

MULTIPLE CHOICE MIDTERM REVIEW

Units 1-5

1. One of the largest steps in the evolution of life is the development of eukaryotic cells from prokaryotic cells. The theory of endosymbiosis explains how some steps in this process may have occurred. Which of the following is evidence for this theory?
 - a. Mitochondria have DNA similar to eukaryotes.
 - b. Cellular membranes of all types are composed of phospholipids.
 - c. All living things use the same genetic code.
 - d. Mitochondria and chloroplasts have double membranes.
2. *Pseudomonas aeruginosa* use quorum sensing to coordinate cell aggregation. They grow within a host without harming it until the density reaches a specific concentration. At this point, they use quorum sensing to aggressively reproduce in order to overtake the host's immune system. Which of the following is a true statement about this process?
 - a. When a specific population density is reached, a chemical signal is released to communicate with nearby bacteria.
 - b. This process is initiated when the bacteria are under attack by an antibiotic.
 - c. This process is used when cell junctions are not present for cellular communication.
 - d. Quorum sensing is used to break down biofilms.
3. The image to the right depicts a macrophage of a mouse extending its plasma membrane to engulf smaller foreign particles. What is the correct term for this process?



- a. Phagocytosis
 - b. Pinocytosis
 - c. Exocytosis
 - d. Upregulation
4. The endomembrane system utilizes several organelles to transport proteins to the extracellular fluid. Trace the correct pathway through the endomembrane system during the creation of a protein.
 - a. Nucleus, smooth ER, rough ER, Golgi apparatus, plasma membrane
 - b. Nucleus, Golgi apparatus, rough ER, smooth ER, plasma membrane
 - c. Nucleus, plasma membrane, smooth ER, rough ER, Golgi apparatus
 - d. Nucleus, rough ER, smooth ER, Golgi apparatus, plasma membrane

5. When calculating water potential of cells in solution, why do animal cells always have a pressure potential of zero.
 - a. Animal cells do not have cell walls.
 - b. The plasma membrane of animal cells is able to stretch indefinitely.
 - c. The plasma membrane of animal cells resists pressure.
 - d. The pressure outside of the cell always equals the pressure inside of the cell.
6. The genetic code is termed “universal”. What does NOT prove this statement?
 - a. The same bases A, T, C, and G compose the DNA of every living organism.
 - b. The same bases A, U, C, and G compose the RNA of every living organism.
 - c. Each set of codons code for the same amino acids in every living organism.
 - d. Every living organism’s DNA is exactly the same.
7. Photosystems are a key component of turning sunlight into chemical energy. Which of the following is not true concerning photosystems?
 - a. Photosystems are protein complexes attached to chlorophyll molecules.
 - b. Chloroplasts contain two types of photosystems: I and II.
 - c. Photosystems transfer light energy between pigment molecules.
 - d. Photosystems I and II differ in the type of pigment molecules that surround the chlorophyll.
8. Viral reproduction is a process that eventually causes harm to the host. The timing and form of harm varies. Which statement is not true concerning this process?
 - a. The lytic cycle is a viral reproduction that causes the death of the host cell.
 - b. The lysogenic cycle causes harm to the host approximately 50% of the time.
 - c. In the lysogenic cycle, viral DNA is incorporated into the host DNA.
 - d. Temperate phages utilize both the lytic and lysogenic cycles.
9. Vaccines are composed of weakened or inactivated pathogens. Once introduced into the body, the immune system recognizes and marks the antigens. This process involves all of the following except which one?
 - a. Antibodies
 - b. Mast cell
 - c. B cell
 - d. Phagocyte
10. The gastrin-somatostatin feedback system is located in the stomach. Somatostatin decreases stomach acid by preventing the release of gastrin. This is an example of what process?
 - a. Upregulation
 - b. Positive feedback
 - c. Quorum sensing
 - d. Negative feedback

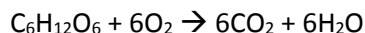
Questions #11-12 refer to the following information:

Vegetables, such as carrots and potatoes, store energy in the form of starch. The energy that they store is used during the next growing season. Animals also use the starch when they ingest it as a source of food.

11. In what part of the plant is starch stored?
 - a. The leaves
 - b. The roots
 - c. The flowers
 - d. The shoots
12. How does starch differ from the energy stores of animals?
 - a. Starch is composed of glucose monomers while animals store energy as galactose monomers.
 - b. Animals store energy as a carbohydrate while starch is a fat.
 - c. Animals store energy as glycogen in the liver.
 - d. Starch is easily digested while animal energy is difficult to digest.
13. The climate in beachfront communities is usually much more moderate than inland communities. Which property of water contributes to this phenomenon?
 - a. High specific heat
 - b. Universal solvent
 - c. Surface tension
 - d. Cohesion
14. Leigh syndrome is a genetic disease that interferes with cellular respiration in mitochondria. This disease usually occurs because of mutations in mitochondrial DNA. If the mutation affects the electron transport chain, what will be a primary result?
 - a. Glucose will not be formed.
 - b. ATP will not be generated.
 - c. FAD will not be reduced.
 - d. Carbon dioxide will not be released.
15. Phospholipids were used in the earliest cellular membranes because of their ability to separate the outer environment from the inner environment. What characteristic enables phospholipids to do this?
 - a. They are hydrophobic.
 - b. They are amphiphilic.
 - c. They are neither hydrophobic or hydrophilic.
 - d. They are hydrophilic.
16. Allosteric regulation is particularly important in cell signaling. Which of the following is true concerning allosteric regulation?
 - a. Activators increase the active site's affinity for the substrate.
 - b. The binding of an inhibitor or activator is irreversible.
 - c. Allosteric inhibitors compete for the active site.
 - d. Inhibitors compete for the active site while activators bind to an allosteric site.

17. Nerve impulses are passed along neurons by depolarization of the membrane. An action potential is triggered when the membrane potential decreases to between -40 and -55 mV. What are the next steps in the pathway?
- Na⁺ gates open causing sodium ions to move into the cell.
 - K⁺ gates open causing potassium ions to move into the cell.
 - The neuron returns to its original state through the action of sodium/potassium pump.
 - Na⁺ gates open causing sodium ions to move out of the cell.

18. In the following equation for cellular respiration, which molecule would be considered the oxidizing agent?

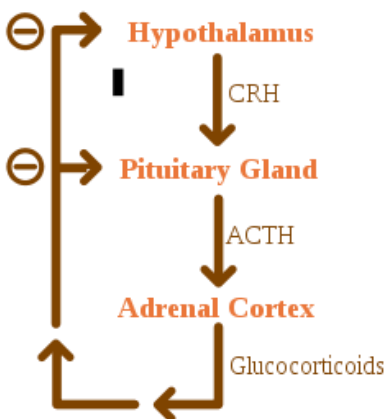


- C₆H₁₂O₆
 - O₂
 - CO₂
 - H₂O
19. In animals with multiple cell layers, a circulatory system is necessary to carry essential molecules throughout the body and to transport waste molecules for excretion. Which of the following is not a component of all circulatory systems?
- Vessels
 - Fluid
 - Heart
 - Capillaries
20. HIV is a particularly dangerous virus because it targets helper T cells. Although there is no cure for HIV, there are several medications that can help to control the disease. One class of medications binds to the protein responsible for initiating the manufacture of DNA from viral RNA. What protein is blocked by this class of medications?
- Integrase
 - DNA polymerase
 - Reverse transcriptase
 - DNA ligase
21. The Calvin cycle comprises a series of reactions during photosynthesis. Which statement is most accurate?
- The Calvin cycle uses NADPH and ATP.
 - The Calvin cycle uses ATP but creates NADPH.
 - The Calvin cycle is light dependent.
 - The Calvin cycle must occur two times to produce 1 G3P molecule.
22. Geckos are lizards found in warm climates throughout the world. They are nocturnal and great climbers. Lacking eyelids, geckos lick their eyes to keep them moist. As reptiles, which of the following is not true about gecko bioenergetics?
- A gecko's body temperature is similar to that of its surroundings.
 - When a gecko is cold, it is more vulnerable to predators.
 - A gecko must constantly hunt for food to stay alive.
 - They maintain a minimal amount of cellular respiration.

23. What will happen if the gene for human growth hormone is inserted into a bacterial cell?
- The bacterium will produce a bacterial version of the protein.
 - The bacterium will not produce the alien protein.
 - The bacterium will expel the human DNA from its DNA.
 - The bacterium will produce the human version of the protein.
24. *Methanobrevibacter smithii* is a member of Archaea. This bacteria lives in the human gut and aids in the digestion of polysaccharides. What is a true statement concerning members of this domain?
- They are multicellular.
 - They cannot survive extreme conditions.
 - They contain ribosomes.
 - Their DNA is located in a nucleus.
25. Suppose that an enzyme is operating at its maximum rate. What could be changed so that products of the catalyzed reaction are produced in larger quantities?
- Add more enzyme.
 - Remove the product.
 - Add more substrate.
 - Change the pH of the solution.
26. Normally, DNA is tightly packaged into cords termed chromatin. For transcription to occur, what molecule unwinds the target genes from the chromatin?
- RNA polymerase
 - DNA polymerase
 - Topoisomerase
 - Single stranded binding protein
27. The unique structure of every protein enables this group of macromolecules to have a variety of functions. Which of the following is not an example of a protein?
- Chitin – gives structural support to exoskeletons of arthropods
 - Hemoglobin – transports oxygen throughout the body
 - Actin – a contractile molecule in muscles
 - Amylase – digestive enzyme that breaks down starch
28. Prion diseases, such as transmissible spongiform encephalopathy (TSE), involve normally-shaped proteins transforming into abnormally-shaped infectious proteins. The conformation of the normal proteins is changed to include high numbers of beta-pleated sheets. At which level of protein structure does this transformation occur?
- Primary
 - Secondary
 - Tertiary
 - Quaternary

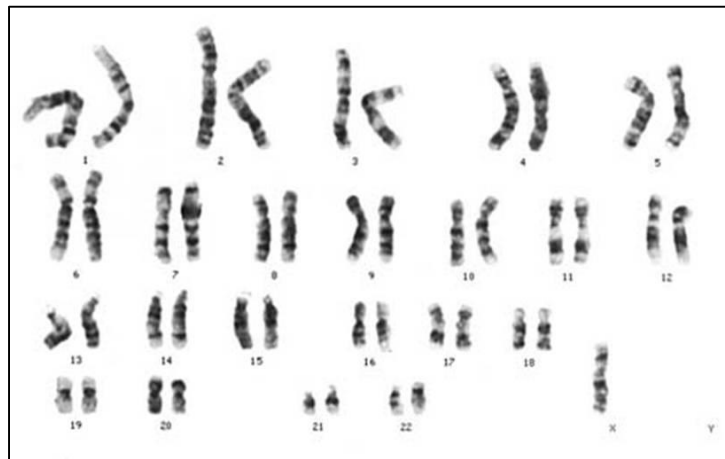
29. Which of the following is not a common feature of life that points to the Last Universal Common Ancestor?
- Mitosis and meiosis for cellular division
 - Lipid bilayer in cellular membranes
 - Sodium and potassium pumps
 - 20 amino acids for assembling proteins
30. The liver is an organ that detoxifies substances, such as alcohol and drugs. Therefore, liver cells have large amounts of what cellular organelle?
- Rough Endoplasmic Reticulum
 - Smooth Endoplasmic Reticulum
 - Mitochondria
 - Vacuole
31. There are a variety of different respiratory systems, such as the outer skin of earthworms, the gills of fish and the lungs of animals. Despite the differences among these systems, what one thing do they have in common?
- Alveoli
 - Coelom
 - Moist surfaces
 - Diaphragm
32. Plant immunity differs somewhat from animal immunity. Which of the following describes a defense strategy that is not present in plants?
- An outer covering serves as the first line of defense.
 - Cells work together to defend against a pathogen.
 - Cells secrete an antimicrobial agent that kills or disables pathogens.
 - Cells can undergo programmed cell death to stop a pathogen from spreading.
33. The cellular membrane is selectively permeable. Which of the following molecules are able to diffuse through the lipid bilayer of the plasma membrane?
- Glucose
 - K⁺
 - Water
 - Sucrose
34. What is the correct classification of the extracellular solution when an animal cell is placed in distilled water?
- Hypotonic
 - Hypertonic
 - Isotonic
 - Equilibrium

35. In recent years, roses have been genetically modified to last longer as cuttings. This modification most likely involves the increased production of what hormone?
- Auxins
 - Cytokinins
 - Gibberellin
 - Estrogen
36. After transcription, mRNA is modified in several ways. Which of the following is not something that happens to mRNA during this process?
- The poly-A tails are excised.
 - Introns are taken out.
 - 5' cap is added.
 - RNA splicing.
37. The image depicts a feedback system in the human body. CRH is corticotropin-releasing hormone and ACTH is adrenocorticotropic hormone. What is the best explanation for the image?



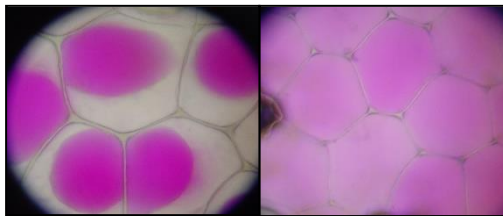
- As a positive feedback loop, as the amounts of glucocorticoids increase, products from the hypothalamus and pituitary gland are also increased.
 - As a negative feedback loop, glucocorticoids reduce the production of CRH in the hypothalamus and ACTH in the pituitary.
 - As a negative feedback loop, CRH inhibits the production of ACTH.
 - As a negative feedback loop, ACTH inhibits the production of glucocorticoids.
38. Many prokaryotes contain plasmids. Which of the following is an incorrect statement concerning plasmids?
- Plasmids are long and coiled, like a spring.
 - Plasmids are independent of the bacterial chromosome.
 - F plasmids increase genetic variability in prokaryotes.
 - R plasmids give the cells immunity to certain antibiotics.

39. The reactions of photosynthesis are completed during several steps. Which is the correct sequence?
- Calvin cycle, photosystem I, photosystem II
 - Photosystem I, Photosystem II, Calvin cycle
 - Photosystem II, Calvin cycle, photosystem I
 - Photosystem II, photosystem I, Calvin cycle
40. Suppose that a plant cell is placed in distilled water. What would happen?
- Turgor pressure would increase.
 - The cell would remain unchanged.
 - The cell would shrivel.
 - The cell would swell and lyse.
41. Gastric acid in the stomach produces an environment with a pH of 1-2. Human stomach cells have several ways to survive this environment. Some cells create a mucous layer that physically protects the cells. Other cells produce bicarbonate a molecule that chemically protects the cells by neutralizing the effects of stomach acid. This ability to keep aspects of cell life in balance and to avoid damage can best be described as what?
- Metabolism
 - Chemical reactions
 - Homeostasis
 - Signal transduction pathways
42. What does this karyotype indicate about the individual?



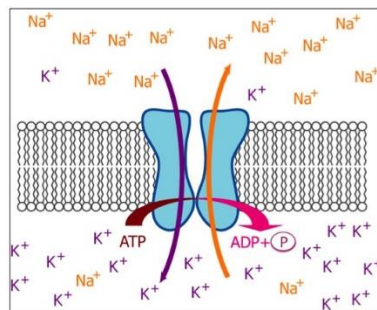
- The individual is haploid.
 - The individual will be female but may have abnormalities.
 - The individual has an extra chromosome.
 - The individual will be male but may have abnormalities.
43. DNA replication is a precise process that must minimize error. Which statement is not true?
- DNA primase adds each new nucleotide to the growing strand.
 - Nucleotides can only be added to the $-OH$ end.
 - Each new strand of DNA contains one template strand and one new strand.
 - Helicase breaks the covalent bonds that hold the nucleotides together.

44. The two photos illustrate an important aspect of plant cell anatomy. What is not a function of the dark stained structure?



- a. Store water
 - b. Create turgor pressure
 - c. Package proteins
 - d. Store pigments
45. Structure and function is a reoccurring theme in biology. How does the structure of ATP relate to its function of storing energy?
- a. Energy is only released when activated by mitochondrial enzymes.
 - b. The hydrolysis of each phosphate group is exergonic.
 - c. The phosphate groups attract each other.
 - d. The hydroxyl group of each phosphate is ionized.
46. Richard Dawkins of Oxford University stated the following: “They are the replicators and we are their survival machines. When we have served our purpose, we are cast aside. But genes are denizens of geologic time: genes are forever.” If genes, in fact, last forever, what will also last forever?
- a. Phospholipids
 - b. Glucose
 - c. Nucleic acids
 - d. Triglycerides
47. An herbicide that interrupts the transfer of electrons and interferes with the synthesis of ATP and NADPH most likely affects which of the following?
- a. Photosystems I and II
 - b. Mitochondrial activity
 - c. Activity in the stroma
 - d. Stomata opening
48. Fish, frogs and humans have closed circulatory systems. A fish has a 2 –chambered heart; a frog has 3-chambered heart; and a mammal has a 4-chambered heart. Which of the following is an incorrect statement about these circulatory systems?
- a. Fish blood is oxygenated via the gills.
 - b. Frogs have one atria and two ventricles.
 - c. Mammalian blood moves from the right ventricle to the lungs.
 - d. Swimming assists in the movement of blood in the fish circulatory system.

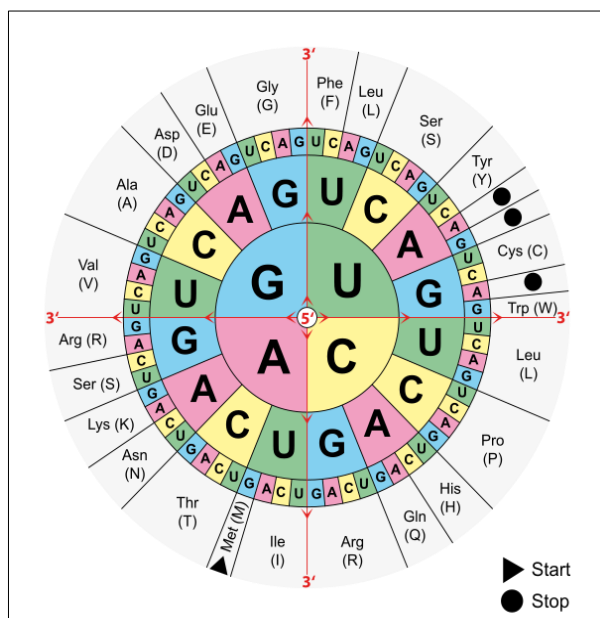
49. Cell-mediated response begins with a signal transduction pathway in which the affected cell turns into a dendritic cell. Which of the following is not something that will happen after this step?
- Helper T cells attach to the cell.
 - Immunoglobulins bind with the antigen.
 - Cytokines communicate with other immune cells.
 - Cytotoxic T cells inject hydrolytic enzymes into the cell.
50. The *trp* operon is a repressible operon in bacteria. The *trp* operon codes for several genes responsible for the production of tryptophan. If tryptophan is present in the environment, what would occur?
- The operon is activated and transcription is amplified.
 - The operon is turned off and transcription stops.
 - An inducer binds to the tryptophan, allowing transcription to continue.
 - A co-repressor binds to tryptophan and transcription is amplified.
51. Milk can be transformed into yogurt via the fermentation of the bacteria *Lacto bacillus*. What is a true statement about this process?
- It will only occur in the presence of oxygen.
 - It does not include glycolysis.
 - It produces less energy than aerobic respiration but is not dependent on oxygen.
 - It regenerates a supply of NADH.
52. Apical dominance occurs in terminal buds and negatively affects the growth of lateral buds. When the terminal bud is removed, apical dominance stops and lateral buds are able to grow. What is removed with the terminal bud that is responsible for this result?
- Ethylene
 - Giberellin
 - Cytokinins
 - Auxin
53. The sodium-potassium pump is an important component of cellular membranes. Based on this illustration, which statement is correct?



- This is an example of facilitated transport.
- Sodium is pumped into the cell.
- This is an example of active transport.
- Potassium moves with its concentration gradient.

54. DNA is known to be antiparallel. To what does this refer?
- A purine will always pair with a pyrimidine.
 - In the phosphate-sugar backbone, the phosphate group is perpendicular to the sugar group.
 - Bases are only added to the 5' end.
 - One strand runs 3' to 5' while the other runs 5' to 3'.
55. In what way does the nucleus of eukaryotic cells differ from prokaryotic cells?
- It consists of a nucleoid region.
 - It contains DNA.
 - It has a double membrane.
 - It may contain plasmids.
56. Some scientists believe that RNA is essential to the evolution of life on Earth. Which of the following is not one of the capabilities of RNA that supports this theory?
- Catalyzation
 - Metabolism
 - Immune defense
 - Replication
57. Gel electrophoresis is a technique that loads a digest into a network of collagen. What is the purpose of gel electrophoresis?
- To separate DNA fragments based on size
 - To create recombinant DNA
 - To isolate restriction enzymes
 - To separate DNA fragments based on polarity
58. Chemiosmosis is an important component of aerobic respiration. Which of the following is not correct about this process?
- It utilizes an integral protein.
 - It results in the generation of ATP.
 - It transports H^+ via active transport.
 - It occurs across the inner membrane of the mitochondria.
59. Which of the following is an example of a positive feedback mechanism?
- Increased blood sugar levels trigger insulin which lowers blood sugar level.
 - Increased body temperature triggers sweating which lowers body temperature.
 - After an injury, the aggregation of platelets initiates the attraction of more platelets, which then form a clot.
 - When blood pressure rises, heart rate slow which lowers blood pressure.
60. EcoRI is a restriction enzyme found in *E. coli* that makes a staggered cut in DNA when it reads the sequence GAATTC. What is the purpose of this behavior?
- To separate pieces of DNA for replication
 - To separate pieces of DNA for translation
 - To defend against invading phages
 - A tool for altering host DNA

Refer to the codon chart below to answer questions #61-62.



61. A codon whose first base is guanine would not code for which amino acid?
- Serine
 - Alanine
 - Valine
 - Glycine
62. The codon that codes for arginine could be transcribed from what DNA sequence?
- 5'-GCT-3'
 - 5'-TCG-3'
 - 5'-CGA-3'
 - 5'-AGC-3'
63. Scientists are currently studying mouse brain cells undergoing development. Cell-to-cell communication is very important in brain tissue. Which type of cell junction would facilitate communication in a mouse cell?
- Plasmodesmata
 - Desmosome
 - Tight junction
 - Gap junction
64. Carbonic anhydrase catalyzes the following reaction:
- $$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$$
- Which of the following is an inaccurate statement about this enzyme?
- Carbonic anhydrase changes shape slightly after CO_2 and H_2O bind to it.
 - If the structure of carbonic anhydrase is altered, it would no longer function.
 - Carbonic anhydrase can catalyze any reaction that requires an enzyme.
 - Carbonic anhydrase lowers the activation energy necessary to start the reaction.

65. A grasshopper has an open circulatory system while a mouse has a closed circulatory system. Which of the following is not something found in a mouse?
- Arteries
 - Heart
 - Hemolymph
 - Veins
66. Active transport and facilitated transport differ in their mechanisms but are similar in that they both use transport proteins in the membrane. Which of the following is used by both types of transport?
- Channel protein
 - Carrier protein
 - Essential protein
 - Peripheral protein
67. If glucose molecules undergo dehydration synthesis, which of the following would not be a result?
- Chitin
 - Cellulose
 - Glycogen
 - Sucrose
68. This paramecium just acquired the dark-colored food particles via endocytosis. From where did the food particles come?



- Endomembrane system
 - Outside the paramecium
 - Central vacuole
 - Products of photosynthesis
69. In prokaryotes, the lac operon is an inducible operon that contains genes that code for enzymes that break glucose down into lactose. Which of the following is not true about the lac operon?
- When lactose is present, no enzymes are made.
 - Lactose inactivates the repressor.
 - When the repressor is active, no enzymes are made.
 - This operon is usually off but can be turned off by an inducer.

70. Before protein can be translated from DNA, the DNA strands must first be transcribed into mRNA. Which of the following is not something that occurs as part of this process?
- a. RNA polymerase attaches to the non-template strand.
 - b. Chromatin-modifying enzymes unwind sections of DNA.
 - c. Introns are removed prior to translation.
 - d. RNA polymerase ends transcription when it reaches a stop sequence.
71. Once pathogens have entered body cells, what type of immune response is triggered?
- a. Innate
 - b. Humoral
 - c. Clonal
 - d. Cell-mediated
72. Once phospholipids made membranes possible, enclosed spaces were available where more complex chemistry could occur. These precursors to life are also known as what?
- a. LUCA
 - b. Protobionts
 - c. Liposome
 - d. Micromolecules
73. Which organism would reproduce via binary fission?
- a. *E. coli* – rod-shaped bacteria that live in the intestines of animals and can cause food poisoning in humans
 - b. Euglena – unicellular, photosynthetic protists found in quiet, inland waters
 - c. Kelp – large algae that grow underwater and can reach up to 80 meters in height
 - d. Poliomyelitis – an acute virus that causes inflammation of the spinal cord

Questions #74-75 refer to the following information:

Auxin is an important hormone in plants. When auxin comes in contact with a plant cell, it binds to an auxin receptor on the surface of the cell. This causes several changes to occur on the inside of the cell, including the transcription of specific genes that produce proteins responsible for cell growth.

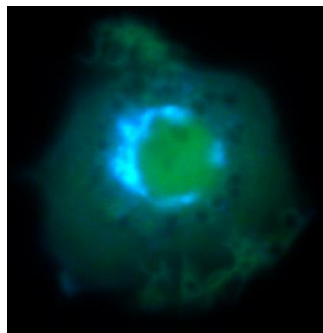
74. By what type of pathway does auxin operate?
- a. Synaptic
 - b. Signal transduction
 - c. Transport
 - d. Enzymatic
75. The mechanism of auxin is also involved in phototropism. Which of the following is a correct statement about auxin's role in phototropism?
- a. Auxin migrates away from sunlight.
 - b. Auxin is produced exponentially in the presence of sunlight.
 - c. Auxin is attracted by sunlight.
 - d. Auxin forces the dark side of the plant to grow away from the sunlight.

76. Endocrine cells secrete hormones that travel throughout the body via the blood vessels. The hormones reach all cells of the body; however, only certain cells will respond to the hormone. What is an accurate explanation for this occurrence?
- Not all cells use endocytosis to engulf particles.
 - Only certain cells have receptor proteins that recognize a specific hormone.
 - The hormones remain in the blood vessel until they reach the target cells.
 - Hemoglobin in the blood only releases the hormones at designated cells.
77. Alanine is an amino acid that has a hydrophobic side chain. Which of the following would be a product of the hydrolysis of several alanine molecules?
- Polypeptide chain
 - NH_3^+
 - CH_3
 - Nucleotide
78. What do viruses have in common with their hosts?
- Genetic code
 - Enzymes
 - Macromolecules
 - Ribosomes
79. Some chemosynthetic bacteria located in the deep sea use an alternate energy source, as seen in the equation below. Which statement is not correct about this process?
- $$\text{CO}_2 + 2\text{H}_2\text{S} = \text{CH}_2\text{O} + \text{H}_2\text{O} + 2\text{S}$$
- Bacteria create energy by using inorganic molecules.
 - This process creates sulfur deposits.
 - These bacteria do not have access to sunlight.
 - The deep zone environment of the bacteria is aerobic.
80. Endotherms vary greatly in size. Elephants can grow up to 7,000 kg; horses can grow up to 1,000 kg; opossum can grow up to 7 kg; and mice can grow up to 25 g. Which animal would have the highest metabolic rate?
- Elephant
 - Horse
 - Opossum
 - Mouse
81. What would be the correct pathway for an amino acid in the cytoplasm during translation?
- $\text{tRNA} \rightarrow \text{P site} \rightarrow \text{A site} \rightarrow \text{polypeptide chain}$
 - $\text{rRNA} \rightarrow \text{tRNA} \rightarrow \text{polypeptide chain}$
 - $\text{mRNA} \rightarrow \text{tRNA} \rightarrow \text{polypeptide chain}$
 - $\text{tRNA} \rightarrow \text{A site} \rightarrow \text{P site} \rightarrow \text{polypeptide chain}$

Questions #82-84 refer to the following information:

Cyanobacteria are a group of photosynthetic bacteria. As organisms that are capable of releasing oxygen as a product of photosynthesis, cyanobacteria are believed to have played a major role in converting the reducing atmosphere of early Earth into an oxidizing one.

82. Prevalent in marine environments, cyanobacteria are often referred to as blue-green algae. This name is misleading because cyanobacteria are prokaryotic while algae are eukaryotic. What is another difference between the two?
- a. Chromosomes
 - b. Ribosomes
 - c. Nucleus
 - d. Plasma membrane
83. The ability of plants and algae to photosynthesize may have evolved from cyanobacteria. What is this theory called?
- a. Transduction
 - b. Abiogenesis
 - c. Endosymbiosis
 - d. Protobiont
84. When a cyanobacterium reproduces, what is the result?
- a. Four cells, each with parent DNA.
 - b. Four cells, each with daughter DNA.
 - c. Two cells, one with parent DNA and one with daughter DNA.
 - d. Two cells, each with half parent / half daughter DNA.
85. The image shows an immune cell called a macrophage. The cell has been prepared with a special staining technique and viewed under a light microscope. The fluorescently-stained protein shown in the image is the Golgi apparatus. This organelle is particularly extensive in cells that specialize in what activity?

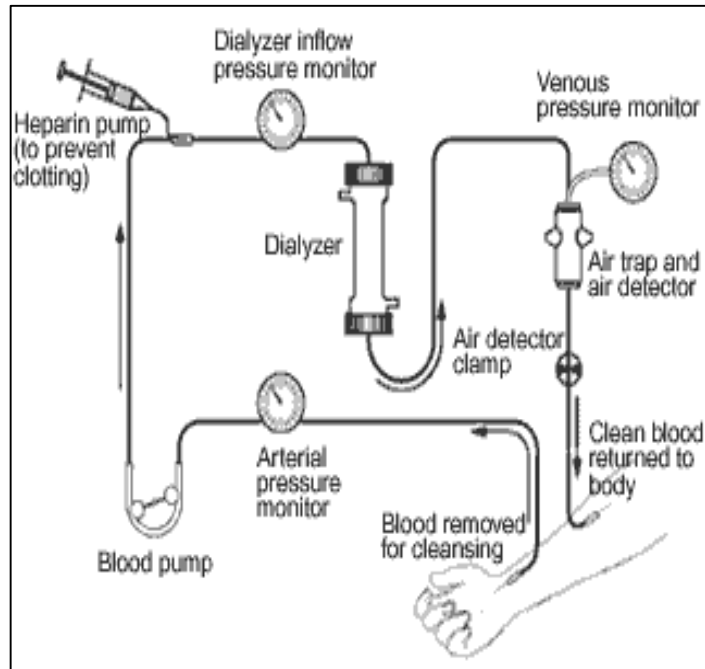


- a. Energy production
- b. Detoxification
- c. Secretion
- d. Digestion

86. Suppose that a man trips while walking across a wood deck. As a splinter enters his foot, which of the following is not something that will be triggered by the innate immune response?
- Mast cells release histamine.
 - Phagocytes remove foreign bacteria.
 - Lymphocytes enter the area.
 - Inflammation occurs near the splinter.
87. An animal cell with a solute potential of -2.0 bar is placed into a solution with a solute potential of -1.5 bar. What is the net direction of water?
- Into the cell
 - Out of the cell
 - The cell is at equilibrium.
 - Equal amounts of water move into and out of the cell.
88. Which is an example of downregulation?
- Cells continually amplifying a signal until an outcome is reached.
 - Type II diabetes is characterized by elevated levels of insulin in the bloodstream and a loss of insulin receptors.
 - An increase in uterine oxytocin receptors in the third trimester of pregnancy, promoting the contraction of the smooth muscle of the uterus.
 - An increase of carbon dioxide receptors characteristic of emphysema.
89. C_4 plants first incorporate carbon dioxide into a 4-carbon compound before entering into the Calvin cycle. This process requires special plant anatomy, but photosynthesis is completed faster and water use is more efficient. In C_4 plants, where does the Calvin cycle occur?
- Stomata
 - Vascular tissue
 - Bundle-sheath cells
 - Mesophyll cells
90. Translation of mRNA into protein is initiated by a start codon AUG. What sequence of tRNA would pair with this codon?
- AUG
 - UAC
 - GUA
 - TAC
91. Which of the following is not correct concerning cell sizes?
- The volume of the cell determines the amount of chemical activity it can carry out per unit time.
 - As a cell grows in size, its surface area to volume ratio increases.
 - Individual cells are limited in size.
 - Prokaryotic cells are generally smaller than eukaryotic cells.

92. Mitochondrial diseases are a type of genetic disease in which the defective gene(s) are located in the mitochondrial DNA. Mitochondrial diseases can present with varied symptoms depending on where in the body the defective mitochondria are located. The symptoms are most serious when the defective mitochondria are located in the muscles, cerebrum or nerves. Why would this be true?
- These cells contain the least amount of mitochondria.
 - Respiration exceeds photosynthesis in these cells.
 - Cell division is the slowest in these cells.
 - These cells use the most energy in the body.
93. While the structure of DNA is universal, every strand of DNA codes for different genes. What structural component allows this versatility?
- Phosphate-sugar backbone
 - Phosphate-base backbone
 - The type of sugar used
 - The order of bases
94. The *Welwitschia mirabilis* is a plant native to Namibia. It has been known to live 1500 years and can survive up to five years with no rain. A predator of the *W. mirabilis* is the zebra, an herbivorous mammal. Which of the following is not a difference between a *W. mirabilis* cell and a zebra cell?
- Cell wall
 - Peroxisome
 - Central vacuole
 - Chloroplast
95. While studying replication in a laboratory setting, a researcher discovers a defect that affects the ability of topoisomerase to operate during replication. What would be a possible result of this defect?
- Okazaki fragments would not be connected to each other.
 - The hydrogen bonds between the bases would not be broken and no replication fork would form.
 - DNA would become overwound and replication would stop.
 - New bases would not be added to the daughter strand.
96. Which statement is incorrect concerning the early earth?
- All the heavier atoms on the periodic table were created by nuclear fusion inside early stars, or when they exploded.
 - None of the heavier elements (above helium) existed at the dawn of the universe.
 - The early atmosphere was composed of He, H₂ and O₂.
 - Water vapor in the air condensed to form the oceans.

97. Kidneys are organs that help maintain homeostasis by filtering the blood to remove waste particles and to regulate the amounts of essential molecules. When kidneys are not functioning optimally, dialysis is used. Dialysis uses the principles of osmosis and diffusion, along with a specialized fluid (dialysate) and pumps, to simulate the action of the kidneys. Blood is removed from the body and passed through a series of semi-permeable membranes contained in a tube termed the dialyzer.



If the dialysate is prepared with 1,800 mg/dL of glucose and normal blood plasma contains between 70 and 125 mg/dL of glucose, what effect can be expected?

- a. Glucose will flow out of the blood plasma and into the dialyzer.
 - b. Glucose will flow into the blood plasma.
 - c. Water will flow out of the blood plasma into the dialysate.
 - d. Water will flow into the blood plasma.
98. In aquatic plants, stomata are located in the upper epidermis. In many land plants, however, stomata are located in the lower epidermis. Why would this adaptation be beneficial for land plants?
- a. Increases camouflage.
 - b. Increases photosynthetic rate.
 - c. Decreases respiration.
 - d. Prevents water loss.

Questions #99-100 refer to the following information:

Hemoglobin is a protein composed of four subunits that carries oxygen and carbon dioxide throughout the body. Oxygen and carbon dioxide each have a separate binding location on hemoglobin. When one oxygen molecule binds to hemoglobin, a conformational change increases the affinity of the molecule for oxygen, enabling three more oxygen molecules to quickly bind. When carbon dioxide binds to a hemoglobin molecule, it lowers its affinity for oxygen.

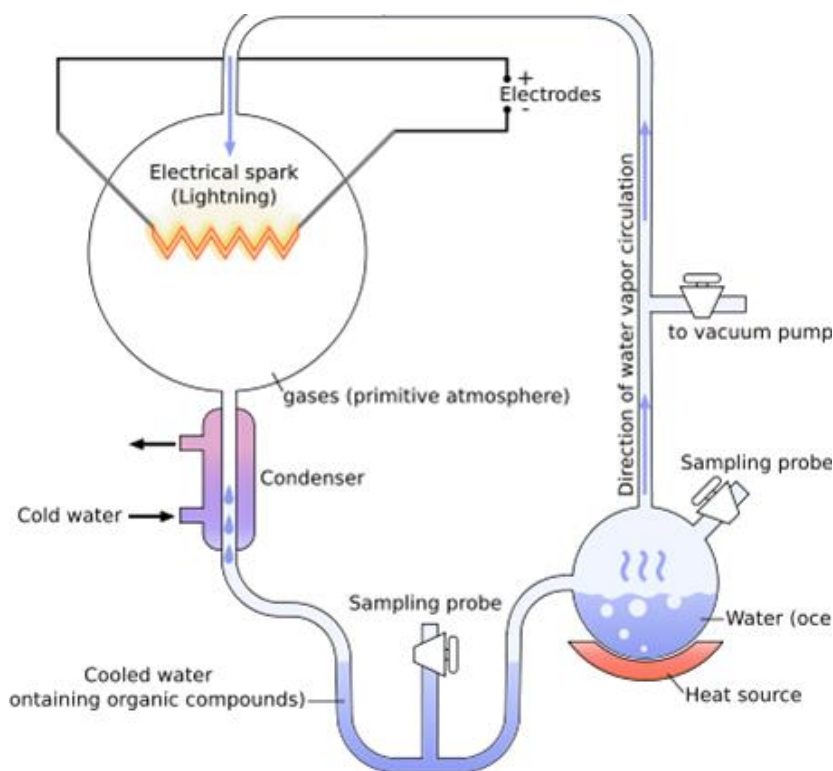
99. Based on the information above, which of the following is not something displayed by hemoglobin?
- Allosteric regulation
 - Cooperativity
 - Catalysis
 - Induced fit
100. Carbon monoxide (CO) can fit in the same binding site as oxygen on the hemoglobin molecule. Hemoglobin, in fact, has a higher affinity for CO than it does for O₂. This means that a small amount of CO can drastically decrease hemoglobin's ability to transport O₂ throughout the body. Carbon monoxide poisoning occurs when people inhale CO and effectively suffocate. What type of molecule is CO?
- Catalytic inhibitor
 - Competitive inhibitor
 - Allosteric inhibitor
 - Noncompetitive inhibitor

QUANTITATIVE

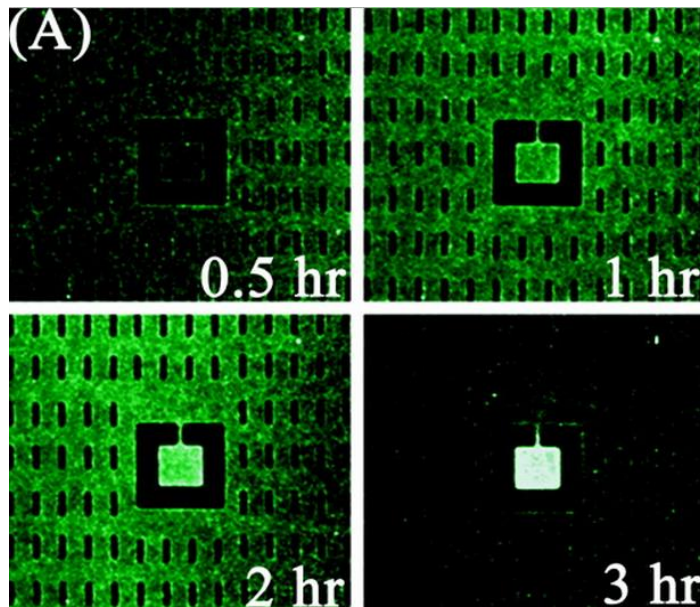
- A turgid plant cell is placed in pure water and has reached osmotic equilibrium. If the solute potential of the cell is -9.0 bar, what is the pressure potential of the cell?
- A bag of dialysis tubing is filled with a solution containing 0.7 M NaCl and 0.2 M sucrose. To two significant figures, what is the solute potential when maintained at 15°C?
- Phycocyanin is an accessory pigment used in photosynthesis. Phycocyanin molecules aggregate in groups on the surface of chlorophyll. A phycocyanin photon has a wavelength of 650 nm. What is the frequency of this photon?
- In cellular respiration, NADH and FADH₂ donate electrons to the electron transport chain. Because NADH donates electrons at a different location on the chain than FADH₂, the two molecules generate a different amount of ATP, with FADH₂ generating 1.5 ATP and NADH generating 2.5 ATP. In a reaction that creates 21 NADH and 7 FADH₂, how many ATP will be generated from the electron transport chain?
- The surface area to volume ratio of a sphere with a diameter of 330nm is x:1. Solve for x.

6. Red blood cells in the body measure $6\text{ }\mu\text{m}$ across. Although capillaries through which they travel are $8\text{--}10\text{ }\mu\text{m}$ across, major blood vessels can be much wider, up to 1 cm . Rounded to two significant figures, how many red blood cells could fit, from side to side, in a major blood vessel?
7. Polymerase Chain Reaction is a technique that is used to amplify sections of DNA. It has come to have a variety of uses, such as cloning, forensic science and the analysis of hereditary disease. If a strand of DNA undergoes 19 cycles of PCR, how many strands of DNA are present?
8. Myoglobin is a protein found in the muscles of vertebrates. High myoglobin levels allow animals to hold their breaths for long durations. It is found in high concentrations in diving mammals, such as whales. The human form of myoglobin contains 154 amino acids. In the translation of myoglobin, how many base pairs long would the mRNA molecule be?

FREE RESPONSE



1. The Miller-Urey Experiment.
 - a. How would you use the experimental setup shown on the diagram on the left to test the Miller-Urey hypothesis of the origin of life on Earth?
 - b. Why did you select the specific chemicals to put in the experiment?
 - c. This experiment was successful in establishing that chemical reactions can result in the synthesis of organic compounds. For these organic compounds to develop into “life” certain characteristics must be met, explain these characteristics.
 - d. An alternate hypothesis to “primordial soup” hypothesis tested here is the “hydrothermal vent” hypothesis. Describe this hypothesis.

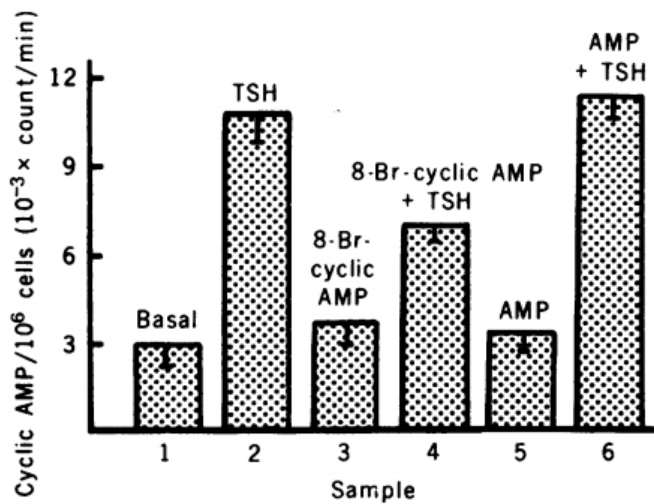


Motion to Form a Quorum

Sungsu Park, Peter M. Wolanin, Emil A. Yuzbashyan, Pascal Silberzan, Jeffry B. Stock, and Robert H. Austin
 Science 11 July 2003: **301** (5630), 188

- Why and how are the *E. coli* bacteria moving into the enclosure or box in the middle of the plate?
- Describe why the cells would move or not move in this manner if they were grown in a nutrient media (liquid/agar) with all the essential nutrients?

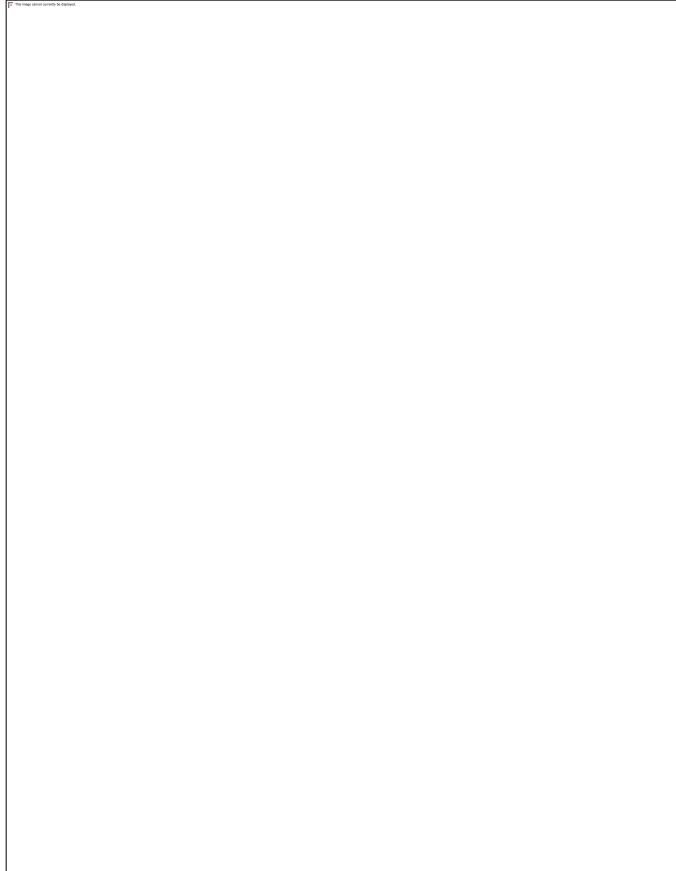
2. The diagram shows *E. coli* bacteria growing in minimal nutrient media at 4 time points as they accumulate into a central 250 μm by 250 μm enclosure (100- μm -wide black walls in the center) via a 40- μm -wide channel (opening). After 3 hours the density of cells is more than seven times greater inside than outside (bright center, dark exterior at the 3 hr mark). The black rectangles are silicone pillars that support the roof of the growing chamber. The attraction of cells to each other is mediated by the sensing of amino acids such as serine, glycine, alanine, cysteine, and aspartate.



3. Normal function of the thyroid gland is regulated by the pituitary gland in the brain through the hormone thyrotropin (also called Thyroid-stimulating hormone: TSH). TSH binds to specific receptors on the membrane of thyroid cells and induces a variety of biological responses. The graph shows the radioactive amounts of cyclic adenosine monophosphate (cAMP) in six experiments with rat thyroid-derived cells that are grown with the chemicals shown on top of each bar. 8-Br-cAMP is a chemical analog of cAMP and mimics the effects of cAMP (chemical formulas shown below graph). The bar designated as basal means no TSH, 8-Br-cAMP, or cAMP were added. Adenylate cyclase is the enzyme that makes cAMP by dehydrating AMP.

cAMP	8-Br-cAMP
Adenosine 3',5'-monophosphate modulates thyrotropin receptor clustering and thyrotropin activity in culture vivi, D Tramontano, FS Ambesi-Impiombato, and J lessinger Science 11 December 1981: 1237-1239	

- Describe the role of adenylate cyclase in the AMP → cAMP reaction.
- Describe the effect of TSH, AMP, and 8-Br-cyclic AMP on the production of cyclic AMP in the cells.
- Describe the feedback mechanism illustrated by Sample #4.



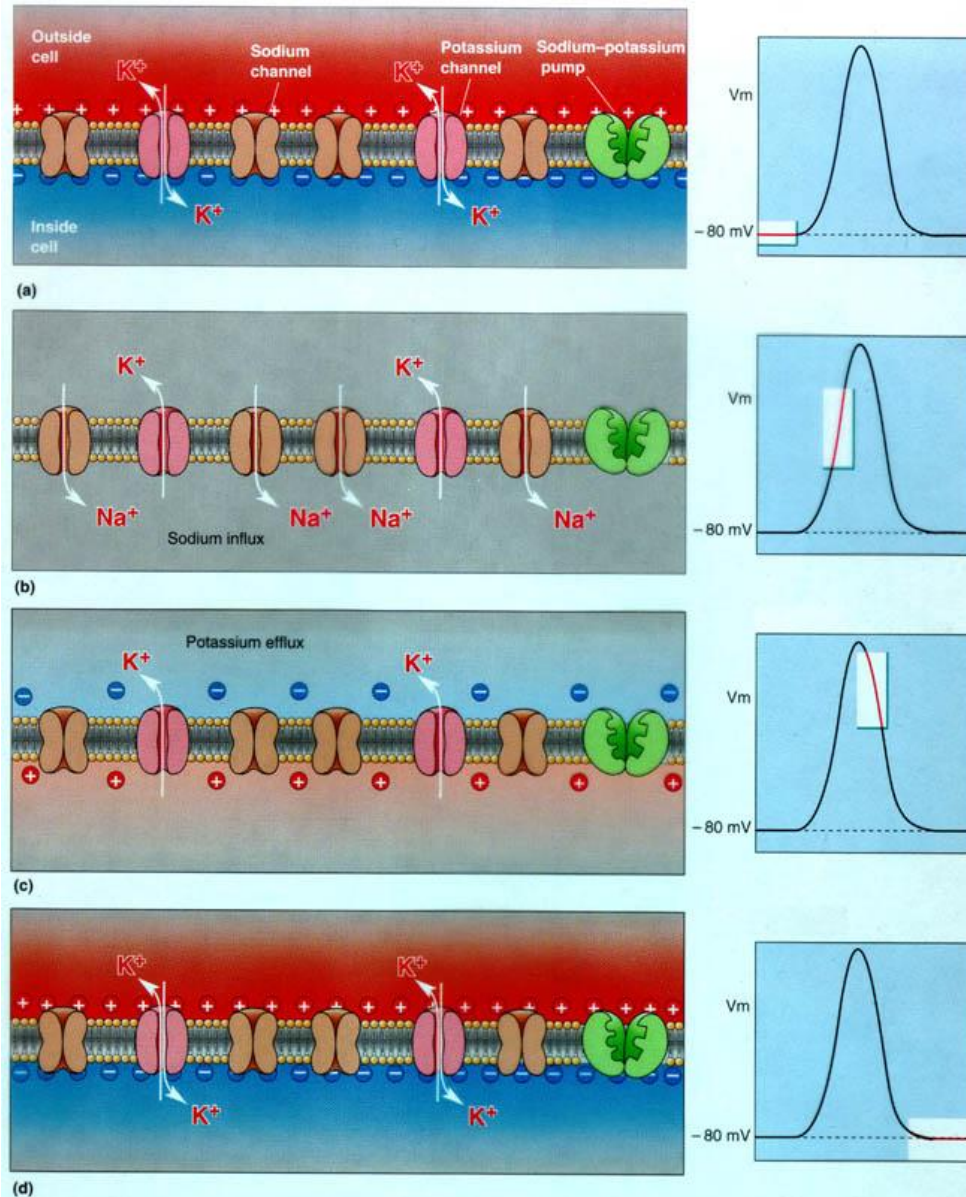
4. To maximize efficiency, the rate of light harvesting at PSII has to equal the rates of electron transfer from water to the PSI reaction center. If electrons are not transferred fast enough, the gateway between light harvesting and electron transfer in PSII is closed or reduced; given that single-celled algae cannot easily escape high light intensities, photodamage occurs if the electrons are not shunted to another acceptor. Various organisms take advantage of PTOX as an electron valve between PSII and PSI (Figure B). PTOX only requires 2 iron molecules (compared with 6 for cytochrome b6f and 12 for PSI), allowing the cells to survive in low-iron environments. When necessary, linear electron flow is reduced, and the electrons are transferred from PSII through PTOX back to O_2 in a closed loop, reducing the electron flux to the Calvin cycle and consuming O_2 . These alternate electron flows provide ecological advantages for organisms in the high-light, low-nutrient environment of the open ocean.

Photosynthesis in the Open Ocean

Jonathan P. Zehr and Raphael M. Kudela Science 13 November 2009: **326** (5955), 945-946.

- Describe the stages of photosynthesis, identifying the reactants and products of each step.
- The electron transport chain illustrated above is used to generate a proton gradient. How does this affect the pH of the lumen and stroma?
- Explain the relationship between environment and type of electron transport utilized (A or B above).

5. The transmission of a nerve impulse along a neuron from one end to the other occurs as a result of electrical changes across the membrane of the neuron. The membrane of an unstimulated neuron is polarized—that is, there is a difference in electrical charge between the outside and inside of the membrane. The inside is negative with respect to the outside.



Polarization is established by maintaining an excess of sodium ions (Na^+) on the outside and an excess of potassium ions (K^+) on the inside. A certain amount of Na^+ and K^+ is always leaking across the membrane through leakage channels, but Na^+/K^+ pumps in the membrane actively restore the ions to the appropriate side (a).

Nerve impulses are passed between neurons by a depolarization of the membrane. An action potential triggers the opening of Na^+ gates, causing sodium ions to move into the cell (b). The influx of Na^+ triggers K^+ pumps to open releasing potassium ions from the cell (c). This

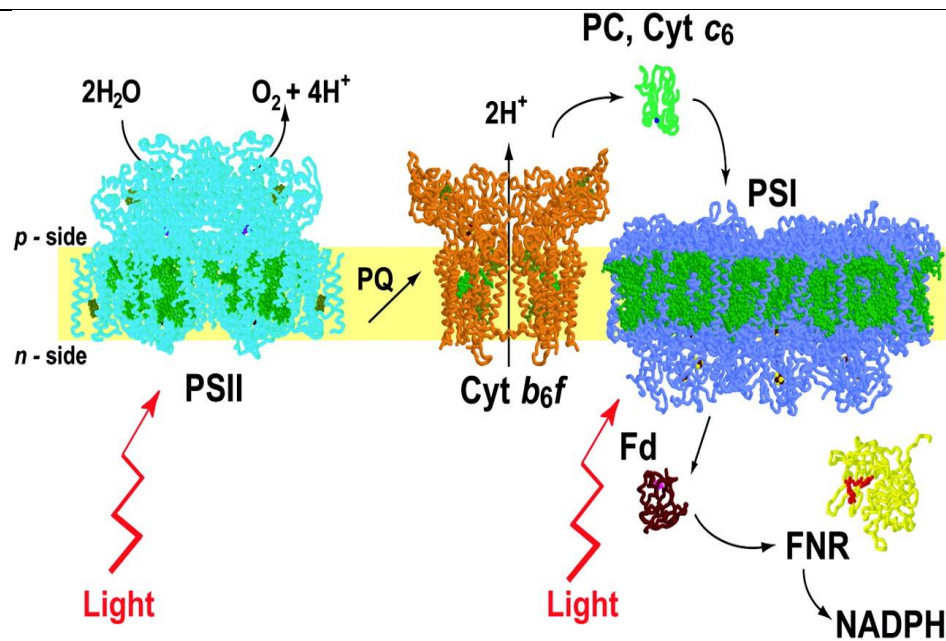
depolarization of the cell signals the next neuron in the pathway to depolarize. The neuron returns to its original state through the action of sodium/potassium pumps embedded in the membrane and the original concentration gradients are reestablished (d).

The pesticide DDT ($\text{C}_{14}\text{H}_9\text{Cl}_5$) was first used in the mid-1900s. At the time it worked very well and was widely used for many years. Today, however, DDT is no longer effective against many of the insect populations it was designed to eradicate.

- Describe the effects these “leaks” would have on the nervous system of the insect.
- In terms of evolution, explain why DDT has become ineffective.
- A farmer treats his cornfields with DDT. The corn is then used as feed for beef cattle. Predict the organism in this food chain that will have the highest concentration of DDT. Explain your reasoning.

http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1961/calvin-lecture.pdf

- How is the capacity of plants to capture the energy from sunlight related to the Calvin cycle shown above?
- How do photosynthetic organisms benefit from the Calvin cycle?
- Describe a possible hypothesis on why the Calvin cycle has many enzymatic reactions?



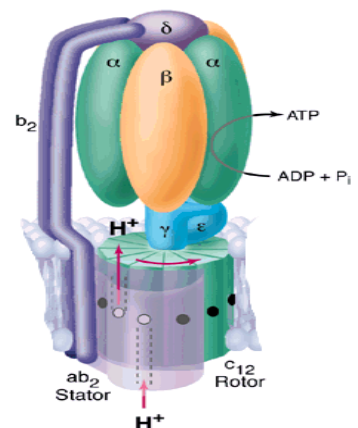
7. The diagram shows the integral membrane protein complexes responsible for electron transport and proton translocation in oxygenic photosynthesis. The structures are from thermophilic cyanobacterial sources. Lumen (*p*) and stromal (*n*) -side soluble electron transfer proteins are plastocyanin (green) or cytochrome c_6 , ferredoxin (Fd, dark brown), and ferredoxin:NADP⁺ reductase (FNR, yellow).

Structure of the Cytochrome b_6f Complex of Oxygenic Photosynthesis: Tuning the Cavity

Genji Kurisu, Huamin Zhang, Janet L. Smith, and William A. Cramer

Science 7 November 2003: **302** (5647), 1009-1014

ATP Synthase



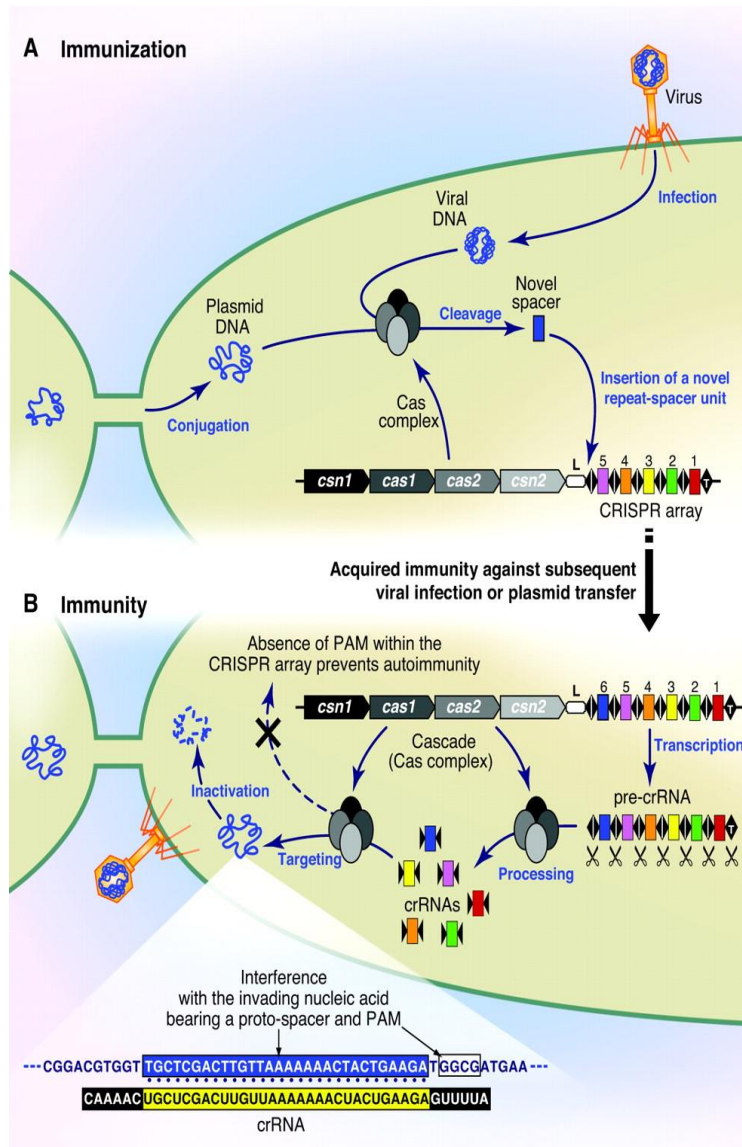
Rotary model of how the *E. coli* F_1F_0 ATP synthase catalyzes the synthesis of ATP (left). The proton-motive force drives rotation of a ring composed of 12 c subunits (10 in the yeast). Protons enter the assembly through a periplasmic inlet channel and bind to the Asp61 carboxylate (open circle) of the c subunits. The protonated binding site (filled circle) then moves from the a_1b_2 stator component to the lipid phase of the membrane. After 12 steps the protons reach an outlet channel on the F1-binding (cytoplasmic) side of the membrane.

Molecular Rotary Motors

Robert H. Fillingame

Science 26 November 1999: **286** (5445), 1687-1688.

- Describe the pathways of electrons and protons in the model shown above.
- Why is water important in the above process?
- How would the ATP synthase be oriented in above model?



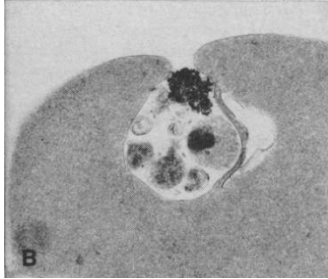
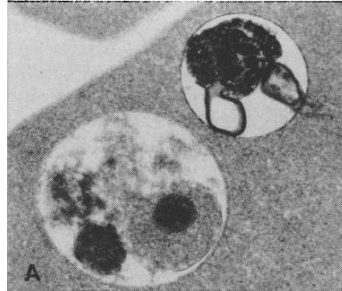
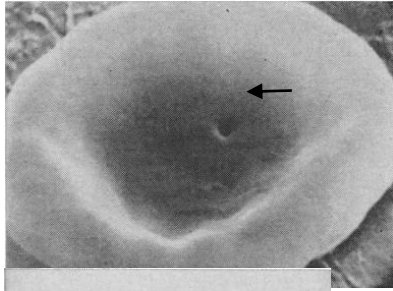
8. Overview of an adaptive microbial immune response. (A)

Immunization process: After insertion of exogenous DNA from viruses or plasmids, a Cas complex recognizes foreign DNA and integrates a novel DNA repeat-spacer unit at the leader end of the CRISPR locus. (B) Immunity process: The CRISPR repeat-spacer array is transcribed into a pre-crRNA that is processed (cut or hydrolyzed) into mature crRNAs, which are subsequently used as a guide by a Cas complex to interfere with the corresponding invading nucleic acid. Repeats are represented as diamonds, spacers as rectangles, and the CRISPR leader is labeled L. Proto-spacer adjacent motifs (PAMs) are nucleic acid signatures that are used to recognize foreign DNA from the bacterium's own DNA.

a) Why must infection by a virus occurred before immunity is acquired by the bacteria?

b) Why are the genes *cas1*, *cas2* important factors to this immune response?

c) How is viral or foreign plasmid DNA recognized by the CRISPR system?

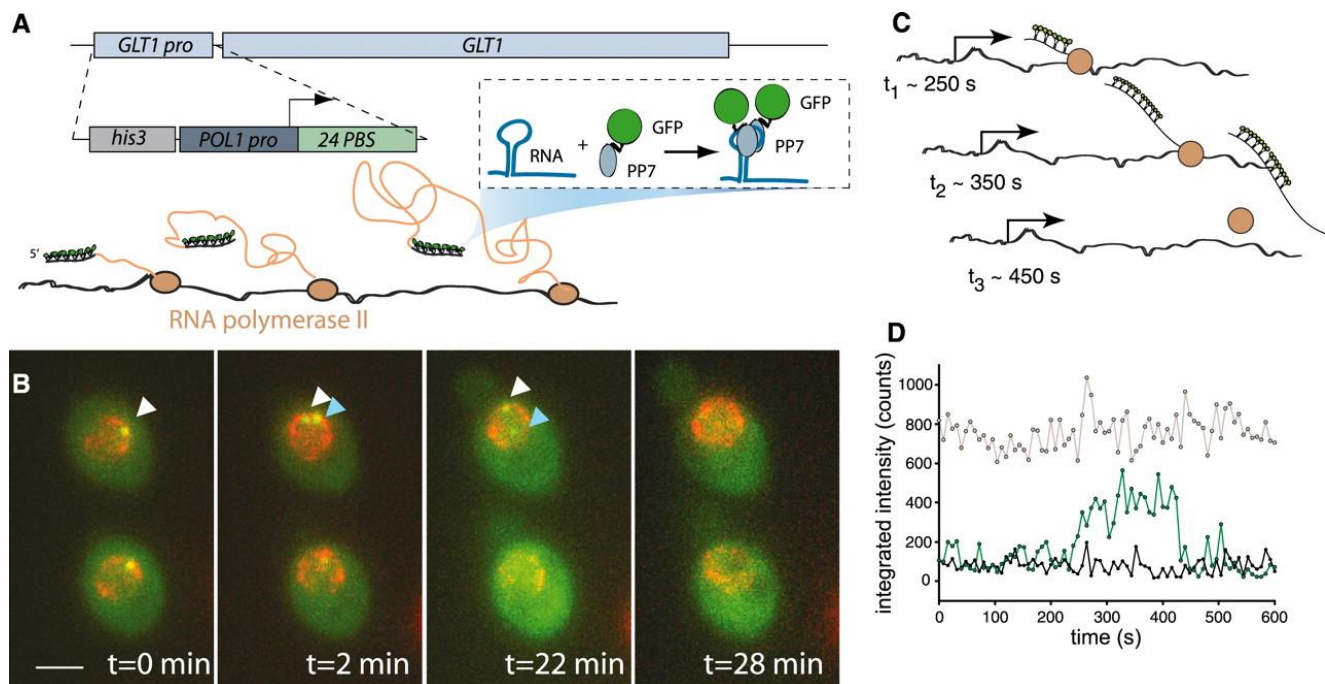


9. (top left) A scanning electron micrograph of a red blood cell with a pit on the surface (9000X). (A) a transmission electron micrograph of two inclusion-bearing vacuoles within red blood cell. Ferritin (a protein that stores iron), hemoglobin (an iron-containing protein that carries oxygen), membranes, and remnants (leftovers) of

mitochondria are present in the vacuoles (17,820X). (B) a transmission electron micrograph of the opening of the vacuole at the surface of the red blood cell (25,000X).

Erythrocytes: Pits and Vacuoles as Seen with Transmission and Scanning Electron Microscopy
Bertram Schnitzer, Doanld L. Rucknagel, Herbert H. Spencer, and Masamichi Aikawa
Science 16 July 1971: 251-252.

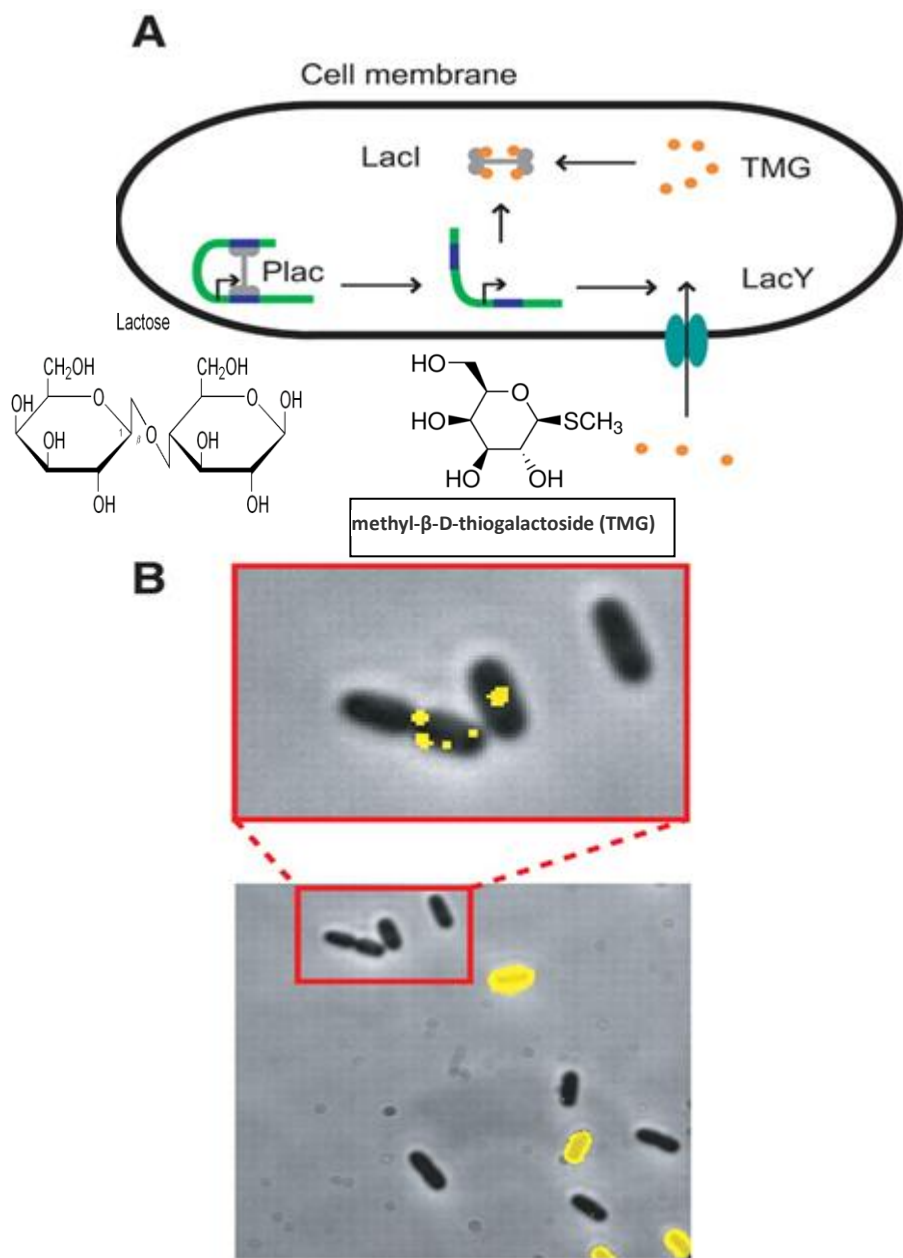
- How is the red blood cell able to make the pit or invagination seen in the cell membrane of the cell in the top left picture?
- Describe the evidence that supports the idea that the vacuoles seen in the above micrographs merged with lysosomes.
- Considering the function of red blood cells in the transport of materials from and to cells, describe a possible function of exocytotic vacuoles seen in the above micrographs.



10. Real-time measurement of fluorescent RNA reveals transcription kinetics. (A) Diagram of the POL1pro-GLT1 reporter gene, obtained by replacing the GLT1 promoter with a cassette containing a *his3* marker, POL1 cell cycle promoter, and 24 PP7 binding sites (PBS). Two reporter genes were constructed by fusing PP7 (a RNA bacteriophage coat protein that binds specific RNA sequences) with green fluorescent protein (GFP) and fusing the gene for tomato fluorescent protein (a protein from coral) with the gene for Nup49 (a nuclear pore protein). The diagram at the bottom of Figure A shows how the PP7-GFP protein will be used to see the transcribe mRNA. (B) Time-dependent activity of individual reporter genes (PP7-GFP, green; Nup49-tomato, red). At time $t = 0$ min, both cells show a transcription site (TS, arrows) near the periphery of the nucleus. At $t = 2$ min, an additional TS corresponding to the duplicated gene has turned on in the upper cell (white and blue arrows). At $t = 22$ min, the nascent bud is visible in both cells, and the TSs of the upper cell are present at opposite sides of the nucleus, but the lower cell TS has turned off. At $t = 28$ min, the bud continues to grow, and both TSs have turned off. Scale bar indicates 3 μ m. (C and D) Diagram of RNAPII progression on the gene with corresponding intensity trace (green line). The gray line is the intensity of a cytosolic mRNA; the black line is a background intensity at an arbitrary position in the nucleus.

Real-Time Observation of Transcription Initiation and Elongation on an Endogenous Yeast Gene
 Daniel R. Larson, Daniel Zenklusen, Bin Wu, Jeffrey A. Chao, and Robert H. Singer
 Science 22 April 2011: 332 (6028), 475-478

- Describe at least two DNA technologies that were or could have been used to produce the genetic constructs shown in Figure A?
- Describe how the process shown in the diagram at the bottom of Figure A labeled "RNA polymerase II" is related to the translation of GLT1 gene to the Glt1p protein.
- Using Figure D, why does the fluorescence for RNAPII progression start at background fluorescence, increases, and then decreases.
- Using Figure C, select a model (t_1 , t_2 , and t_3) that would show the greatest fluorescence in Figure D. Provide an explanation for your selection.



11. Lactose metabolism is controlled by the lac operon (DNA loop), which consists of the lacZ, lacY, and lacA genes encoding β -galactosidase, lactose permease, and transacetylase, respectively. Expression of the operon is negatively regulated by a transcription factor, the lac repressor (LacI), which dissociates from its specific binding sequences of DNA, the lac operators, in the presence of an inducer to allow transcription (Fig. A). The repressor LacI and permease LacY form a positive feedback loop. Expression of permease increases the intracellular concentration of the inducer lactose or the analog TMG (insets under Figure A), which causes dissociation of LacI (lactose repressor) from the promoter (Plac), leading to even more expression of permeases. Cells with a sufficient number of permeases will quickly reach a state of full induction (highlighted cells in Figure B), whereas cells with too few permeases will stay uninduced. (B) After 24 hours of growth in media containing 30 μ M TMG, strain SX700 expressing a LacY-YFP (yellow fluorescent protein) fusion

exhibits all-or-none fluorescence in a fluorescence-phase contrast overlay (bottom, image dimensions 31 μ m $\times$ 31 μ m). Fluorescence imaging with high sensitivity reveals single molecules of permease in the uninduced cells (top, image dimensions 8 μ m $\times$ 13 μ m).

A Stochastic Single-Molecule Event Triggers Phenotype Switching of a Bacterial Cell
 Paul J. Choi, Long Cai, Kirsten Frieda, and X. Sunney Xie
 Science 17 October 2008: 322 (5900), 442-446.

- If there is no lactose or analog- such as TMG, present, why will the E. coli cells not produce the proteins involve in lactose metabolism?
- The boxed cells in figure B show cells will single molecules of permease present within the cells, why are these cells not fully fluorescent?
- At a concentration of 30 μ M of TMG, about half of the E. coli cells can metabolize lactose and other half cannot (B), describe a possible explanation for this phenomena

ANSWER KEY

1. D
2. C
3. A
4. D
5. A
6. D
7. D
8. B
9. B
10. D
11. B
12. C
13. A
14. B
15. B
16. A
17. A
18. B
19. D
20. C
21. A
22. C
23. D
24. C
25. A
26. A
27. A
28. B
29. A
30. B
31. C
32. B
33. C
34. A
35. B
36. A
37. B

38. A
39. D
40. A
41. C
42. B
43. A
44. C
45. B
46. C
47. A
48. B
49. B
50. B
51. C
52. D
53. C
54. D
55. C
56. C
57. A
58. C
59. C
60. C
61. A
62. B
63. D
64. C
65. C
66. B
67. D
68. B
69. A
70. A
71. D
72. B
73. A
74. B

75. A
76. B
77. C
78. A
79. D
80. D
81. D
82. C
83. C
84. D
85. C
86. C
87. A
88. B
89. C
90. B
91. B
92. D
93. D
94. B
95. C
96. C
97. C
98. D
99. C
100. B
1. 9.0 bars
2. -38 bars
3. 4.6×10^{14} seconds
4. 63
5. 3.4×10^{-13}
6. 1.7×10^3
7. 5.2×10^5
8. 462

Question 1

- a) You would need to put the primitive gases thought to be present in the early Earth's atmosphere in the compartment with the electrodes: hydrogen, methane, carbon monoxide and dioxide, ammonia, and hydrogen sulfide gases. The water compartment is heated to include water vapor in the gaseous mixture. Cold water running through the condenser cools the products of the gaseous mixture. If organic compounds are produced, they would be found in the cooled water.
- b) The presence of these gases in early Earth's atmosphere is best supported by the physical and geological history of the Earth.
- c) The 7 characteristics of life are energy processing such as fermentation, cellular respiration, and photosynthesis, having order in the form of cells, being able to adapt to one's environment through natural selection, responding to the environment, regulating homeostasis through a semi-permeable membrane and utilization of energy, growth and developing, and reproduction.
- d) The hydrothermal vent hypothesis states that life may have arisen at hydrothermal vents under the ocean, given the inorganic molecules (such as methane and ammonia) are released from these vents and the high temperatures at this location increase the instability of the molecules and the rate of chemical reactions.

Essential knowledge 1.D.1: There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence.

LO 1.30 The student is able to evaluate scientific hypotheses about the origin of life on Earth. [See **SP 6.5**]

Essential knowledge 1.D.2: Scientific evidence from many different disciplines supports models of the origin of life.

LO 1.32 The student is able to justify the selection of geological, physical, and chemical data that reveal early Earth conditions.

[See **SP 4.1**]

Question 2

- a) Since nutrients, particularly amino acids, are scarce in the media- the bacteria have protein receptors in the cell membrane that bind certain amino acids. The binding of the amino acids by the receptors lets the bacterium where there might be more nutrients and sets a cascade of chemical signaling within the cell that leads to the coordinated movement of the flagella towards the source or direction of the nutrients.
- b) In nutrient media with all the essential nutrients, the bacteria would probably decrease the expression of the receptors because they have no need to know the possible concentration gradient of the nutrients. If the protein receptors would be present on the cell membrane of the bacteria, they would be saturated with nutrients and the cell would not have a way to gauge the relative difference in activation of the receptors, which could be one possible mechanism of action.

Essential knowledge 2.E.3: Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection.

LO 2.40 The student is able to connect concepts in and across domain(s) to predict how environmental factors affect responses to information and change behavior. [See **SP 7.2**]

Essential knowledge 3.D.1: Cell communication processes share common features that reflect a shared evolutionary history.

LO 3.33 The student is able to use representation(s) and appropriate models to describe features of a cell signaling pathway. [See **SP 1.4**]

Essential knowledge 3.D.3: Signal transduction pathways link signal reception with cellular response.

LO 3.36 The student is able to describe a model that expresses the key elements of signal transduction pathways by which a signal is converted to a cellular response. [See **SP 1.5**]

Question 3

- a) Adenylate cyclase is an enzyme in the AMP → cAMP reaction. Therefore, it lowers the activation energy required for the reaction when the AMP (reactant) binds to the active site of the enzyme.
- b) TSH stimulates the cell to produce cAMP. The graph shows that cells grown with TSH produce almost 4 times as much cAMP as cells that have not been stimulated by it. 8-Br-cAMP has little effect on the rate of reaction when added with AMP but decreases the effectiveness of TSH when added together. AMP (when added alone) has no impact on cAMP production over the basal rate.
- c) 8-Br-cAMP is an allosteric regulator. TSH stimulates a production of cAMP by adenylate cyclase (sample 2). When cAMP concentration reaches a threshold (TSH induced cAMP +added 8-Br-cAMP), 8-Br-cAMP seems to produce negative feedback loop on the signaling pathway.

Essential knowledge 4.B.1: Interactions between molecules affect their structure and function

LO 4.17 The student is able to analyze data to identify how molecular interactions affect structure and function. [See **SP 5.1**]

Essential knowledge 3.D.1: Cell communication processes share common features that reflect a shared evolutionary history.

LO 3.33 The student is able to use representation(s) and appropriate models to describe features of a cell signaling pathway. [See **SP 1.4**]

Essential knowledge 3.D.3: Signal transduction pathways link signal reception with cellular response.

LO 3.36 The student is able to describe a model that expresses the key elements of signal transduction pathways by which a signal is converted to a cellular response. [See **SP 1.5**]

Question 4

- a) Light and water are the reactants of the light-dependent reaction of photosynthesis. NADPH and ATP are the products; oxygen is a byproduct. These products are used in the Calvin cycle, along with carbon dioxide, to phosphorylate intermediates to make them chemically reactive to decompose into smaller sugars or join together to make larger sugars; the NADPH is an electron donor to allow the isomerization or joining (condensation) of the intermediates of the Calvin cycle.
- b) Electrons, donated by the lysis of water, move through the electron transport chain of photosystems II and I and allow for the transport of protons into the lumen of the chloroplast. The increase of the protons in the lumen would increase the pH of the stroma and decrease the pH of the lumen. The equilibrium pH of the lumen and stroma will be dictated by the efficiency of the ATP synthase in converting the proton gradient into the energy stored in ATP.

- c) In high-light, low nutrient environments such as the open ocean, increased electron flow (from photons) cannot be utilized to generate glucose (because of a lack of nutrients). To prevent damage from this excessive electron flow, PTOX is utilized to recycle the electrons back to water.

LO 2.4 The student is able to use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store and use free energy. [See **SP 1.4, 3.1**]

LO 2.5 The student is able to construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store or use free energy. [See **SP 6.2**]

Question 5

- a) The “leaks” in the cell membrane caused by DDT delay or stop the nerve signals in the nervous system; all functions of the nervous system would be negatively affected; if homeostasis is disturbed past a threshold, death would result for the organisms affected.
- b) The overuse of DDT has selected for variants in the insect population that are resistant to the effects of DDT. The variants have been positively selected for, and their population has increased- making DDT useless as an insecticide.
- c) The consumers at the top of the food chain would have the greater concentration of DDT. Since top level consumers must consume many low-level consumers/producers that have DDT, the DDT accumulates in their tissues more than the low-level consumers/producers.

LO 4.5 The student is able to construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [See **SP 6.2**]

LO 4.6 The student is able to use representations and models to analyze situations qualitatively to describe how interactions of subcellular structures, which possess specialized functions, provide essential functions. [See **SP 1.4**]

Question 6

- a) Without an energy source to recharge the ADP to ATP, the enzymes of the Calvin cycle would not be able to add a phosphate to intermediates in the cycle and make the chemical reactions be spontaneous and possible. The Calvin cycle is anabolic and requires added electrons in one of the steps of the cycle; these electrons come from the light dependent reactions of photosynthesis in the form of NADPH.
- b) The Calvin cycle produces carbohydrates that allow cells to store more energy in a more chemically stable form than ATP. The carbohydrates could be stored, and the organisms have energy when they need it and where they need it; the organisms become less dependent on the Sun.
- c) The incorporation of carbon dioxide into carbohydrates requires chemical reactions that are not spontaneous or close to being not spontaneous; therefore, evolution had to survey the free energy landscape to find steps that could be catalyzed by enzymes and close enough to the spontaneous threshold to be activated by phosphorylation. Luckily for life, a possible pathway, the Calvin cycle, was discovered by chemical evolution.

LO 2.1 The student is able to explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow and to reproduce. [See **SP 6.2**]

LO 2.2 The student is able to justify a scientific claim that free energy is required for living systems to maintain organization, to grow or to reproduce, but that multiple strategies exist in different living systems. [See **SP 6.1**]

LO 2.3 The student is able to predict how changes in free energy availability affect organisms, populations and ecosystems. [See **SP 6.4**]

Question 7

- a) Electrons are excited quantumly in photosystem II; the excited electrons are passed to plastoquinone (PQ), leaving an electron void in photosystem II that enables the extraction of electrons from water. PQ passes the electrons to Cytochrome b_6f , which uses the electrons to push 2 protons into intermembrane space and passes the electrons to Cytochrome c_6 . Cytochrome c_6 passes electrons to photosystem I, which excites electrons and passes electrons to ferredoxin, ferredoxin reductase takes electrons from ferredoxin and gives them to NADPH
- b) Water provides the stream of electrons that are given to photosystem II and I to create the proton gradient to generate ATP and the reducing power in NADPH.
- c) The ATP synthase would be situated in the membrane with rotors facing up or into the lumen of thylakoids and the ATP-binding out or into the stroma of the chloroplast. The concentration of protons is greater in the lumen of thylakoids and ATP synthase needs the flow of electrons through the complex to generate ATP from ADP and phosphate.

LO 2.4 The student is able to use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store and use free energy. [See **SP 1.4, 3.1**]

LO 2.5 The student is able to construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store or use free energy. [See **SP 6.2**]

Question 8

- a) The bacterium must process the foreign DNA and incorporate it into the CRISPR system; transcription of the CRISPR array includes the newly encountered DNA, and the Cas complex can cut the array transcript and use the crRNAs to interfere with the invading DNA.
- b) The genes *cas1* and *cas2* produce proteins that form the Cas complex. The Cas complex is a large protein complex that recognizes foreign DNA sequence, is able to cleave the DNA sequence, and insert a specific segment of the foreign DNA sequence into the CRISPR array. Without this signature recognizing complex, the system will not have a way to remember the foreign DNA it had come in contact with.
- c) The foreign DNA is recognized by having PAMs, a small number of nucleotides that are always present right after the spacer. The bacterium uses PAMs to prevent the Cas complex from cutting up its (the bacterium's) own DNA. Foreign DNA is also recognized by the sense and antisense hydrogen bonding between the crRNAs and the foreign DNA. The hydrogen bonding between the sequences is recognized by proteins that cut the foreign DNA and recycle the nucleotides for its own use in the cell cycle.

LO 3.29 The student is able to construct an explanation of how viruses introduce genetic variation in host organisms. [See **SP 6.2**]

LO 2.29 The student can create representations and models to describe immune responses. [See **SP 1.1, 1.2**]

LO 4.5 The student is able to construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [See **SP 6.2**]

LO 4.6 The student is able to use representations and models to analyze situations qualitatively to describe how interactions of subcellular structures, which possess specialized functions, provide essential functions. [See **SP 1.4**]

Question 9

- a) With the assistance of proteins, the phospholipid bilayers fuse at one end of the vacuole and expose the interior of the vacuole to the outside of cell, while maintain the integrity of the cell membrane. In the micrograph, we are looking at the inside of the exiting vacuole from the outside of the cell.
- b) The evidence that supports the fusing of the vacuoles with lysosomes is the remnants of mitochondria and proteins that have been broken down by proteinases and/or other enzymes present in lysosomes.
- c) A possible function of the removal of proteins and mitochondria from the inside of the cell in vacuoles is to improve the efficiency of cellular function and recycling of materials for reuse in other parts of the organism. Red blood cells must be uncluttered to transport materials more effectively; Red blood cells have a 7 month life span, so they don't require many mitochondria towards the end of their lifecycle.

LO 2.13 The student is able to explain how internal membranes and organelles contribute to cell functions. [See **SP 6.2**]

LO 4.4 The student is able to make a prediction about the interactions of subcellular organelles. [See **SP 6.4**]

LO 4.5 The student is able to construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [See **SP 6.2**]

LO 4.6 The student is able to use representations and models to analyze situations qualitatively to describe how interactions of subcellular structures, which possess specialized functions, provide essential functions. [See **SP 1.4**]

Question 10

- a) Some of the DNA technologies that were used to produce the genetic constructs shown in Figure A are DNA cloning of yeast plasmids, gene splicing, transformations of yeast, PCR, and CRE-LOX recombination.
- b) RNA polymerase II transcribes RNA that leaves the nucleus is translated into proteins by the ribosomes by matching 3-bases codons with transfer RNAs carrying the corresponding amino acid. Water is removed from the amino and carboxyl groups of adjacent amino acids or polypeptide in the ribosomes and the protein continues to grow until a stop codon is reached.
- c) The PP7-GFP attaches to mRNA. At first, the RNA polymerase must find the promoter and begin polymerizing the mRNA. When the mRNA begins to be made, the PP7-GFP protein binds the mRNA and the fluorescence signal is registered in the nucleus. As the mRNA gets longer, the fluorescence

increases. Eventually, the mRNA is transported to the cytoplasm and the fluorescence in the nucleus decreases.

- d) The model that should show the greatest fluorescence would be t_3 , because there are more PP7-GFPs on the mRNA and the quantity of PP7-GFPs is proportional to the fluorescence signal.

LO 3.5 The student can justify the claim that humans can manipulate heritable information by identifying at least two commonly used technologies. [See **SP 6.4**]

LO 3.4 The student is able to describe representations and models illustrating how genetic information is translated into polypeptides. [See **SP 1.2**]

LO 3.31 The student is able to describe basic chemical processes for cell communication shared across evolutionary lines of descent. [See **SP 7.2**]

LO 3.33 The student is able to use representation(s) and appropriate models to describe features of a cell signaling pathway. [See **SP 1.4**]

Question 11

- a) The LacI repressor binds to the DNA molecule and creates a loop that prevents RNA polymerase from binding the promoter of the lac operon. Since RNA polymerase cannot bind the DNA, it can produce the mRNA needed to produce the proteins that catalyzed the reactions that metabolize lactose to glucose, which is the only substrate of glycolysis and subsequent Krebs cycle and respiration pathways needed for ATP production.
- b) The permease-GFP fusion protein must get to the cell membrane to let more lactose or analog into the cell, and you need more than one molecule of permease to flip the genetic switch. Once the level of lactose reaches a threshold, it will bind the LacI repressor and a burst of mRNA will be produced, flipping the genetic switch to metabolizing lactose.
- c) The LacI repressor randomly dissociates, albeit not often, from the Lac operon promoter, and a small burst of mRNA from the lac operon is transcribed before the repressor re-attaches to the promoter. In half of the cells, the small burst of gene activity is enough to generate permease at the cell membrane, allowing the small concentration of TMG to enter the cell and inhibit the repressor binding of the promoter and inducing transcription from the lac promoter. Full transcription from the lac promoter will make the cell totally permeable to lactose or TMG and the enzymes to metabolize lactose will be present, making the cell acquire a new phenotype (lactose processing).

LO 2.15 The student can justify a claim made about the effect(s) on a biological system at the molecular, physiological or organismal level when given a scenario in which one or more components within a negative regulatory system is altered. [See **SP 6.1**]

LO 2.16 The student is able to connect how organisms use negative feedback to maintain their internal environments. [See **SP 7.2**]

LO 2.17 The student is able to evaluate data that show the effect(s) of changes in concentrations of key molecules on negative feedback mechanisms. [See **SP 5.3**]

LO 2.18 The student can make predictions about how organisms use negative feedback mechanisms to maintain their internal environments. [See **SP 6.4**]

LO 2.19 The student is able to make predictions about how positive feedback mechanisms amplify activities and processes in organisms based on scientific theories and models. [See **SP 6.4**]

LO 2.20 The student is able to justify that positive feedback mechanisms amplify responses in organisms. [See **SP 6.1**]