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Name Leonie Hoeher Period

Chapter 11: Cell Communication

Chapters 9, 10, and 11 form three of the most difficult chapters in the book. The special challenge in Chapter 11 is not that the material is so difficult, but that most of the material will be completely new to you. Cell communication is normally not covered in standard high school biology books, yet perhaps no other section of biology has grown as much as cell signaling has in the last ten years. Take your time with this section, and you will be rewarded with a knowledge base that will be most helpful in this course and courses to come.

Concept 11.1 External signals are converted into responses within the cell

1. What is a signal transduction pathway?

A signal transduction pathway converts a received signal to a cellular response in a series of steps.

2. How does yeast mating serve as an example of a signal transduction pathway?

The two yeast mating types (a & α) exchange mating factors that bind to receptors on opposite cell and induce a change in cells that leads to their fusion, which creates a new cell.

3. Complete the chart of local chemical signaling in cell communication in animals.

Local Signaling Types	Specific Example
Paracrine	numerous cells simultaneously receive & respond to local signaling molecules, for example the secretion of a growth factor that stimulates cell growth + division
Synaptic	an electrical signal triggers the release of a neurotransmitter in a nerve cell, which diffuse across the synapse and stimulate the target cell

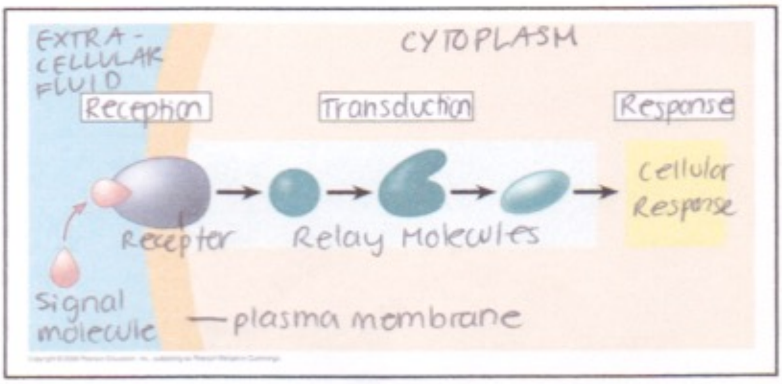
4. How does a hormone qualify as a long-distance signaling example?

Hormones qualify as long-distance signals because they are released into the blood vessels (circulatory system) and travel to other parts of the body to reach target cells that can respond to the hormone.

5. A signal transduction pathway has three stages. Use Figure 11.6 to label the missing parts of the preview figure below, and then explain each step.

Reception

The cell detects the signalling molecule, which binds to a receptor protein



Transduction

The receptor protein changes shape and converts signal to relay molecules that can turn the signal into a specific cellular response. Triggers a signal transduction pathway that occurs in series of steps.

Response

The transduced signal triggers a cellular response in the cell

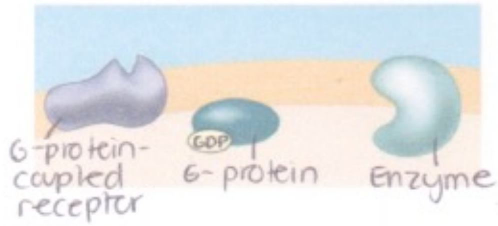
Concept 11.2 Reception: A signal molecule binds to a receptor protein, causing it to change shape

6. Explain the term *ligand*. (This term is not restricted to cell signaling. You will see it in other situations during the year.)

A ligand is a molecule that specifically binds to another molecule (often a larger one).

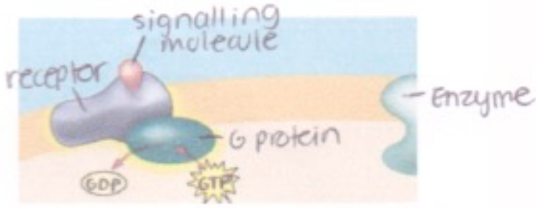
7. The text will explain three major types of membrane receptors in Figure 11.7. This material is of fundamental importance, so we will work thorough the specific figures for each type of membrane receptor. The first example is a *G protein-linked receptor*. In the first figure, label the components and then describe the role of the three components.

The G protein-linked receptor will receive the signaling molecule. The G-protein is in its inactive form when bonded to GDP. The enzyme is not activated yet.



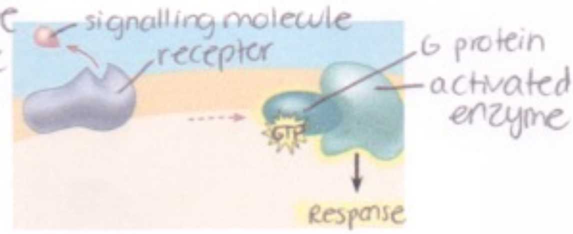
8. Label and then describe what happens in step 2.

The signalling molecule binds to the receptor, which causes it to change shape. The inactive G protein binds to the receptor, which lets GTP take the place of GDP, activating the G protein.



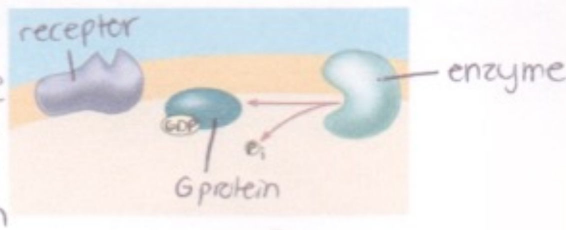
9. Label then describe what happens in step 3. (The yellow box at the bottom right is important!)

The active G protein moves along membrane and binds to an enzyme, causing shape change. The enzyme is activated and can trigger the cellular response.



10. Equally important to starting a signal is stopping a signal. Step 4 stops the signal. (Failure to do so can lead to serious problems, like cancer.) Label and then describe how the signal is halted.

The G protein functions as a GTPase enzyme as well, hydrolyzing its GTP back to GDP and releasing a phosphate group. The G protein is inactive again and enzyme returns to original state. This function of the G protein allows the pathway to shut down quickly and free the G protein to be reused.



11. What activates a G protein?

The G protein is activated once the signalling molecule binds to the recepter and allows the G protein to bind to recepter as well.

12. A G protein is also a GTPase enzyme. Why is this important?

This is important because it can change its GTP back to GDP, rapidly shutting down the pathway & allowing for reuse.

13. The second type of receptor described is *receptor tyrosine kinase*. Explain what a kinase enzyme does.

A kinase enzyme can catalyze the transfer of phosphate groups.

14. How does tyrosine kinase function in the membrane receptor?

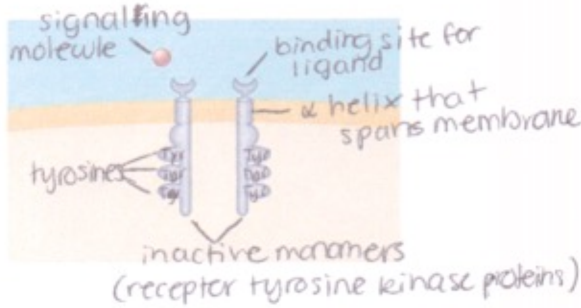
Tyrosine kinase are membrane recepters that can attach phosphates to tyrosines (amino acid).

15. What is a key difference between receptor tyrosine kinases and G protein-coupled receptors?

A key difference is that the recepter tyrosine kinase can trigger multiple pathways with a single ligand-binding event.

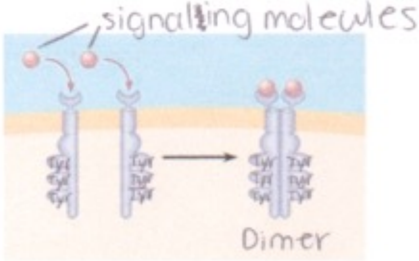
16. Provide all of the missing labels on the diagram; then explain what happens in step 1.

The two recepters exist as individual monomers in part 1. The intracellular tail contains multiple tyrosines and connects to the transmembrane α helix, which connects to the extracellular binding site.



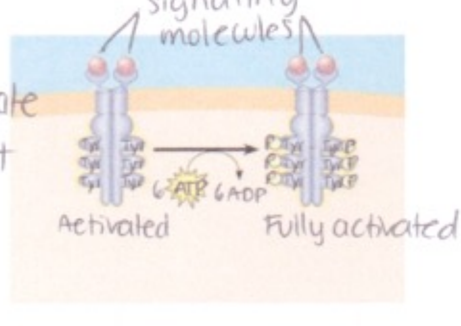
17. Label step 2 and then describe what happens to receptors tyrosine kinases when signaling molecules have attached.

When the signaling molecules attach, the two recepters associate closely and form what is known as a dimer.



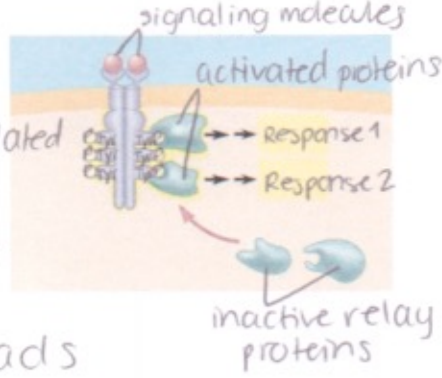
18. Label and explain how the receptors are activated in step 3.

After dimerization, the tyrosine kinase regions are activated. Then each of those adds a phosphate from an ATP molecule to a different tyrosine on the other monomer. After the P-groups are added, the dimer is fully activated.



19. Use step 4 to explain how the activated receptor can stimulate multiple cellular response pathways.

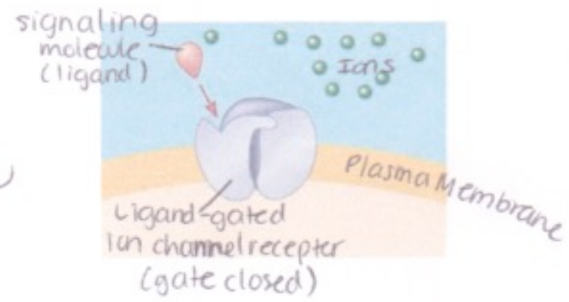
The activated recepter can now be recognized by specific relay proteins that bind to a phosphorylated tyrosine, which changes their shape. This activated form of the proteins can trigger a signal transduction pathway that leads to a cellular response.



20. Each activated protein in the figure above triggers a signal transduction pathway leading to a cellular response.

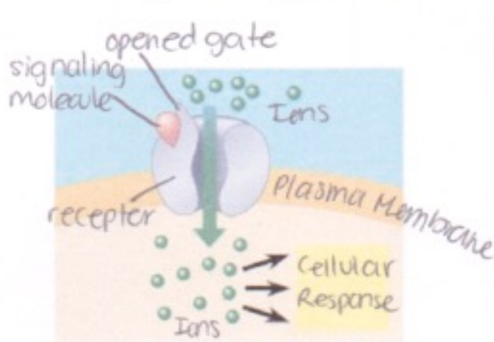
21. Moving to *ion channel receptors*, the example in Figure 11.7 shows the flow of ions into the cell. Ion channel receptors can also stop the flow of ions. These comparatively simple membrane receptors are explained in three steps. In the first step, label the diagram and then explain the role of the labeled molecules.

The signaling molecule will bind to a site on the ligand-gated ion channel recepter, which will allow ions to flow through to change the ion concentration within the cell.



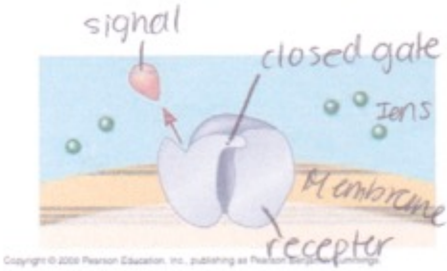
22. Label the diagram and then explain what has happened with the binding of the ligand to the receptor.

The ligand binds, causing the gate to open and allowing specific ions to flow through, which can quickly change the concentration of that ion within the cell. This change can directly affect some cell activity.



23. The ligand attachment to the receptor is brief. Label and explain what happens as the ligand dissociates.

When the ligand breaks away, the gate immediately closes, stopping the flow of ions.

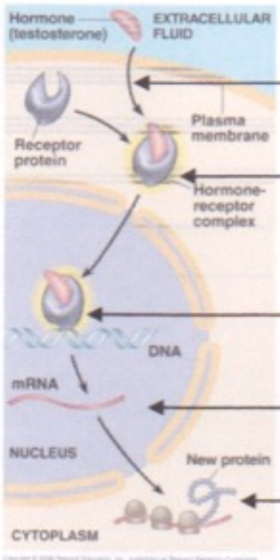


24. In what body system are *ligand-gated ion channels* and *voltage-gated ion channels* of particular importance?

They are important in the nervous system of the body.

25. Intracellular receptors are found in the cytoplasm or nucleus of the cell, where they bond to chemical messengers that are hormones (& hydrophobic) or very small, like nitric oxide.

26. This diagram uses testosterone, a hydrophobic hormone, to detail how intracellular receptors work. At each arrow, add an explanation of what is happening in the cell.



The testosterone passes through the plasma membrane

The hormone binds to receptor protein in cytoplasm, which activates it

The hormone-recepter complex goes into nucleus and binds to specific genes

The band protein acts as a transcription factor & stimulates the transcription of the gene to mRNA

The mRNA is translated into a certain protein by ribosomes

27. An important idea, *transcription factors*, is introduced in Figure11.8. Explain the function of transcription factors in the cell.

Transcription factors are proteins that control which genes are transcribed into mRNA in a cell at a particular time.

Concept 11.3 Transduction: Cascades of molecular interactions relay signals from receptors to target molecules in the cell

28. What are two benefits of multistep pathways like the one in Figure 11.9?

- Possibility of great amplification of a signal
- More opportunities for coordination and regulation of responses

29. Explain the role of these two categories of enzymes in transduction.

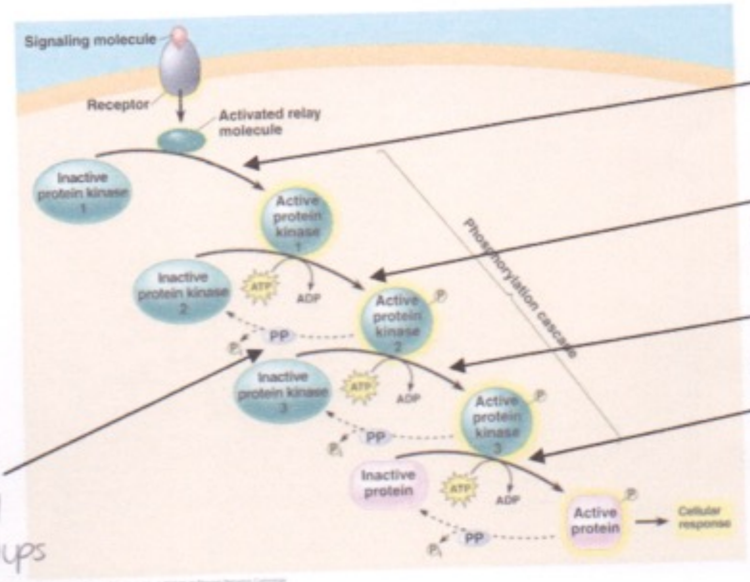
Protein kinase

Transfers phosphate groups from ATP to a protein

Protein phosphatases

Removes phosphate groups from proteins rapidly

30. Using Figure 11.9 as your guide, explain what is occurring in the cell at each arrow.



Relay molecule activates protein kinase 1

Active PK1 transfers phosphate from ATP to inactive PK2, activating it

Active PK2 catalyzes phosphorylation + activation of PK3

Active PK3 phosphorylates a protein that triggers the cell's response

Enzymes (PPs) catalyze removal of phosphate groups from the proteins, making them inactive & available for reuse

31. What is the difference between a first messenger and a second messenger?

The first messenger is the extracellular signaling molecule and second messengers spread through the cell by diffusion, carrying a signal.

32. Two common *second messengers* are cyclic AMP (cAMP) and calcium ions (Ca^{2+}). Explain the role of the second messenger cAMP in Figure 11.11 from the text.

The second messenger, cAMP, broadcasts a signal to the cytoplasm after synthesis by adenylyl cyclase.

33. What is the important relationship between the second messenger and *protein kinase A*?

The second messenger (cAMP) activates protein kinase A, which then phosphorylates various other proteins. This is important to the pathway.

34. Figure 11.11 explains how to initiate a cellular response; how might that response be inhibited?

Phosphodiesterase converts cAMP to AMP, stopping its function. Also, certain G protein systems inhibit adenylylcyclase, which would stop the production of cAMP.

35. Using your new knowledge of cell signaling, explain the mechanism of disease in cholera.

People acquire vibrio cholerae, which is a bacterium that forms a biofilm inside the intestine and produces a toxin that chemically modifies a G protein involved in salt & water secretion. The G protein remains stuck in its active form, stimulating cAMP production, which causes high salt & water secretion (diarrhea).

36. List three types of pathways often induced by calcium ions.

Muscle cell contraction
Secretion of certain substances
Cell division

37. What happens to the cytoplasmic concentration of calcium when it is used as a second messenger?

When it is used as a second messenger, calcium levels rise in the cytoplasm.

Concept 11.4 Response: Cell signaling leads to regulation of transcription or cytoplasmic activities

38. When cell signaling causes a response in the nucleus, what normally happens?

When cell signalling causes a response in the nucleus, (specific) genes are usually turned on or off by activation of a transcription facter, which starts/stops synthesis of mRNA and subsequent protein production.

39. When cell signaling causes a response in the cytoplasm, what normally happens?

When cell signaling causes cytoplasmic response, the activity of a protein is regulated, whether it's an enzyme, ion channel, or relay protein.

40. Figure 11.15 shows a single molecule of epinephrine resulting in the formation of multiple molecules of glucose-1-phosphate!

41. Figure 11.18 shows four different cellular results from a single signaling molecule. Briefly describe each response.

Cell A

Pathway leads to one single response

Cell B

Pathway can branch, leading to two responses (w/ sometimes receptor tyrosine kinases)

Cell C

Cross-talk occurs between two pathways (2 pathways converge for 1 response)

Cell D

Different receptor protein leads to different response

42. How do scaffolding proteins enhance a cellular response?

Scaffolding proteins enhance cellular response by attaching to several other relay proteins and may facilitate phosphorylation cascades or enhance speed & accuracy of signal transfers. (And directly activate some ~~relay~~ proteins)

Concept 11.5 Apoptosis (programmed cell death) integrates multiple cell-signaling pathways

43. What specifically happens to a cell during the process of apoptosis?