

The wnt signaling pathway is critical towards proper embryonic development in organisms, including axis formation and cell determination in organs such as bone, heart, and muscle, and it also has other effects throughout an organism. Indeed, the wnt signaling pathway highlights many important concepts you learned about in this class. Please answer the following 15 questions regarding this pathway.

1. The wnt proteins that initiate the wnt signaling pathway are glycoproteins. The name of the receptor that the wnt proteins bind to is frizzled. What type of receptor is frizzled?

- A. An intracellular receptor
- B. A transmembrane receptor**

Since the wnt proteins are glycoproteins, they will have polar/hydrophilic carbohydrates bound to them. Since the wnt proteins are thus hydrophilic, they will not be able to cross the plasma membrane, so they must bind a membrane receptor to start the wnt signaling pathway. Indeed, frizzled is a transmembrane receptor protein.

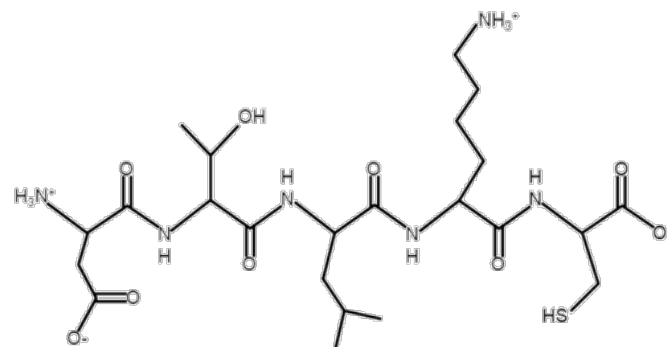
2. In the absence of a ligand, the wnt signaling pathway is not activated and the cytoplasmic protein β -catenin is phosphorylated extensively and gene expression does not occur. Which of the following processes will not occur in this case?

- A. Transcription of the gene under control of β -catenin**
- B. Translation of β -catenin
- C. DNA replication of the gene under control of β -catenin
- D. Transcription of β -catenin
- E. DNA replication of β -catenin

β -catenin will still be replicated, transcribed, and translated since β -catenin is phosphorylated. The gene under control of β -catenin will still be replicated but it will not be transcribed since gene expression is reduced.

3. A portion of the primary sequence of the frizzled receptor is shown to the right. Below are five statements.

1. There are four peptide bonds in this sequence.
2. All of the amino acid R groups in this sequence are polar.
3. There is one basic amino acid and one acidic amino acid in this sequence.
4. One of the amino acids has an R group with a carboxyl group.
5. Some of the R groups can form ionic bonds.



How many of these statements are TRUE?

- A. One
- B. Two
- C. Three
- D. Four**
- E. Five

Statements 1, 3, 4, and 5 are true. Not all of the R groups are polar.

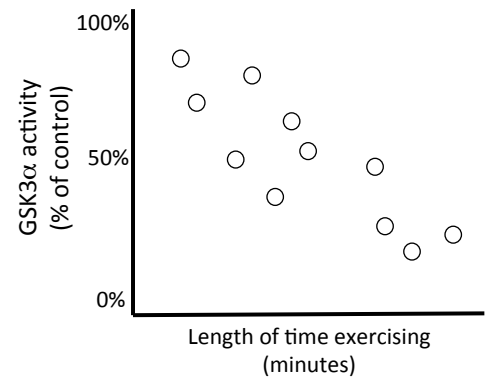
4. The wnt glycoproteins are produced in cells and secreted so that they can initiate the wnt signaling pathway in other cells. What cellular structure produces the wnt proteins? What cellular structure modifies the wnt proteins to make them glycoproteins?

- A. The rough ER makes the wnt proteins and the rough ER modifies them to make them glycoproteins.
- B. Free ribosomes make the wnt proteins and the rough ER modifies them to make them glycoproteins.
- C. Free ribosomes make the wnt proteins and the Golgi modifies them to make them glycoproteins.
- D. The rough ER makes the wnt proteins and the smooth ER modifies them to make them glycoproteins.

Since the wnt proteins are secreted, they will be made by the rough ER. The rough ER also adds sugar groups to proteins making glycoproteins.

5. In the absence of a ligand, the wnt signaling pathway is not activated because the enzyme GSK3 α phosphorylates other proteins which are ultimately degraded by the cell. Researchers collected data on the activity of GSK3 α exercise (shown at the right). During exercise, the intracellular hydrogen ion concentration increases. What possible effect is exercise having on the activity of GSK3 α ?

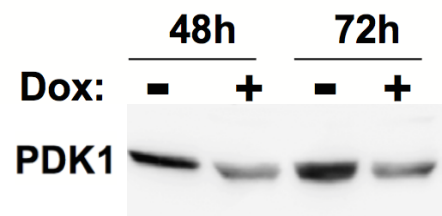
- A. Exercise is increasing the activation energy for the reaction that GSK3 α catalyzes
- B. The change in pH is affecting the tertiary structure of GSK3 α
- C. The more alkaline conditions are causing GSK3 α to be less active and thus hydrolyzed in the cell
- D. Exercise is increasing the rates of transcription of the GSK3 α gene



Since the pH is changing (becoming more acidic), the tertiary structure of GSK3 α may be changing, and thus its function may change, resulting in lower activity

6. The wnt signaling pathway regulates cellular respiration by activating a protein PDK1 that prevents pyruvate from being oxidized to acetyl CoA. Researchers investigated the effects that a drug (Dox) has on this process by introducing Dox to cells and performing a western blot at two time periods after Dox was introduced (data shown to the right). What can you conclude about the effects of Dox?

- A. Less ATP will be generated by chemiosmosis in the presence of Dox
- B. The intermembrane space will be more acidic when Dox is added to cells
- C. NADH concentrations will be lower in the mitochondria in the presence of Dox
- D. If Dox is added to cells, pyruvate will pass more easily through the mitochondrial membrane



The western blot shows that there is less PDK protein in the presence of Dox. Since PDK prevents pyruvate from being oxidized to acetyl CoA, if there is less PDK then there will be more acetyl CoA, so the citric acid cycle and oxidative phosphorylation will proceed at higher rates. Therefore the electron transport chain will pass more hydrogen ions to the intermembrane space, making it more acidic.

7. While plants do not use the wnt signaling pathway, they use other pathways to help regulate photosynthesis. For example, NADP⁺ reductase is the enzyme that controls the rate that NADP⁺ is reduced, and its activity may be regulated by certain pathways. What effect would a decrease in NADP⁺ reductase activity have on a plant cell?

- A. NADPH concentrations would increase
- B. The thylakoid space would become more basic
- C. Less water would be oxidized
- D. Photosystem II would stop working
- E. The cell would make less G3P

If NADP reductase had lower activity, then less NADPH would be made, and the Calvin cycle would not be able to make as much G3P.

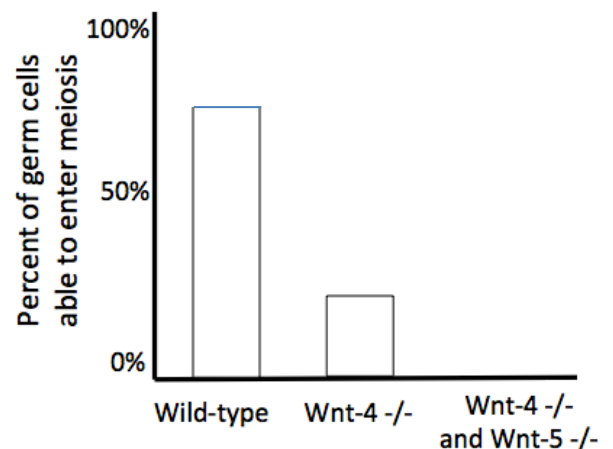
8. One of the proteins involved in the wnt signaling pathway is named dishevelled. At some point in the cell cycle, dishevelled has been shown to interact with kinetochores. What process might dishevelled contribute to?

- A. Attachment of microtubules to chromosomes
- B. Duplication of chromosomes to form sister chromatids
- C. Holding chromosomes together during crossing over
- D. Formation of asters and the early mitotic spindle
- E. Increasing gene expression by unpacking chromosomes

Kinetochores are a protein complex at the centromere of each chromosome, and are involved in attaching microtubules to the chromosomes during prometaphase.

9. Wnt proteins are known to affect meiosis. Researchers investigated the effects of two specific wnt proteins, wnt-4 and wnt-5, on the ability of female ovarian cells to enter meiosis. They collected data (shown at the right) from wild-type ovarian cells, from ovarian cells that were missing both wnt-4 alleles (wnt-4 ^{-/-}) and from ovarian cells that were missing both wnt-4 alleles and both wnt-5 alleles (wnt-4 ^{-/-} and wnt-5 ^{-/-}). What conclusion can you make from these data?

- A. All wild-type female germ cells are able to enter meiosis
- B. Female germ cells are unable to enter meiosis in the absence of wnt-4
- C. Wnt-5 is required for female germ cells to enter meiosis
- D. Both wnt-4 and wnt-5 are necessary for female germ cells to enter meiosis



When wnt-4 was eliminated (wnt-4 ^{-/-}), ~25% of the cells were still able to enter meiosis, so wnt-4 may not be completely necessary for these cells to enter meiosis. However, when wnt-5 was eliminated in the double mutant (wnt-4 ^{-/-} and wnt-5 ^{-/-}), no cells entered meiosis, so wnt-5 must be absolutely necessary for cells to enter meiosis.

10. Familial exudative vitreoretinopathy (FEVR) is an autosomal dominant genetic disorder that results in abnormal blood vessel growth in the eye. Mutations in the *frizzled* gene lead to this disorder. Suppose that a man with FEVR has a baby with a woman who does not have FEVR. What are the chances that their baby has FEVR?

- A. There is a 0% chance because the father has two identical *frizzled* alleles
- B. There is a 50% chance because the father has two different *frizzled* alleles
- C. There is a 100% chance because the father has two identical *frizzled* alleles
- D. There is a 0% chance or a 50% chance because you don't know what *frizzled* alleles the father has
- E. There is a 50% chance or a 100% chance because you don't know what *frizzled* alleles the father has

You know that the mother is homozygous recessive because she does not have FEVR, and that the father is either heterozygous or homozygous dominant because he has FEVR, but you don't know for sure. Doing two different Punnett squares yield either a 50% chance or a 100% chance that their baby will have FEVR.

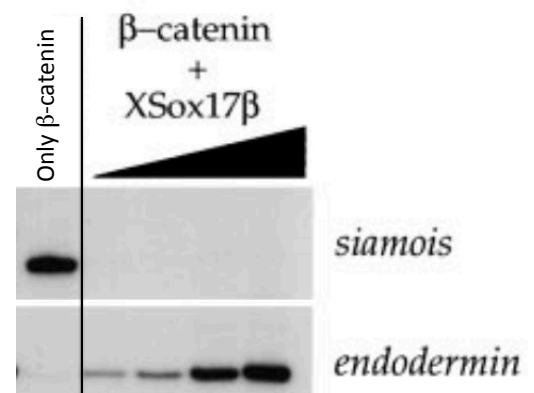
11. In the absence of a ligand, the wnt signaling pathway is not active and a repressor named Groucho blocks expression of target genes by blocking general transcription factor binding sites. What region of DNA does Groucho bind to?

- A. 5-cap
- B. Distal control element
- C. Enhancer
- D. Poly-A tail
- E. TATA box

General transcription factors bind to the TATA box, which is part of the promoter.

12. When the wnt signaling pathway is active, the protein β -catenin is able to regulate the expression of many genes. Researchers investigated the effects of β -catenin on the expression of two genes, *siamois* and *endodermin*, in frog embryos in the presence of β -catenin only and in the presence of β -catenin and increasing amounts of another protein, XSox17 β . A northern blot of their results is shown to the right. Below are four statements about these data:

1. The *siamois* gene is repressed by XSox17 β
2. XSox17 β might be a specific transcription factor for the *endodermin* gene
3. XSox17 β likely degrades the *siamois* protein
4. In the absence of XSox17 β , β -catenin might initiate expression of proteins that remove methyl groups from the *endodermin* gene



How many of these statements are TRUE based on these data?

- A. Zero
- B. One
- C. Two
- D. Three
- E. Four

*Statements 1 and 2 are true. Since this is a northern blot (which measures RNA levels), it is not likely that XSox17 β degrades the *siamois* protein (as you don't have any information to conclude this). If methyl groups were removed from DNA, then that DNA would be unpacked, and more gene*

expression would occur, but in this case there is no expression of the endodermin gene in the absence of XSox17b.

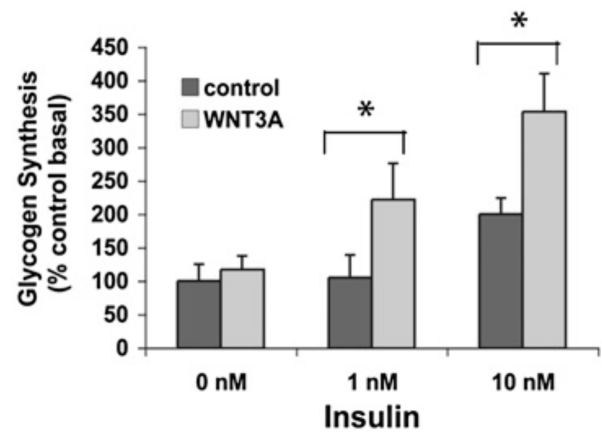
13. Researchers investigated the effects of one of the wnt proteins, WNT3A, on glycogen synthesis in cells. What molecules are required to synthesize glycogen in a cell?

- A. Glucose and water only
- B. Amino acids and a specific enzyme only
- C. Glucose and a specific enzyme only
- D. Amino acids, a specific enzyme, and water only
- E. Glucose, a specific enzyme, and water only

Building larger molecules from monomers (like building glycogen from glucose) are dehydration reactions, which do not require water. They do require the monomers (glucose) and an enzyme to link them together.

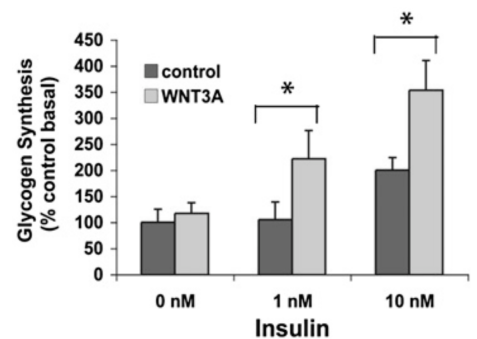
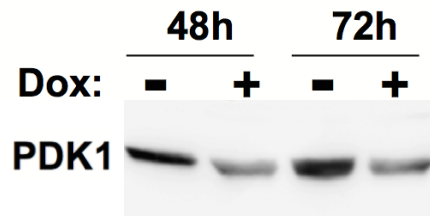
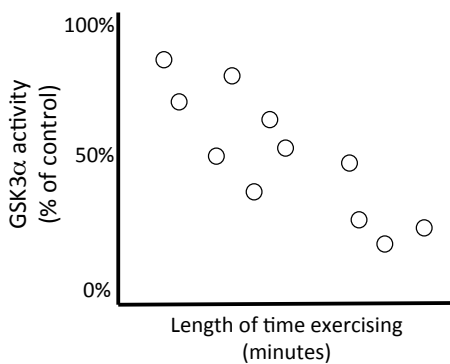
14. Researchers added WNT3A to cells in the presence of insulin and measured glycogen synthesis rates. Glycogen is a polysaccharide made of glucose monomers. Which of the following would produce the OPPOSITE effect of what WNT3A has on glycogen synthesis?

- A. Exposing glycogen to hydrolytic enzymes in lysosomes
- B. Preventing pyruvate from entering mitochondria in skin cells
- C. Increasing the expression levels of glucose transporters in liver cells
- D. Altering the light reactions so that they could take place in the dark



If glycogen is exposed to hydrolytic enzymes in lysosomes, glycogen would be broken down. This is the opposite of what WNT3A does, as WNT3A causes glycogen to be made.

15. How many of the following figures about the wnt signaling pathway show correlation and not causation?



- A. Zero
- B. One
- C. Two
- D. Three

The western blot and glycogen synthesis graph show causation as they involved changing a variable in an experiment and measuring the response. The GSK3 graph shows correlation as they measured the length of time exercising and plotted this against GSK3 activity, but it does not imply that exercising has anything to do with GSK3 activity.

16. Which type of evolutionary mechanism always results in a selective advantage?

Natural selection leads to selective advantages because some organisms outcompete others and have more offspring.

Natural selection

17. What happens to NADPH when the Calvin cycle is active in a chloroplast?

During the Calvin cycle, NADPH donates a hydrogen (and pair of electrons), so NADPH is oxidized to NADP+.

NADPH is oxidized to NADP+

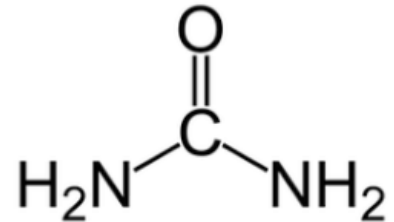
18. NF-κB is a molecule that regulates gene expression. NF-κB binds to the promotor to allow RNA polymerase to begin transcribing DNA. What type of molecule is NF-κB?

Transcription factors bind to promotors to initiate transcription.

Transcription factor

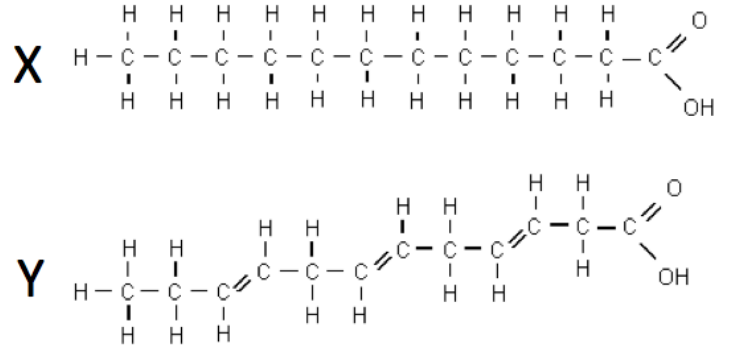
19. Urea (shown to the right) is produced when amino acids are hydrolyzed and is found in large quantities in urine. In the kidneys, the urea concentration is lower inside kidney cells than in the urine. What method of transport would a urea molecule use to exit a kidney cell?

Urea contains amine and carbonyl groups, making it hydrophilic. For urea to move up its concentration gradient it would need the help of a transport protein through the form of active transport.



Active transport

20. Two different fatty acids (X and Y) are shown at the right. Suppose that phospholipids will be made with only these fatty acids and used to make a cell membrane. What would the relationship be between the percentages of these fatty acids in the membrane and membrane fluidity? Draw two straight lines on the graph and clearly label one for fatty acid X and one for fatty acid Y.



Fatty acid X is saturated and fatty acid Y is unsaturated. The fluidity of a membrane is directly proportional to unsaturated fatty acid content. Therefore, as unsaturated fatty acids (Y) increase in proportion, fluidity should increase. Conversely, as saturated fatty acids (X) increase in proportion, fluidity should decrease.

