LEC 12 Q CYTOLOGY:

1. Which of the following best describes autocrine signaling?

A. Cells respond to signaling molecules that they themselves produce
B. Signaling molecules are carried through the circulation to distant target cells
C. Signaling occurs through direct cell-to-cell contact
D. Signaling molecules act on neighboring cells via the extracellular matrix

2. Which type of signaling involves a molecule secreted by endocrine cells and transported through the blood to distant target cells?

A. Paracrine signaling
B. Autocrine signaling
C. Endocrine signaling
D. Direct interaction

3. Which of the following signaling molecules is a lipophilic hormone?

A. Insulin
B. Epinephrine
C. Cortisol
D. Serotonin

4. What is the primary function of Heat Shock Proteins (HSP) in steroid nuclear receptor activation?

A. To facilitate the binding of steroid hormones to the receptor
B. To keep the steroid receptor inactive in the cytosol
C. To transport the receptor to the nucleus
D. To degrade the steroid hormone once it binds

5. Which process occurs after the binding of a lipophilic hormone to its intracellular receptor?

A. The receptor dimerizes and translocates to the nucleus
B. The receptor undergoes endocytosis
C. The receptor is phosphorylated
D. The receptor activates a secondary messenger

6. Which of the following components is NOT part of the GPCR signaling pathway?

A. Ligand
B. Transducer
C. Effector molecules
D. Transcription factors

7. What is the role of GTP in the activation of heterotrimeric G proteins?

A. GTP binds to the β subunit to activate the G protein
B. GTP replaces GDP on the α subunit, activating the G protein
C. GTP acts as a secondary messenger
D. GTP inactivates the α subunit of the G protein

8. Which of the following describes the inactivation of G proteins?

A. Hydrolysis of GTP to GDP by the α subunit
B. Hydrolysis of GDP to GTP by the α subunit
C. Deactivation of the βγ complex
D. Binding of a secondary messenger

9. Which of the following is the primary function of protein kinase A (PKA) in the cAMP signaling pathway?

A. To synthesize cAMP
B. To phosphorylate target proteins and regulate cellular processes
C. To activate G proteins
D. To bind to and activate adenylyl cyclase

10. Which type of receptor is associated with intrinsic kinase activity, and becomes autophosphorylated upon ligand binding?

A. G-protein coupled receptors (GPCRs)
B. Ion channel receptors
C. Receptor Tyrosine Kinases (RTKs)
D. Cytokine receptors

11. What is the role of the βγ complex in GPCR signaling?

A. It activates adenylyl cyclase to produce cAMP
B. It dissociates from the G protein and activates effector molecules independently
C. It initiates the exchange of GDP for GTP on the α subunit
D. It translocates to the nucleus to regulate gene expression

12. What is the function of secondary messengers like cAMP, Ca^{2+}, and cGMP in signaling pathways?

A. To deactivate signaling molecules
B. To amplify and propagate the signal
C. To bind to receptors and activate primary pathways
D. To degrade signaling proteins after they have been used

13. Which of the following is a key feature of receptor tyrosine kinases (RTKs)?

A. They are intracellular receptors that do not require a ligand
B. They mediate signals by forming dimers and autophosphorylating
C. They use GTP to activate downstream effectors
D. They are primarily involved in the transport of hormones into the cell

14. In the JAK/STAT signaling pathway, what is the role of JAK kinases?

A. To bind to the receptor and phosphorylate STAT proteins
B. To dimerize and translocate to the nucleus
C. To phosphorylate the receptor, creating docking sites for STAT
D. To activate the transcription factors CREB and NF-kB

15. Which of the following best describes integrin signaling?

A. Integrins bind to ECM components and activate nonreceptor tyrosine kinases like FAK
B. Integrins initiate G protein signaling through cAMP
C. Integrins trigger the production of secondary messengers like cAMP
D. Integrins directly activate GPCRs in response to ligands

16. What is the primary function of secondary messengers in cellular signaling?

A. To directly bind to the receptor and initiate signal transduction
B. To amplify the signal and propagate it within the cell
C. To degrade the ligands once they bind to receptors
D. To produce more signaling molecules from precursor proteins

17. What is the purpose of phosphatases like Protein Phosphatase 1 in signaling pathways?

A. To reverse the activation of signaling pathways by dephosphorylating target proteins
B. To increase the concentration of secondary messengers
C. To activate kinases like PKA
D. To amplify the signal through phosphorylation

18. Which of the following is true about lipophilic hormones?

A. They require a receptor on the cell surface to activate signaling
B. They cannot diffuse through the cell membrane
C. They generally act intracellularly to regulate gene expression
D. They activate signaling through cAMP or other secondary messengers

Answers:

1. **A**
2. **C**
3. **C**
4. **B**
5. **A**
6. **D**
7. **B**
8. **A**
9. **B**
10. **C**

11. **B**
12. **B**
13. **B**
14. **C**
15. **A**
16. **B**
17. **A**
18. **C**

19. Which of the following signaling molecules is derived from amino acids?

A. Eicosanoids
B. Peptide hormones
C. Small molecule neurotransmitters
D. Steroids

20. Which of the following is a key characteristic of lipophilic hormones?

A. They require a carrier protein to enter the cell
B. They bind to surface receptors to initiate signaling
C. They are hydrophobic and can diffuse through the cell membrane
D. They are hydrophilic and require ion channels for transport

21. Which class of hormones includes estradiol, testosterone, and cortisol?

A. Peptide hormones
B. Eicosanoids
C. Small molecule neurotransmitters
D. Steroids

22. Which of the following statements is true about steroid nuclear receptors (NR)?

A. They are located in the plasma membrane
B. They remain bound to Heat Shock Proteins (HSP) in their active form
C. Upon hormone binding, they dissociate from Heat Shock Proteins and activate gene expression
D. They function as secondary messengers in the cytoplasm

23. What is the result of steroid receptor dimerization?

A. Activation of a protein kinase
B. Translocation to the nucleus for gene expression regulation
C. Initiation of G-protein signaling
D. Degradation of the receptor protein

24. What is the main role of secondary messengers like cAMP and Ca^{2+}?

A. To directly bind to surface receptors
B. To amplify the signal inside the cell

C. To degrade the ligand after it binds to the receptor
D. To activate protein synthesis directly

25. Which of the following is the primary action of cAMP in a signaling pathway?

A. To inhibit protein kinase A (PKA)
B. To activate PKA by binding to its regulatory subunits
C. To bind to DNA and regulate gene expression directly
D. To activate integrin signaling

26. What is the role of adenylyl cyclase in cAMP signaling?

A. To degrade cAMP after it is produced
B. To catalyze the conversion of ATP into cAMP
C. To phosphorylate PKA subunits
D. To transport cAMP to the nucleus

27. Which of the following is the function of GTP-bound α subunit in GPCR signaling?

A. To bind to the receptor and activate downstream effectors
B. To dissociate from the G protein and phosphorylate the receptor
C. To bind to and activate adenylyl cyclase
D. To inhibit the βγ complex

28. In GPCR signaling, how is the G protein inactivated?

A. By the hydrolysis of GTP to GDP by the α subunit
B. By the binding of cAMP to the α subunit
C. By dissociation of the βγ complex from the α subunit
D. By binding of GDP to the βγ complex

29. Which enzyme is responsible for the hydrolysis of cAMP, terminating the signal?

A. Protein phosphatase 1
B. Phosphodiesterase
C. Adenylyl cyclase
D. Protein kinase A (PKA)

30. Which of the following best describes the role of Regulator of G protein Signaling (RGS) proteins?

A. To facilitate the exchange of GDP for GTP on G proteins
B. To increase the duration of G protein signaling
C. To enhance the GTPase activity, promoting faster deactivation of G proteins
D. To activate G protein-coupled receptors directly

31. In receptor tyrosine kinase (RTK) signaling, what happens immediately after receptor dimerization?

A. The receptor is internalized into the cell
B. The receptor autophosphorylates on tyrosine residues
C. The G protein is activated
D. Secondary messengers like cAMP are produced

32. What is the main effect of receptor autophosphorylation in RTK signaling?

A. It creates docking sites for downstream signaling proteins
B. It inhibits the receptor's kinase activity
C. It induces receptor endocytosis
D. It activates secondary messengers like cAMP

33. Which of the following is true regarding the JAK/STAT pathway?

A. STAT proteins directly bind to the receptor without phosphorylation
B. JAK kinases cross-phosphorylate each other and the receptor
C. STAT proteins remain in the cytoplasm and do not affect gene expression
D. The JAK/STAT pathway is not involved in immune cell regulation

34. What is the role of focal adhesion kinase (FAK) in integrin signaling?

A. To bind integrins to the extracellular matrix
B. To activate secondary messengers like cAMP
C. To phosphorylate integrins and trigger downstream signaling
D. To mediate the endocytosis of integrin receptors

35. Which of the following is a characteristic feature of integrin signaling?

A. Integrins activate G protein signaling directly
B. Integrin activation leads to phosphorylation of FAK and Src
C. Integrins initiate secondary messenger pathways like cAMP
D. Integrins directly activate RTK signaling pathways

36. Which of the following best describes the crosstalk between different signaling pathways?

A. It refers to the direct activation of one pathway by another
B. It leads to the degradation of secondary messengers
C. It involves the competition of signaling pathways for the same receptors
D. It ensures that only one signaling pathway is active at a time

Answers:

19. **C**
20. **C**

21. **D**
22. **C**
23. **B**
24. **B**
25. **B**
26. **B**
27. **C**
28. **A**
29. **B**
30. **C**
31. **B**
32. **A**
33. **B**
34. **C**
35. **B**
36. **A**

37. Which of the following best describes the role of Heat Shock Proteins (HSPs) in steroid hormone signaling?

A. HSPs function as secondary messengers to amplify the signal
B. HSPs keep the steroid hormone receptor inactive in the cytoplasm by preventing dimerization
C. HSPs assist in the translocation of the receptor to the nucleus
D. HSPs are released to activate the G-protein pathway once the receptor binds the hormone

38. In the context of GPCR signaling, which of the following is true about the βγ complex?

A. The βγ complex activates adenylyl cyclase to produce cAMP
B. The βγ complex dissociates from the α subunit to activate secondary messengers
C. The βγ complex directly phosphorylates target proteins, bypassing the need for a kinase
D. The βγ complex primarily functions by directly binding to ion channels or other downstream effectors

39. Which of the following is an example of "crosstalk" between different signaling pathways?

A. The activation of protein kinase A (PKA) by cAMP, leading to gene expression
B. Integration of the MAPK pathway and PI3K/Akt pathway through common signaling molecules like Ras
C. The hydrolysis of GTP by G proteins to inactivate downstream signaling
D. Activation of G-protein coupled receptors (GPCRs) by neurotransmitters leading to ion channel opening

40. Which of the following steps in steroid receptor signaling is responsible for the receptor's translocation to the nucleus?

A. Hormone binding and receptor dimerization
B. The release of Heat Shock Proteins (HSPs)
C. Phosphorylation of the receptor complex
D. The dimerized receptor binding to the DNA in the cytoplasm

41. In receptor tyrosine kinase (RTK) signaling, what is the consequence of receptor dimerization and autophosphorylation?

A. It activates the G-protein signaling pathway
B. It creates docking sites for downstream signaling proteins that facilitate further signal amplification
C. It leads to the production of secondary messengers like cAMP and IP3
D. It results in the internalization of the receptor into vesicles

42. Which of the following is the primary role of Ras in cell signaling?

A. To initiate the phosphorylation cascade within the MAPK pathway
B. To transport secondary messengers like cAMP into the nucleus
C. To activate the GTPase activity of the α subunit in GPCR signaling
D. To bind to adenylyl cyclase and inhibit the production of cAMP

43. How do GTPase-activating proteins (GAPs) influence the duration of G protein signaling?

A. They promote the binding of GDP to the α subunit, leading to faster activation of the G protein
B. They inhibit the dissociation of the βγ complex from the α subunit, prolonging the signal
C. They accelerate the hydrolysis of GTP to GDP, leading to faster deactivation of the G protein
D. They increase the affinity of the α subunit for GTP, prolonging activation

44. In the MAPK signaling pathway, which of the following best describes the function of MAPK?

A. MAPK activates Ras by binding to its GTP-bound form
B. MAPK phosphorylates transcription factors to regulate gene expression
C. MAPK directly deactivates G proteins by hydrolyzing GTP
D. MAPK is a secondary messenger that activates adenylyl cyclase to produce cAMP

45. Which of the following molecules acts as a primary effector in the activation of PKA by cAMP?

A. Protein phosphatase 1
B. Adenylyl cyclase
C. The regulatory subunit of PKA
D. The catalytic subunit of PKA

46. How does receptor autophosphorylation influence the activation of downstream signaling molecules in receptor tyrosine kinase (RTK) pathways?

A. It facilitates the binding of GTP to Ras, promoting its activation
B. It recruits and activates adapter proteins that transmit the signal to the nucleus
C. It phosphorylates and activates secondary messengers like cAMP
D. It inhibits the binding of downstream proteins by preventing docking

47. Which of the following is a critical step in the inactivation of a G protein-coupled signaling pathway?

A. Phosphorylation of the βγ complex
B. The exchange of GDP for GTP on the α subunit
C. Hydrolysis of GTP to GDP by the α subunit, inactivating it
D. Receptor dimerization and internalization

48. Which of the following is a direct consequence of the binding of STAT proteins to a receptor in the JAK/STAT pathway?

A. The receptor undergoes autophosphorylation
B. STAT proteins dimerize and translocate to the nucleus
C. JAK proteins phosphorylate the receptor
D. Secondary messengers like cAMP are produced

49. In integrin signaling, how does focal adhesion kinase (FAK) contribute to downstream signal transduction?

A. It dephosphorylates integrins to terminate the signal
B. It acts as a secondary messenger to activate MAPK
C. It undergoes autophosphorylation, creating docking sites for downstream signaling molecules
D. It binds to the ECM and directly activates protein kinase A

50. Which of the following is the primary function of integrins in cell signaling?

A. To activate receptor tyrosine kinases directly
B. To mediate the binding between cells and the extracellular matrix (ECM)
C. To promote the production of secondary messengers like IP3
D. To facilitate the exchange of GDP for GTP on G proteins

Answers:

37. **B**
38. **D**
39. **B**
40. **A**
41. **B**
42. **A**
43. **C**
44. **B**

45. **D**
46. **B**
47. **C**
48. **B**
49. **C**
50. **B**

51. Which of the following is most likely the direct effect of steroid hormone receptor dimerization in the nucleus?

A. Activation of phospholipase C to increase intracellular calcium levels
B. Recruitment of coactivators to the promoter region of target genes
C. Activation of G protein-coupled receptor pathways
D. Dissociation of Heat Shock Proteins (HSPs) from the receptor

52. In the process of GPCR signaling, what happens after the α subunit of the G protein binds GTP?

A. The α subunit dissociates from the βγ complex and activates downstream effectors such as adenylyl cyclase
B. The α subunit activates the phospholipase Cβ pathway, generating inositol triphosphate (IP3)
C. The βγ complex dissociates and interacts with ion channels, leading to changes in cell membrane potential
D. The receptor undergoes internalization, terminating the signal

53. Which of the following is a key characteristic of autocrine signaling?

A. The signaling molecule is produced by one cell and acts on a distant target cell
B. The signaling molecule is produced by a cell and acts on the same cell or cells of the same type
C. The signal transduction involves G protein-coupled receptor (GPCR) activation
D. The signaling molecule enters the bloodstream to affect cells at distant sites

54. Which of the following describes the function of protein kinase A (PKA) in the context of cAMP signaling?

A. PKA phosphorylates target enzymes to enhance their catalytic activity
B. PKA directly activates adenylyl cyclase to produce more cAMP
C. PKA binds to cAMP to produce IP3 and DAG
D. PKA is responsible for the hydrolysis of GTP in G proteins

55. Which of the following events occurs immediately after ligand binding to a receptor tyrosine kinase (RTK)?

A. Activation of secondary messengers like cAMP or IP3
B. Dimerization of the receptor and autophosphorylation of the cytoplasmic tyrosine residues

C. Inhibition of MAPK pathway activation
D. Activation of G proteins and downstream cAMP production

56. In receptor tyrosine kinase (RTK) signaling, how does the creation of docking sites upon autophosphorylation influence downstream signaling?

A. Docking sites recruit proteins that activate secondary messengers like cAMP
B. Docking sites facilitate the recruitment of signal transducers such as Ras, leading to further phosphorylation cascades
C. Docking sites activate G proteins that initiate MAPK signaling
D. Docking sites inhibit protein phosphorylation, preventing further signal amplification

57. Which of the following best describes the role of calcium ions (Ca^{2+}) as a secondary messenger in cell signaling?

A. Calcium ions bind to cAMP to amplify the signal in response to a receptor activation
B. Calcium ions modulate the activity of kinases and phosphatases, leading to signal amplification
C. Calcium ions act directly to activate protein kinases such as PKA and MAPK
D. Calcium ions regulate gene expression by directly binding to transcription factors in the nucleus

58. What is the primary function of G-protein-coupled receptor kinases (GRKs) in GPCR signaling?

A. To phosphorylate the receptor and initiate the dissociation of the G protein
B. To activate the α subunit of the G protein and trigger the production of secondary messengers
C. To phosphorylate the receptor to promote its internalization and desensitize the receptor
D. To bind to the βγ complex and inhibit its activity in the signaling pathway

59. Which of the following is the result of the activation of phospholipase C (PLC) by Gαq in GPCR signaling?

A. The production of cAMP from ATP
B. The hydrolysis of phosphoinositides to generate IP3 and DAG
C. The activation of MAPK cascades via Ras
D. The increase in calcium influx from extracellular sources

60. Which of the following is true about integrin signaling through focal adhesion kinase (FAK)?

A. FAK activation leads to phosphorylation of integrins, which blocks their interaction with the ECM
B. FAK activation is not involved in any signaling pathways but merely stabilizes the ECM-integrin bond
C. FAK undergoes autophosphorylation upon integrin clustering, providing docking

sites for downstream signaling proteins
D. FAK is exclusively activated by receptor tyrosine kinases and not integrins

61. In the JAK/STAT signaling pathway, what is the role of the STAT protein once phosphorylated?

A. STAT proteins dimerize and translocate to the nucleus, where they activate transcription of target genes
B. STAT proteins dephosphorylate JAKs to turn off the signaling pathway
C. STAT proteins activate MAPK cascades to induce rapid responses
D. STAT proteins bind to the receptor, preventing further JAK phosphorylation

62. Which of the following statements about eicosanoids is most accurate?

A. Eicosanoids such as prostaglandins are lipid-soluble hormones that can cross cell membranes to initiate intracellular signaling
B. Eicosanoids are synthesized from cholesterol and act by binding to intracellular steroid receptors
C. Eicosanoids are derived from arachidonic acid and act primarily through G protein-coupled receptors (GPCRs)
D. Eicosanoids act by directly regulating gene expression through nuclear hormone receptors

63. Which of the following steps in steroid hormone signaling is dependent on receptor dimerization?

A. The receptor translocates to the nucleus
B. The Heat Shock Proteins (HSPs) dissociate from the receptor
C. The hormone binds to the receptor
D. The receptor binds to DNA to regulate gene expression

64. What is the role of the βγ subunit in G-protein coupled receptor (GPCR) signaling?

A. The βγ subunit activates adenylyl cyclase to produce cAMP
B. The βγ subunit directly phosphorylates target proteins and activates second messengers
C. The βγ subunit dissociates from the α subunit and can activate other signaling pathways, including ion channels
D. The βγ subunit binds directly to the receptor to initiate the G-protein signaling cascade

65. In the context of GPCR signaling, how does GTP binding to the α subunit affect the G protein complex?

A. GTP binding causes the α subunit to dissociate from the βγ subunit, activating downstream effectors
B. GTP binding inactivates the α subunit, preventing further signaling
C. GTP binding prevents the dissociation of the βγ complex from the α subunit
D. GTP binding induces receptor internalization, terminating the signal

Answers:

51. **B**
52. **A**
53. **B**
54. **A**
55. **B**
56. **B**
57. **B**
58. **C**
59. **B**
60. **C**
61. **A**
62. **C**
63. **A**
64. **C**
65. **A**

66. Which of the following is most characteristic of lipophilic (hydrophobic) hormones, such as steroid hormones, in terms of their action on target cells?

A. They require membrane-bound receptors to initiate intracellular signaling.
B. They activate second messenger systems like cAMP and cGMP.
C. They diffuse across the cell membrane and interact with intracellular receptors.
D. They bind to surface receptors that activate G-proteins.

67. Which of the following is the correct sequence of events during the activation of a G-protein coupled receptor (GPCR) signaling pathway?

A. Ligand binding → GTP hydrolysis → Receptor dimerization → Activation of secondary messengers.
B. Ligand binding → Conformational change → G-protein activation → Effector molecule activation.
C. Ligand binding → Effector molecule activation → GTP binding → cAMP generation.
D. Ligand binding → Receptor endocytosis → GTP hydrolysis → Dissociation of the βγ subunit.

68. In the context of GPCR signaling, what is the role of adenylate cyclase?

A. It hydrolyzes GTP to GDP to terminate G-protein signaling.
B. It converts ATP to cAMP, a secondary messenger involved in signal amplification.
C. It binds to the βγ subunit of the G-protein to inhibit its activation.
D. It activates the MAPK pathway, leading to gene expression changes.

69. What is the function of Heat Shock Proteins (HSPs) in the steroid hormone signaling pathway?

A. They bind to the DNA to promote gene transcription.
B. They dissociate from the receptor to activate it upon hormone binding.
C. They inhibit the receptor's dimerization, preventing nuclear translocation.
D. They enhance the nuclear import of transcription factors.

70. Which of the following best describes how integrins contribute to cellular signaling?

A. Integrins activate receptor tyrosine kinases, which then initiate a MAPK signaling cascade.
B. Integrins transmit signals through focal adhesion kinase (FAK) upon binding to the extracellular matrix (ECM).
C. Integrins activate G-protein signaling to regulate intracellular calcium levels.
D. Integrins bind to lipophilic hormones, facilitating their nuclear translocation.

71. In the JAK/STAT signaling pathway, what is the role of JAK kinases?

A. JAK kinases dephosphorylate STAT proteins to turn off the signaling pathway.
B. JAK kinases phosphorylate tyrosine residues on the receptor and STAT proteins, activating them.
C. JAK kinases produce secondary messengers like cAMP to propagate the signal.
D. JAK kinases bind to integrins, initiating cell migration in response to cytokine signaling.

72. Which of the following is most likely to occur after the dissociation of Gα from the Gβγ complex in GPCR signaling?

A. Activation of phosphodiesterase to reduce cAMP levels.
B. Activation of an effector molecule such as adenylyl cyclase or phospholipase C.
C. Inhibition of phospholipase A2 and subsequent reduction of eicosanoid production.
D. Gα subunit undergoes dephosphorylation, terminating the signal.

73. What distinguishes the primary response from the secondary response in cell signaling?

A. The primary response involves activation of secondary messengers, whereas the secondary response involves gene expression.
B. The primary response is typically faster and involves the activation of immediate early genes.
C. The primary response always results in cell division, while the secondary response does not.
D. The primary response involves the production of lipophilic hormones, while the secondary response involves peptide hormones.

74. Which of the following best describes the action of Ras in RTK (Receptor Tyrosine Kinase) signaling?

A. Ras hydrolyzes GTP to GDP to terminate the signaling cascade.
B. Ras activates MAPK signaling by binding to and phosphorylating downstream effector proteins.
C. Ras forms a complex with PKA to translocate to the nucleus and induce gene expression.
D. Ras binds to integrins, triggering cellular adhesion to the extracellular matrix.

75. In the signaling pathway involving eicosanoids, which of the following best describes the action of prostaglandins?

A. Prostaglandins activate adenylate cyclase to produce cAMP.
B. Prostaglandins bind to nuclear receptors to alter gene expression.
C. Prostaglandins mediate inflammation and affect vascular tone via GPCR activation.
D. Prostaglandins act as secondary messengers to increase intracellular calcium levels.

76. Which of the following is true regarding the mechanism of action of lipophilic hormones like steroids?

A. They bind to receptors on the cell surface and activate G-proteins.
B. They diffuse across the plasma membrane, bind to intracellular receptors, and modulate gene expression.
C. They require transport proteins in the blood and act as secondary messengers.
D. They activate ion channels to increase cellular calcium levels.

77. Which of the following events occurs during receptor tyrosine kinase (RTK) activation?

A. The receptor undergoes internalization to terminate signaling.
B. Tyrosine residues within the receptor's intracellular domain undergo phosphorylation, creating docking sites.
C. The βγ complex dissociates from the G-protein and activates cAMP production.
D. A secondary messenger like IP3 is produced to release calcium from intracellular stores.

78. What is the primary effect of increased calcium (Ca^{2+}) levels in cell signaling?

A. Calcium inhibits protein kinase C (PKC) activity, leading to signal termination.
B. Calcium binds to calmodulin, which activates downstream kinases such as CaMKII.
C. Calcium directly binds to and activates adenylyl cyclase to generate cAMP.
D. Calcium activates GTPase activity in the α subunit of G-proteins.

79. What is the main role of cyclic AMP (cAMP) in cell signaling pathways?

A. To bind to G-proteins and activate secondary messengers.
B. To act as a primary messenger to activate receptor tyrosine kinases.
C. To activate protein kinase A (PKA), which phosphorylates target proteins.
D. To promote the hydrolysis of ATP into cGMP.

80. Which of the following is a critical feature of autocrine signaling?

A. The signaling molecule acts on a different cell type, located far from the source.
B. The signaling molecule only affects the cell that produces it, leading to self-regulation.
C. The signaling molecule enters the bloodstream to reach distant tissues.
D. The signaling molecule binds to nuclear hormone receptors, initiating transcription.

Answers:

66. **C**
67. **B**
68. **B**
69. **B**
70. **B**
71. **B**
72. **B**
73. **B**
74. **B**
75. **C**
76. **B**
77. **B**
78. **B**
79. **C**
80. **B**

81. Which of the following best describes the role of secondary messengers like cAMP in signal transduction?

A. They amplify the signal by activating specific protein kinases that target multiple cellular processes.
B. They directly bind to DNA to regulate gene expression.
C. They bind to G-proteins to activate effector molecules like phospholipase C.
D. They increase calcium ion concentration to mediate cell division.

82. In the mechanism of action of steroid hormones, what occurs after the hormone binds to the nuclear receptor (NR)?

A. The receptor undergoes phosphorylation, which activates the downstream signaling pathway.
B. The receptor dimerizes and translocates to the nucleus to activate gene expression.
C. The receptor is internalized by the cell and processed in the lysosome.
D. The receptor recruits secondary messengers to activate effector proteins.

83. In G-protein coupled receptor (GPCR) signaling, what is the primary consequence of the GTP-GDP exchange on the α subunit of the G-protein?

A. The α subunit dissociates from the receptor and binds to the βγ subunit.
B. The α subunit activates adenylate cyclase to produce cAMP.
C. The α subunit hydrolyzes GTP to GDP, leading to termination of the signal.
D. The α subunit initiates receptor endocytosis to reduce receptor availability.

84. Which of the following accurately describes the function of phospholipase C (PLC) in GPCR signaling pathways?

A. PLC synthesizes cAMP from ATP.
B. PLC produces DAG and IP3, which increase intracellular calcium levels and activate protein kinase C.
C. PLC hydrolyzes GTP to GDP, terminating the signal.
D. PLC directly phosphorylates transcription factors to alter gene expression.

85. What is the role of GTPase-activating proteins (GAPs) in the regulation of G-protein signaling?

A. GAPs promote the exchange of GDP for GTP, activating the G-protein.
B. GAPs accelerate the hydrolysis of GTP to GDP, leading to the inactivation of the G-protein.
C. GAPs enhance the dissociation of G-protein subunits, amplifying the signal.
D. GAPs recruit effector molecules to the G-protein complex to propagate the signal.

86. Which of the following is true about receptor tyrosine kinases (RTKs)?

A. RTKs require secondary messengers like cAMP or cGMP for activation.
B. RTKs contain an extracellular ligand-binding domain, a single transmembrane helix, and an intracellular tyrosine kinase domain.
C. RTKs undergo phosphorylation on serine and threonine residues to activate downstream signaling.
D. RTKs bind directly to G-proteins to initiate signaling cascades.

87. In the JAK/STAT signaling pathway, what is the primary function of the STAT proteins after phosphorylation by JAK?

A. STAT proteins form a dimer and translocate to the nucleus to activate gene expression.
B. STAT proteins bind to the receptor to prevent further phosphorylation.
C. STAT proteins dissociate from the receptor to terminate signaling.
D. STAT proteins activate phospholipase C to produce second messengers.

88. Which of the following best describes the mechanism by which integrins mediate cell signaling?

A. Integrins interact with cell surface receptors to initiate the MAPK signaling pathway.
B. Integrins activate focal adhesion kinase (FAK) upon clustering with the

extracellular matrix (ECM), triggering downstream signaling.
C. Integrins bind to steroid hormones, initiating gene transcription in the nucleus.
D. Integrins activate G-protein signaling to increase intracellular cAMP levels.

89. In the GPCR pathway, what is the role of the βγ complex after G-protein activation?

A. The βγ complex binds to adenylyl cyclase to produce cAMP.
B. The βγ complex activates ion channels or phospholipase C to mediate cellular responses.
C. The βγ complex dissociates from the receptor to amplify the signal.
D. The βγ complex translocates to the nucleus to activate gene expression.

90. Which of the following is the main characteristic of lipophilic (hydrophobic) signaling molecules like steroids compared to hydrophilic signaling molecules?

A. Lipophilic molecules bind to cell surface receptors, while hydrophilic molecules bind to intracellular receptors.
B. Lipophilic molecules diffuse across the cell membrane and act on intracellular receptors, while hydrophilic molecules require a receptor on the plasma membrane.
C. Lipophilic molecules rely on second messengers like cAMP, while hydrophilic molecules do not.
D. Lipophilic molecules trigger G-protein activation, while hydrophilic molecules do not.

91. In the process of receptor activation in the JAK/STAT pathway, what is the primary event that occurs after ligand binding?

A. The receptor dimerizes and becomes phosphorylated on tyrosine residues.
B. The receptor undergoes internalization, and JAK is deactivated.
C. The receptor recruits GTP-bound Gα subunits to initiate signaling.
D. The receptor activates adenylyl cyclase to generate cAMP.

92. Which of the following secondary messengers activates protein kinase A (PKA) in response to GPCR signaling?

A. DAG (Diacylglycerol)
B. cAMP (Cyclic AMP)
C. IP3 (Inositol trisphosphate)
D. Ca^{2+} (Calcium ions)

93. What is the primary consequence of phosphorylation of a transcription factor like CREB by PKA?

A. The transcription factor translocates to the cytoplasm to initiate translation.
B. The transcription factor binds to the promoter region of target genes, initiating their transcription.
C. The transcription factor is degraded, terminating signaling.
D. The transcription factor activates protein synthesis in the ribosome.

94. Which of the following best describes the function of protein phosphatase 1 in GPCR signaling?

A. Protein phosphatase 1 activates PKA by dephosphorylating its catalytic subunits.
B. Protein phosphatase 1 dephosphorylates target proteins, terminating the signal.
C. Protein phosphatase 1 synthesizes cAMP from ATP.
D. Protein phosphatase 1 activates phospholipase C by removing inhibitory phosphorylation.

95. Which of the following is true regarding eicosanoids like prostaglandins in cellular signaling?

A. Eicosanoids act through intracellular receptors to regulate gene expression.
B. Eicosanoids, produced from arachidonic acid, bind to GPCRs to mediate inflammatory responses.
C. Eicosanoids directly activate adenylyl cyclase to generate cAMP.
D. Eicosanoids inhibit protein kinase A (PKA) activity, thereby reducing cellular responses.

96. What occurs when a lipophilic hormone binds to its intracellular receptor, causing receptor dimerization?

A. The receptor complex is translocated to the plasma membrane, where it activates ion channels.
B. The receptor complex binds to DNA in the nucleus to regulate gene expression.
C. The receptor complex binds to G-proteins, activating a secondary messenger cascade.
D. The receptor complex is degraded in the lysosome to terminate signaling.

97. Which of the following best describes how secondary messengers like cAMP and Ca^{2+} contribute to signal amplification in cell signaling pathways?

A. Secondary messengers directly bind to the receptor to initiate a cellular response.
B. Secondary messengers activate a series of intracellular proteins, each amplifying the signal.
C. Secondary messengers decrease the sensitivity of the receptor to the ligand.
D. Secondary messengers prevent the phosphorylation of target proteins, terminating the signal.

98. In the activation of receptor tyrosine kinases (RTKs), what is the main consequence of receptor autophosphorylation?

A. It activates the kinase domain of the receptor and creates docking sites for downstream signaling proteins.
B. It triggers endocytosis of the receptor, terminating the signaling process.
C. It results in the dissociation of the receptor from the cell membrane.
D. It produces secondary messengers like cAMP that activate protein kinase A (PKA).

99. Which of the following is true about the function of G-proteins in cell signaling?

A. G-proteins are composed of three subunits: α, β, and γ, and are activated when GDP is exchanged for GTP.
B. G-proteins are always active, and their signaling is independent of receptor activation.
C. G-proteins are directly activated by steroid hormone binding to intracellular receptors.
D. G-proteins directly bind to DNA to initiate transcriptional changes in the cell.

100. What is the primary mechanism by which ion channels are regulated in response to GPCR activation?

A. Ion channels are opened directly by secondary messengers like cAMP or IP3.
B. Ion channels are activated by phosphorylation of the channel proteins.
C. Ion channels are modulated by the βγ subunit of G-proteins, leading to an influx of ions.
D. Ion channels are activated by ligand binding to the receptor's extracellular domain.

Answers:

81. **A**
82. **B**
83. **B**
84. **B**
85. **B**
86. **B**
87. **A**
88. **B**
89. **B**
90. **B**
91. **A**
92. **B**
93. **B**
94. **B**
95. **B**
96. **B**
97. **B**
98. **A**
99. **A**
100. **C**

101. Which of the following describes the role of the MAPK (Mitogen-Activated Protein Kinase) pathway in cellular signaling?

A. It regulates protein synthesis by directly activating ribosomes.
B. It transduces signals from RTKs to the nucleus to control gene expression related to cell growth, differentiation, and survival.
C. It functions to phosphorylate IP3, which increases calcium release.
D. It phosphorylates G-protein subunits, activating secondary messengers.

102. Which statement best describes the primary function of phosphoinositide 3-kinase (PI3K) in cell signaling?

A. PI3K catalyzes the formation of IP3 to release calcium from intracellular stores.
B. PI3K phosphorylates inositol lipids in the plasma membrane to recruit proteins like AKT, promoting cell survival and metabolism.
C. PI3K activates MAPK through phosphorylation of Raf.
D. PI3K generates cAMP to activate PKA and regulate gene expression.

103. In the Wnt signaling pathway, what is the effect of β-catenin stabilization in the cytoplasm?

A. β-catenin inhibits the activation of transcription factors involved in cell proliferation.
B. β-catenin accumulates and translocates to the nucleus, activating the transcription of genes involved in cell proliferation and differentiation.
C. β-catenin prevents the phosphorylation of target proteins by kinases.
D. β-catenin binds to G-protein subunits to propagate the signal.

104. In the TGF-β (Transforming Growth Factor-beta) signaling pathway, which of the following occurs after receptor activation?

A. The receptor undergoes dimerization, followed by phosphorylation of its intracellular kinase domain, activating Smad proteins.
B. The receptor activates adenylyl cyclase, leading to an increase in cAMP.
C. The receptor recruits G-proteins to generate secondary messengers like IP3 and DAG.
D. The receptor forms a complex with GTP-bound Ras, leading to MAPK activation.

105. Which of the following is a consequence of Rho GTPase activation in the regulation of the actin cytoskeleton?

A. Rho GTPase causes the disassembly of microtubules to facilitate cell movement.
B. Rho GTPase induces the formation of stress fibers and focal adhesions, promoting cell contraction and migration.
C. Rho GTPase activates cAMP production, resulting in inhibition of cell division.
D. Rho GTPase stabilizes the microtubule network, preventing cell movement.

106. What is the function of the SH2 (Src Homology 2) domain in signaling proteins?

A. It mediates protein-protein interactions by binding to phosphorylated tyrosine residues on target proteins.
B. It catalyzes the phosphorylation of downstream target proteins.
C. It recruits GTPase-activating proteins (GAPs) to terminate signaling.
D. It binds directly to lipid molecules like DAG to activate signaling pathways.

107. How does the Notch signaling pathway primarily influence cellular behavior?

A. Notch signaling promotes the phosphorylation of proteins involved in cell survival.
B. Notch signaling mediates direct cell-to-cell communication, where ligand binding leads to cleavage of the Notch receptor and nuclear translocation of the intracellular domain to regulate gene expression.
C. Notch signaling activates G-proteins to induce changes in the actin cytoskeleton.
D. Notch signaling induces the release of calcium from the endoplasmic reticulum to regulate gene expression.

108. Which of the following best describes the role of cAMP in the activation of Protein Kinase A (PKA)?

A. cAMP activates PKA by binding directly to its catalytic subunits, releasing them from the regulatory subunits.
B. cAMP directly phosphorylates target proteins to alter their activity.
C. cAMP serves as a secondary messenger to activate receptor tyrosine kinases (RTKs).
D. cAMP activates G-proteins, which then activate adenylate cyclase.

109. In the process of GPCR desensitization, which of the following events typically occurs?

A. The receptor undergoes internalization through clathrin-mediated endocytosis to prevent overstimulation of the signaling pathway.
B. The receptor is phosphorylated by MAPK to enhance its signaling activity.
C. G-proteins are deactivated by GAPs to prevent further signaling.
D. The receptor is replaced by a different GPCR to maintain the signaling cascade.

110. Which of the following is a direct result of Ras activation in signal transduction?

A. Ras promotes the activation of PI3K, leading to AKT phosphorylation and increased cell survival.
B. Ras activates protein phosphatases to terminate signaling.
C. Ras directly activates cAMP production to activate PKA.
D. Ras phosphorylates transcription factors to modulate gene expression.

111. How does the NF-κB signaling pathway contribute to the immune response?

A. It activates the transcription of cytokines, chemokines, and other immune-related genes that control inflammation and immune cell activity.
B. It induces the release of calcium from intracellular stores to activate immune cell functions.
C. It stimulates protein synthesis by binding to ribosomal RNA in the nucleolus.
D. It phosphorylates histones to initiate chromatin remodeling and transcriptional silencing.

112. What is the primary effect of calcium signaling in cell activation?

A. Calcium ions act as secondary messengers to regulate protein phosphorylation and activate transcription factors.

B. Calcium ions directly bind to G-protein receptors to initiate signaling.
C. Calcium ions activate the synthesis of eicosanoids from membrane phospholipids.
D. Calcium ions inhibit phospholipase C to prevent further signaling.

113. Which of the following is a characteristic feature of G-protein-coupled receptor (GPCR) signaling via the β-adrenergic pathway?

A. GPCRs initiate signal transduction through the activation of cAMP, which in turn activates PKA.
B. GPCRs directly phosphorylate target proteins in the cytoplasm.
C. GPCRs activate receptor tyrosine kinases to induce a growth response.
D. GPCRs release calcium from the endoplasmic reticulum by activating IP3.

114. Which of the following best describes the role of FAK (Focal Adhesion Kinase) in integrin-mediated signaling?

A. FAK promotes the assembly of microtubules to regulate cell shape.
B. FAK is activated upon integrin binding to the extracellular matrix (ECM) and promotes cell migration and survival through phosphorylation of target proteins.
C. FAK inhibits cell adhesion to the ECM by cleaving integrin receptors.
D. FAK activates the MAPK pathway to induce cytokine release.

115. What is the primary consequence of ligand binding to a receptor that activates a Gαq protein?

A. Activation of adenylyl cyclase, leading to an increase in cAMP levels.
B. Activation of phospholipase C, leading to the production of DAG and IP3, which release calcium and activate protein kinase C (PKC).
C. Inhibition of phosphatases to maintain signaling.
D. Activation of Ras to initiate MAPK signaling.

116. Which of the following best describes the function of the protein β-arrestin in GPCR desensitization?

A. β-arrestin binds to the GPCR and prevents further G-protein activation by sterically hindering the receptor.
B. β-arrestin activates secondary messengers like cAMP.
C. β-arrestin phosphorylates the GPCR to enhance its signaling ability.
D. β-arrestin is a G-protein that propagates the signal to the nucleus.

117. What is the role of the protein Akt (also known as Protein Kinase B) in cellular signaling?

A. Akt inhibits the activation of MAPK by dephosphorylating it.
B. Akt phosphorylates and inactivates key apoptotic proteins, promoting cell survival.
C. Akt activates phospholipase C to generate DAG and IP3.
D. Akt directly activates transcription factors in the nucleus to regulate cell division.

118. How does the Hedgehog signaling pathway influence cell fate decisions?

A. Hedgehog signaling activates the NF-κB pathway, promoting inflammation.
B. Hedgehog signaling inhibits the activity of the Gli family of transcription factors in the absence of ligand binding.
C. Hedgehog signaling promotes the phosphorylation of MAPK to regulate cell growth.
D. Hedgehog signaling leads to the internalization of the receptor for further signaling.

119. What is the role of the ubiquitin-proteasome pathway in the regulation of cellular signaling?

A. It promotes the accumulation of signaling proteins by tagging them for degradation.
B. It regulates the activation of G-proteins through degradation of GAPs.
C. It controls the degradation of phosphorylated proteins to terminate signaling pathways.
D. It activates transcription factors through phosphorylation of target genes.

120. Which of the following pathways is directly regulated by the binding of a ligand to a receptor tyrosine kinase (RTK)?

A. The MAPK pathway, which regulates cell proliferation and survival.
B. The PI3K/Akt pathway, which modulates cell metabolism and survival.
C. The JAK/STAT pathway, which regulates immune response.
D. All of the above.

Answers:

101. **B**
102. **B**
103. **B**
104. **A**
105. **B**
106. **A**
107. **B**
108. **A**
109. **A**
110. **A**
111. **A**
112. **A**
113. **A**
114. **B**
115. **B**
116. **A**
117. **B**
118. **B**
119. **C**
120. **D**

121. Which of the following best explains the role of cAMP in regulating PKA activity in cells?

A. cAMP directly phosphorylates transcription factors to activate gene expression.
B. cAMP binds to the regulatory subunits of PKA, releasing the catalytic subunits to initiate phosphorylation of target proteins.
C. cAMP activates Ras proteins to initiate MAPK signaling pathways.
D. cAMP binds to G-protein subunits to propagate the signaling cascade.

122. What is the main function of the PI3K-AKT signaling pathway in cell survival?

A. It activates transcription factors to promote cell cycle arrest.
B. It inhibits apoptosis by phosphorylating and inactivating pro-apoptotic proteins like Bad and caspases.
C. It induces the release of calcium from the ER to activate transcription factors.
D. It increases the synthesis of extracellular matrix components.

123. In the TGF-β signaling pathway, which of the following proteins are directly phosphorylated by the activated receptor?

A. MAPK proteins
B. Smad proteins
C. PI3K
D. NF-κB proteins

124. Which of the following is an important consequence of the activation of integrin receptors in cell adhesion and migration?

A. Activation of integrins promotes the assembly of focal adhesions, linking the actin cytoskeleton to the extracellular matrix.
B. Activation of integrins triggers the degradation of the extracellular matrix to allow cell migration.
C. Integrin activation leads to the release of cAMP, which in turn inhibits focal adhesion kinase (FAK).
D. Activation of integrins induces the release of calcium from intracellular stores to activate calcineurin.

125. In the Notch signaling pathway, what is the role of the γ-secretase complex?

A. γ-Secretase cleaves the intracellular domain of the Notch receptor, allowing it to translocate to the nucleus and regulate gene expression.
B. γ-Secretase binds to the extracellular domain of Notch, preventing receptor internalization.
C. γ-Secretase phosphorylates the Notch ligand, enhancing its affinity for the Notch receptor.
D. γ-Secretase activates transcription factors in response to Notch binding.

126. Which of the following is a key feature of Wnt signaling in developmental biology?

A. Wnt signaling activates β-catenin degradation through phosphorylation, preventing gene activation.
B. Wnt signaling inhibits the formation of transcriptional complexes in the nucleus.
C. Wnt signaling involves β-catenin accumulation in the cytoplasm and translocation to the nucleus to activate gene expression.
D. Wnt signaling promotes the breakdown of extracellular matrix components during tissue remodeling.

127. Which of the following molecules is a common downstream effector in both MAPK and PI3K-AKT pathways?

A. JAK
B. Ras
C. mTOR
D. CREB

128. In GPCR signaling, the activation of Gαq leads to which of the following events?

A. Activation of adenylyl cyclase and increased cAMP levels.
B. Activation of phospholipase Cβ, leading to the generation of IP3 and DAG and the release of calcium from intracellular stores.
C. Activation of phosphodiesterase, decreasing cAMP levels.
D. Activation of Rho GTPases to regulate the actin cytoskeleton.

129. Which of the following proteins is involved in the regulation of the actin cytoskeleton via the Rho family GTPases?

A. AKT
B. Rac
C. ERK
D. CREB

130. Which of the following best describes the effect of the Hedgehog signaling pathway in development?

A. Hedgehog signaling activates β-catenin, promoting gene expression that drives stem cell differentiation.
B. Hedgehog signaling prevents the cleavage of the Gli transcription factor, thereby inhibiting its function.
C. Hedgehog signaling involves the activation of smoothened, leading to the accumulation of Gli proteins that regulate target gene expression.
D. Hedgehog signaling promotes the degradation of extracellular matrix proteins during tissue remodeling.

131. Which of the following is the primary function of the NF-κB signaling pathway in immune cells?

A. To stimulate the release of calcium from intracellular stores to activate T-cell receptor signaling.

B. To regulate inflammatory responses by activating the transcription of cytokines and chemokines.
C. To mediate DNA repair in response to oxidative stress.
D. To promote cell cycle progression by inhibiting CDK inhibitors.

132. Which of the following secondary messengers is primarily involved in the activation of protein kinase C (PKC)?

A. cAMP
B. Inositol trisphosphate (IP3)
C. Diacylglycerol (DAG)
D. Calcium ions

133. Which of the following cellular processes is most directly regulated by the JAK-STAT signaling pathway?

A. Transcriptional regulation of immune response genes, including those involved in cytokine signaling.
B. Activation of G-protein coupled receptors to mediate cell signaling.
C. Regeneration of actin filaments to enhance cell migration.
D. Activation of MAPK to stimulate cell proliferation.

134. Which of the following is an effect of the activation of receptor tyrosine kinases (RTKs)?

A. Activation of phospholipase Cγ, leading to the generation of DAG and IP3.
B. Dimerization and autophosphorylation of the RTK intracellular domain, recruiting SH2-domain-containing proteins.
C. Release of calcium ions from the extracellular space.
D. Activation of Rho GTPases to mediate cell adhesion.

135. What is the role of the protein Rb (retinoblastoma) in cell cycle regulation?

A. Rb inhibits the transition from G1 to S phase by sequestering E2F transcription factors.
B. Rb activates cyclin-dependent kinases to promote cell cycle progression.
C. Rb promotes DNA repair by phosphorylating DNA damage response proteins.
D. Rb dephosphorylates histones to initiate DNA replication.

136. What is the role of the phosphatase calcineurin in immune signaling?

A. Calcineurin activates NF-κB to promote inflammation.
B. Calcineurin dephosphorylates NFAT, allowing it to translocate to the nucleus and initiate transcription of immune response genes.
C. Calcineurin inhibits the MAPK pathway to suppress immune cell activation.
D. Calcineurin activates PI3K to promote cell survival in immune cells.

137. Which of the following molecules is primarily responsible for the propagation of signals through the Ras-MAPK signaling cascade?

A. PI3K
B. cAMP
C. GTP-bound Ras
D. Inositol phosphate (IP)

138. How does the receptor tyrosine kinase (RTK) pathway activate the MAPK signaling cascade?

A. RTKs activate PI3K, which leads to the activation of MAPK through phosphorylation of Ras.
B. RTKs activate GTPases, which directly activate MAPK in the cytoplasm.
C. RTKs dimerize and phosphorylate themselves, leading to activation of the MAPK pathway through Ras and Raf.
D. RTKs release calcium ions to activate MAPK signaling in the nucleus.

139. In cell signaling, which of the following events occurs as a result of receptor internalization during receptor-mediated endocytosis?

A. Receptor degradation in lysosomes, leading to termination of signaling.
B. The receptor becomes unresponsive to subsequent ligand binding.
C. The internalized receptor is recycled back to the membrane to enhance signaling.
D. The receptor activates secondary messengers to propagate signaling.

140. In the context of cellular communication, how do GTPases like Rac, Cdc42, and Rho contribute to signal transduction?

A. They activate protein kinase cascades to regulate transcriptional responses.
B. They modulate the actin cytoskeleton to control cell migration and adhesion.
C. They initiate MAPK signaling by phosphorylating downstream kinases.
D. They facilitate G-protein activation to propagate signals.

Answers:

121. **B**
122. **B**
123. **B**
124. **A**
125. **A**
126. **C**
127. **C**
128. **B**
129. **B**
130. **C**
131. **B**
132. **C**
133. **A**
134. **B**
135. **A**

136. **B**
137. **C**
138. **C**
139. **A**
140. **B**

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