

Passage I

Human bone is composed of two portions:

1) a hard mineral portion made up primarily of calcium; and 2) a softer, organic, collagen-like matrix. 99% of the body's calcium is contained in bone tissue. Bone is a dynamic substance, continuously being resorbed and reformed throughout the lifespan of a person. This renewal process is directly related to the maintenance of an adequate level of calcium in the blood stream. There are several important molecules that affect this relationship, such as vitamins C and D, calcitonin and parathyroid hormone.

Vitamin C is required for the formation and maintenance of connective tissue, including synthesis of bone matrix. A deficiency in vitamin C results in scurvy. Although the effects of calcitonin are minute, it acts to decrease bone resorption, helping to precisely calibrate bone quantity and arrangement. Parathyroid hormone stimulates formation and activity of osteoclasts, which break down bone cells, and impair new bone formation. Vitamin D acts as a hormone in its activated form, stimulating absorption of calcium by the small intestine. Vitamin D also acts on bone tissue to enhance the effect of parathyroid hormone. Although vitamin D can be obtained from diet, it is one of the few hormones humans can successfully synthesize themselves when skin is exposed to ultraviolet light.

There are two common diseases that affect bone metabolism, osteomalacia and osteoporosis. Osteomalacia generally affects children more often than adults and is known as rickets in children. A deficiency in vitamin D causes the inadequate mineralization of new bone matrix and results in a lower ratio of mineral to organic matter in bone tissue than would be observed normally. Many sufferers have bowed legs, as this disease leads to distortion of the bones, especially the long bones. Osteoporosis, on the other hand, is mainly a disease of the elderly, striking postmenopausal women most often. More bone is resorbed than formed, leading to a reduction in bone mass. The remaining bone has a normal ratio of mineral to organic matter content. Scientists have yet to understand why the body loses bone mass. However, studies show that an increase in weight-bearing activity promotes increases in

bone mass, while a lack of activity allows for further bone loss.

1. In order to maintain normal bone tissue, the body would have to increase the level of calcitonin in response to what condition?
 - A) The level of calcium in the plasma is high
 - B) The level of parathyroid hormone is too low
 - C) There is a dietary deficiency of calcium
 - D) There is a dietary deficiency of vitamin D
2. Which of the following persons would be most likely to have osteomalacia?
 - A) A child with a dietary deficiency in fat-soluble vitamins living in a tropical climate
 - B) A child with a dietary deficiency in fat-soluble vitamins living in a northern climate
 - C) A child with a dietary deficiency in water-soluble vitamins living in a tropical climate
 - D) A child with a dietary deficiency in water-soluble vitamins living in a northern climate
3. When taking a calcium supplement, nutritionists recommend that it include vitamin D because
 - A) the activated form of vitamin D enhances the uptake of calcium by bone tissue.
 - B) vitamin D is needed to prevent osteomalacia.
 - C) the activated form of vitamin D enhances the action of calcitonin.
 - D) the activated form of vitamin D stimulates the absorption of calcium into the blood.
4. Which of the following circumstances would likely result in a case of osteomalacia?
 - A) Metabolic deficiency of parathyroid hormone
 - B) Metabolic deficiency of parathyroid hormone and impairment of conversion of vitamin D to its active form
 - C) Metabolic deficiency of parathyroid hormone and an inability of the active form of vitamin D to act on its target tissue
 - D) Impairment of conversion of vitamin D to its active form and an inability of the active form of vitamin D to act on its target tissue

5. Hypocalcaemia (low levels of calcium in the blood) will trigger an increase of:
- A) osteoclast activity.
 - B) osteoclast activity and vitamin C.
 - C) osteoclast activity and parathyroid hormone.
 - D) parathyroid activity and vitamin C.
6. A tumour necessitated the removal of the parathyroid gland. What effect would the post-operative patient experience?
- A) A drastic change in the ratio of mineral to matrix tissues in bones
 - B) An increase in calcitonin production to compensate for calcium deficiency in the plasma
 - C) Calcification of some organs due to accumulation of calcium in the plasma
 - D) Severe neural and muscular problems due to deficiency of calcium in the plasma
7. Early migration of humans into more northerly latitudes, such as Europe, altered the environmental factors humans were exposed to. To prevent diseases such as osteomalacia, anthropologists hypothesize that:
- A) the amount of melanin in the skin decreased while consumption of dairy products increased.
 - B) the amount of melanin in the skin decreased as did the consumption of dairy products.
 - C) the amount of melanin in the skin increased while consumption of dairy products increased.
 - D) the amount of melanin in the skin increased as did the consumption of dairy products.
8. Which of the following is not an expected symptom of scurvy?
- A) Bleeding under the skin
 - B) Fluctuating blood pressure and heart rate
 - C) Tingling sensation in the extremities
 - D) Brittle bones
9. Which is not a function of the skeleton?
- A) Mineral storage
 - B) Protection of vital organs
 - C) Production of blood cells
 - D) Detoxification of poisons.

Passage II

Norman, born and raised in South Carolina, is training to become a U.S. Marine. Over the course of his one-year training course, Norman makes several trips to different locations to learn new skills.

Shortly after joining the training program, Norman's unit went to Florida to learn to skin dive. Norman, being a marine-in-training, was in excellent physical condition. However, the first time he went diving, Norman noticed that he experienced elevated pulse and respiratory rates. Norman performed several more dives over the course of the week, and by the third dive, his heart and breathing rates were no longer elevated. By the end of the week, his skin had become darker.

Several months later, Norman's unit went to the Rocky mountains to learn to ski. Once again, Norman noticed that the first time he went skiing, his heart and ventilation rates were faster than normal. By the end of the week, although there was a decrease in heart and breathing rates, the rates were still slightly elevated. Norman also noticed that his appetite had increased over the course of the week and that he had significantly increased his food intake but this had no effect on his weight. Norman didn't notice the same magnitude of increase in his food intake during the diving trip.

Norman calculated the actual amount of work that he performed during the skiing and diving trips and found that there was not enough difference in the work performed to account for the observed difference in appetite. The physical work of diving and skiing were approximately equal but the amount of calories ingested during the skiing trip were greater than the diving trip.

10. Control of heart rate, muscle coordination, and appetite is maintained by the:

- A) brain stem, cerebellum, and hypothalamus respectively
- B) brain stem, hypothalamus, and cerebrum respectively
- C) hypothalamus, cerebrum, and the brainstem respectively
- D) cerebellum, hypothalamus, and brain stem respectively

11. Norman noted that even though his skin blood vessels were usually constricted to conserve body heat in the cold environment of the mountains they would occasionally dilate for short periods of time. What would be the most probably physiological purpose for this periodic vasodilation?

- A) Maintain normal muscle tone
- B) Maintain normal skin tone
- C) Maintain sufficient oxygenation of cells
- D) Reduce excessive blood pressure

12. The initial increase in heart and breathing rates during the skin diving training was probably due to:

- A) elevated core body temperature caused by swimming in warm water.
- B) activation of the parasympathetic autonomic nervous system by the new experience.
- C) activation of the sympathetic autonomic nervous system by the new experience.
- D) hypoxia caused by the inability to supply sufficient oxygen for the strenuous exercise of swimming at sea level.

13. The prolonged increase in heart rate and breathing rates during the snow skiing trip was probably due to:

- A) depressed core body temperature (hypothermia) caused by exposure to cold temperatures at high altitude.
- B) hypoxia caused by insufficient blood hemoglobin concentration to supply oxygen for exercise at the low oxygen pressure found at high altitudes.
- C) activation of the parasympathetic autonomic nervous system by the new experience.
- D) activation of the sympathetic autonomic nervous system by the new experience.

14. During the initial skin diving session, when his heart and breathing rates were elevated, Norman noticed that he produced more urine than usual. This was probably due to:

- A) inability to cool the skin through evaporative water loss.
- B) increased blood pressure caused by excitement or anxiety.
- C) reduced blood pressure caused by excitement or anxiety.
- D) absorption of water from the ocean.

15. The effect of the parasympathetic autonomic nervous stimulation on the heart is:

- A) to release adrenaline and excite the heart.
- B) to release adrenaline and slow the heart.
- C) to release acetylcholine and excite the heart.
- D) to release acetylcholine and slow the heart.

16. When Norman was skin diving under the water, he could clearly hear the “lub-dub” of his heart beating? The “lub” sound the heart makes is caused by the:

- A) closing of the mitral and tricuspid valves.
- B) closing of the pulmonary and aortic valves.
- C) sound of blood rushing into the atria.
- D) sound of blood rushing into the ventricles.

17. The darkening of the skin during tanning:

- A) is naturally healthy and is a sign of vigor in humans
- B) is a direct response to exposure to visible light
- C) protects the dermis from damage by increasing the number of pigment-producing cells
- D) protects the dermis from damage by increasing the production of pigment in melanocytes.

Passage III

Inflammatory bowel disease (IBD) is a group of inflammatory conditions of the large, and sometimes small, intestine. Crohn's disease (CD) and ulcerative colitis (UC) are the two most common forms of IBS. The main difference between CD and UC is the location and nature of the inflammatory changes in the gut. CD can affect any part of the gastrointestinal tract, from mouth to anus. UC, in contrast, is restricted to the colon. CD usually involves all layers of the digestive tract while UC affects only the mucosa (inner lining of the tract). The first symptoms usually experienced by a sufferer of CD are abdominal pain and diarrhea following meals, while a progressive loosening of a bloody stool is the first symptom of UC.

Management of IBD is achieved by drug therapy to suppress the inflammation which leads to diarrhea, but there is no known cure. The cause of IBS is controversial, with genetic, pathogenic, and immunogenic theories all having been advanced.

IBD tends to run in families, with 20% of patients having a relative with the disorder. The incidence of CD in North America and Europe is 1 in 600,000 but are lower in Africa and Asia. Incidence rates are higher in northern latitudes of northern countries and in particular ethnic groups. If IBS is genetically linked, it is not inherited in a simple Mendelian manner.

Some research suggests that IBD is an autoimmune disease. An antigen in the body, perhaps in the digestive tract, is recognized as foreign by the immune system. This antigen may then stimulate the body's defenses to produce an inflammatory response that continues without control. Recently the "helminthic theory" was put forward, suggesting that a lack of traditional targets, parasites such as roundworms and whipworms, stimulates or perhaps increase this autoimmune response. Rates of IBD have increased in countries where in parasitic infection rates have decreased.

There is also a lingering suspicion that the inflammation is triggered by some bacterium or other organism that takes up residence in the gastrointestinal system. *Mycobacterium paratuberculosis*, a bacteria found in cows, sheep and goats, causes Johne's disease which has many similarities to CD. This theory has also had a

resurgence since the discovery that the bacterium *Helicobacter pylori* may play a causal role in gastric ulcers.

18. An ulcer that penetrated the wall of the intestine would allow the contents of the gastrointestinal tract to enter:

- A) the pleural cavity.
- B) the peritoneal cavity.
- C) the lumen of the intestine.
- D) the perineum.

19. What process would be most disrupted by an inflammation of the colon?

- A) Absorption of nutrients
- B) Absorption of water
- C) Digestion
- D) Secretion of digestive enzymes

20. Normally the immune system avoids attacking the tissues of its own body because:

- A) the body does not make any antigens that the immune system could recognize.
- B) it changes its antibodies to be specific only to foreign antigens.
- C) a special intracellular process recognizes only foreign antigens.
- D) it suppresses cells specific to the body's own antigens.

21. The fact that there appears to be a genetic component to IBD which does not demonstrate Mendelian inheritance patterns, suggests that:

- A) the disease is polygenic.
- B) the gene for the disease is recessive.
- C) the gene for the disease has incomplete dominance.
- D) the gene for the disease has limited expressivity.

22. If the genetic and autoimmune theories of IBD are true, then the gastrointestinal antigen being targeted by the immune system is probably on:

- A) the chromosomes carrying the genes for the disease.
- B) the surface of the proteins encoded by the genes for the disease.
- C) part of the DNA segments constituting the genes for the disease.
- D) Stretches of the mRNA's coded for by the genes for the disease.

23. Which of the following would make you question the involvement of a bacterial infection in UC?

- A) The presence of worms in the gut of the patient.
- B) The similarity of the ulcers to that of gastric ulcers.
- C) The presence of similar conditions in other mammals.
- D) The presence of symptoms outside the gastrointestinal tract.

24. The helminthic theory holds that:

- A) roundworm infection causes IBD
- B) a genetic protection against IBD is triggered by the presence of roundworms
- C) *Mycobacterium paratuberculosis* causes IBD
- D) the absence of roundworms increases the autoimmune response of the body.

25. Crohn's disease is different from ulcerative colitis because

- A) CD affects the entire GI tract and is probably caused by a bacteria.
- B) CD affects only the mucus membrane of the colon and is probably caused by a bacteria.
- C) CD affects the entire GI tract and is not treatable by surgery.
- D) CD affects only the mucus membrane of the colon and is not treatable by surgery.

Passage IV

A set of experiments was carried out to isolate unusual mutants in the bacterium *Staphylococcus*. It is known that normal staph cells grow well on a minimal nutrient medium containing agar and a solution of glucose, salts, and ammonia. Staph can also grow on a medium containing more complex sugars like lactose, because they normally have the enzymes needed to convert complex sugars to glucose. Overnight, a single bacterial cell can grow into a culture of millions of cell that appears as a raised colony on the medium.

Experiment 1

A sample of normal staph was treated with X-rays in order to produce genetic mutations in the bacterial cells. The bacteria were then spread across a dish containing a minimal nutrient media. The medium also contained the antibiotic ampicillin, which kills normal staph bacteria. The culture was incubated overnight and examined. No bacterial cultures were found growing in the Petri dish.

Experiment 2

The experiment was repeated exactly as before, using the same original sample. This time when the culture was examined after incubation, two colonies of bacteria (Colony A and Colony B) were found growing on the medium.

Experiment 3

Samples from both colonies grown in Experiment 2 were spread across two different ampicillin-containing media. Medium X was the typical minimal medium while Medium Y contained the same ingredients, with the exception that instead of glucose, lactose was the only nutrient sugar present. After incubation, the four dishes were examined and the results are shown in Table 1.

Table 1. Results of Experiment 3

	Medium X	Medium Y
Colony A	growth	growth
Colony B	growth	no growth

26. What conclusions can be drawn from Experiment 1?
- A) All bacterial cells became ampicillin-resistant.
 - B) No ampicillin-resistant mutations were produced.
 - C) Mutations were produced, but none that were ampicillin-resistant.
 - D) No mutations were produced.
27. What conclusions can be drawn from Experiment 2?
- A) All bacterial cells except two became ampicillin-resistant.
 - B) At least two bacterial cells were mutated and became ampicillin-resistant colonies.
 - C) Colony A and Colony B can grow without glucose in the medium.
 - D) A variety of mutants were produced with the second dose of X-rays.
28. What do the results of Experiment 3 suggest about how Colony A and Colony B are similar to each other?
- A) Both can grow on glucose, lactose, and ampicillin.
 - B) Both can grow on glucose and lactose.
 - C) Both can grow on glucose and ampicillin.
 - D) Both can grow on lactose and ampicillin.
29. What might be a reasonable hypothesis for explaining why Colony B is unable to grow on Medium Y?
- A) The gene for the enzyme that converts lactose to glucose had mutated.
 - B) Lactose is not nutritious when mixed with ampicillin.
 - C) A gene in the cells that made up Colony A had mutated, enabling them to out-compete the cells of Colony B in the lactose medium.
 - D) The mutagenic X-rays affected the lactose in the medium.

30. If ampicillin-resistance arose by mutation in Experiment 2, when did the mutation that prevented Colony B from growing in the lactose medium arise?
- A) in Experiment 1
 - B) in Experiment 2
 - C) in Experiment 1 or Experiment 2
 - D) in Experiment 3
31. If a culture taken from the original x-rayed sampled in Experiment 1 was spread across a fresh dish of minimal medium without antibiotics, what would you expect to observe after incubation?
- A) The cells that produced Colony A in Experiment 2 would die on the medium.
 - B) Only cells that produced Colony A in Experiment 2 would be able to grow.
 - C) One or two colonies would be growing on the medium.
 - D) Colonies would be growing everywhere on the medium.
32. Which of the following would not be a mechanism by which cells in Colony A could convey their ampicillin-resistance to other cells?
- A) Transduction
 - B) Conjugation
 - C) Transformation
 - D) Transference
33. Which statement about antibiotics and antibiotic drug use is false?
- A) Most antibiotics are non-specific, also killing beneficial bacteria that normally occur in the body.
 - B) Antibiotic use can accelerate the evolution of antibiotic resistance in diseases such as tuberculosis.
 - C) Antibiotics accelerate the rate of mutation in the targeted bacteria, causing resistance to appear in the bacteria.
 - D) Antibiotic-resistance genes can move between different species of bacteria through a process called "horizontal gene transfer."

Passage V

Enzymes act as biological catalysts that help speed up reactions by lowering the activation energy needed to bring reactants to their “transition state.” In this unstable condition, bonds can break and the reaction proceeds. The reaction itself is often described in the following way:



E = enzyme
S = substrate(s)
ES = enzyme-substrate complex
P = product(s)

Enzymes can carry out their catalytic functions only with particular substrates, and only under particular environmental conditions (such as pH and temperature). This characteristic of enzymes is referred to as enzyme specificity. The enzyme specificity in four different enzymes is shown in the Figure 1.

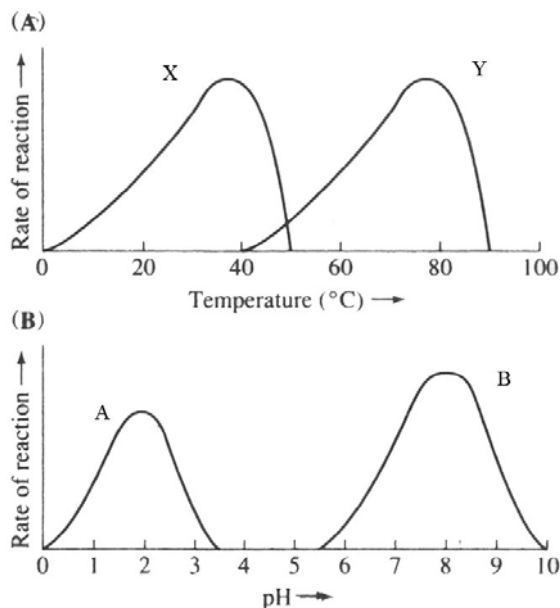


Figure 1. Activity of four enzymes at varying temperature and pH.

34. Enzymes A and B in the figure are both protein-digesting enzymes found in humans. Where would they most likely be found?
- A) A in the small intestine; B in the stomach
B) A in the mouth; B in the small intestine
C) A in the stomach; B in the small intestine
D) A in the small intestine; B in the mouth
35. Which statement is true concerning enzymes A and B?
- A) They could not possible be at work in the same part of the body.
B) At a pH of 4.5, enzyme A works slower than enzyme B.
C) They have different temperature ranges at which they work best.
D) At their appropriate pH ranges, both enzymes work equally fast.
36. What conclusion may be drawn concerning enzymes X and Y?
- A) Neither enzyme is likely to be a human enzyme.
B) Enzyme X is more likely to be a human enzyme.
C) Enzyme Y is more likely to be a human enzyme.
D) Both enzymes are likely to be human enzymes.
37. At which temperatures might enzymes X and Y both work?
- A) Above 40°C
B) Below 50°C
C) Above 50°C and below 40°C
D) Between 40°C and 50°C
38. An enzyme-substrate complex can form when the substrate(s) binds to the active site of the enzyme. Which environmental condition might alter the conformation of an enzyme in the figure to the extent that its substrate is unable to bind?
- A) Enzyme X at 40°C
B) Enzyme A at pH 4
C) Enzyme Y at pH 2
D) Enzyme B at 37°C

39. At 35°C, the rate of the reaction catalyzed by enzyme X begins and levels off. Which hypothesis best explains this observation?
- A) The enzyme has become saturated with substrate.
 - B) The temperature is too far below optimum.
 - C) Both A and B
 - D) Neither A nor B
40. In which of the following environmental conditions would digestive enzyme B be unable to bring its substrate(s) to the transition state?
- A) At any temperature below optimum.
 - B) At any pH lower than 5.5.
 - C) At any temperature higher than 37°C
 - D) At any pH where the rate of reaction is not maximum.
41. If the change in heat of a chemical reaction is negative and the change in entropy is positive, what can you conclude about the reaction?
- A) It requires energy.
 - B) It is endergonic.
 - C) It is spontaneous.
 - D) It will not reach equilibrium.
42. Which statement most completely describes the nature and function of enzymes?
- A) Enzymes are molecules that are involved in digestion.
 - B) Enzymes are proteins produced by living organisms that facilitate chemical reactions.
 - C) Enzymes are proteins in bodily secretions that protect the body from infection.
 - D) Enzymes are inorganic chemicals that act as catalysts to increase the rate of a reaction, without being used up themselves.
43. Which of the following could result in negative feedback of enzyme activity?
- A) A substrate molecule binding to the active site in the enzyme.
 - B) A lack of substrate available for catalysis.
 - C) A product molecule binding to an allosteric site on the enzyme.
 - D) The product of a reaction destroying the enzyme.

Passage VI

Muscular dystrophy (MD) is one of the most common genetic diseases found in North America with one in every 4000 boys (and rarely in girls) suffering from the degenerative disease. Although normally inherited, it is estimated that 30% of cases are due to a spontaneous genetic mutation. MD results in the progressive degeneration of skeletal and cardiac muscle fibers, weakening the muscle and leading ultimately to death from either cardiac or respiratory failure. Duchenne muscular dystrophy (DMD) is the most common form of MD, affecting children at birth. However, some people are struck with similar symptoms later in life, with a related, but milder, form of MD known as Becker's muscular dystrophy (BMD).

DMD is caused by a mutation in the gene which codes for the protein *dystrophin*, rendering it nonfunctional. Also the result of a mutation, BMD is usually characterized by a partially functional dystrophin product, accounting for its later onset. The protein dystrophin is found on the inner surface of the plasma membrane in normal muscle tissue. The gene that codes for dystrophin is the longest known gene in the human body at 2.4 megabases in length, accounting for 0.1% of the genome.

Therapeutic alteration of the genome as a treatment for genetic disorders (gene therapy) poses formidable challenges. Among them is the problem of targeting altered genes to the correct cells. One method of introducing genes into cells is to coat the DNA with an envelope of cationic, amphipathic lipids. The packets formed in this way are called liposome-DNA complexes. The lipids present their charged surface to the DNA molecules giving them an outer hydrophobic surface coating which enables the DNA to cross the plasma membrane.

44. The liposome-DNA complex crosses a membrane composed of:

- A) lipids and proteins.
- B) lipids and DNA.
- C) lipids, DNA, and proteins.
- D) lipids only.

45. Which of the following best explains the high incidence of muscular dystrophy in males?

- A) Fathers, who have the disease, pass it on their sons, but not to their daughters.
- B) Mothers, who are carriers of the disease, pass it on to their sons, but not to their daughters.
- C) The disease is sex-linked and the gene which codes for dystrophin occurs on the Y chromosome.
- D) The disease is sex-linked and the gene which codes for dystrophin occurs on the X chromosome.

46. Lipids used to complex with DNA must be cationic because DNA is:

- A) negatively charged and hydrophobic.
- B) negatively charged and hydrophilic.
- C) positively charged and hydrophobic.
- D) positively charged and hydrophilic.

47. Targeting therapeutic genes to specific cells is important because:

- A) all cells contain and express the same genes
- B) all cells contain, but do not express, the same genes
- C) inherited defective genes are only found in some cells of the body
- D) different cells contain different genes

48. Would an exogenous gene introduced into somatic cells be passed from parent to offspring?

- A) No, because changes to somatic cells are not passed down
- B) No, because foreign DNA is not passed to offspring
- C) Yes, because the DNA will be localized into the cell's nuclei
- D) Yes, because all DNA is passed from parent to offspring during meiosis

49. The functions of dystrophin likely include all but which of the following?

- A) Protection of elements within the membrane during contraction of cells
- B) Maintenance of the structural integrity of the plasma membrane
- C) Keeping ion channels within the cells open
- D) Recognition of protein hormones important to the functioning of the cells

50. The high rate of spontaneous mutation in the dystrophin gene is probably due to:

- A) the folding of the gene into the chromosome allows for transposition of nearby bases.
- B) the long length of the gene is statistically more likely to undergo point mutations.
- C) the presence of another gene affecting the dystrophin gene.
- D) X-inactivation results in only one copy being available to be inherited by offspring.

51. Which of the following signs would be expected when diagnosing DMD?

- A) Abnormally enlarged muscle fibers
- B) Decreased levels of creatinine kinase in the muscle cells
- C) A normal electrocardiogram
- D) Increased levels of dystrophin in the muscle tissue

52. Analysis of the dystrophin gene obtained from numerous patients identified large deletions, often in different locations. One of the most common deletions occurred in the center of the gene. The sequence of this segment was determined to be:

5'--GCCATAGAGCGA--3'

Which of the following sequences of DNA is complementary to this sequence?

- A) 5'--TCGCTCTATGGC--3'
- B) 5'--CGGUUUCUCGCU--3'
- C) 5'--CGGTATCTCGCT --3'
- D) 5'--CGGUAUCUCGCU--3'

Passage VII

Cats come in basically two colors: black and red (or orange). All other colors are modifications to these basic colors, either to the pigment itself or the arrangement of the pigment in the hair shaft. The genetics of coat color, pattern, and length involves no less than 14 identified loci, many of which exhibit Mendelian inheritance patterns. For example, the length of fur is controlled by a single locus, with short-hair being completely dominant to long-hair.

Although most of these genes are autosomal, the gene which converts the default black fur color to red is X-linked. Calico cats (also known as tortoiseshells) are characterized by patches of red and black fur. The patches can be quite large or the coat can have a brindled appearance with intermixed red and black hairs.

Calico cats can also have white in their pattern and this is controlled by another locus, the piebald spotting gene, a semi-dominant gene with very variable expression. The gene affects the embryonic cells which will become pigment-producing skin cells. These cells are initially formed along the neural crest and then migrate all over the body during skin formation. Areas which lack these pigment-producing cells, result in white patches. The presence of white in the coat, usually results in a patchy pattern as opposed to a brindled pattern.

53. Which of the following would not explain the dilution (paling) of calico coat color from red/black to cream/blue?

- A) Epistatic genes
- B) Polygenes
- C) A "dilution" gene
- D) Pleiotropy

54. If a breeder were to cross a long-haired, red female with a homozygous short-haired, black male, what are the chances of a short-haired calico kitten being produced in the F1 and F2 generations?

- A) 1/2 and 3/16
- B) 1/4 and 3/16
- C) 1/2 and 1/16
- D) 1/4 and 1/16

55. Which of the following genetic disorders would likely result in the production of a viable, but infertile, male calico cat?

- A) XYY
- B) XXY
- C) X0
- D) XY

56. Which genetic mechanism is most likely responsible for the patchy pattern observed in calico cats?

- A) Random X-deactivation will result in result in each cell expressing either black or orange.
- B) Deactivation of the paternal X-chromosome.
- C) Deactivation of the maternal X-chromosome.
- D) A gene which controls the size and distribution of the pigment patches.

57. Which of the following areas would most likely be white in a cat with the piebald spotting gene?

- A) Back
- B) Face
- C) Tail
- D) Paws

58. The phenotype of an organism is dependent on:

- A) genotype.
- B) penetrance.
- C) polygenes.
- D) All of the above.

59. Cells destined to become skin cells originate from the

- A) Ectoderm
- B) Endoderm
- C) Mesoderm
- D) Metaderm

60. Inbreeding can reduce the fitness of a population in the short term because it causes an increase in the:

- A) genetic diversity of the population.
- B) levels of aggression in the population.
- C) rate of spontaneous mutations.
- D) incidence of expression of deleterious recessive traits.

Passage VIII

Sweat is a bodily fluid containing between 0.1% – 0.4% sodium chloride, sodium lactate, and urea suspended in water. It is less concentrated than blood plasma and is secreted by the activity of sweat glands under the control of pseudomotor neurons. These neurons are part of the sympathetic nervous system, relaying information from the hypothalamus.

When sweat evaporates from the skin surface, energy as latent heat of evaporation is lost from the body and this reduces body temperature. Experiments have now confirmed that sweating only occurs as a result of a rise in core body temperature. Blood from the carotid vessels flows to the hypothalamus and these experiments have indicated its role in thermoregulation. Inserting a thermistor against the eardrum gives an acceptable estimate of hypothalamic temperature.

Humans can suffer from a condition known as hypohidrotic ectodermal dysplasia. It is caused by a faulty gene located on the X-chromosome. In females, during development, one X-chromosome is deactivated in each cell, resulting in a patchy distribution of sweat glands on the skin. In females, two copies of this gene could result in a dangerous condition, where the woman is unable to sweat at all. In genetically normal males, a patchy distribution of sweat glands is not possible, and one copy of the faulty renders them unable to sweat properly.

61. The transport of electrolytes in sweat from blood plasma to the sweat glands is best accounted for by which of the following processes?

- A) active transport
- B) osmosis
- C) simple diffusion
- D) all of the above

62. Drinking iced water results in a lowering of core body temperature. Thus, exposing the skin to heat while drinking iced water would result in which of the following?

- A) an increase in sweating followed by a decrease in sweating.
- B) An increase in sweating
- C) A decrease in sweating
- D) No change in sweat production

63. Hypohidrosis is only one of a 150 symptoms related to ectodermal dysplasia. Which of the following conditions could also be associated with ectodermal dysplasia?

- A) Thinning of the bones
- B) Weakened or absent dentin in the teeth.
- C) Benign cysts in the urinary tract
- D) Hyperthyroidism

64. In humans, eccrine sweat glands are greatest in their concentration in the hands, feet and head because:

- A) it is a visual signal to other humans that you are nervous or hot.
- B) the position of the sweat glands take advantage of the counter-current heat exchange properties of these extremities.
- C) there is a greater proportion of ectodermal tissue in these structures.
- D) information from these areas reaches the hypothalamus first and therefore it improves the efficiency of the response.

65. In regulatory systems, the phenomenon of negative feedback:

- A) provides a means of control.
- B) provides information about the system.
- C) increases the pace of the system.
- D) decreases the pace of the system.

66. Why is evaporative cooling used only as a last resort by animals in deserts?

- A) It is ineffective in dissipating heat at extremely high temperatures.
- B) Water is usually a limited resource in deserts.
- C) Sweating requires little energy expenditure.
- D) Re-setting the internal thermostat is required.

67. Imagine an animal that can alter its shape from a sphere to a ribbon. Its volume does not change with the shape, but the exposed surface area does change with the shape. If this animal is attempting to dissipate heat, it should form a:

- A) sphere, which has a high surface area to volume ratio
- B) sphere, which has a low surface area to volume ratio
- C) ribbon, which has a high surface area to volume ratio
- D) ribbon, which has a low surface area to volume ratio

68. Body temperature in humans is normally controlled by homeostatic feedback mechanisms. A fever is a condition where the body temperature is higher than normal, usually during a bacterial or viral infection. Which of the following is the most likely causal mechanism of a fever?

- A) An increase in basal metabolic rate that produces more heat than the feedback system can cope with.
- B) A change in the “set-point” of the negative feedback loop.
- C) A decrease in the ability to cool, for example, by shutting down sweating.
- D) An increase in the delay between a rise in body temperature and its detection in the brain.

69. The most effective method for producing an increase in the total amount of water lost through the skin during a certain period would be:

- A) inhibiting kidney function.
- B) decreasing salt consumption.
- C) increasing water consumption.
- D) Raising the environmental temperature.

Passage IX

Sickle cell anemia is inherited as an autosomal recessive trait, most common to people of African descent. Approximately 1 in 500 African Americans is affected and about 1 in 12 is a heterozygotic carrier. The sickle cell trait is the result of a mutation affecting a base in one of the genes involved in the production of hemoglobin. Hemoglobin, in adults, is made up of four polypeptide chains attached to the prosthetic group heme. The polypeptide chains influence the oxygen-carrying capacity of the molecule. A change in the base sequence of the triplet coding for one amino acid out of the normal 146 amino acids in the β chains gives rise to the production of sickle cell hemoglobin. The physiological effect of this is to lower the oxygen-carrying capacity of these red blood cells. Structurally, the abnormal hemoglobin causes the red blood cell to “sickle” in shape, causing it to get stuck in smaller capillaries and sharp bends. In the heterozygous condition, individuals show the sickle-cell trait, but the red blood cells appear normal and only about 40% of the hemoglobin is abnormal.

In parts of the world where malaria caused by *Plasmodium falciparum* is endemic, instances of the sickle cell anemia trait are elevated. Malaria is caused by protozoan parasites, which are transmitted by mosquitoes from person to person. There are several different forms of malaria, each resulting from a different protozoan. It has been shown that individuals with the sickle cell trait are incapable of contracting the disease. The parasites spend a large proportion of their lifecycle in the red blood cells but fail to thrive in the presence of the abnormal hemoglobin.

70. The passage suggests that sickle-cell anemia involves a point mutation involving:

- A) the inversion of a valine residue with a glutamic acid residue in one of the polypeptide chains of hemoglobin.
- B) the deletion of a valine residue from a polypeptide chain in hemoglobin.
- C) the insertion of a valine residue into a polypeptide chain of hemoglobin.
- D) the substitution of a valine residue for a glutamic acid residue in a polypeptide chain of hemoglobin.

71. The continued presence of the allele that causes sickle cell anemia in areas where

- falciparum malaria is prevalent is most likely the result of which mechanism?
- A) Inbreeding depression
 - B) Frequency-dependent selection
 - C) Heterozygotic advantage
 - D) Genetic drift
72. Which of the following processes will likely be most affected by the presence of the sickle cell trait?
- A) The production of carbon dioxide, water and ATP during the Krebs cycle and oxidative phosphorylation
 - B) The production of carbon dioxide and ATP from ADP in the electron transport chain
 - C) Fermentation of pyruvate to lactate and ATP
 - D) Production of pyruvate and ATP in glycolysis
73. For a woman living in the United States, which genotype would be the most advantageous to have?
- A) homozygous for the sickle cell allele
 - B) heterozygous for the sickle cell allele
 - C) homozygous for the normal hemoglobin allele
 - D) it doesn't matter; all are equally advantageous
74. Sickle cell disease is caused by:
- A) Missense mutation
 - B) Nonsense mutation
 - C) Frameshift mutation
 - D) RNA splicing mutation
75. Which of the following mutations to a gene is least likely to affect an organism?
- A) A single base change near to the 5' end of the open reading frame.
 - B) A single base change near to the 3' end of the open reading frame.
 - C) A single base deletion near to the 5' end of the open reading frame.
 - D) A single base deletion near to the 3' end of the open reading frame.

76. The frequency of the sickle cell allele in the central African population is 0.12. If that population were in Hardy-Weinberg equilibrium, what percentage of the population would you expect to be heterozygous for sickle cell?
- A) 1.44%
 - B) 10.5%
 - C) 21.1%
 - D) 42.2%
77. Which of the following would not happen in the United States if malaria once again became a widespread disease?
- A) Depending on the type of malaria, overtime, the sickle cell allele would become more prevalent in the population
 - B) Because of antibiotic resistance in malaria strains, many individuals would die of malaria
 - C) Individuals who were heterozygous for the sickle cell allele would be less susceptible to certain kinds of malaria.
 - D) There would be an increase in the mosquito population in the U.S.
78. Global warming may result in more cases of malaria because
- A) humans' immune systems are weakened by increased temperatures.
 - B) habitats favorable to some insects will increase.
 - C) most rodents cannot survive in hot climates.
 - D) as temperatures rise, people will move closer to the equator.

Passage X

The ABO blood group is the primary determinant in blood transfusions. In humans, the gene that controls glycoproteins on the surface of red blood cells involves three alleles (i_A , i_B , i), six genotypes, and four phenotypes. The i_A and i_B alleles are codominant with respect to each other and are dominant with respect to the i allele. Individuals homozygous for the i allele have group O blood. Individuals with the genotype i_A or i_B have group A and B blood respectively. People with blood group A produce antibodies to the B antigen while people with blood group B produce antibodies to A antigens. The O blood type produces antibodies to both A and B antigens.

These blood groups are important because differences in the glycoproteins on the surface of red blood cells can cause severe problems during blood transfusions. The reason has to do with the immune system, the body's mechanism to combat invasion by foreign particles or organisms. One function of the immune system is to produce antibodies, which are proteins that have the special property of adhering only to substances that are foreign to the body, that is, anything that is non-self. A foreign substance that induces the body to make antibodies against it is called an antigen. When blood is transfused, the A or B glycoproteins on blood cells of one individual may be recognized as "foreign", as antigens, by the immune system of another. The antibodies that are produced against the A and B antigens on foreign blood cells act as a glue and cause the cells to clump together. Such clumps can block arterioles (thrombosis) and are often fatal.

Another blood group antigen series is the Rh factor. Like the ABO blood group series, Rh factor is multi-allelic (i.e. there are more than two alleles). However, only two phenotypic classes are easily recognized: Rh positive and Rh negative. Rh⁺ individuals have the Rh antigen on their red blood cells while Rh⁻ individuals do not. Rh⁺ is thus dominant over Rh⁻. Rh⁻ individuals do not usually have anti-Rh antibodies in their blood unless they have been exposed to Rh⁺ red blood cells, either from a blood transfusion or during a pregnancy in which an Rh⁻ mother had an Rh⁺ child.

79. A woman of blood type O claims a child of blood type AB, and alleges that the father is a man of blood type B. The most likely explanation is that

- A) these are biological parents.
- B) neither is a possible parent of the child.
- C) she is the mother but the man is not the father.
- D) she is not the mother but the man's blood type does not rule him out as the father.

80. If the man in question X is found to have previously fathered a child of blood type O, the chance that a child of the man and woman in the question would be blood type O is:

- A) 0.
- B) 25%.
- C) 33%.
- D) 50%.

81. The man in question X with a phenotype B will possess which of the following genotypes?

- A) $i_A i$
- B) $i_B i$
- C) ii
- D) $i_A i_B$

82. The gene for the rare autosomal dominant condition, nail patella syndrome, is 10 centimorgans from the ABO blood locus. If an affected man had a type A affected mother and a type B normal father. He is blood type AB and is married to a type O woman with normal nails. What is the probability his expected first child will have normal nails and type B blood?

- A) 0.05
- B) 0.25
- C) 0.33
- D) 0.5

83. On the basis of the ABO blood grouping system, a person with blood group O can donate blood to people with:

- A) blood group AB only.
- B) either blood group A or blood group B.
- C) blood group O only.
- D) any blood group.

84. Erythroblastosis fetalis (Rh-related hemolytic anemia) may result if

- A) the Rh⁺ mother is sensitized to the Rh-antigen and the baby is Rh-
- B) the Rh- mother is sensitized to the Rh⁺ antigen and the baby is Rh-
- C) the Rh- mother is sensitized to the Rh⁺ antigen and the baby is Rh⁺
- D) the Rh⁺ mother is sensitized to the Rh-antigen and the baby is Rh⁺

85. Alleles are genes that:

- A) are always sex-linked and are transmitted from mothers to their sons.
- B) are linked to one chromosome only.
- C) occupy corresponding positions on homologous chromosomes.
- D) arise during the cross-over process.

86. If you examine the serum of a child who is blood type AB, you would expect to find anti-A and anti-B isoagglutins:

- A) Immediately after birth
- B) At age 6 years
- C) Both
- D) Neither

87. Which sequence most accurately describes antibody-mediated immunity?

- I. B cell divides and gives rise to clone
- II. Antibodies produced
- III. Cells differentiate, forming plasma cells
- IV. Activated helper T cell interacts with B cell displaying same antigen complex
- V. B cell activated

- A) I, II, III, IV, V
- B) III, II, I, IV, V
- C) IV, V, II, IV, I
- D) IV, V, I, III, II

Passage XI

The electrocardiogram (EKG) is a record of the electrical changes that take place in the myocardium during the cardiac cycle. Since body fluids, with their various electrolytes, can conduct an electrical current, depolarizations and repolarizations that occur in muscle cells can be detected from the surface of the body. By placing electrodes at specific skin locations, the electrical sequences associated with the contraction and relaxation of the atria and ventricles can be viewed pictorially using an instrument that monitors and records these events.

Electrical impulses move through the cardiac conduction system in the following sequence:

1. the S-A node or pacemaker (in the right atrium with fibers extending across to the left atrium)
2. the A-V node (also in the right atrium)
3. the A-V bundle or bundle of His (in the interventricular septum)
4. the Purkinji fibers (in the walls of the ventricles)

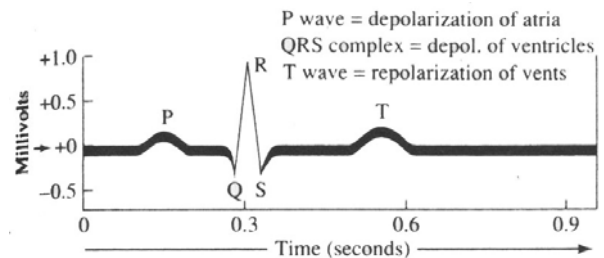


Figure 1. Electronic changes in the heart during the cardiac cycle.

The process of depolarization triggers the cardiac cycle. The cycle is divided into two major phases, both named for events in the ventricle: the period of ventricular contraction and blood ejection, systole, followed by the period of ventricular relaxation and blood filling, diastole.

During the very fast first part of systole, the ventricles are contracting but all valves in the heart are closed thus no blood can be ejected. Once the rising pressure in the ventricles becomes great enough to open the aortic and pulmonary valves, the ventricular ejection or systole occurs. Blood is forced into the aorta and pulmonary trunk as the contracting ventricular muscle fibers shorten. The volume of blood ejected from a ventricle during systole is termed stroke volume.

During the very first part of diastole, the ventricles begin to relax, and the aortic and pulmonary valves close. No blood is entering or leaving the ventricles since once again all the valves are closed. Once ventricular pressure falls below atrial pressure, the atrioventricular (AV) valves open. Atrial contraction occurs towards the end of diastole, after most of the ventricular filling has taken place. The ventricle receives blood throughout most of diastole, not just when the atrium contracts.

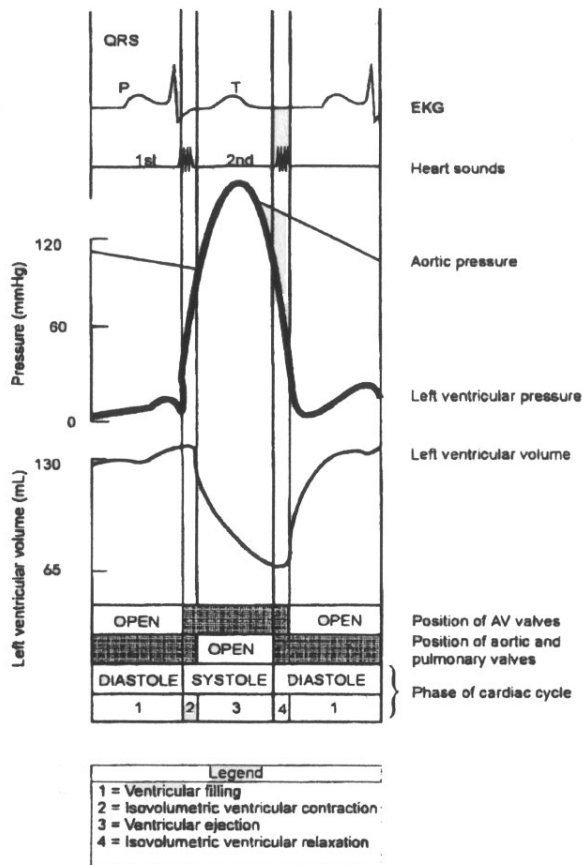


Figure 2. Electronic and pressure changes in the heart and aorta during the cardiac cycle.

88. Position P on the EKG of Figure 2 probably corresponds to:

- A) the beginning of ventricular systole.
- B) the beginning of ventricular diastole.
- C) atrial contraction.
- D) ventricular contraction.

89. The first heart sound represented in Figure 2 is probably made when:

- A) during ventricular diastole; blood in the ventricle is forced against the closed atrioventricular valve.
- B) during ventricular systole; blood in the arteries is forced against the aortic and pulmonary artery pocket valves.
- C) during ventricular systole; blood in the ventricle is forced against the closed atrioventricular valve.
- D) during ventricular diastole; blood in the arteries is forced against the aortic and pulmonary artery pocket valves.

90. Would you expect the walls of the atria or ventricles to be thicker?

- A) Ventricles, because ventricular stroke volume is high.
- B) Ventricles, because ventricular stroke volume is low.
- C) Atria, because blood ejection due to atrial contraction is high.
- D) Atria, because blood ejection due to atrial contraction is low.

91. The wall of the left ventricle is at least three times as thick as that of the right ventricle.. This feature aids circulation by assuring that:

- A) the left ventricle has a higher blood capacity than the right ventricle at all times.
- B) the right ventricle has a higher blood capacity than the left ventricle at all times.
- C) blood entering the pulmonary artery is at a much higher pressure than blood entering the aorta.
- D) blood entering the aorta is at much higher pressure than blood entering the pulmonary artery.

92. According to Figure 2, the opening of the aortic and pulmonary valves is not associated with:

- A) a drop and rise in left ventricular volume.
- B) ventricular stroke volume.
- C) a rise and fall in aortic pressure.
- D) the third phase of the cardiac cycle.

93. According to Figure 1, the P wave is most closely associated with the electrical events between the:

- A) S-A node and A-V node.
- B) S-A node and Purkinji fibers.
- C) A-V node and A-V bundle.
- D) A-V bundle and Purkinji fibers.

94. According to Figure 1, the largest net change in voltage associated with a specific event during the cardiac cycle is:

- A) closest to 1.5 mV.
- B) closest to 1.0 mV.
- C) closest to 0.5 mV.
- D) closest to -0.5 mV.

95. The time interval required for the cardiac impulse to travel from the pacemaker into the ventricular walls can be estimated by measuring:

- A) the height of the P wave.
- B) the combined heights of the P wave and the QRS complex.
- C) the distance between the P wave and the QRS complex.
- D) the distance between the P and T waves.

96. With respect to Figure 1, which statement best explains the absence of wave depicting repolarization of the atria?

- A) Atrial repolarization occurs at a point beyond the T wave.
- B) Atrial repolarization occurs at about the same time as ventricular depolarization.
- C) Atrial repolarization distinctly occurs between the P wave and the QRS complex, but the electrical change is so slight that the normal instruments used are not sensitive enough.
- D) The atria do not have to repolarize at every cardiac cycle.

97. If damaged heart tissue prolongs depolarization of the ventricles, what change might be detected in the patient's EKG?

- A) A second QRS complex will be present.
- B) The QRS complex will be absent.
- C) A higher QRS complex.
- D) A wider QRS complex.

98. Innervations of the S-A node and A-V node to maintain the normal heart rate comes from:

- A) sensory neurons of the somatic nervous system.
- B) motor neurons of the somatic nervous system.
- C) motor neurons of the sympathetic autonomic nervous system.
- D) motor neurons of the parasympathetic autonomic nervous system.

99. Which of the following should have no effect on the normal EKG?

- A) Potassium ion concentrations
- B) Chloride ion concentrations
- C) Sodium ion concentrations
- D) Calcium ion concentrations

100. A molecule of CO₂ that is generated in the cardiac muscle of the left ventricle would not pass through which of the following structures before leaving the body?

- A) Right atrium
- B) Left atrium
- C) Right ventricle
- D) Left ventricle