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Membrane Receptors & GPCR Signaling

Exam — Cell Membrane

High school / pre-med / IB-style questions on membrane receptor types (GPCRs, ion channels, RTKs, intracellular receptors) with a focus on GPCR logic: why cells need membrane receptors, why cascades and amplification exist, second messengers (cAMP, IP3/DAG, Ca^{2+}), and how signals are turned off (desensitization, GTP hydrolysis, PDE).

50 items — Printable Exam

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1 **A peptide hormone is released into the blood and reaches many tissues, but only some tissues respond. What is the MOST direct reason a peptide hormone typically needs a membrane receptor to affect a cell?**

A Peptide hormones are too large to exist in blood without receptors.

B Peptide hormones are usually polar, so they cannot freely diffuse through the lipid bilayer to reach intracellular targets.

C Peptide hormones must be converted into ATP before a cell can respond.

D Peptide hormones can only act on cells that have mitochondria.

E Peptide hormones only work by binding directly to DNA in the nucleus.

2 **Which signaling molecule is MOST likely to act through a G-protein-coupled receptor (GPCR) on the cell surface?**

A Cortisol (a steroid hormone)

B Thyroid hormone (lipid-soluble)

C Adrenaline/epinephrine (a catecholamine)

D Nitric oxide (a gas)

E Oxygen

3 **A student says: "If a hormone binds a receptor, the hormone must enter the cell." Which statement is the best correction?**

A Correct—binding always requires the hormone to pass through the membrane first.

B Incorrect—many hormones bind membrane receptors and trigger intracellular signaling without entering the cell.

C Incorrect—hormones never bind receptors; they bind enzymes.

D Correct—only steroid hormones can bind receptors.

E Incorrect—hormones act only by changing membrane cholesterol content.

4 Which structural feature is most characteristic of GPCRs?

A A single transmembrane helix and a ligand-binding domain inside the nucleus

B Seven transmembrane segments (typically alpha-helices)

C A pore that directly conducts Na^+ and K^+ ions when the ligand binds

D A cytosolic catalytic domain that phosphorylates tyrosine residues by itself

E Two lipid bilayers surrounding the receptor protein

5 A heterotrimeric G protein is best described as:

A A DNA-binding protein made of three chromosomes

B A three-subunit protein (, ,) that binds GDP/GTP and relays signals from GPCRs

C A membrane lipid made of three fatty acids

D A receptor that directly phosphorylates glucose

E An ion channel with three gates

6 In the classic GPCR cycle, which event MOST directly switches the G subunit into its active state?

A Phosphorylation of G by the receptor

B Exchange of GDP for GTP on G

C Hydrolysis of ATP to ADP on G

D Binding of oxygen to G

E Removal of the membrane lipids around the receptor

7 A student says: "GPCRs amplify signals because one hormone molecule can enter and directly activate thousands of enzymes." What is the best correction?

A Correct—hormones enter cells and directly activate thousands of enzymes by themselves.

B Incorrect—amplification usually occurs because one activated receptor can activate many G proteins, each triggering downstream enzyme activity and second messengers.

C Incorrect—amplification is impossible in biology; responses are always one-to-one.

D Correct—amplification is caused mainly by increased diffusion speed of hormones.

E Incorrect—GPCRs are channels, so no cascades are involved.

8 Why do cells often use multi-step signaling cascades instead of a single-step "receptor → final response" system?

A Cascades always make responses slower and less controllable, which cells prefer.

B Cascades allow amplification and also provide multiple control points for regulation and integration of signals.

C Cascades are needed because receptors cannot bind ligands tightly.

D Cascades are used only in plants, not animals.

E Cascades prevent the need for ATP in signaling.

9 **A key trade-off of using signaling cascades (like GPCR → second messengers → kinases) is that cascades:**

A Prevent signal amplification

B Can be slower than direct ion channel signaling, but allow amplification and fine-tuned regulation

C Require the ligand to enter the nucleus

D Always produce identical responses in every tissue

E Work only in bacteria

10 **Which receptor type is most likely to produce the FASTEST response after ligand binding?**

A Intracellular nuclear receptor

B Receptor tyrosine kinase (RTK)

C Ligand-gated ion channel

D GPCR signaling through a kinase cascade

E A receptor that only changes gene transcription after hours

11 **Acetylcholine can act through two receptor families: nicotinic and muscarinic. Which statement is correct?**

A Nicotinic receptors are GPCRs; muscarinic receptors are ligand-gated ion channels.

B Muscarinic receptors are GPCRs; nicotinic receptors are ligand-gated ion channels.

C Both nicotinic and muscarinic receptors are intracellular receptors.

D Both are receptor tyrosine kinases.

E Neither receptor binds acetylcholine directly.

12 **Which statement best distinguishes an RTK (receptor tyrosine kinase) from a GPCR?**

A RTKs have 7 transmembrane helices; GPCRs have one.

B RTKs often dimerize and autophosphorylate tyrosine residues; GPCRs signal mainly by activating heterotrimeric G proteins.

C RTKs are always ion channels; GPCRs are always enzymes.

D GPCRs can only respond to steroid hormones; RTKs respond only to light.

E GPCRs work only in bacteria; RTKs work only in plants.

13 **Insulin is best matched with which receptor type?**

A Ligand-gated ion channel

B GPCR (Gs)

C Receptor tyrosine kinase (RTK)

D Intracellular nuclear receptor

E Voltage-gated sodium channel

14 **A hormone binds a GPCR and causes a rapid increase in intracellular cAMP. Which G type is the BEST match?**

A G s

B G i

C G q

D Tubulin

E Actin

15 **A GPCR activation leads to a DECREASE in cAMP levels. Which G type is the BEST match?**

A G s

B G i

C G q

D RNA polymerase

E Myosin

16 **A signal activates a GPCR that increases intracellular Ca^{2+} by releasing Ca^{2+} from the endoplasmic reticulum. Which pathway is most consistent with this?**

A G s → adenylyl cyclase → cAMP

B G i → inhibition of adenylyl cyclase

C G q → phospholipase C → IP3 + DAG

D RTK → direct opening of Na^{+} channels

E Steroid receptor → DNA binding → immediate Ca^{2+} release

17 **Which statement about IP3 and DAG is correct?**

A IP3 remains in the membrane and activates protein kinase C directly.

B DAG diffuses through the cytosol to bind receptors on the ER.

C IP3 diffuses in the cytosol and can trigger Ca^{2+} release from the ER; DAG stays in the membrane and helps activate protein kinase C.

D Both IP3 and DAG are steroid hormones.

E IP3 is a membrane channel; DAG is a nuclear transcription factor.

18 Which molecule is a classic SECOND messenger produced/used inside cells during signaling?

A Insulin (in the bloodstream)

B cAMP

C A GPCR protein

D A hormone receptor gene

E Hemoglobin

19 Which option is NOT a second messenger in the typical GPCR sense?

A Ca^{2+}

B cAMP

C IP3

D DAG

E Adrenaline/epinephrine (the extracellular signal)

20 **A drug inhibits phosphodiesterase (PDE), the enzyme that breaks down cAMP. In a cell using a cAMP pathway, the MOST likely result is:**

- A cAMP signals become weaker and shorter
- B cAMP signals become stronger and/or last longer
- C cAMP can no longer be produced by adenylyl cyclase
- D The GPCR is converted into an ion channel
- E The hormone must now enter the nucleus to work

21 **A mutation makes phosphodiesterase (PDE) much more active than normal. A GPCR pathway that relies on cAMP would most likely show:**

- A Exaggerated cAMP signaling because cAMP is preserved
- B Reduced cAMP signaling because cAMP is broken down too quickly
- C No change because PDE only affects DNA replication
- D A switch from GPCR signaling to RTK signaling
- E Immediate opening of ligand-gated ion channels

22 **A G subunit cannot hydrolyze GTP back to GDP (its "timer" is broken). After receptor activation, what is the MOST likely effect?**

- A The signal turns off faster than normal
- B The G protein stays active longer, prolonging downstream signaling
- C The receptor cannot bind ligand anymore
- D Second messengers cannot be produced under any conditions
- E The membrane becomes impermeable to water

23 **A different mutation prevents GDP from leaving G , even after a GPCR is activated. What happens to signaling through that G protein?**

A Signaling increases because GDP locks G in the active form

B Signaling decreases because G cannot bind GTP and therefore cannot activate downstream effectors

C Signaling becomes independent of receptors

D The GPCR turns into a transcription factor

E The cell produces more DNA to compensate

24 **A patient has been exposed to high levels of the SAME hormone continuously for days. The tissue response gradually decreases even though hormone concentration stays high. Which mechanism best explains this?**

A Random mutation eliminates all receptors in every cell instantly

B Receptor desensitization/downregulation (e.g., phosphorylation, arrestin binding, internalization)

C The hormone becomes lipid-soluble over time

D The hormone is converted into ATP

E The nucleus moves outside the cell

25 **Which description best matches GPCR desensitization in basic terms?**

A The ligand is destroyed by ribosomes

B The receptor is modified so it couples less effectively to G proteins, often followed by receptor internalization

C The cell membrane dissolves, preventing signaling

D The receptor moves into the nucleus to bind DNA

E All GPCRs permanently stop working after one signal

26 **Chronic exposure to a strong agonist often leads to fewer receptors on the cell surface. This is best termed:**

A Upregulation

B Downregulation

C Depolarization

D Translation

E Independent assortment

27 **A tissue is exposed to a receptor blocker (antagonist) for a long time. The blocker is suddenly removed. The tissue now responds excessively to normal hormone levels. The best explanation is:**

A The hormone has become more concentrated automatically

B Receptor upregulation occurred during blockade, increasing receptor number/sensitivity

C The cell ran out of ATP, making responses stronger

D The nucleus moved closer to the membrane

E Ion channels became irrelevant because GPCRs turned into DNA

28 **Two different tissues are exposed to the same hormone at the same concentration. Tissue A responds strongly; Tissue B does not respond at all. Which is the MOST direct explanation?**

A Tissue B has DNA, but Tissue A does not.

B Tissue B lacks the appropriate receptor (or key downstream signaling components) for that hormone.

C Tissue B has too much oxygen, preventing signaling.

D Tissue A has no membrane, so hormones enter freely.

E The hormone must be converted into glucose only in Tissue A.

29 **A common student confusion is: "If two pathways both raise cAMP, they must cause the same effect." Why is this often false?**

A cAMP cannot activate any proteins, so it has no effects.

B Different cell types express different downstream targets (enzymes, transcription factors), so the same second messenger can produce different outcomes.

C cAMP always leaves the cell immediately.

D Only one hormone in the body uses cAMP.

E cAMP signals only in the nucleus, never in the cytoplasm.

30 **Which statement best captures why amplification is useful in physiology?**

A It allows a tiny extracellular signal to create a large intracellular response, even at very low hormone concentrations.

B It prevents receptors from binding ligands, protecting the cell from signals.

C It makes membranes less selective so more molecules can cross.

D It eliminates the need for feedback control.

E It ensures every tissue responds identically to every hormone.

31 A student argues: "Amplification is always good, so cells should amplify as much as possible." What is the best counterargument?

A Amplification has no cost and never causes problems.

B Too much amplification can increase noise/overreaction and must be balanced by feedback and shut-off mechanisms.

C Amplification prevents any cellular response from happening.

D Amplification only exists in plants.

E Amplification requires hormones to bind DNA directly.

32 Which event is the MOST immediate "amplification step" in a classic GPCR → cAMP pathway?

A One GPCR activating multiple G proteins over time

B A hormone being synthesized in the endocrine gland

C A ribosome translating a receptor protein

D Oxygen binding hemoglobin

E DNA replication in S phase

33 A cell is injected with cAMP directly (bypassing the receptor). Which result is MOST likely in a pathway where cAMP activates protein kinase A (PKA)?

A No response, because receptors are always required for any signaling.

B Downstream effects may still occur, because cAMP is downstream of the receptor and can activate PKA directly.

C The GPCR will automatically bind more hormone.

D The cell membrane will become impermeable to ions.

E DNA will be cut into pieces as part of normal signaling.

34 A signaling pathway uses cAMP, but two different hormones produce opposite effects in the same cell. Which explanation is MOST plausible?

A cAMP sometimes becomes DNA, causing opposite effects.

B The hormones may activate different receptors that engage different downstream branches, or they may regulate different target proteins despite both involving cAMP.

C Opposite effects are impossible if cAMP is involved.

D cAMP always increases every cellular process.

E The cell must be dead if it shows opposite responses.

35 Which event most directly turns OFF a G -mediated signal at the G protein level?

A G binding GDP and releasing Pi after hydrolysis

B The ligand binding to the receptor more strongly

C The receptor moving into the nucleus

D The cell wall thickening

E Ribosomes converting GTP into ATP

36 **Which mechanism MOST directly ensures that a second messenger signal (like cAMP) does not last forever?**

A DNA replication

B Enzymatic breakdown/removal (e.g., PDE breaks down cAMP; pumps remove Ca^{2+})

C Formation of microtubules

D Random mutation

E Protein synthesis in ribosomes

37 **Which statement best explains how GPCR signaling can be BOTH amplified AND specific?**

A Amplification always destroys specificity.

B Specificity comes from receptor type, cell-specific downstream proteins, and where/when the signal occurs—even if steps are amplified.

C Specificity occurs only because hormones are different colors.

D Specificity occurs because all cells have identical pathways.

E Specificity occurs only in the nucleus; membrane signals are never specific.

38 **A student asks: "If the cell could just let hormones enter, why evolve receptors at all?" Which answer is most accurate?**

A Cells evolved receptors mainly to make membranes thicker.

B Receptors allow controlled detection, amplification, and regulation of signals—especially for hydrophilic signals that cannot cross membranes.

C Receptors exist only because cells cannot produce hormones.

D Receptors prevent all signaling from happening accidentally.

E Receptors are only used for transporting oxygen.

39 **Which example best illustrates amplification in sensory physiology using a GPCR?**

A A single photon activates a visual GPCR (rhodopsin), triggering many downstream molecules and a measurable electrical response.

B A single ion passes through an ion channel and instantly creates a whole muscle contraction.

C A steroid hormone binds DNA directly and creates an immediate action potential in milliseconds.

D A ribosome translates one protein and the cell becomes invisible.

E A mitochondrion divides and that directly activates a receptor.

40 **Olfactory (smell) receptors are famous for being:**

A Ligand-gated chloride channels found only in bacteria

B A large family of GPCRs that detect many different odor molecules

C Receptor tyrosine kinases that directly phosphorylate odor molecules

D Nuclear receptors that bind odor molecules inside the nucleus

E Enzymes that break down odors in blood plasma

41 **Which statement about the subunits of a heterotrimeric G protein is most accurate?**

A They have no role and are just "packaging" for the subunit.

B They can also participate in signaling (for example, by modulating certain ion channels) in addition to the subunit.

C They are DNA molecules, not proteins.

D They are only found inside the nucleus.

E They replace ATP synthase in mitochondria.

42 A GPCR pathway changes a cell's behavior within seconds, while a steroid hormone pathway changes gene expression over hours. Which explanation best accounts for this time difference?

A GPCRs use DNA replication, which is faster than transcription.

B GPCRs often modify existing proteins via second messengers and phosphorylation, while steroid receptors often change transcription and protein production.

C Steroid hormones cannot enter cells, so they take longer to find receptors.

D GPCR signals must always wait for mitosis, which is fast.

E Steroid hormone signaling is faster because it bypasses receptors.

43 A student asks: "If amplification exists, why doesn't a cell respond maximally to just one hormone molecule every time?" Which is the best answer?

A Cells never amplify signals; amplification is a myth.

B Cells have thresholds, feedback, messenger breakdown, and limited receptor activation time; amplification is real but controlled.

C A single hormone molecule always causes maximal response in all tissues.

D Hormone molecules are too heavy to bind receptors one at a time.

E Amplification only happens during meiosis.

44 **A tissue reaches its maximal response when only ~10% of receptors are occupied by hormone. This BEST illustrates:**

A Receptor reserve ("spare receptors") due to amplification

B That receptors are unnecessary

C That the hormone must enter the nucleus

D That the membrane has become leaky

E That enzymes have stopped working

45 **Half the GPCRs in a tissue are irreversibly blocked, but the tissue can still reach the same maximal response (though it takes more hormone). What is the BEST interpretation?**

A There were spare receptors; losing some shifts sensitivity but not necessarily the maximum

B Blocking receptors always increases sensitivity

C GPCRs are not involved in this tissue at all

D The hormone changed into a steroid hormone

E The cell wall compensates for receptor loss

46 **A competitive antagonist binds the same receptor site as the hormone but does not activate signaling. Which outcome is most expected?**

A The hormone response becomes stronger at every concentration.

B More hormone is required to get the same effect, because the antagonist competes for receptor binding.

C The antagonist permanently destroys the receptor by definition.

D The receptor becomes a nuclear receptor.

E Competitive antagonists always increase cAMP.

47 **A student thinks GPCR signaling is "pointless" because the receptor does not make the final response directly. Which analogy best captures why GPCR signaling is useful?**

A A light switch that directly builds a house

B A door key that opens a single door and nothing else

C A microphone connected to an amplifier: a small input can create a large, controllable output

D A rock falling randomly down a hill

E A book that cannot be read

48 **Which statement is the BEST definition of "signal transduction"?**

A The conversion of glucose to ATP

B The process of converting an external signal into an internal cellular response through receptors and intracellular pathways

C The movement of red blood cells through capillaries

D The production of hormones in endocrine glands

E The replication of DNA during S phase

49 **Which option correctly identifies a FIRST messenger vs a SECOND messenger?**

A First: cAMP; Second: adrenaline

B First: IP3; Second: hormone receptor

C First: adrenaline (outside cell); Second: cAMP (inside cell)

D First: ATP synthase; Second: mitochondria

E First: DNA; Second: RNA

50 A GPCR is activated, but adenylyl cyclase (the enzyme that makes cAMP) is nonfunctional. Which result is most likely for a Gs-coupled pathway?

A cAMP still rises because cAMP is made directly by the receptor

B cAMP does not rise; downstream cAMP-dependent effects are greatly reduced even if the receptor and G protein are normal

C The pathway automatically switches to IP3/DAG even with no changes

D The hormone becomes lipid-soluble and enters the nucleus

E The cell immediately undergoes mitosis

#	Ans	Answer Text
	B	
2	C	Adrenaline/epinephrine (a catecholamine)
	B	
4	B	Seven transmembrane segments (typically alpha-helices)
	B	
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