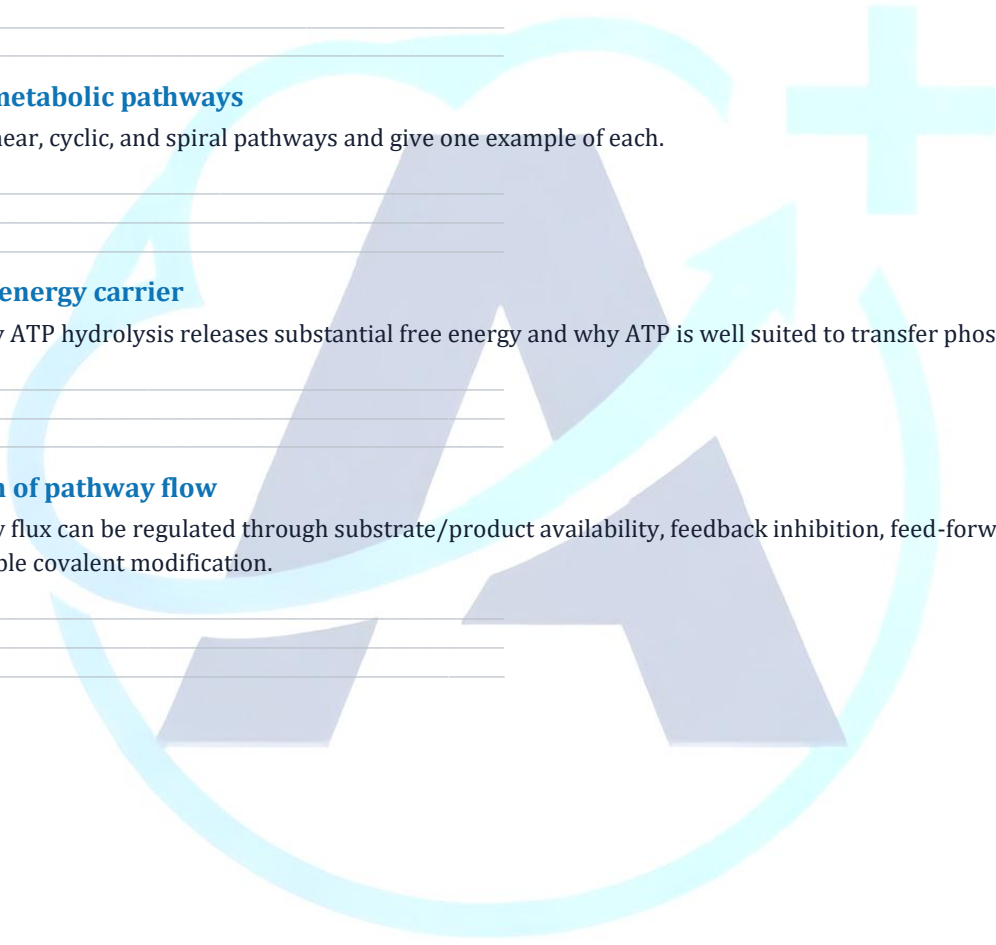
Compare linear, cyclic, and spiral pathways and give one example of each.

4. ATP as an energy carrier

Explain why ATP hydrolysis releases substantial free energy and why ATP is well suited to transfer phosphoryl groups.

5. Regulation of pathway flow

Explain how flux can be regulated through substrate/product availability, feedback inhibition, feed-forward activation, and reversible covalent modification.



Answers — Introduction to Metabolism

MCQ Answer Grid

01 C	02 A	03 D	04 B	05 C
06 A	07 D	08 B	09 A	10 C
11 D	12 B	13 C	14 A	15 D
16 B	17 C	18 A	19 B	20 D
21 A	22 C	23 B	24 D	25 A

★ High-Yield MCQ Notes

- ★ Q1: C — Cell biochemistry and metabolic routes are broadly similar | Source: p. 2
- ★ Q3: D — Bioenergetics is part of thermodynamics | Source: p. 4
- ★ Q4: B — It remains unchanged | Source: p. 5
- ★ Q5: C — [C], [D], and the reverse rate constant | Source: p. 5
- ★ Q6: A — $K_{eq} = [C][D]/[A][B]$ | Source: p. 6
- ★ Q7: D — 3 | Source: p. 6
- ★ Q8: B — Products predominate at equilibrium | Source: p. 6
- ★ Q9: A — Catabolism degrades; anabolism synthesizes | Source: p. 7
- ★ Q10: C — participates in both catabolic and anabolic processes | Source: p. 7
- ★ Q12: B — Cyclic — citric acid cycle | Source: p. 10
- ★ Q13: C — To provide smaller usable amounts of energy | Source: p. 11
- ★ Q14: A — the flow of material through a metabolic pathway | Source: p. 12
- ★ Q15: D — Substrate supply, product removal, and enzyme activity | Source: p. 12
- ★ Q16: B — an early step, usually the first committed step | Source: p. 13
- ★ Q17: C — an early metabolite activates a later pathway enzyme | Source: p. 13
- ★ Q18: A — Protein kinases | Source: p. 14
- ★ Q19: B — It may activate one enzyme but deactivate another | Source: p. 14
- ★ Q20: D — Acetyl CoA | Source: p. 21
- ★ Q21: A — Fatty acid synthesis in cytosol and breakdown in mitochondria | Source: p. 16
- ★ Q22: C — Greater resonance stabilization of hydrolysis products | Source: p. 17
- ★ Q23: B — a relatively poor phosphoryl-group donor | Source: p. 18
- ★ Q24: D — PEP and 1,3-bisphosphoglycerate | Source: p. 19
- ★ Q25: A — Its concentration is about fivefold higher than ATP | Source: p. 20

True / False Answers

Ans	Correction / confirmation	Source
F	Equilibrium means forward and reverse rates are balanced; concentrations need not be equal.	p. 6
T	This is the chapter definition of feed-forward activation.	p. 13
F	Protein phosphatases remove phosphoryl groups; protein kinases add them.	p. 14

Ans	Correction / confirmation	Source
T	The chapter uses this as an example of compartmentation.	p. 16
F	The chapter emphasizes that in vitro and in vivo conditions are often very different.	p. 22

Written Model Answers

1. ★ DR. WAEL SPECIAL — Reaction rate and equilibrium

- Forward rate = $k[A][B]$.
- $K_{eq} = [C][D]/[A][B]$.
- $K_{eq} = k_1/k_{-1}$.
- $K_{eq} = 10^3$ favors products, so C and D are much higher than A and B at equilibrium.

Source focus: p. 5

2. Catabolic, anabolic, and amphibolic reactions

- Catabolic reactions degrade molecules and release/provide energy.
- Anabolic reactions synthesize molecules for maintenance, growth, and reproduction.
- Amphibolic reactions participate in both catabolic and anabolic pathways.

Source focus: p. 7

3. Forms of metabolic pathways

- Linear: each product becomes the next substrate; serine biosynthesis.
- Cyclic: a closed loop regenerates intermediates; citric acid cycle.
- Spiral: repeated enzyme set progressively extends a structure; fatty acid biosynthesis.

Source focus: p. 10

4. ATP as an energy carrier

- Hydrolysis reduces electrostatic repulsion.
- Products are better solvated than ATP.
- Hydrolysis products have greater resonance stabilization.
- ATP has intermediate phosphoryl-group transfer potential, allowing it to accept from higher-energy donors and donate to lower-energy acceptors.

Source focus: p. 17

5. Regulation of pathway flow

- Flux depends on substrate supply, product removal, and pathway enzyme activities.
- Feedback inhibition lets an end product inhibit an early/committed step.
- Feed-forward activation lets an early metabolite stimulate a later enzyme.
- Kinases and phosphatases rapidly and reversibly change enzyme phosphorylation; cascades can amplify signals.

Source focus: p. 12

Glycolysis

Exam profile 60 MCQ • 15 True/False • 5 MCQ Case Studies • 5 Written. Focus: ten steps, ATP/NADH accounting, carbon flow, pyruvate fate, transporters, and regulation.

Part A — Multiple Choice Questions

1. ★ Glycolysis is best defined as:

A	ten enzyme-catalyzed reactions converting glucose to pyruvate
B	eight reactions converting pyruvate to glucose
C	ten reactions converting acetyl-CoA to glucose
D	six reactions converting glucose directly to CO ₂

2. ★ Where are the glycolytic enzymes located?

A	In the mitochondrial matrix
B	In the nucleus
C	In the cytosol
D	In the lysosomal lumen

3. Why can't muscle cells produce ethanol from pyruvate?

A	Lack lactate dehydrogenase
B	Lack pyruvate dehydrogenase
C	Lack pyruvate decarboxylase
D	Lack hexokinase

4. ★ What is the net yield of glycolysis per glucose?

A	4 ATP and 0 NADH
B	2 ATP and 4 NADH
C	0 ATP and 2 NADH
D	2 ATP and 2 NADH

5. ★ Which energy pattern correctly describes the two stages of glycolysis?

A	Hexose +2 ATP; triose -4 ATP
B	Hexose -4 ATP; triose +2 ATP
C	Hexose -2 ATP; triose +4 ATP
D	Hexose +4 ATP; triose -2 ATP

6. ★ Which set lists the four kinases of glycolysis?

A	Hexokinase, aldolase, enolase, GAPDH
B	PGI, PFK-1, TPI, pyruvate kinase
C	Hexokinase, PFK-1, PGK, pyruvate kinase
D	Hexokinase, PGI, mutase, enolase

7. ★ In step 1, hexokinase transfers the γ -phosphoryl group of ATP to:

A	the C-1 oxygen of glucose
B	the C-6 oxygen of glucose
C	the C-2 oxygen of glucose
D	the C-3 oxygen of glucose

8. ★ Why does phosphorylation help trap glucose inside the cell?

A	G6P becomes nonpolar and diffuses slowly
B	G6P binds irreversibly to the plasma membrane
C	G6P is immediately transported into the nucleus
D	G6P is charged and cannot exit through glucose transporters

9. Which statement reflects the broad substrate specificity of hexokinase?

A	It phosphorylates glucose but not mannose or fructose
B	It phosphorylates fructose but not glucose or mannose
C	It can phosphorylate glucose, mannose, and fructose
D	It phosphorylates mannose but not glucose or fructose

10. ★ Compared with hexokinases I-III, glucokinase has:

A	a higher K_m for glucose
B	a lower K_m for glucose
C	the same K_m at all glucose levels
D	no measurable interaction with glucose

11. ★ Which feature is characteristic of glucokinase?

A	It is strongly inhibited by G6P
B	It is active at higher glucose levels
C	It is most active at very low glucose
D	It is absent from the liver

12. Which option correctly identifies the FALSE statement(s)? I. The largest free-energy changes occur in reactions 1, 3, and 10. II. Hexokinase, phosphofructokinase-1, and pyruvate kinase are regulated.

A	Neither I nor II
B	I only
C	II only
D	Both I and II

13. ★ Step 2 converts G6P to F6P by:

A	glucose 6-phosphate isomerase
B	phosphofructokinase-1
C	phosphoglycerate kinase
D	triose phosphate isomerase

14. What chemical change occurs in step 2?

A	A ketose is converted to an aldose
B	An aldehyde is reduced to an alcohol
C	An aldose is converted to a ketose
D	A phosphate group is removed from glucose

15. ★ Which statement about PFK-1 is correct?

A	It catalyzes the first ATP-producing step
B	It converts DHAP directly to pyruvate
C	It is a near-equilibrium control-free step
D	It catalyzes the first committed step

16. ★ PFK-2 synthesizes:

A	fructose 2,6-bisphosphate
B	fructose 1,6-bisphosphate

C	glucose 6-phosphate
D	1,3-bisphosphoglycerate

17. ★ Aldolase cleaves fructose 1,6-bisphosphate into:

A	G6P and F6P
B	3PG and 2PG
C	GAP and DHAP
D	PEP and pyruvate

18. Which aldolase class is found in plants and animals?

A	Class I
B	Class II
C	Class III
D	Class IV

19. Hexokinase IV (glucokinase) differs from other hexokinases because:

A	It is absent from liver
B	It is active at very low glucose
C	It is inhibited by fructose-6-phosphate
D	It is active at high glucose

20. ★ Which carbon assignment is correct immediately after aldolase cleavage?

A	DHAP comes from C4–C6 and GAP from C1–C3
B	DHAP comes from C1–C3 and GAP from C4–C6
C	Both trioses come only from C1–C3
D	Both trioses come only from C4–C6

21. ★ What is the main role of triose phosphate isomerase in step 5?

A	Convert GAP into pyruvate
B	Convert F6P into F1,6BP
C	Convert 2PG into PEP
D	Convert DHAP into GAP

22. ★ Why do steps 6–10 occur twice per molecule of glucose?

A	Two GAP molecules enter the payoff sequence
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A+ ACADEMY

B	Two glucose molecules enter each pathway turn
C	Each enzyme has two catalytic sites
D	ATP must be produced in pairs only

23. The inhibition of hexokinase by glucose-6-phosphate (G6P) is:

A	a near-equilibrium step
B	feedback inhibition
C	NADH production
D	feed-forward activation

24. ★ Which change occurs in the GAPDH reaction?

A	NAD ⁺ is reduced to NADH
B	NADH is oxidized to NAD ⁺
C	ATP is reduced to ADP
D	FAD is reduced to FADH ₂

25. ★ The product formed directly by GAPDH is:

A	3-phosphoglycerate
B	2-phosphoglycerate
C	phosphoenolpyruvate
D	1,3-bisphosphoglycerate

26. ★ Which enzyme catalyzes the first ATP-generating step of glycolysis?

A	Hexokinase
B	Phosphofructokinase-1
C	Pyruvate kinase
D	Phosphoglycerate kinase

27. ★ In step 7, ATP is formed when a phosphoryl group is transferred from:

A	3-phosphoglycerate to ATP
B	2-phosphoglycerate to AMP
C	1,3-bisphosphoglycerate to ADP
D	pyruvate to ADP

28. ★ Steps 6 and 7 together illustrate:

A	oxidative phosphorylation in mitochondria
B	direct glucose transport by insulin
C	substrate-level phosphorylation coupled to oxidation
D	ATP hydrolysis without redox change

29. Phosphoglycerate mutase converts:

A	2PG to 3PG using ATP
B	PEP to 2PG using NADH
C	3PG to 2PG without ATP input
D	GAP to 1,3BPG using ATP

30. ★ Enolase catalyzes which transformation?

A	PEP to pyruvate by hydration
B	3PG to 2PG by oxidation
C	GAP to 1,3BPG by reduction
D	2PG to PEP by dehydration

31. ★ How many magnesium ions participate in the enolase mechanism described?

A	One
B	Three
C	Four
D	Two

32. ★ Why does PEP have very high phosphoryl-group transfer potential?

A	It contains no phosphate group
B	It is fully reduced and uncharged
C	It binds ATP more tightly than ADP
D	It exists in an unstable enol form

33. Why is ATP considered an ideal energy-currency molecule?

A	Highest transfer potential
B	Maximum cellular stability
C	Lowest transfer potential
D	Intermediate transfer potential

34. ★ Which statement about pyruvate kinase is correct?

A	It catalyzes a reversible isomerization step
B	It catalyzes an irreversible substrate-level phosphorylation
C	It consumes ATP during the hexose stage
D	It produces NADH from NAD ⁺

35. ★ What is the ATP ledger at steps 1, 3, 7, and 10 per glucose?

A	+1, +1, -2, -2 ATP
B	-1, -1, +2, +2 ATP
C	-2, 0, +1, +1 ATP
D	0, -2, +2, 0 ATP

36. Which statement about feeder pathways is correct?

A	Only glucose can ever enter glycolysis
B	Glycerol cannot feed into glycolysis
C	Carbohydrates can enter glycolysis through feeder routes
D	Muscle never uses hexokinase for entry

37. Conversion of dihydroxyacetone phosphate (DHAP) to glyceraldehyde 3-phosphate (GAP) is catalyzed by:

A	a kinase
B	an aldolase
C	an isomerase
D	a mutase

38. ★ Under aerobic conditions, glycolytic NADH can be oxidized by:

A	aldolase in the cytosol
B	the membrane-associated electron transport system
C	triose phosphate isomerase
D	hexokinase at the membrane

39. ★ Why is NAD^+ regeneration essential under anaerobic conditions?

A	GAPDH requires NAD^+ for continued glycolysis
B	Hexokinase requires NAD^+ to bind glucose
C	PFK-1 requires NAD^+ to bind ATP
D	Enolase requires NAD^+ to remove water

40. ★ Fermentation differs from respiration because glycolytic electrons are transferred to:

A	an organic molecule rather than ultimately to oxygen
B	oxygen rather than an organic molecule
C	ATP rather than any redox acceptor
D	water rather than an electron acceptor

41. The reaction catalyzed by pyruvate kinase:

A	is inhibited by ATP
B	is inhibited by F1,6BP
C	produces NADH
D	is reversible

42. ★ In anaerobic glycolysis, formation of lactate or ethanol allows cells to:

A	generate additional net NADH
B	regenerate NAD^+ from NADH
C	avoid producing any ATP
D	convert ATP directly to glucose

43. ★ Muscle lactate dehydrogenase catalyzes:

A	an irreversible conversion of lactate to ethanol
B	a reversible conversion between pyruvate and lactate
C	a reversible conversion of glucose to pyruvate
D	an irreversible conversion of acetyl-CoA to lactate

44. During lactate recycling, skeletal-muscle lactate is transported to the:

A	kidney cortex only
B	brain ventricles
C	liver
D	small intestine

45. ★ Lactic acidosis is associated with:

A	increased lactic acid and decreased blood pH
B	decreased lactic acid and increased blood pH
C	increased ATP and increased blood pH
D	decreased pyruvate and unchanged blood pH

46. ★ How much ATP is generated per glucose when the final anaerobic product is lactate?

A	0 ATP
B	4 ATP
C	6 ATP
D	2 ATP

47. ★ Which glycolytic steps have large actual ΔG values and are metabolically irreversible?

A	Steps 2, 4, and 8
B	Steps 1, 3, and 10
C	Steps 5, 6, and 7
D	Steps 7, 8, and 9

48. ★ When cellular ATP is needed, which molecules help relieve ATP inhibition of PFK-1?

A	AMP and fructose 2,6-bisphosphate
B	ATP and citrate
C	G6P and citrate
D	PEP and pyruvate

49. Which factor does NOT contribute to energy release during ATP hydrolysis?

A	Solvation effects
B	Proton gradient
C	Resonance stabilization
D	Electrostatic repulsion

50. ★ Which pair inhibits PFK-1 when energy is abundant?

A	AMP and F2,6BP
B	ATP and citrate
C	ADP and AMP
D	GAP and DHAP

51. ★ SGLT1 is described as a transporter that:

A	uses insulin-dependent transport in adipocytes
B	uses Na ⁺ -dependent cotransport in intestine and kidney
C	moves fructose in the small intestine
D	moves glucose bidirectionally in the liver

52. ★ Which transporters provide basal glucose transport in most tissues without insulin?

A	GLUT2 and GLUT4
B	SGLT1 and GLUT5
C	GLUT4 and GLUT5
D	GLUT1 and GLUT3

53. What is the net production of ATP and NADH during glycolysis?

A	2 ATP and 4 NADH
B	4 ATP and 2 NADH
C	4 ATP and 4 NADH
D	2 ATP and 2 NADH

54. ★ Which transporter moves glucose into and out of the liver?

A	GLUT1
B	GLUT4
C	GLUT5
D	GLUT2

55. ★ Insulin stimulates high rates of glucose uptake mainly through:

A	GLUT4 in striated muscle and adipose tissue
B	GLUT2 in liver and kidney
C	GLUT5 in small intestine
D	SGLT1 in brain and liver

56. Which transporter is associated with fructose transport in the small intestine?

A	GLUT5
B	GLUT1
C	GLUT2
D	GLUT4

57. ★ Which hexokinase forms are allosterically inhibited by physiological G6P?

A	Glucokinase only
B	Hexokinases I, II, and III
C	All four hexokinase forms
D	PFK-1 and pyruvate kinase

58. ★ Which statement correctly describes ATP regulation of PFK-1?

A	ATP is only an activator of PFK-1
B	ATP is only a product of PFK-1
C	ATP is both a substrate and an allosteric inhibitor
D	ATP has no regulatory role at PFK-1

59. In glycolysis, how are glucose carbons split between GAP and DHAP?

A	Both derive from C4-C6
B	GAP C1-C3; DHAP C4-C6
C	GAP C4-C6; DHAP C1-C3
D	Both derive from C1-C3

60. ★ Which regulation of pyruvate kinase is an example of feed-forward activation?

A	ATP activates pyruvate kinase
B	F1,6BP activates pyruvate kinase
C	Glucagon directly activates pyruvate kinase
D	G6P inhibits pyruvate kinase

Part B — True / False

1. ★ All glycolytic enzymes are located in the cytosol. [T / F]
2. ★ The hexokinase reaction in step 1 is reversible under cellular conditions. [T / F]
3. ★ All four glycolytic kinases shown require Mg^{2+} and use a similar mechanism. [T / F]
4. ★ Glucokinase has a lower K_m for glucose than hexokinases I–III. [T / F]
5. The G6P-to-F6P isomerization is near-equilibrium in cells. [T / F]
6. ★ PFK-1 catalyzes the first committed step of glycolysis. [T / F]
7. ★ Aldolase cleavage is a major irreversible control point of glycolysis. [T / F]
8. ★ Triose phosphate isomerase converts DHAP to GAP and forms only the D-isomer of GAP. [T / F]
9. ★ GAPDH oxidizes NADH to NAD^+ during step 6. [T / F]
10. ★ Phosphoglycerate kinase catalyzes the first ATP-generating step of glycolysis. [T / F]
11. Phosphoglycerate mutase requires direct ATP input to convert 3PG to 2PG. [T / F]
12. ★ Enolase removes water from 2PG to produce PEP. [T / F]
13. ★ Anaerobic conversion to lactate or ethanol helps regenerate NAD^+ needed for glycolysis. [T / F]
14. ★ GLUT2 is the insulin-responsive transporter that drives glucose uptake in skeletal muscle. [T / F]
15. ★ Fructose 1,6-bisphosphate activates pyruvate kinase in a feed-forward mechanism. [T / F]

Part C — MCQ Case Studies

1. ★ A patient has just eaten a carbohydrate-rich meal. Hepatocytes are exposed to a large rise in blood glucose. Which enzyme feature best supports rapid hepatic phosphorylation of glucose under these conditions?

A	Glucokinase becomes active at higher glucose concentrations
B	Hexokinase I is activated by accumulated G6P
C	PFK-1 becomes insensitive to ATP inhibition
D	GLUT5 becomes the main hepatic glucose transporter

2. ★ After insulin release, a skeletal muscle cell markedly increases glucose uptake. Which transporter most directly accounts for this response?

A	GLUT2
B	GLUT4
C	GLUT5
D	SGLT1

3. ★ A cell has abundant ATP and citrate. Which immediate regulatory response is most likely?

A	PFK-1 activity increases
B	GAPDH consumes more NAD ⁺
C	PFK-1 activity decreases
D	Pyruvate kinase loses ATP inhibition

4. ★ During intense exercise with limited oxygen availability, muscle must keep glycolysis running. Which reaction is most important for restoring the cofactor required by GAPDH?

A	Lactate is oxidized to pyruvate, consuming NAD ⁺
B	PEP is hydrated to 2PG, generating NADH
C	Pyruvate is reduced to lactate, regenerating NAD ⁺
D	G6P is converted to F6P, generating NAD ⁺

5. ★ A pathway signal causes fructose 1,6-bisphosphate to rise. Which downstream change represents feed-forward activation?

A	Hexokinase is inhibited
B	PFK-1 is inhibited
C	GLUT4 is removed from the membrane
D	Pyruvate kinase is activated

Part D — Written Questions

1. The ten steps of glycolysis

Write the ten glycolytic steps in order, naming the enzyme and the major energy/redox event at each step.

2. Hexokinase versus glucokinase

Compare hexokinases I–III with glucokinase in K_m , operating glucose range, G6P inhibition, and tissue role.

3. PFK-1 as the major committed control step

Explain the PFK-1 reaction and describe its regulation by ATP, citrate, AMP, and fructose 2,6-bisphosphate.

4. Fate of pyruvate and NAD^+ regeneration

Compare aerobic and anaerobic handling of glycolytic reducing equivalents, including ethanol/lactate formation and lactate recycling.

5. Integrated regulation of glycolysis

Summarize the major irreversible checkpoints and explain how glucose transport, hexokinase, PFK-1, and pyruvate kinase are regulated.



Answers — Glycolysis

MCQ Answer Grid

01 A	02 C	03 C	04 D	05 C
06 C	07 B	08 D	09 C	10 A
11 B	12 A	13 A	14 C	15 D
16 A	17 C	18 A	19 D	20 B
21 D	22 A	23 B	24 A	25 D
26 D	27 C	28 C	29 C	30 D
31 D	32 D	33 D	34 B	35 B
36 C	37 C	38 B	39 A	40 A
41 A	42 B	43 B	44 C	45 A
46 D	47 B	48 A	49 B	50 B
51 B	52 D	53 D	54 D	55 A
56 A	57 B	58 C	59 C	60 B

★ High-Yield MCQ Notes

★ Q1: A — ten enzyme-catalyzed reactions converting glucose to pyruvate | Source: p. 4

★ Q2: C — In the cytosol | Source: p. 4

★ Q4: D — 2 ATP and 2 NADH | Source: p. 4

★ Q5: C — Hexose -2 ATP; triose +4 ATP | Source: p. 4

★ Q6: C — Hexokinase, PFK-1, PGK, pyruvate kinase | Source: p. 7

★ Q7: B — the C-6 oxygen of glucose | Source: p. 7

★ Q8: D — G6P is charged and cannot exit through glucose transporters | Source: p. 7

★ Q10: A — a higher K_m for glucose | Source: p. 8

★ Q11: B — It is active at higher glucose levels | Source: p. 8

★ Q13: A — glucose 6-phosphate isomerase | Source: p. 9

★ Q15: D — It catalyzes the first committed step | Source: p. 9

★ Q16: A — fructose 2,6-bisphosphate | Source: p. 9

★ Q17: C — GAP and DHAP | Source: p. 10

★ Q20: B — DHAP comes from C1–C3 and GAP from C4–C6 | Source: p. 10

★ Q21: D — Convert DHAP into GAP | Source: p. 10

★ Q22: A — Two GAP molecules enter the payoff sequence | Source: p. 6

★ Q24: A — NAD^+ is reduced to NADH | Source: p. 12

★ Q25: D — 1,3-bisphosphoglycerate | Source: p. 12

★ Q26: D — Phosphoglycerate kinase | Source: p. 13

★ Q27: C — 1,3-bisphosphoglycerate to ADP | Source: p. 13

A+ ACADEMY

- ★ Q28: C — substrate-level phosphorylation coupled to oxidation | Source: p. 13
- ★ Q30: D — 2PG to PEP by dehydration | Source: p. 14
- ★ Q31: D — Two | Source: p. 14
- ★ Q32: D — It exists in an unstable enol form | Source: p. 14
- ★ Q34: B — It catalyzes an irreversible substrate-level phosphorylation | Source: p. 15
- ★ Q35: B — -1, -1, +2, +2 ATP | Source: p. 15
- ★ Q38: B — the membrane-associated electron transport system | Source: p. 17
- ★ Q39: A — GAPDH requires NAD⁺ for continued glycolysis | Source: p. 17
- ★ Q40: A — an organic molecule rather than ultimately to oxygen | Source: p. 18
- ★ Q42: B — regenerate NAD⁺ from NADH | Source: p. 18
- ★ Q43: B — a reversible conversion between pyruvate and lactate | Source: p. 18
- ★ Q45: A — increased lactic acid and decreased blood pH | Source: p. 18
- ★ Q46: D — 2 ATP | Source: p. 19
- ★ Q47: B — Steps 1, 3, and 10 | Source: p. 19
- ★ Q48: A — AMP and fructose 2,6-bisphosphate | Source: p. 20
- ★ Q50: B — ATP and citrate | Source: p. 22
- ★ Q51: B — uses Na⁺-dependent cotransport in intestine and kidney | Source: p. 20
- ★ Q52: D — GLUT1 and GLUT3 | Source: p. 20
- ★ Q54: D — GLUT2 | Source: p. 20
- ★ Q55: A — GLUT4 in striated muscle and adipose tissue | Source: p. 20
- ★ Q57: B — Hexokinases I, II, and III | Source: p. 21
- ★ Q58: C — ATP is both a substrate and an allosteric inhibitor | Source: p. 22
- ★ Q60: B — F1,6BP activates pyruvate kinase | Source: p. 22

Case Study Answer Grid

01 A	02 B	03 C	04 C	05 D
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★ Case Study Notes

- ★ Q1: A — Glucokinase becomes active at higher glucose concentrations | Source: p. 8
- ★ Q2: B — GLUT4 | Source: p. 20
- ★ Q3: C — PFK-1 activity decreases | Source: p. 22
- ★ Q4: C — Pyruvate is reduced to lactate, regenerating NAD⁺ | Source: p. 18
- ★ Q5: D — Pyruvate kinase is activated | Source: p. 22

True / False Answers

Ans	Correction / confirmation	Source
T	The chapter places the glycolytic enzymes in the cytosol.	p. 4
F	Step 1 is labeled metabolically irreversible.	p. 7
T	The chapter explicitly states this for hexokinase, PFK-1, PGK, and pyruvate kinase.	p. 7
F	Glucokinase has the higher K_m ($\sim 10^{-2}$ M).	p. 8
T	Step 2 is described as near-equilibrium.	p. 9
T	Step 3 is irreversible and the first committed step.	p. 9
F	Aldolase is near-equilibrium and is not a control point.	p. 10
T	This is stated for step 5.	p. 10
F	GAPDH reduces NAD^+ to NADH while GAP is oxidized.	p. 12
T	Step 7 is the first ATP-generating step.	p. 13
F	The shift occurs without ATP energy input.	p. 14
T	Step 9 is a dehydration reaction.	p. 14
T	Regeneration of NAD^+ permits continued GAPDH activity.	p. 18
F	GLUT4 is insulin responsive in striated muscle and adipose tissue; GLUT2 is hepatic.	p. 20
T	The chapter identifies this as feed-forward activation.	p. 22

Written Model Answers

1. The ten steps of glycolysis

- 1 Hexokinase: glucose $\rightarrow$ G6P, ATP consumed, irreversible.
- 2 PGI: G6P $\rightarrow$ F6P, near-equilibrium.
- 3 PFK-1: F6P $\rightarrow$ F1,6BP, ATP consumed, irreversible/committed.
- 4 Aldolase: F1,6BP $\rightarrow$ DHAP + GAP.
- 5 TPI: DHAP $\rightarrow$ GAP.
- 6 GAPDH: GAP $\rightarrow$ 1,3BPG, $NAD^+ \rightarrow$ NADH.
- 7 PGK: 1,3BPG $\rightarrow$ 3PG, ATP formed.
- 8 Phosphoglycerate mutase: 3PG $\rightarrow$ 2PG.
- 9 Enolase: 2PG $\rightarrow$ PEP + H_2O removed.
- 10 Pyruvate kinase: PEP $\rightarrow$ pyruvate, ATP formed, irreversible.

Source focus: p. 6

2. Hexokinase versus glucokinase

- Hexokinases I–III: low K_m , active at normal glucose, inhibited by G6P, distributed in multiple tissues.
- Glucokinase: higher K_m , active at higher glucose, not inhibited by G6P, prominent in liver and supports handling of glucose loads.

Source focus: p. 8

3. PFK-1 as the major committed control step

- PFK-1 transfers phosphate from ATP to F6P to form F1,6BP.
- The step is metabolically irreversible and the first committed step.
- ATP and citrate inhibit PFK-1.
- AMP and F2,6BP relieve ATP inhibition/activate glycolytic flux when ATP is needed.

Source focus: p. 9

4. Fate of pyruvate and NAD⁺ regeneration

- Aerobic: NADH can be oxidized through the membrane-associated electron transport system, which requires O₂.
- Anaerobic: lactate or ethanol formation consumes NADH and regenerates NAD⁺ for GAPDH.
- Muscle LDH interconverts pyruvate and lactate.
- Lactate can travel from skeletal muscle to the liver, where it is reconverted to pyruvate.

Source focus: p. 17

5. Integrated regulation of glycolysis

- Large- ΔG irreversible steps: 1, 3, and 10.
- Glucose transport: GLUT4 responds to insulin in striated muscle/adipose; GLUT2 is hepatic; GLUT1/3 support basal uptake.
- Hexokinases I–III are inhibited by G6P; glucokinase is not.
- PFK-1 is inhibited by ATP/citrate and activated by AMP/F2,6BP.
- Pyruvate kinase is activated by F1,6BP and inhibited by ATP; glucagon/PKA phosphorylation decreases liver/intestinal PK activity.

Source focus: p. 19





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