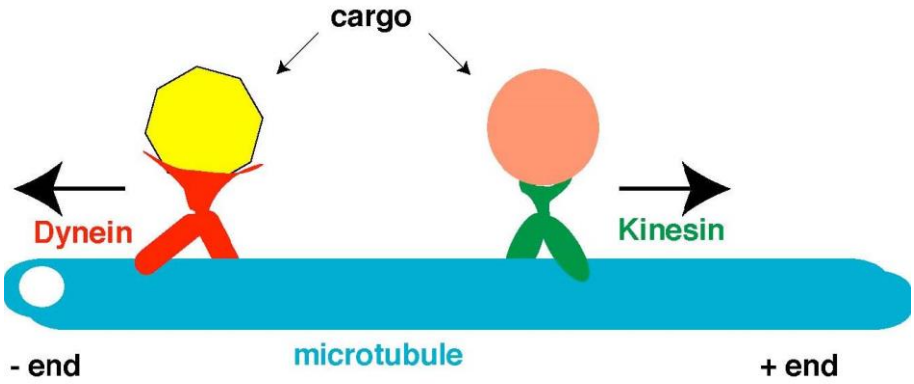
USABO Semifinal 2014

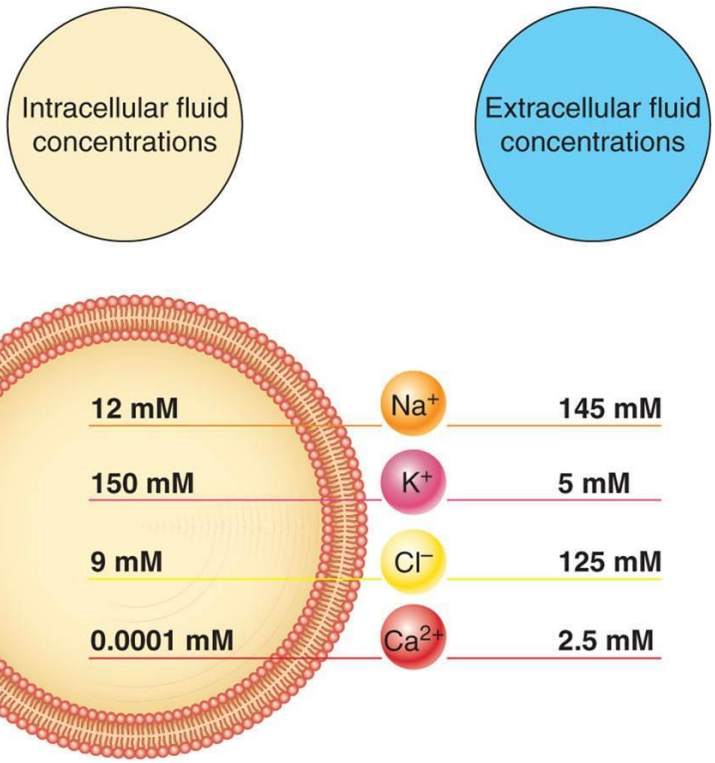
Part A.

1. E. (Note the words All, always and only, which most of the time indicate that statement is incorrect because biology abounds with many examples of exceptions). The word can does not indicate that scaffold is involved ALL of the times, therefore, I do not see the reason why this statement could not be true.
2. E. Microtubules serve as tracks for two classes of motor proteins — namely, kinesins and dyneins. Kinesins moving along microtubules usually carry cargo such as organelles and vesicles from the center of a cell to its periphery. Dyneins are important in sliding microtubules relative to one other during the beating of cilia and flagella on the surfaces of some eukaryotic cells. Take a look here: https://www.youtube.com/watch?v=gfKYBFGF0O0



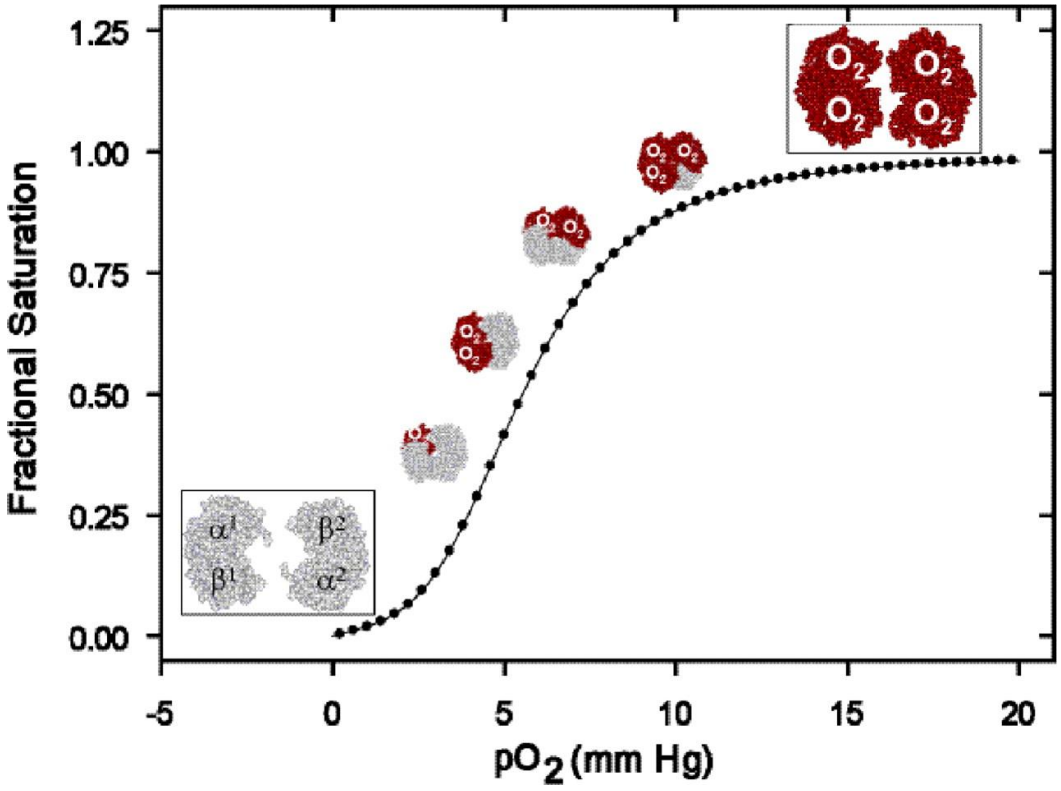
3. C. You should know it by heart.

Ionic Species	Typical Intracellular Concentration	Typical Plasma Concentration	Typical Equilibrium Potential	Typical P_X/P_{Na} [*1]
Na^+	10-15 mM	135-145 mM	+60 mV	1
K^+	140 mM	4 mM	-95 mV	50
Cl^-	4-15 mM	98-106 mM	-50 to -85mV	50
Ca^{2+}	100 nM [*2]	2.0-2.6 mM	+130 mV	< 0.1



4. True. In biochemistry, a macromolecule exhibits cooperative binding if its affinity for its ligand changes with the amount of ligand already bound.
   Cooperative binding is a special case of allostery. Cooperative binding requires that the macromolecule have more than one binding site, since cooperativity results from the interactions between binding sites. The most

famous example of cooperative binding is haemoglobin. The binding affinity of hemoglobin for oxygen is increased by the oxygen saturation of the molecule, with the first oxygens bound influencing the shape of the binding sites for the next oxygens, in a way favourable for binding. This positive cooperative binding is achieved through steric conformational changes of the hemoglobin protein complex; i.e., when one subunit protein in hemoglobin becomes oxygenated, a conformational or structural change in the whole complex is initiated, causing the other subunits to gain an increased affinity for oxygen. As a consequence, the oxygen binding curve of hemoglobin is sigmoidal, or S-shaped, as opposed to the normal hyperbolic curve associated with noncooperative binding.



5. False. Hemoglobin exists in two forms, a taut (tense) form (T) and a relaxed form (R). At high partial pressures of oxygen (such as those present in the alveoli), the relaxed (high affinity, R) state is favoured. Inversely, at low partial pressures (such as those present in respiring tissues), the (low affinity, T) tense state is favoured. Low affinity means that oxygen is easily released to surrounding tissues. Thus, in the lungs in order to pick up oxygen, haemoglobin must be in high affinity R state.

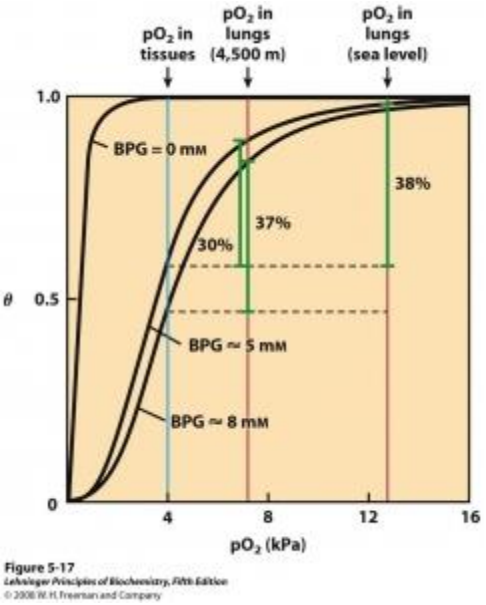
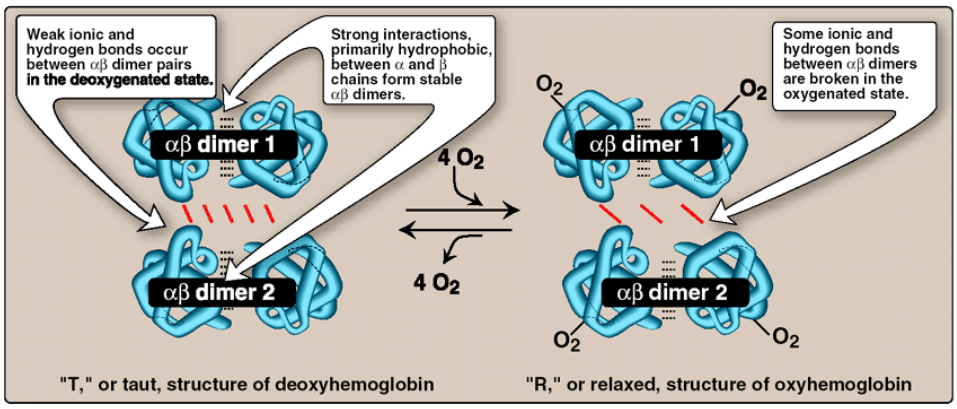


Figure 5-17

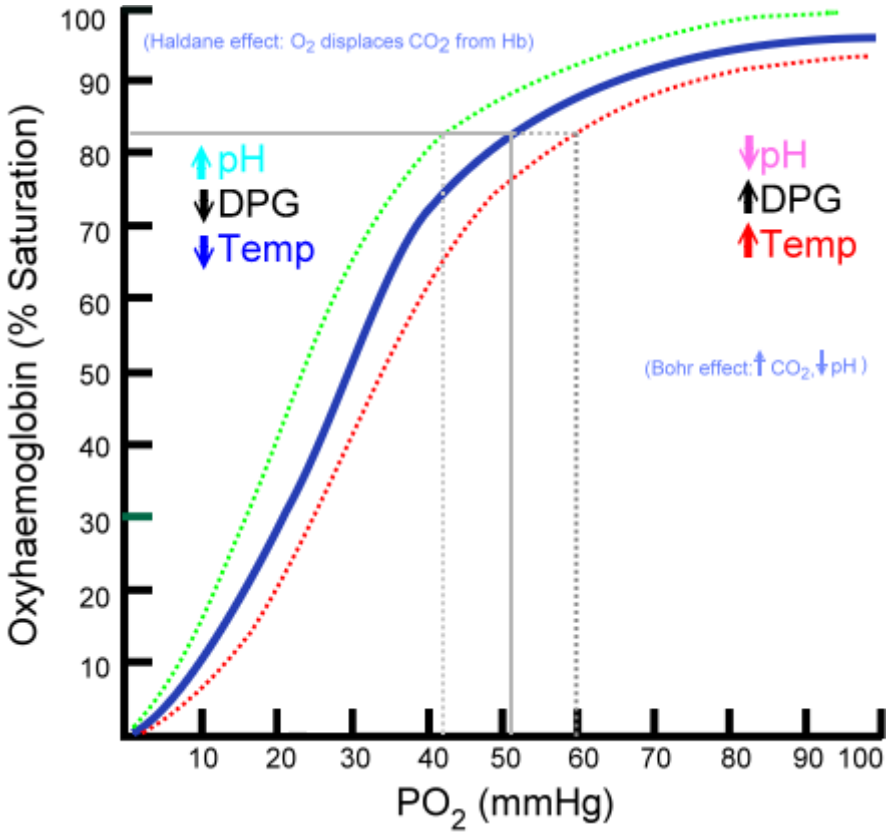


R and T States of Hemoglobin

- Two major conformations of Hb:
  R state and **T state**
- O_2 binds to Hb in either one, but it has to R state

- T = Tense state
  - More interactions, more stable
  - Lower affinity for O_2
- R = Relaxed state
  - Fewer Interactions, more flexible
  - Higher affinity for O_2

6. False. 2,3-diphosphoglycerate (2,3-DPG), binds with greater affinity to deoxygenated hemoglobin typically found in tissues than to oxygenated hemoglobin found in the lungs. Pure hemoglobin releases only 8% of oxygen to the tissues, however hemoglobin with 2,3-BPG allows it to release 66% of the oxygen to the tissues. It also acts to stabilize the oxygen affinity of the hemoglobin in the tense state, since the oxygen affinity is low. This effect makes it difficult for oxygen to bind to the hemoglobin which allows it be released to areas with low oxygen concentration. This is why hemoglobin is such an effective oxygen carrier. It is able to saturate itself with oxygen at high oxygen level in the lungs and retain the oxygen until it reaches the tissues which have a lower oxygen concentration.



7. True. The relaxed (R) state has a high affinity to oxygen.

8. **D.** A, B and C are all lipophilic and thus have receptors inside the cell. ADH is lipophobic and hydrophilic and thus do not cross plasma membrane. E is gas which are very small (14+16=30 Da) and can easily dissolve in the plasma membrane. Thus, it has intracellular receptors.

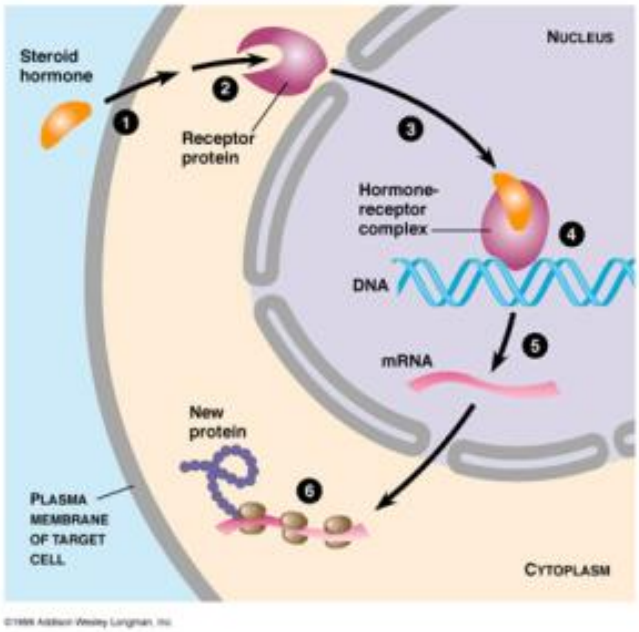
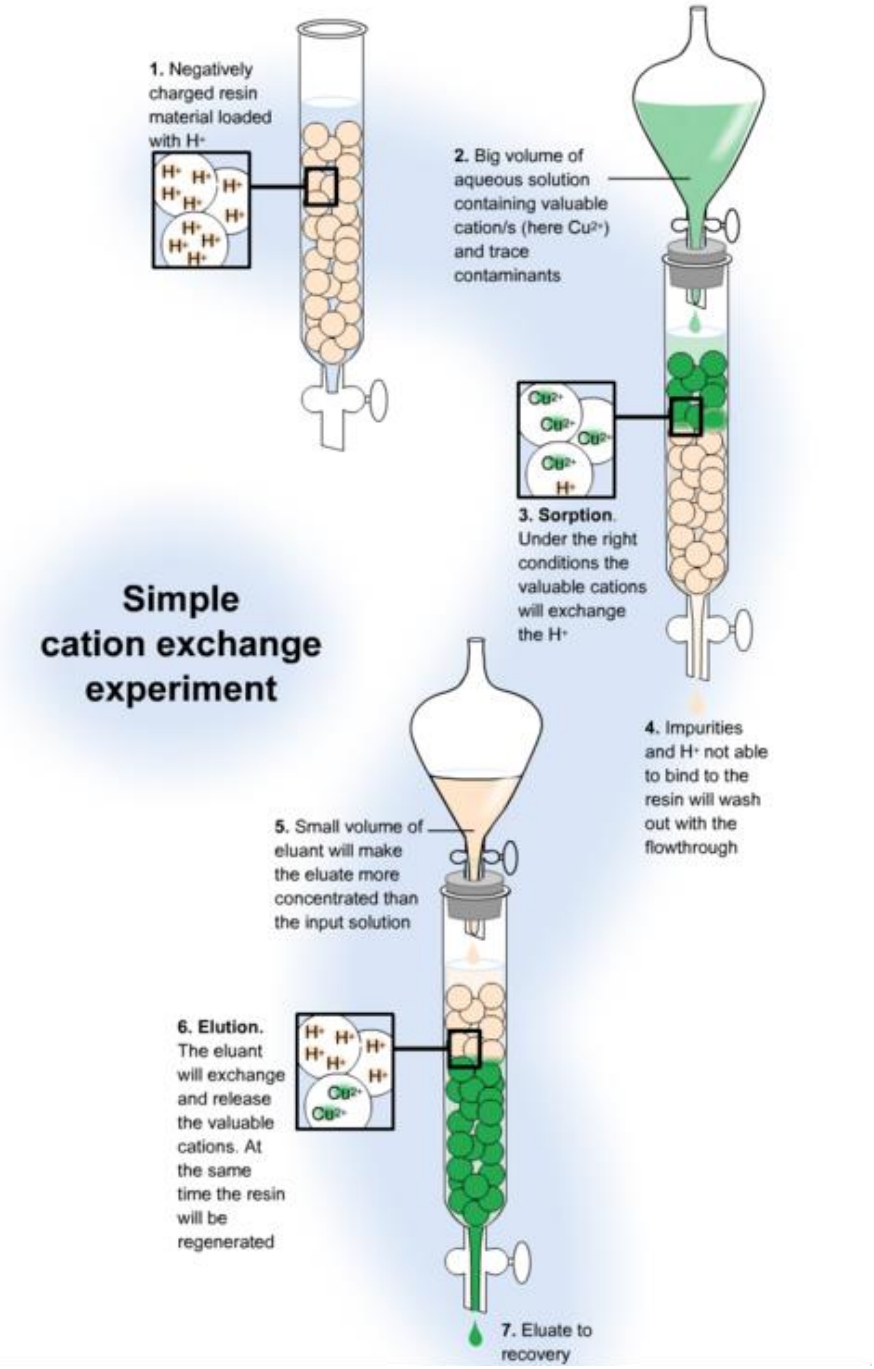


TABLE 7-1 Comparison of Peptide, Steroid, and Amino Acid–Derived Hormones

			TYROSINE DERIVATIVES	
	PEPTIDE HORMONES	STEROID HORMONES	Catecholamines	Thyroid Hormones
Synthesis and storage	Made in advance; stored in secretory vesicles	Synthesized on demand from precursors	Made in advance; stored in secretory vesicles	Made in advance; precursor stored in secretory vesicles
Release from parent cell	Exocytosis	Simple diffusion	Exocytosis	Simple diffusion
Transport in blood	Dissolved in plasma	Bound to carrier proteins	Dissolved in plasma	Bound to carrier proteins
Half-life	Short	Long	Short	Long
Location of receptor	Cell membrane	Cytoplasm or nucleus; some have membrane receptors also	Cell membrane	Nucleus
Response to receptor-ligand binding	Activation of second messenger systems; may activate genes	Activation of genes for transcription and translation; may have nongenomic actions	Activation of second messenger systems	Activation of genes for transcription and translation
General target response	Modification of existing proteins and induction of new protein synthesis	Induction of new protein synthesis	Modification of existing proteins	Induction of new protein synthesis
Examples	Insulin, parathyroid hormone	Estrogen, androgens, cortisol	Epinephrine, norepinephrine	Thyroxine (T_4)

Gland		Hormone	Chemical Class	Representative Actions	Regulated By
Hypothalamus		Hormones released from the posterior pituitary and hormones that regulate the anterior pituitary (see below)			
Pituitary gland					
Posterior pituitary (releases neuro-hormones made in hypothalamus)		Oxytocin	Peptide	Stimulates contraction of uterus and mammary gland cells	Nervous system
		Antidiuretic hormone (ADH)	Peptide	Promotes retention of water by kidneys	Water/salt balance
Anterior pituitary		Growth hormone (GH)	Protein	Stimulates growth (especially bones) and metabolic functions	Hypothalamic hormones
		Prolactin (PRL)	Protein	Stimulates milk production and secretion	Hypothalamic hormones
		Follicle-stimulating hormone (FSH)	Glycoprotein	Stimulates production of ova and sperm	Hypothalamic hormones
		Luteinizing hormone (LH)	Glycoprotein	Stimulates ovaries and testes	Hypothalamic hormones
		Thyroid-stimulating hormone (TSH)	Glycoprotein	Stimulates thyroid gland	Thyroxine in blood; hypothalamic hormones
		Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates adrenal cortex to secrete glucocorticoids	Glucocorticoids; hypothalamic hormones
Thyroid gland		Triiodothyronine (T_3) and thyroxine (T_4)	Amine	Stimulate and maintain metabolic processes	TSH
		Calcitonin	Peptide	Lowers blood calcium level	Calcium in blood
Parathyroid glands		Parathyroid hormone (PTH)	Peptide	Raises blood calcium level	Calcium in blood
Pancreas		Insulin	Protein	Lowers blood glucose level	Glucose in blood
		Glucagon	Protein	Raises blood glucose level	Glucose in blood
Adrenal glands					
Adrenal medulla		Epinephrine and norepinephrine	Amine	Raise blood glucose level; increase metabolic activities; constrict certain blood vessels	Nervous system
Adrenal cortex		Glucocorticoids	Steroid	Raise blood glucose level	ACTH
		Mineralocorticoids	Steroid	Promote reabsorption of Na^+ and excretion of K^+ in kidneys	K^+ in blood
Gonads					
Testes		Androgens	Steroid	Support sperm formation; promote development and maintenance of male secondary sex characteristics	FSH and LH
Ovaries		Estrogens	Steroid	Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics	FSH and LH
		Progesterone	Steroid	Promotes uterine lining growth	FSH and LH
Pineal gland		Melatonin	Amine	Involved in biological rhythms	Light/dark cycles

9. B. A protein with pH 5.6 has lots of hydrogen ions bound to it, thus it should carry an excessive positive charged. Cation exchangers contain negatively charged polymer as a stationary phase. Thus, positively charged molecules are attracted to a negatively charged solid support. As the protein is positive, to retain it in the column we need cation exchanger.



The pH of the buffer can be altered to reduce the protein's charge and disrupt its interaction with the stationary phase. For proteins bound to a cation exchange stationary phase, increasing the buffer pH will lead to a lesser positive charge on the protein, and subsequent elution from the column. For proteins bound to an anion exchange stationary phase, decreasing the buffer pH will lead to a lesser negative charge on the protein, and subsequent elution from the column.

Resin Type	Cation Exchanger	Anion Exchanger
Net charge of molecule of interest	+	−
Charge of resin	−	+
Running conditions	0.5–1.5 pH units below the pI of the molecule of interest	0.5–1.5 pH units above the pI of the molecule of interest

10. A. It seems correct because both human and bacterial cell have plasma membrane but with different phospholipids involved (for example, cardiolipin is found almost exclusively in certain membranes of bacteria and in the inner mitochondrial membrane of eukaryotes), bacteria may contain peptidoglycan in its wall which is composed of molecules that have no counterparts in gut cells, bacteria have different and more simple proteins than do human cells. Because their metabolism differs quite significantly, gut cells and bacterial cells should have different proportions pf CHNOPS.

B is incorrect because bacteria DO have macromolecules such as polysaccharides or proteins which are composed of monomers.

C. You should memorize the fact that in nature only L-amino acids and only D-sugars exist. However, some bacteria have both D- and L-amino acids.

D. The image on the right explains everything:

I would strongly recommend to remember that bacterial ribosomes are 70S (30S + 50S) while eukaryotic ribosomes are 80S (40S + 60S)

Below you will find some info about Svedberg units:

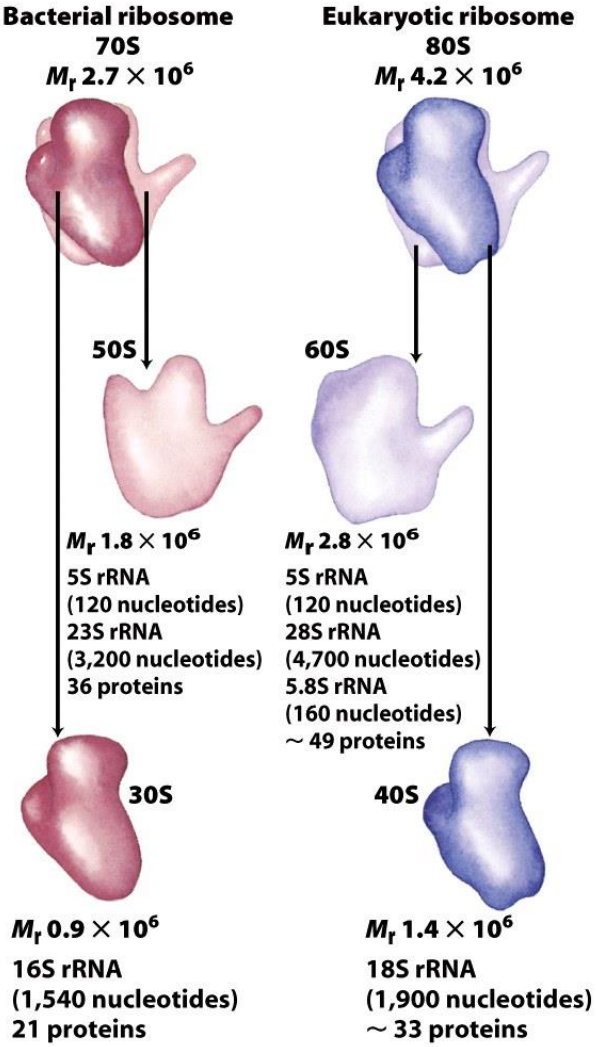
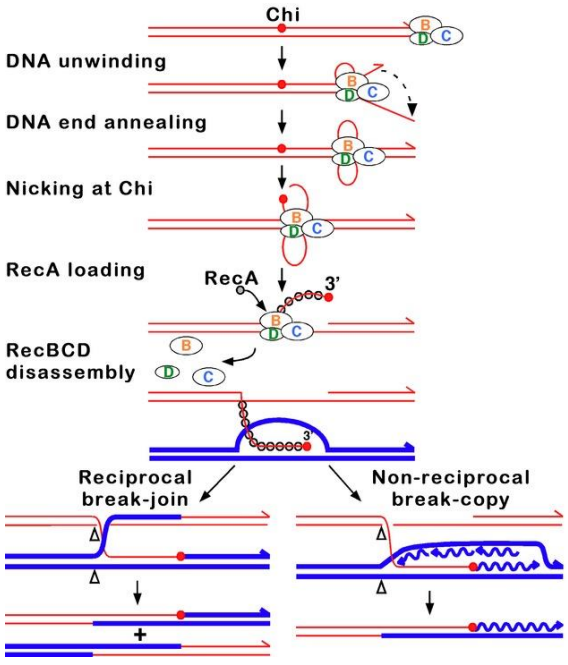


Figure 27-15
Lehninger Principles of Biochemistry, Fifth Edition

The Svedberg

A few molecular complexes, such as ribosomes and proteasome, are measured in svedberg units, abbreviated S. This is not an SI unit agreed upon by chemical commissions, but rather a curious hold-out from a technique used to measure mixtures of macromolecules, historically called **colloids**. The unit itself honors Theodor Svedberg (as with other eponymous units, such as the newton and the joule). Svedberg invented the ultracentrifuge, which is the device used to quantify sedimentation coefficients for colloids like ribosomes. The svedberg is a time unit: it is the ratio of velocity to acceleration in a centrifugal field. This is useful because the particle achieves terminal velocity when the centrifugal force is balanced by the viscosity of the media, just as the terminal velocity is achieved by a parachutist when the acceleration due to gravity matches the wind resistance. The value of 1 S is 10^{-13} seconds. It measures particles, although it is not just size- but also shape-dependent. Thus, the svedberg units are not additive, which explains why the bacterial 30S and 50S particles combine to make a 70S ribosome.

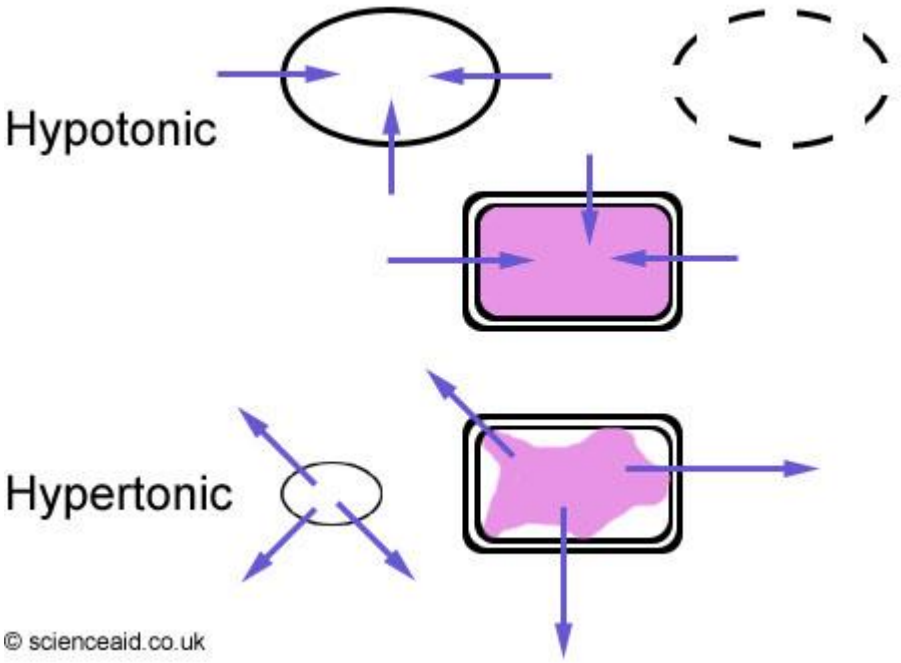
Statement E is incorrect because homologous recombination is a major DNA repair process in bacteria. The RecBCD pathway is the main recombination pathway used in bacteria to repair double-strand breaks in DNA. Take a look at how this process is carried out.



11. D. Specific heat capacity is the amount of heat required to raise the temperature of one gram of a substance by one degree Celsius. Every substance has its own specific heat capacity, with the specific heat capacity of water being 1 cal/(g°C). Water's high heat capacity is a property caused by hydrogen bonding among water molecules. To come to the right answer you should always try to associate chemical properties with physiological response. That is, if you know that water has an electronegative

oxygen and can thus form hydrogen bonds, this means that water is quite stable and needs more energy to disrupt those bonds.

12. A. Distilled water is water that has many of its impurities removed through distillation thus it is hypoosmotic (has more water and less solutes). Thus, water will diffuse in both types of cells and plant cell will become turgid (a plant cell fully inflated with water).



You should also note that it is quite probable that the liver cell will burst as it does not have a cell wall whereas the plant cell will become very turgid (firm, bloated) but will not burst as it has a tough cellulose wall.

13. D. On the exterior you should find hydrophilic amino acids (polar and/or charged). In this case only serine has –OH group which is highly polarized due to electronegative oxygen. Again, I would highly recommend to learn the chemical properties of every single amino acid because Olympiad organizer like to put some problems associated with amino acids:

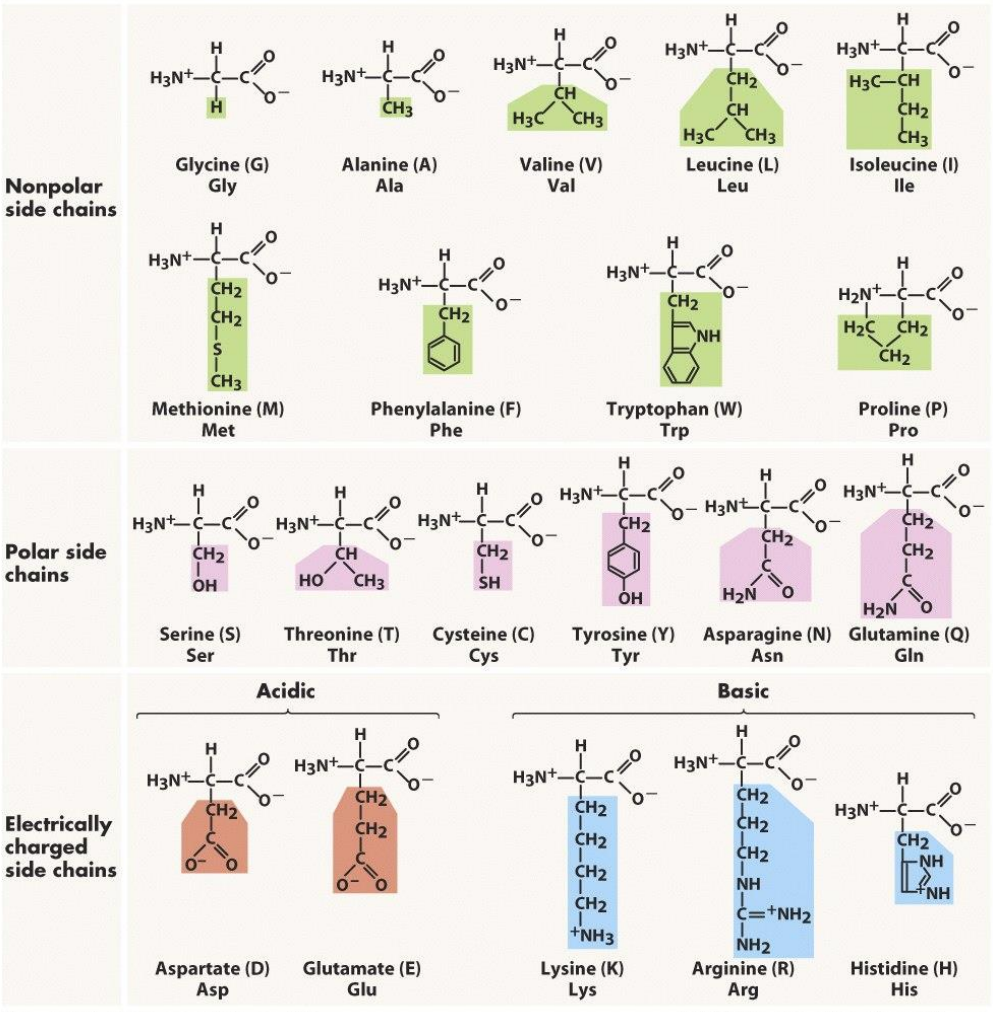
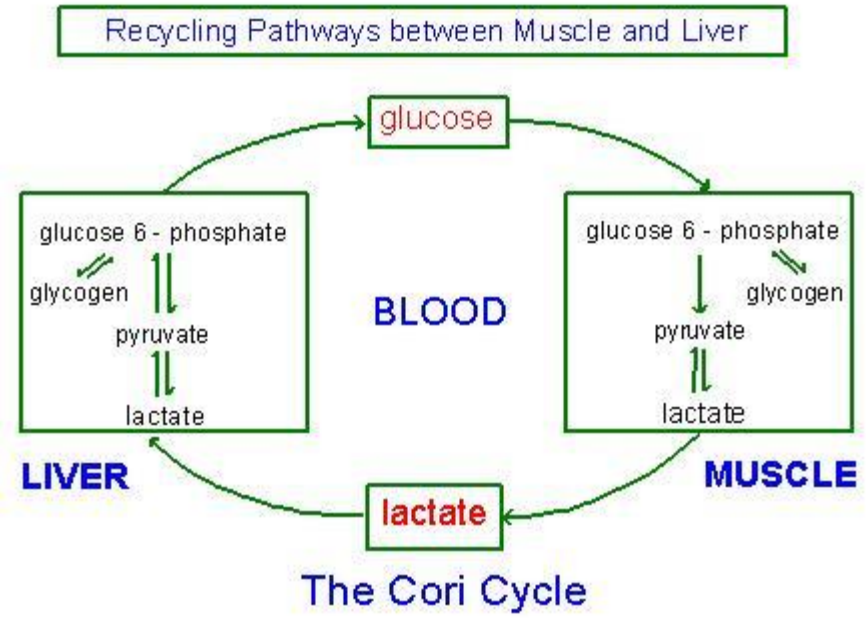
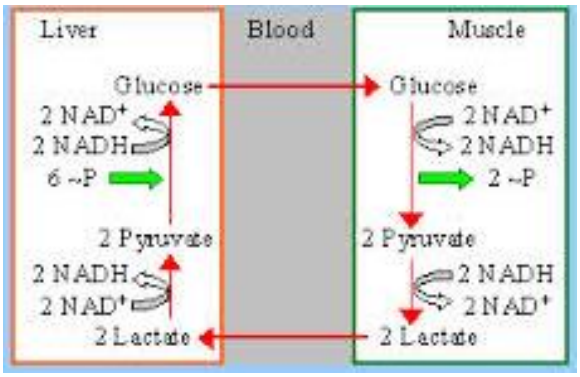


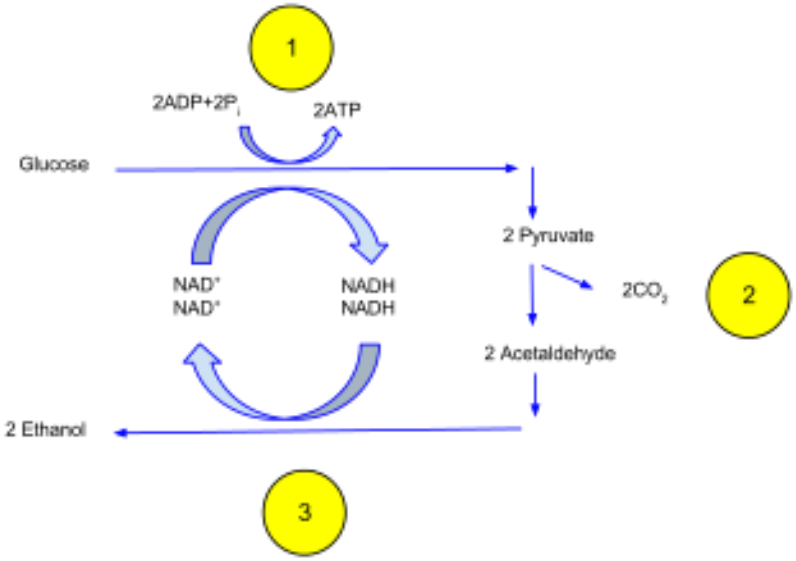
Figure 3-5 Biological Science, 2/e

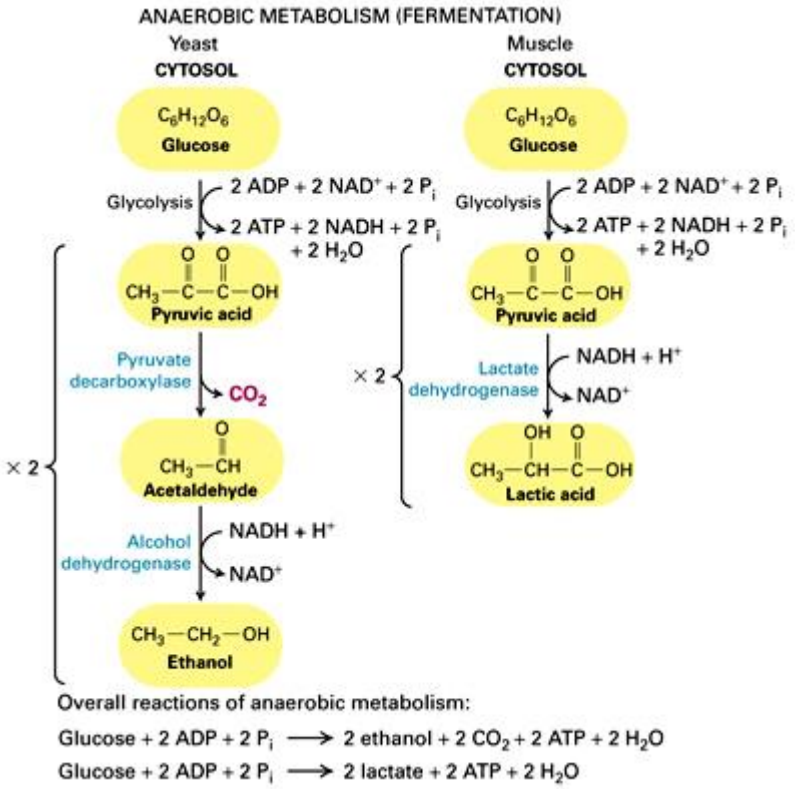
14. D. Anaerobic respiration involves the incomplete breakdown of glucose. It releases around 5% of the energy released by aerobic respiration, per molecule of glucose. The waste product is lactic acid rather than carbon dioxide and water: glucose → lactic acid (+ little energy).
The Cori cycle (also known as Lactic acid cycle) refers to the metabolic pathway in which lactate produced by anaerobic glycolysis in the muscles moves to the liver and is converted to glucose, which then returns to the muscles and is metabolized back to lactate.



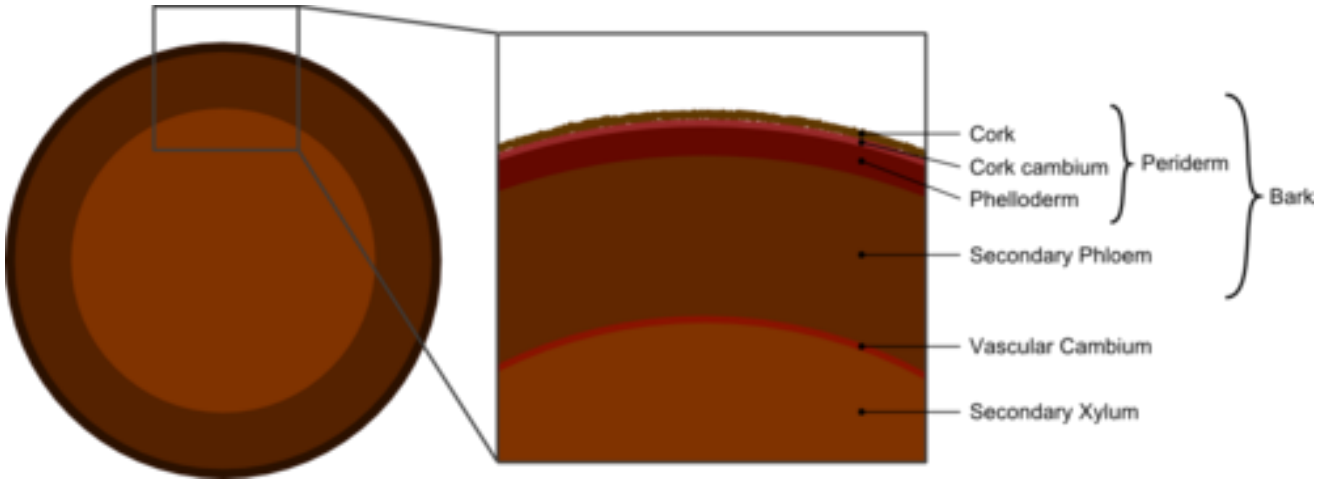
A statement is incorrect because lactate is produced from pyruvate and pyruvate is the end product of glycolysis.
Statement B is incorrect because high sugar concentration is not converted to lactic acid, instead it is used to synthesis glycogen or lipids.
Statement C is the first you should rule out because animal cells do not carry out alcoholic fermentation. It is widespread in fungi (yeast as an example) and plants.



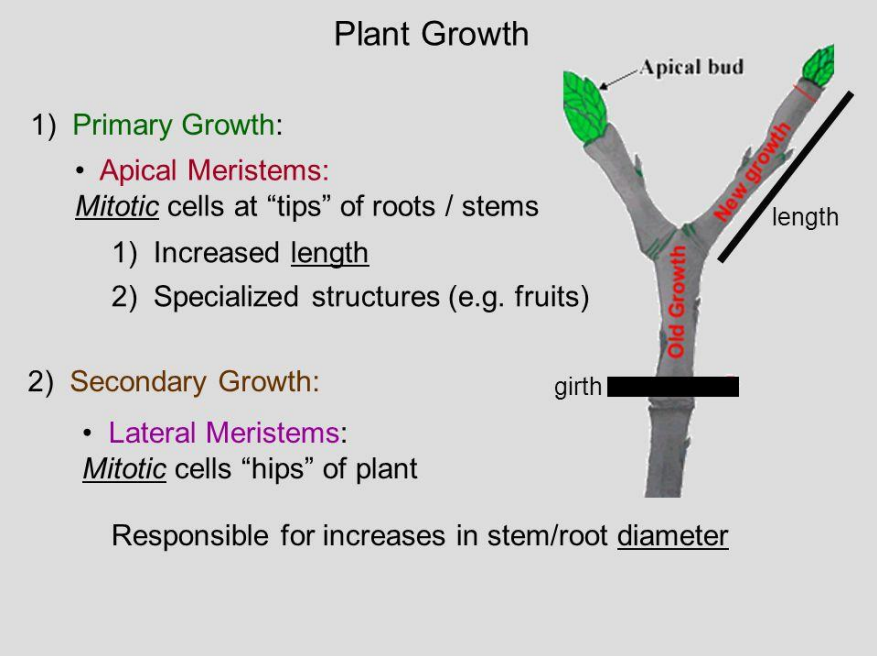


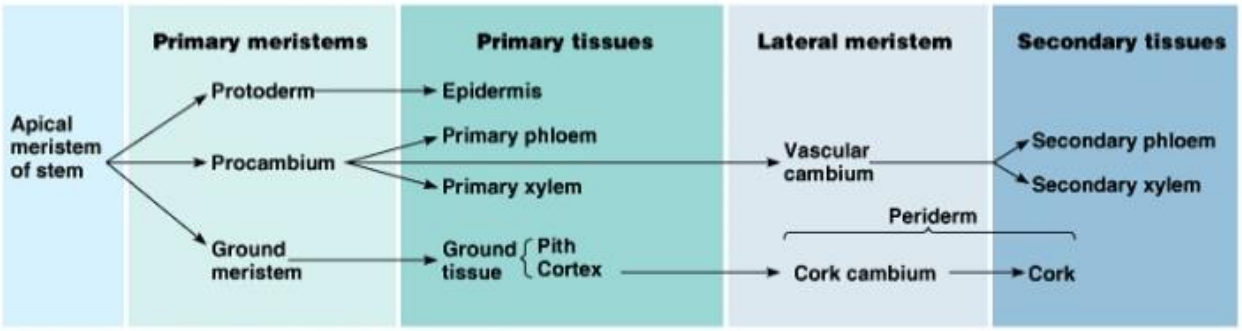


15. A. Secondary phloem is closer to cork cambium than vascular cambium. Phloem is the living tissue that carries organic nutrients (known as photosynthate), in particular sucrose, to all parts of the plant where needed. Primary phloem is laid down by the apical meristem and develops from the procambium. Secondary phloem is laid down by the vascular cambium to the inside of the established layer(s) of phloem. The vascular cambium is the source of both the secondary xylem (inwards, towards the pith) and the secondary phloem (outwards), and is located between these tissues in the stem and root. Pith, or medulla, is a tissue in the stems of vascular plants. Pith is composed of soft, spongy parenchyma cells, which store and transport nutrients throughout the plant. In eudicots, pith is located in the center of the stem. In monocots, it extends also into flowering stems and roots. The pith is encircled by a ring of xylem; the xylem, in turn, is encircled by a ring of phloem. The phelloderm, which is not always present in all barks, is a layer of cells formed by and interior to the cork cambium.
Cork cambium, or phellogen, is vital to producing the bark that covers a healthy tree. It is a lateral meristem and is responsible for secondary growth that replaces the epidermis in roots and stems. Cells that grow inwards from the phellogen are termed phelloderm, and cells that develop outwards are termed phellem or cork.

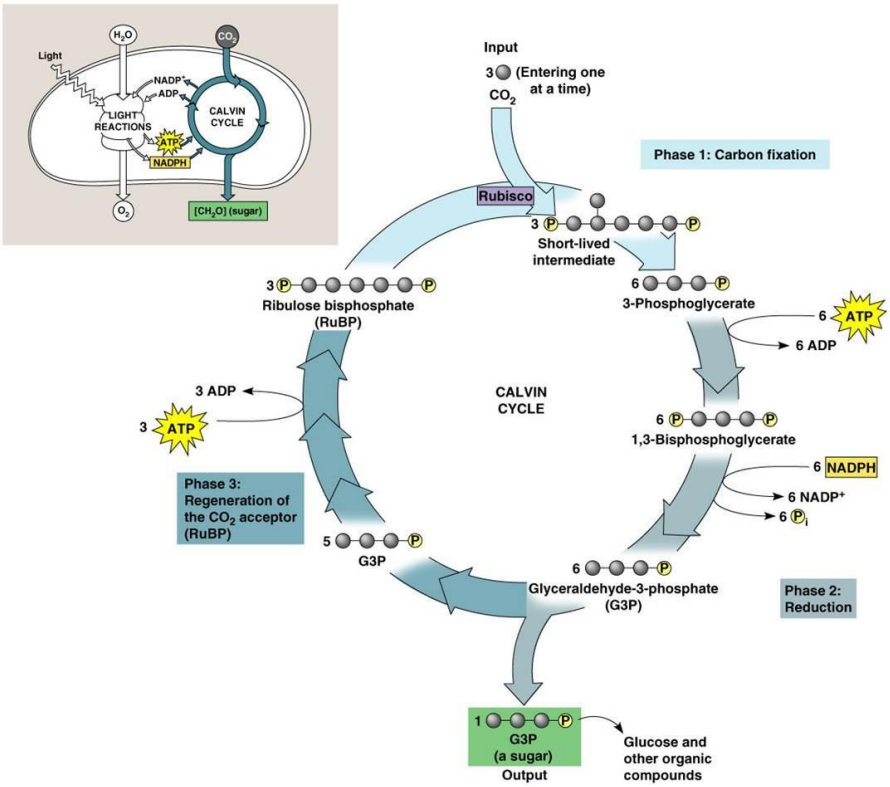


Bark includes all tissues of a plant exterior to the vascular cambium, thus, when a tree sheds its bark with cork cambium, it sheds phelloderm and secondary phloem at the same time, leaving vascular cambium unexposed. I am not sure if in this case plant sheds only cork cambium or bark.



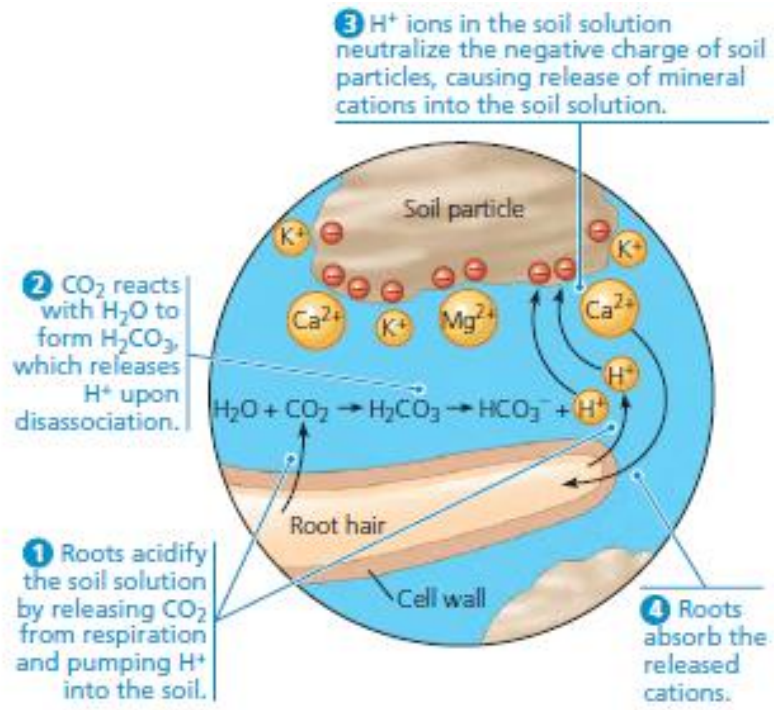


16. C. First of all, remember that to synthesis one PGAL molecule, three CO_2 molecules must be use:

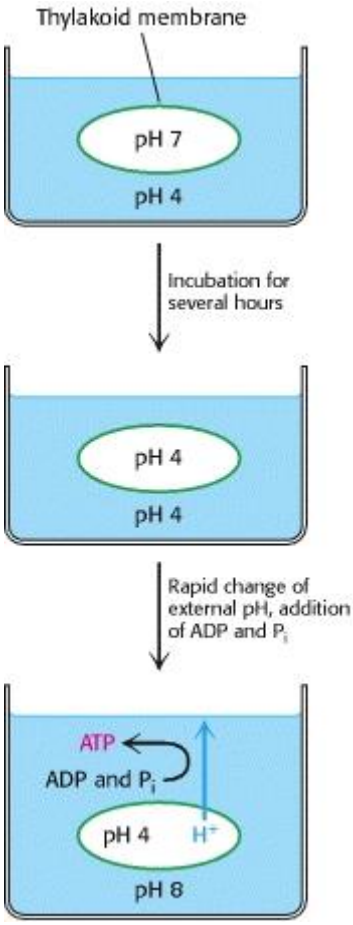


It is only in photosynthesis that carbon dioxife is being taken up wherease in cellular metabolism carbon dioxide is released. As we are asked to calculate the net molecules being taken up by the leaf, I would say that we had 3*8.0*10^6 molecules of CO_2 which give us a total of 24x10^6 molecules. Two glucose molecules were used and and this gives off 6 x2=12 CO_2 moleulces after respiration.

17. C. Cations are held by negatively charged particles of clay and humus. As pH increases (becomes less acid), the number of negative charges on the colloids increase, thereby increasing cation exchange capacity. As pH decrease, more hydrogen binds to negative soil particles and thus replaces positively charged mineral such as magnesium or calcium and these are consequently washed away. This results in D. Reduced growth, E. Reduced germination, B. Decreased seedling survival and A. Decreased disease resistance. We are left with C.



Most plants prefer slightly (in the task, we have got STRONGLY) acidic soil because the high H^+ concentrations can displace positively charged minerals from soil particles, making them more available for absorption. Adjusting soil pH for optimal crop growth is tricky because a change in hydrogen ion concentration may make one mineral more available but another less available.



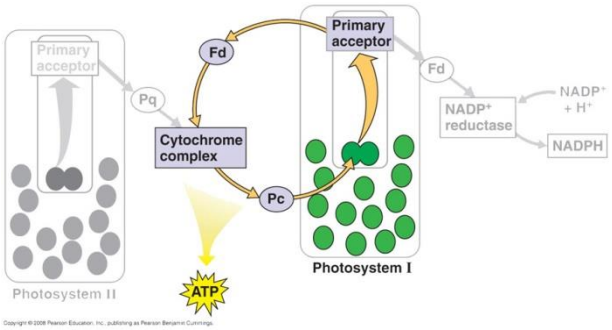
18. C.

A – would prove that a flash of light directly stimulates ADP phosphorylation.

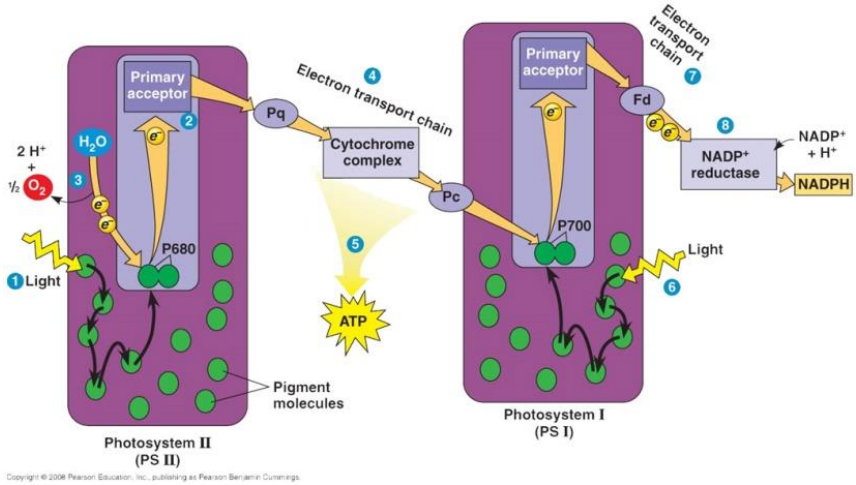
B – chlorophyll is a pigment molecule not an enzyme.

C – it is chloroplasts that produce ATP. This is a correct statement and here http://www.ncbi.nlm.nih.gov/books/NBK22519/ you can find the experiment itself.

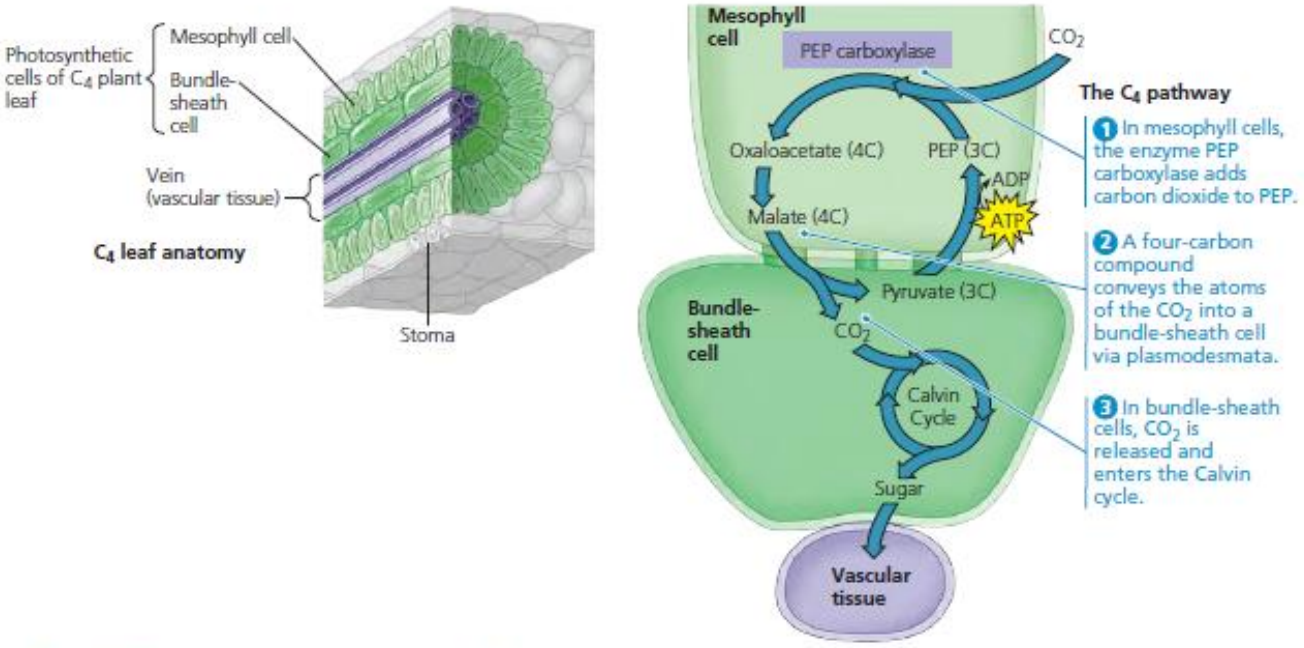
D – Cyclic electron flow do not produce NADPH. Cyclic electron flow avoids both photosystem II and the donation of electrons to NADP+. Electrons instead are passed from photosystem I to an electron transport chain, resulting in proton pumping, and then returned to reduce photosystem I, returning that photosystem to its ground state.



E – Not protons but electrons.



19. C. Remember the diagram from Campbell.



▲ **Figure 10.20 C_4 leaf anatomy and the C_4 pathway.** The structure and biochemical functions of the leaves of C_4 plants are an evolutionary adaptation to hot, dry climates. This adaptation maintains a CO_2 concentration in the bundle sheath that favors photosynthesis over photorespiration.

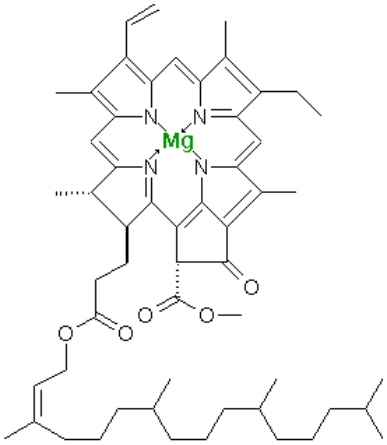
20. D. Magnesium is essential for chlorophyll formation and a cofactor for many enzyme reactions. Below is a molecule of chlorophyll with magnesium ion at the centre.

TABLE 36.1

Mineral Elements Required by Plants

ELEMENT	ABSORBED FORM	MAJOR FUNCTIONS
MACRONUTRIENTS		
Nitrogen (N)	NO_3^- and NH_4^+	In proteins, nucleic acids, etc.
Phosphorus (P)	$H_2PO_4^-$ and HPO_4^{2-}	In nucleic acids, ATP, phospholipids, etc.
Potassium (K)	K^+	Enzyme activation; water balance; ion balance; stomatal opening
Sulfur (S)	SO_4^{2-}	In proteins and coenzymes
Calcium (Ca)	Ca^{2+}	Affects the cytoskeleton, membranes, and many enzymes; second messenger
Magnesium (Mg)	Mg^{2+}	In chlorophyll; required by many enzymes; stabilizes ribosomes
MICRONUTRIENTS		
Iron (Fe)	Fe^{2+} and Fe^{3+}	In active site of many redox enzymes and electron carriers; chlorophyll synthesis
Chlorine (Cl)	Cl^-	Photosynthesis; ion balance
Manganese (Mn)	Mn^{2+}	Activation of many enzymes
Boron (B)	$B(OH)_3$	Possibly carbohydrate transport (poorly understood)
Zinc (Zn)	Zn^{2+}	Enzyme activation; auxin synthesis
Copper (Cu)	Cu^{2+}	In active site of many redox enzymes and electron carriers
Nickel (Ni)	Ni^{2+}	Activation of one enzyme
Molybdenum (Mo)	MoO_4^{2-}	Nitrate reduction

LIFE 8e, Table 36.1



MAGNESIUM

- Key element of chlorophyll production
- Improves utilization and mobility of phosphorus
- Activator and component of many plant enzymes
- Directly related to grass tetany
- Increases iron utilization in plants
- Influences earliness and uniformity of maturity

21. B. Apical dominance occurs when the shoot apex inhibits the growth of lateral buds so that the plant may grow vertically. It is important for the plant to devote energy to growing upward so that it can get more light to undergo photosynthesis. If the plant utilizes available energy for growing upward, it may be able to outcompete other individuals in the near vicinity.
The petiole is the stalk attaching the leaf blade to the stem. So statement A is inappropriate as those stalks do not give advantage of reaching more sun. However, it does increase the efficiency of photosynthesis due to increased surface area.
Statement C is incorrect because this protects from dehydration and also stunts the growth because less carbon dioxide is available.
The lateral bud is located in the axil of each leaf grow to form branches. They also increase photosynthetic efficiency due to more leaves.
Intercalary meristem occurs between mature tissues sections in the vicinity of the leaf attachment; are common in grasses; helps regenerate parts removed (by lawnmowers, herbivores, etc.). But they have limited advantage to increasing exposure to light because grass is eaten by herbivores and never reaches big heights.

22. A. ABA plays a major role in drought signalling. When a plant begins to wilt, ABA accumulates in the leaves and causes stomata to close rapidly, reducing transpiration and preventing further water loss. By affecting second messengers such as calcium, ABA causes potassium channels in the plasma membrane of guard cells to open, leading to a massive loss of potassium ions from the cells. The accompanying osmotic loss of water reduces guard cell turgor and leads to closing of the stomatal pores (see Figure 36.15). In some cases, water shortage stresses the root system before the shoot system, and ABA transported from roots to leaves may function as an "early warning system." Many mutants that are especially prone to wilting are deficient in ABA production.

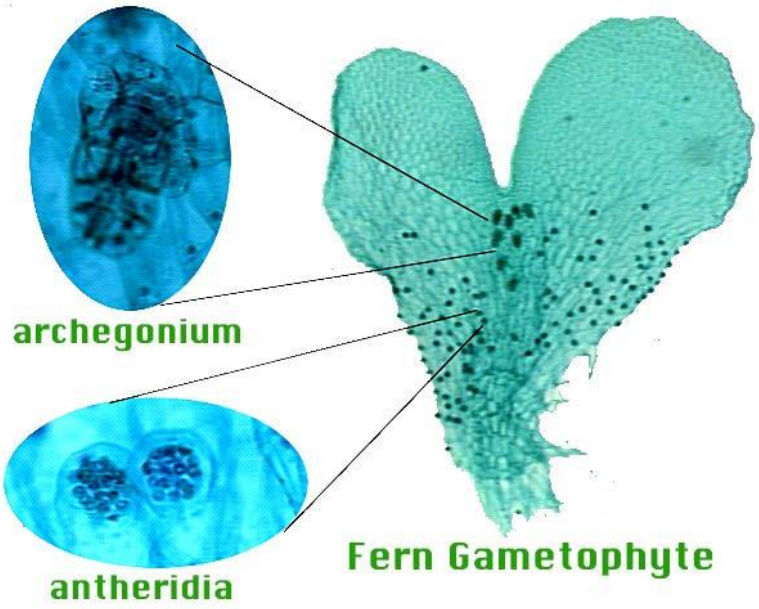
TABLE 37.1

Plant Growth Hormones

HORMONE	TYPICAL ACTIVITIES
Abscisic acid	Maintains seed dormancy and winter dormancy; closes stomata
Auxins	Promote stem elongation, adventitious root initiation, and fruit growth; inhibit axillary bud outgrowth and leaf abscission
Brassinosteroids	Promote stem and pollen tube elongation; promote vascular tissue differentiation
Cytokinins	Inhibit leaf senescence; promote cell division and axillary bud outgrowth; affect root growth
Ethylene	Promotes fruit ripening and leaf abscission; inhibits stem elongation and gravitropism
Gibberellins	Promote seed germination, stem growth, and fruit development; break winter dormancy; mobilize nutrient reserves in grass seeds

LIFE 8e, Table 37.1

23. A. Archegonia and antheridia are reproductive organs. Moving onto land required the development of new forms of reproduction. Algae shed their gametes into the water, but on land gametes must be protected against desiccation. Plants produce gametes within gametangia (protective layers of tissue that prevent gametes from drying out). Egg is fertilized within female gametangium (called the archegonium) and embryo develops for some time inside archegonium.

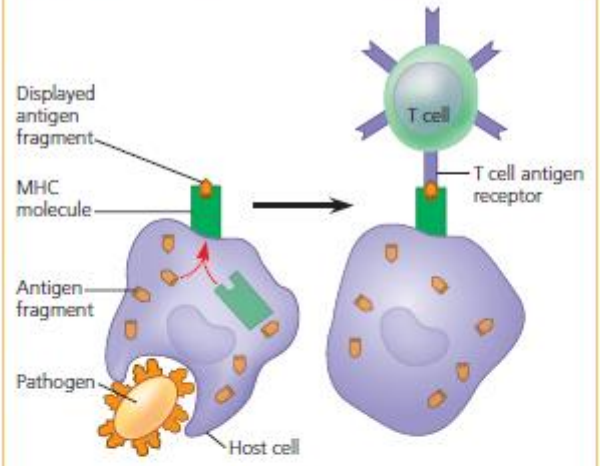


24. E. Endurance exercise is a strong stimulus for the proliferation of mitochondrial enzymes. The increase in mitochondrial density is associated with an increase in the duration one can perform endurance exercise and the ability to spare total body glycogen stores (Fittz et al., 1975). Generally, more lipids are used to generate ATP as a result of the increased mitochondrial density in response to exercise. A large body of research suggests that the enhancement of mitochondrial density in skeletal muscle is a key component in the development of performance in endurance sport. In a general sense, building more mitochondria allows an athlete to function closer to their potential.

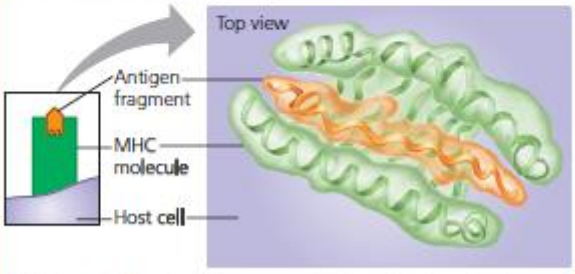
Note that building muscle muscle does NOT involve an increase in number of muscle fibers (muscle cells actually do not divide after we grow up). Through exercise, the muscular work performed against a progressively challenging overload leads to increases in muscle mass and cross-sectional area, referred to as hypertrophy. Muscular hypertrophy is an increase in muscle mass and cross-sectional area. The increase in dimension is due to an increase in the size (not length) of individual muscle fibers. Both cardiac (heart) and skeletal muscle adapt to regular, increasing workloads that exceed the pre-existing capacity of the muscle fiber. With cardiac muscle, the heart becomes more effective at squeezing blood out of its chambers, whereas skeletal muscle becomes more efficient at transmitting forces through tendinous attachments to bones.

Skeletal muscle has two basic functions: to contract to cause body movement and to provide stability for body posture. Each skeletal muscle must be able to contract with different levels of tension to perform these functions. Progressive overload is a means of applying varying and intermittent levels of stress to skeletal muscle, making it adapt by generating comparable amounts of tension. The muscle is able to adapt by increasing the size and amount of contractile proteins, which comprise the myofibrils within each muscle fiber, leading to an increase in the size of the individual muscle fibers and their consequent force production.

▼ **Figure 43.12 Antigen recognition by T cells.**



(a) Antigen recognition by a T cell. Inside the host cell, an antigen fragment from a pathogen binds to an MHC molecule and is brought up to the cell surface, where it is displayed. The combination of MHC molecule and antigen fragment is recognized by a T cell.



(b) A closer look at antigen presentation. As shown in this ribbon model, the top of the MHC molecule cradles an antigen fragment, like a bun holding a hot dog. An MHC molecule can display many different antigen fragments, but the antigen receptor of a T cell is specific for a single antigen fragment.

25. B. Each mammalian Toll-like receptor (TLR)

recognizes a molecular pattern characteristic of a group of pathogens. Lipopolysaccharide, flagellin, CpG DNA (DNA containing unmethylated CG sequences), and double-stranded (ds) RNA are all found in bacteria, fungi, or viruses, but not in animal cells. Together with other recognition and response factors, TLR proteins trigger internal innate immune defenses.

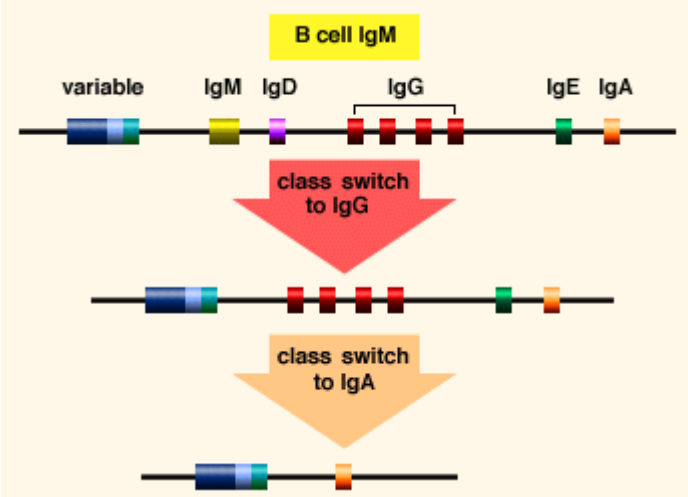
MHC (major function of MHCs are to bind to peptide fragments derived from pathogens and display them on the cell surface for recognition by the appropriate T-cells), immunoglobulin receptor (there is no such thing as immunoglobulin receptor but B cell's receptors have the same structure as immunoglobulins; B-cell receptor or BCR is a transmembrane receptor protein located on the outer surface of B-cell) and T-cell receptor (is a molecule found on the surface of T lymphocytes that is responsible for recognizing antigens bound to major histocompatibility complex (MHC) molecules) are all involved in specific immunity mediated by lymphocytes. NMDA receptors are the predominant molecular particles for controlling synaptic plasticity and memory function.

Features	Class I MHC pathway	Class II MHC pathway
Composition of stable peptide-MHC complex	Polymorphic α chain, β2 microglobulin, peptide	Polymorphic α and β chains, peptide
Types of APC	All nucleated cells	DCs, MQs, B cells endothelial cells, thymic epithelium
Responsive T cells	CD8+ T cells	CD4+ T cells
Source of protein antigens	Cytosolic proteins (mostly synthesized in the cell; may enter cytosol from phagosome)	Endosomal/lysosomal proteins (internelized from extracellular environment)
Enzyme responsible for peptide generation	Cytosolic proteasome	Endosomal & lysosomal proteases (e.g. cathepsin)
Site of peptide loading of MHC	Endoplasmic reticulum	Specialized vesicular compartment
Molecules involved in transport of peptides & loading of MHC molecules	TAP	Invariant chain, DM

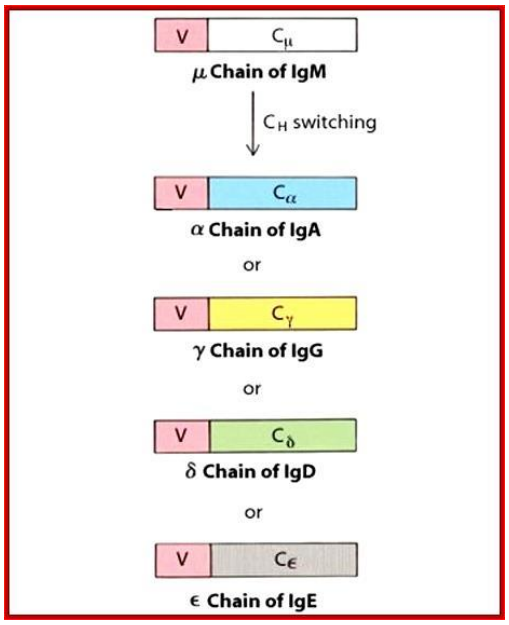
Difference between helper T cells (CD4) and cytotoxic T (CD8) cells

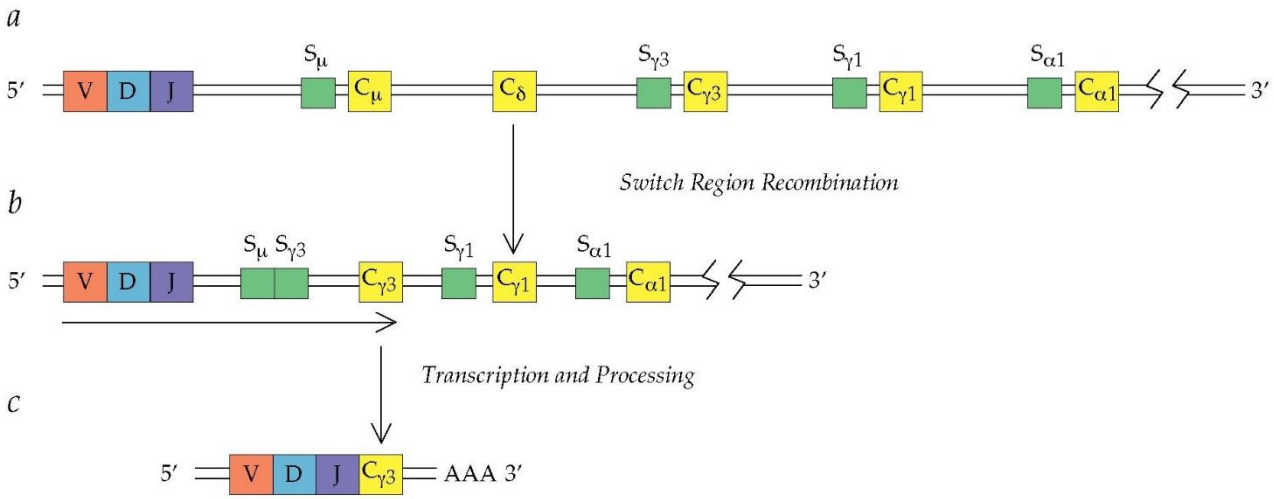
Helper T cells	Cytotoxic T cells
Carries CD4 marker	Carries CD8 cells
Helps or induce immune response.	Predominantly cytotoxic
Recognizes antigens in association with class II MHC	Recognize antigens in association with class I MHC
APCs are activated to kill intracellular microorganisms by secreting cytokines.	Destroy virus-infected and tumor cells directly

26. False. Immunoglobulin class switching (or isotype switching, or isotypic commutation, or class switch recombination (CSR)) is a biological mechanism that changes a B cell's production of antibody from one class to another; for example, from an isotype called IgM to an isotype called IgG.
If activated B cells encounter specific signalling molecules via their CD40 and cytokine receptors (both modulated by T helper cells), they undergo antibody class switching to produce IgG, IgA or IgE antibodies that have defined roles in the immune system.
During class switch recombination the constant region portion of the antibody-heavy chain is changed, but the variable region of the heavy chain stays the same; thus, class switching does not affect antigen specificity.
Switching is unidirectional--an IgG-producing cell cannot go back to production of IgM, for instance. It is highly improbable that any antibody can undergo switching to ANY other isotype.
27. True. Switching to H chain classes IgG, IgA, and IgE involves irreversible DNA recombination.



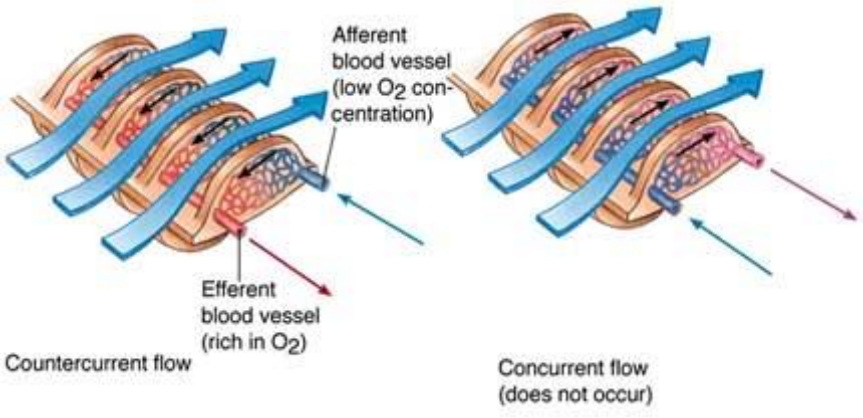
28. False. Class switching occurs by a mechanism called class switch recombination (CSR) binding. Class switch recombination is a biological mechanism that allows the class of antibody produced by an activated B cell to change during a process known as isotype or class switching. During CSR, portions of the antibody heavy chain locus are removed from the chromosome, and the gene segments surrounding the deleted portion are rejoined to retain a functional antibody gene that produces antibody of a different isotype.
29. True. During class switch recombination the constant region portion of the antibody-heavy chain is changed, but the variable region of the heavy chain stays the same; thus, class switching does not affect antigen specificity.



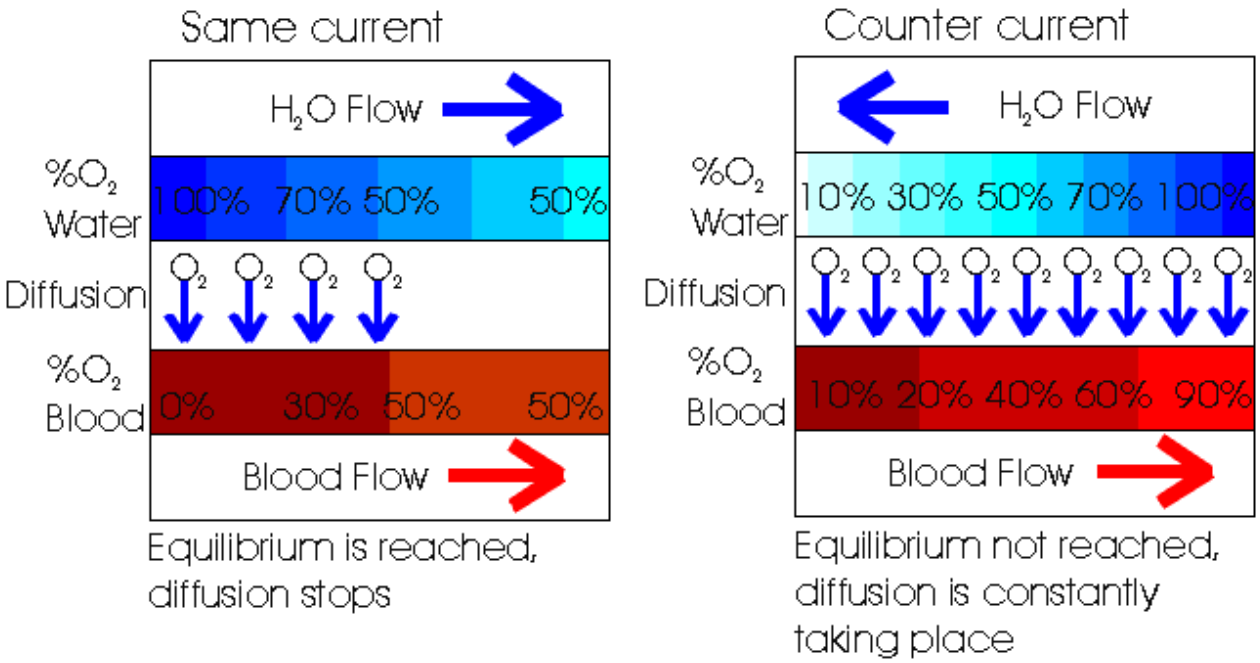


30. C. Duchenne muscular dystrophy is a neuromuscular condition caused by the lack of a protein called dystrophin. In skeletal and cardiac muscles, dystrophin is part of a group of proteins (a protein complex) that work together to strengthen muscle fibers and protect them from injury as muscles contract and relax. The dystrophin complex acts as an anchor, connecting each muscle cell's structural framework (cytoskeleton) with the lattice of proteins and other molecules outside the cell (extracellular matrix). Skeletal and cardiac muscle cells without enough functional dystrophin become damaged as the muscles repeatedly contract and relax with use. The damaged cells weaken and die over time, causing the characteristic muscle weakness and heart problems seen in Duchenne muscular dystrophy. Fibrosis is a prominent pathological feature of muscle biopsies from patients with DMD.
GM2 gangliosidoses are associated with Tay-Sachs disease. Thus statement A is incorrect.
Statement B is incorrect because lactic acid is not that toxic and is quickly reverted to glucose in the Cori cycle.
Statement D is incorrect because Duchenne muscular dystrophy is characterized by the absence, not presence, of dystrophin.
Statement E is quite logical on its own but dystrophin is found in muscle cells not in walls of the blood vessels thus they are unaffected.

31. B. The skin of most bony and cartilaginous fishes is covered by scales which prevent oxygen diffusion. The operculum of a bony fish is the hard bony flap covering and protecting the gills. They open as the mouth closes, causing the pressure inside the fish to drop. Water then flows towards the lower pressure across the fish's gill lamellae, allowing some oxygen to be absorbed from the water.



The efficiency of fish gills stems from a simple adaptation known as countercurrent exchange: The blood in the capillaries flows in the opposite direction from the water in the adjacent channels. Dissolved gases diffuse faster between fluids with a large difference in gas concentration (a high concentration gradient) than between fluids with only a small difference.

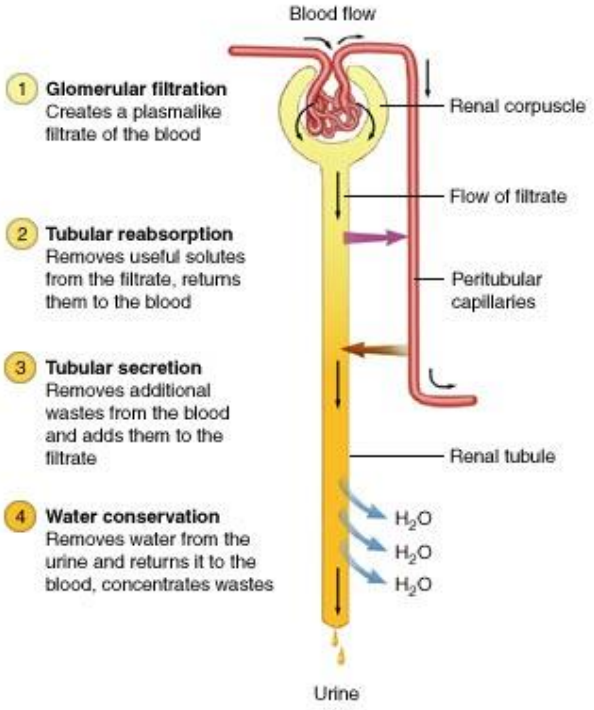


In the fish gill, low-oxygen blood enters the capillaries, encountering water at the end of its travel through the gills, which is thus relatively low in oxygen. As blood travels in the direction opposite to the water, it encounters "fresher" water with ever-higher oxygen concentrations. Thus, along the capillary, a steep diffusion gradient favours transfer of oxygen into the blood.

To promote ventilation, most gill-bearing animals either move their gills through the water or move water over their gills. For example, crayfish and lobsters have paddle-like appendages that drive a current of water over the gills, whereas mussels and clams

move water with cilia. Thus, statement D seems correct.

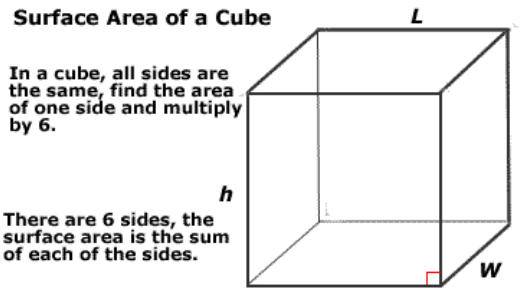
There are a number of fishes that, in addition to or in place of gill breathing, have developed special organs through which they can breathe atmospheric air at the water surface. This occurs almost exclusively in freshwater fishes. In lungfishes these organs are, both in function and in structure, primitive lungs like those of amphibians. The name lungfish is thus well applied: these fishes have lungs that are derived from the swim bladder (an organ used for buoyancy in most bony fishes), which is connected to the alimentary tract. The inner surfaces of these air-breathing organs are covered with a great number of honeycomb-like cavities supplied with fine blood vessels. In order to breathe, the fish swims upward and positions its head so that the tip of the snout barely touches the water surface. The mouth is then opened wide, and the fish sucks in air from just above the water—a process often accompanied by a characteristic sound. The Australian lungfish reportedly breathes air through the nasal openings, the mouth remaining closed. In contrast to the more advanced bony fishes, lungfishes have a particular opening (choana) that connects the nasal cavity with the mouth.



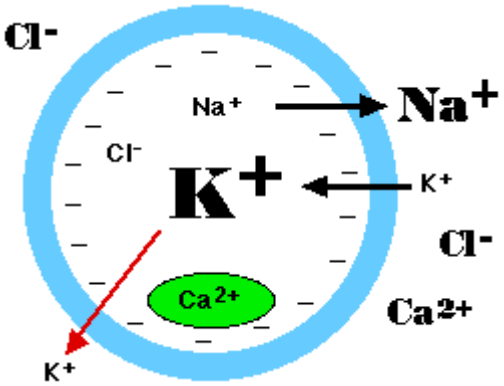
32. D. Notice that statement B and C are almost the same, thus these must be true. The animal's body temperature drops during hibernation, and its heartbeat and breathing slow down, therefore, it uses very little energy. When at rest, these animals reduce their metabolisms drastically, which results in their body temperature dropping to that of the surrounding environment (thus D is incorrect). Hibernation is a state of inactivity and metabolic depression in endotherms (mammals and birds are the only extant endothermic groups of animals), thus endothermic heat production is the only way these hibernators can warm up.

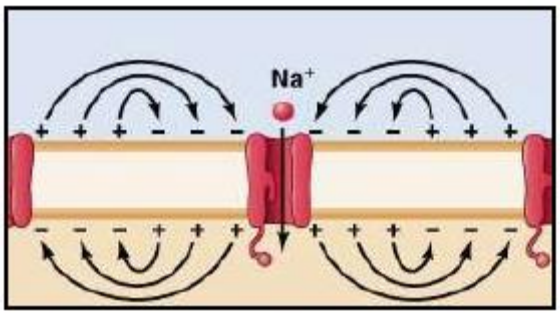
33. C. Remember the diagram on the right.

34. D. Firstly, let's calculate the overall volume of melted material. The formula we use is Volume of a cube = side times side times side, that is 3 x 3 x 3 + 4 x 4 x 4 + 5 x 5 x 5 = 216. Thus, our large cube has 6 cm per side (cube root out of 216). Thus, the surface are of a large cube is 6 x 6 x 6 = 216, whereas surface area of all three small cubes is 3 x 3 x 6 + 4 x 4 x 6 + 5 x 5 x 6 = 300. The ratio is then 300:216 =25:18.



35. **A.** Chloride are you are concentrated on the outside of the cell. And thus diffusion occurs from the outside to the inside, not the other way round.

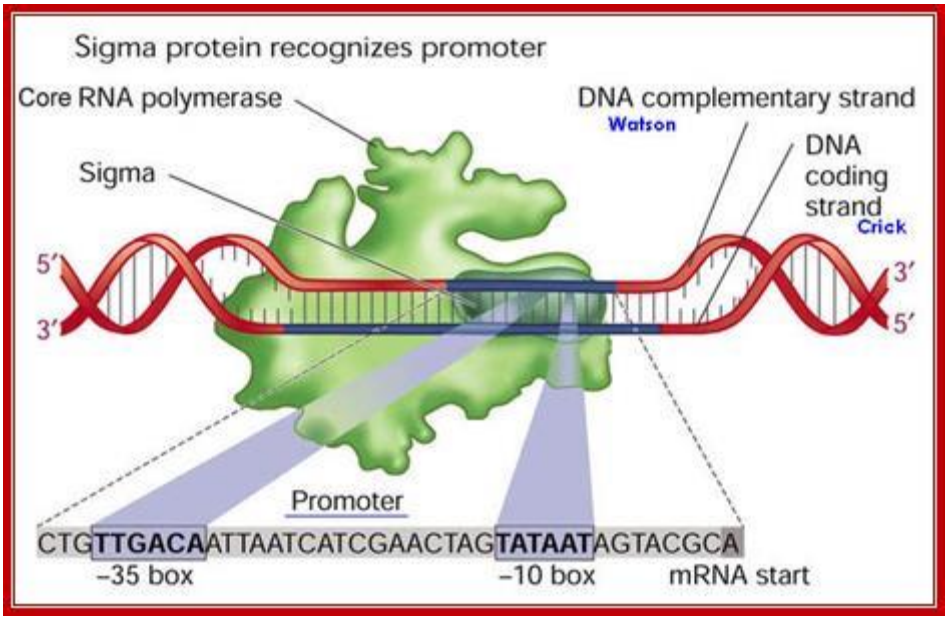




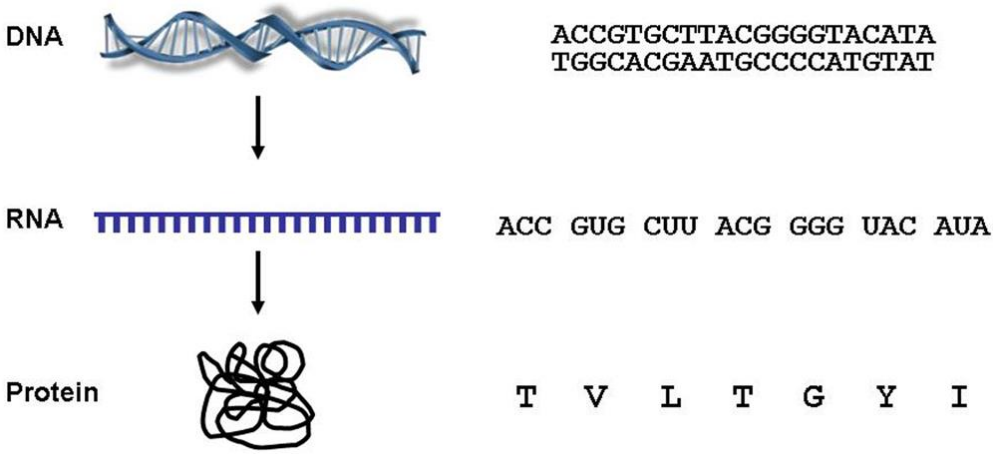
B is incorrect because action potential is initiated in the centre of axon so one of the action potentials will move towards the cell body and the other will move towards the tip of the axon, but NOT from the cell body.

An action potential is generated as Na^+ flows inward across the membrane (thus D is correct), the membrane is repolarizing as K^+ flows outward (E is correct).
If you electrically stimulate an axon halfway along it's length, APs will be generated in both directions (see the picture above). Depolarization of the action potential spreads to the neighbouring region of the membrane reinitiating the action potential there.
Sodium/potassium pump works continuously, so I do not know if it is activated. Thus, I would say that it is operating throughout the whole action potential and does not need to be activated.

36. **B**. A sigma factor (σ factor) is a protein needed only for initiation of RNA synthesis. It is a bacterial transcription initiation factor that enables specific binding of RNA polymerase to gene promoters. The specific sigma factor used to initiate transcription of a given gene will vary, depending on the gene and on the environmental signals needed to initiate transcription of that gene. Promoter is the site of initiation, thus B statement is correct.

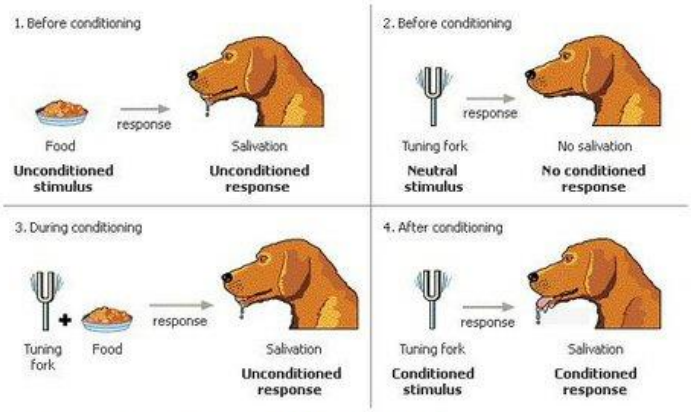


C statement is incorrect because prokaryotic organisms have many polycystronic genes (for example, *lac* operon which include three genes or *trp* operon which includes 5 genes).
Statement A is false. DNA polymerase is the primary nucleotide polymerization enzyme in all organisms during REPLICATION. RNA polymerase is used for transcription.
D is incorrect because for transcription only one strand is used as a template. Note that both strands code for different amino acid sequence. Look at the picture below and try to write down amino acid sequence if the template strand is the first one (in the picture, the template strand is below).



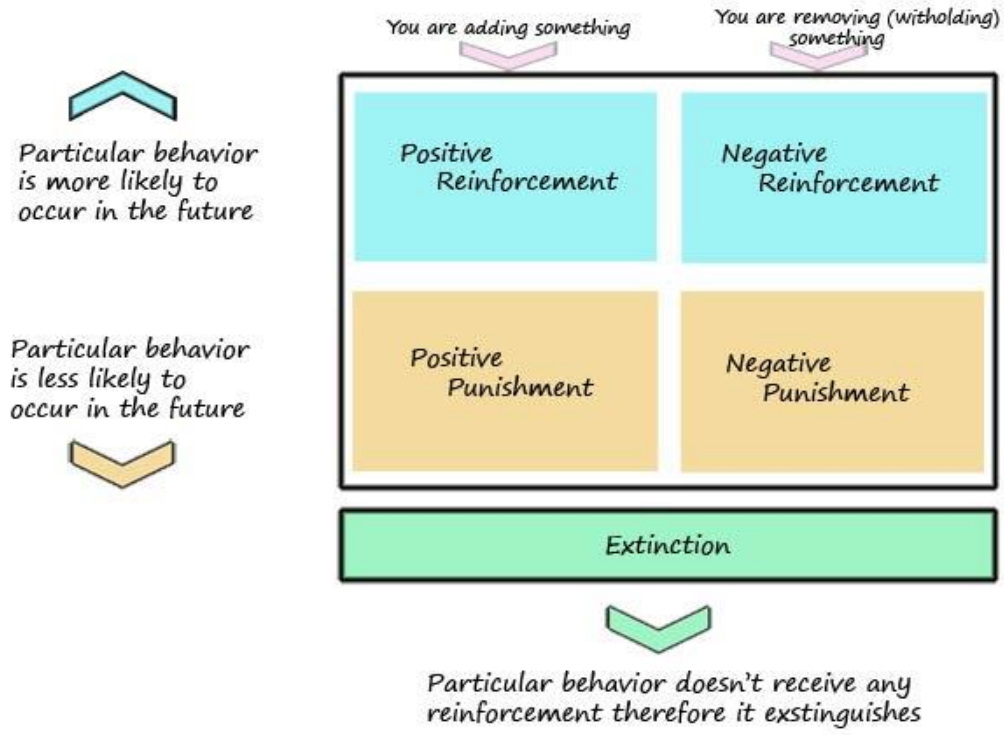
E is incorrect because RNA has uracil instead of thymine.

37-39



Classical Conditioning (Source: schoolworkhelper.com)

Let's first consider each of the terms separately: **Classical condition**ing occurs when a stimulus is associated with a particular response and operant conditioning is a learning process that involves shaping behaviours by using reinforcement or punishment. In classical conditioning, for example, if a dog hears a bell before receiving its food all the time, then the dog will associate the bell with the arrival food. **Operant conditioning** for example, a child will continue to eat his vegetables if his is reinforced with a treat afterwards. These two methods of learning help shape our behaviours today. If no harm is done to these geese then operant conditioning cannot take place.



Cultural learning (I think it should be social learning): Many animals learn to solve problems by observing the behaviour of other individuals. Young wild chimpanzees, for example, learn how to crack open oil palm nuts with two stones by copying experienced chimpanzees. This type of learning through observing others is called social learning.

Habituation is a form of learning in which an organism decreases or ceases to respond to a stimulus after repeated presentations. Essentially, the organism learns to stop responding to a stimulus which is no longer biologically relevant. For example, organisms may habituate to repeated sudden loud noises when they learn these have no consequences. Habituation usually refers to a reduction in innate behaviours.

First described by Konrad Lorenz, **imprinting** is said to occur when innate behaviours are released in response to a learnt stimulus. Most imprinting promotes survival of newborn animals and shapes their future breeding activities. Imprinting has a number of characteristics. Characteristics of imprinting:

1. Critical sensitive period

Imprinting occurs at a particular time (termed the sensitive period) during early postnatal life. For example, in anserine birds such as ducks and geese, the time for imprinting is 24-48 hours after hatching when the 'following response' is learnt. At this time a gosling learns to follow his mother who is normally the first large moving creature in his world. In fact, of course, the visual stimulus that he imprints on does not necessarily have to be Mother Goose. In these species imprinting can occur on any object within a certain size range regardless of its colour or shape. Movement helps to attract attention but is by no means essential.

Although the dominant sense involved in imprinting is sight, sound and olfaction are also involved. In a variety of experiments, young chicks and ducklings were imprinted on humans, wooden blocks and classically even old gum boots. They bonded with a single item and would follow it wherever it went. Rather like Mary and her little lamb, Konrad and his little gosling were to go on to form a life long association. Although Lorenz was the first to record his observations in a scientific manner, the essence of imprinting had long been recognised. Indeed, Chinese peasants have for centuries capitalised on the tendency to imprint in making ducks more effective in the control of snails that otherwise damage rice crops. By imprinting ducklings onto a special stick, the peasants can not only take their brood out to the paddy fields as required but, by planting the stick sequentially in different parts of the plantation, they can ensure that molluscs in all areas can be subjected to predation.

Imprinting seems more important in precocial species, in which the offspring are less dependent on their mothers for food and warmth, than in altricial species which often confine their more vulnerable, and often hairless, young to nests. This is why many horse breeders are recognising the life-long benefits of thorough handling of their foals during the first 24 hours of life. Altricial neonates, on the other hand, are unlikely or unable to stray from their home base in the first few days of life and therefore do not need the same response. They learn similar lessons rather later in life during what are called "socialisation periods". These apply when the animal's sensory, motor and thermoregulatory systems are fully functional and they learn to move away from their mother and to interact with others of the same and other species. The window of opportunity for learning varies according on the species. In dogs it is from 3-10 weeks and in cats 2-7 weeks, while in primates it is usually 6-12 months. Stimuli that the youngsters of each species are exposed to during these window periods will be accepted as being “normal”. We do well to exploit this limited learning opportunity in our companion animals.

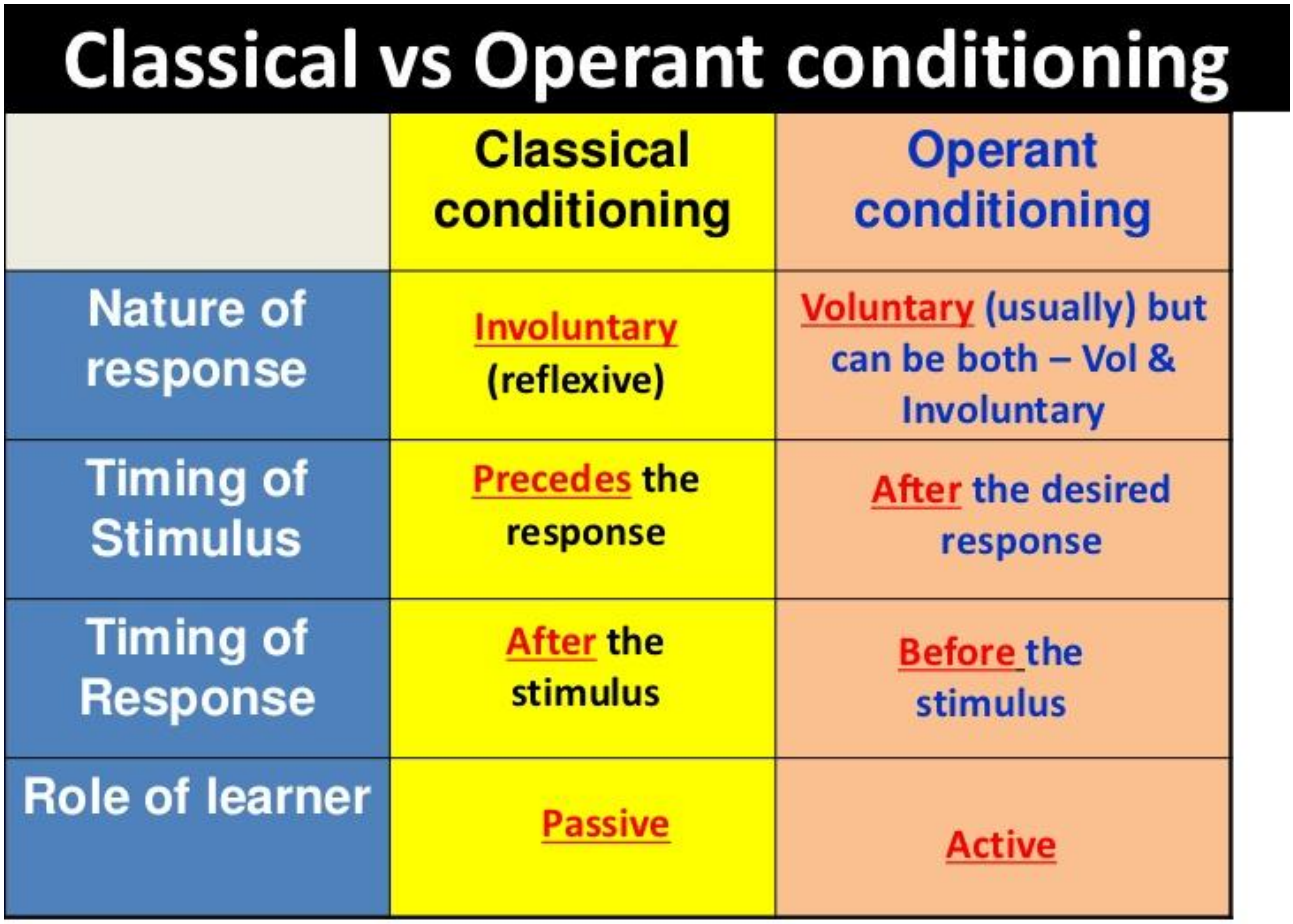
2. Imprinting is irreversible:
The imprinted knowledge is retained for life. Of all forms of learning, imprinting is the least likely to be forgotten or unlearned.

3. Imprinting establishes an individual animal's preference for a certain species
Contrary to what one might predict to be their genetic tendency, once they have imprinted, animals will always prefer to follow the learned stimulus rather than a member of their own species. The following response in ducks that have imprinted on humans means that the ducks will preferentially follow any human rather any duck.

4. Some behaviours are affected by imprinting more than others
Not all behaviours are affected by imprinting. Lorenz noted with some amusement that jackdaws that had imprinted on him would court his favour by presenting him with juicy fresh earthworms and would even attempt to introduce these into his ear-holes. However, when not sexually aroused, these birds would happily join other jackdaws in flight. In sexually dimorphic species (in which the external appearance of males and females differ), sexual imprinting varies depending on whether the youngster is male or female. So, while a male mallard duckling will identify his future mate by relating it to the appearance of his mother (or attachment figure), the same does not apply for a female. While falcons imprinted on humans require a combination of human and avian stimuli to elicit sexual responses.

5. Stressful stimuli fortify imprinting
If there is an increased level of stress at the time of the original imprinting, the learning is more robust that normal. So if, in the laboratory set up illustrated in the figure below, obstacles are placed in the runway between the duckling and the followed object then the following response the duckling subsequently exhibits is more determined and energetic. It may be that this enhances an individual duck family's level of imprinting at times of greatest need, for instance when the threat of predators or the distraction of other broods is a particular problem.

37. C. Habituation may be operating in this case because after a certain time, elephant adapts to stimuli and begins to ignore them because they no longer are biologically relevant.
38. A. Classical conditioning seems to act here a stimulus (conditioned stimulus is crashing sound and unconditioned stimulus is orange frog) is associated with a particular response (child cringes).



39. E. Operant conditioning seems to be at work here as bee gets a positive reinforcement (sugar water).

40. B. Genetic drift describes random fluctuations in the numbers of gene variants in a population. Genetic drift takes place when the occurrence of variant forms of a gene, called alleles, increases and decreases by chance over time. Typically, genetic drift occurs in small populations, where infrequently occurring alleles face a greater chance of being lost. Once it begins, genetic drift will continue until the involved allele is either lost by a population or until it is the only allele present in a population at a particular locus. Both possibilities decrease the genetic diversity of a population. Genetic drift is common after population bottlenecks, which are events that drastically decrease the size of a population. In these cases, genetic drift can result in the loss of rare alleles and decrease the gene pool. Genetic drift can cause a new population to be genetically distinct from its original population, which has led to the hypothesis that genetic drift plays a role in the evolution of new species. Big population sizes do not experience harsh effects of genetic drift.
Statement A is incorrect because gene migration is not directly related to the size of the population. The bigger the population, the greater the rates of emigration. The smaller the population, the greater the rates of immigration. In population genetics, gene flow (also known as gene migration) is the transfer of alleles or genes from one population to another. Migration into or out of a population may be responsible for a marked change in allele frequencies (the proportion of members carrying a particular variant of a gene). Immigration may also result in the addition of new genetic variants to the established gene pool of a particular species or population. Maintained gene flow between two populations can also lead to a combination of the two gene pools, reducing the genetic variation between the two groups. It is for this reason that gene flow strongly acts against speciation, by recombining the gene pools of the groups, and thus, repairing the developing differences in genetic variation that would have led to full speciation and creation of daughter species.
Statement C is incorrect because mutations occur rarely and if they do not occur in germ cell, they are not passed to offsprings and thus cannot influence population size.
Natural selection and sexual selection are both influenced not by quantity but quality of individuals (who have specific phenotypic characteristics). Thus statements D and E are incorrect.
A useful outline of population genetics: http://biolympiads.blogspot.co.uk/2014/08/populatio-genetics-iii.html

41-44 A useful guide to biostatistics: http://biolympiads.blogspot.co.uk/2014/08/biostatistics-part-1.html and http://biolympiads.blogspot.co.uk/2014/08/biostatistics-part-3.html.
41. True. 1.78 is in our confidence interval. In this case p value is 0.95, which leaves alpha value 1-0.95=0.05, or 5%.
42. False.
43. False.
44. False, the confidence interval was determined to compare two populations. If we want to compare mean value of one population with a certain number, we need other statistical test.
45. A. This statement seems correct because splicing occurs in nucleus, where the majority of this aberrant molecule is found, and improper exon sequence will still be translated into a protein product.
D is incorrect because translation occurs in the cytoplasm and we were told that this molecule is rarely found in the cytoplasm.
C is incorrect because we were told that this molecule binds to mRNA, thus it cannot bind to ribosome and initiate translation.
D is incorrect because we were told that this molecule binds to the middle of mRNA whereas 5‘cap and poly-A tail are at the beginning and end of mRna molecule, rspectively.
E is incorrect because this molecule lead to improper protein production, which means that we get some kind of product of a gene, so if mRNA was confined to nucleus, then it would not reach translation machinery and produce no protein at all.
46. B. Statement B is correct one because a mutation in operator site does not allow repressor to bind and this leads to constitutive expression. Constitutive expression means unrestricted expression which operates all the time. Introducing a plasmid containing wild-type lac operon, shows that mutation involves nondiffusible component because a molecule synthesized using correct information coded in F plasmid could reverse the mutation in E.coli, which is not the case because we were told that it does not restore the normal phenotype.
Statement E is incorrect because a promoter is an essential site for gene expression and if mutation occurs there, this leads to inactivity of the gene regulated by that promoter.
Statement D is incorrect because it would result in constitutive repression of beta-galactosidase expression which is not the case here.
Statement E is incorrect because if mutation occurred in activating system, this would lead to decreased expression, which is once again not the case in this situation.
Statement A is incorrect because promoter is essential for initiation of gene expression and if a mutation disables this gene sequence, no expression of the gene occurs (in this case we have unrestricted expression).
Statement C is incorrect because if we have no functioning repressor, beta-galactosidase gene expression IS indeed constitutive. However, when we introduce a functioning plasmid which has genes needed to synthesize a diffusible repressor, we do not observe inducible repression, that is lac operon in mutant is still being expressed even in the presence of foreign repressor.
47-50.
To answer this question I would suggest sketching a small table like this:
Note a key word inbred which means a pure-breeding strain.

Inbred lines	AA x aa		
F1 (P1)	Aa	P(A) = 0.5,P(a)=0.5	2pq=1.0 (because we have only heterozygotes) H(P1) =1.0
F2	1 AA,2 Aa, 1 aa	P(A) = 0.5, P(a)=0.5	2pq=2/4=0.5

	To get F2 generation we need to cross Aa x Aa which gives 1 AA, 2 Aa, 1 aa. The total number of A alleles is 2+2= 4, the total number of a alleles is 2+2=4.		H(P2) =0.5

In all cases of HHWE(fA) we should get the same number because from the third column you can see that we have got the same allele frequencies. That is HHWE(fA)=2*0.5*0.5=0.5

47. In this case we have got 0.5<1.0 which is TRUE (A).

48. In this case we have got 0.5>1.0 which is FALSE (B).

49. In this case we have got 0.5<0.5 which is FALSE (B).

50. In this case we have got 0.5>0.5 which is FALSE (B).

51.C. Allolactose and tryptophan are both involved in negative regulation of gene expression which involves repressor protein. In this case effectors, such as allolactose and tryptophan, bind to repressor and alter its conformation leading to either its binding or its release to or from the operator.

E is incorrect because RNA polymerase and transcription factors interact with the promoter, whereas allolactose and tryptophan do not interact with genome directly.

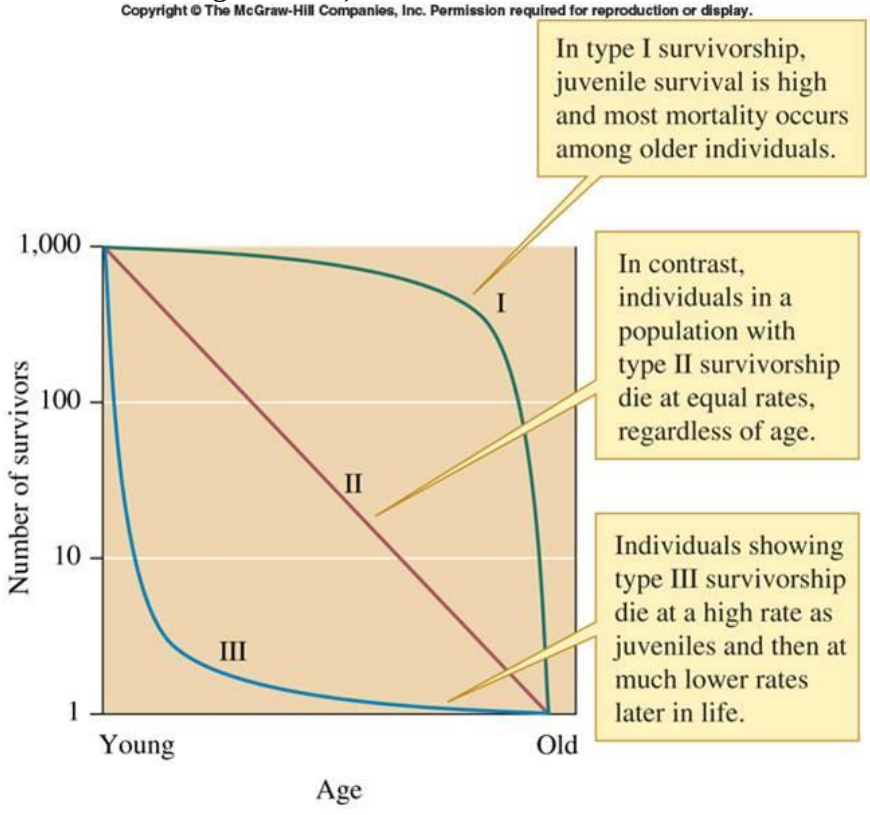
D is incorrect because allolactose and tryptophan do not interact with genome directly. Operator is a DNA sequence.

A are B are incorrect because allolactose and tryptophan are both involved in negative regulation of gene expression and cAMP with CAP are involved in positive gene regulation.

52. A. One very important mechanism for regulating population size is density dependence. The density of a population is simply how many organisms are living in a given area. Density-dependent factors are factors where the effects on the size or growth of a population vary with the density of the population itself. There are several types of density-dependent factors, but they all have two things in common: they influence the rates of births and deaths, and the effect increases as population size increases.

When the density of a population is low (few individuals in a given area), resources are not limiting. There are plenty of resources for everyone. More individuals can give birth, and fewer individuals will die. Overall, the population will grow in size and become denser.

When the density of a population is high (many individuals in a given area), resources are more limited for each individual. Because of this, more individuals will die, fewer individuals will be born, and the population size will decrease and become less dense.

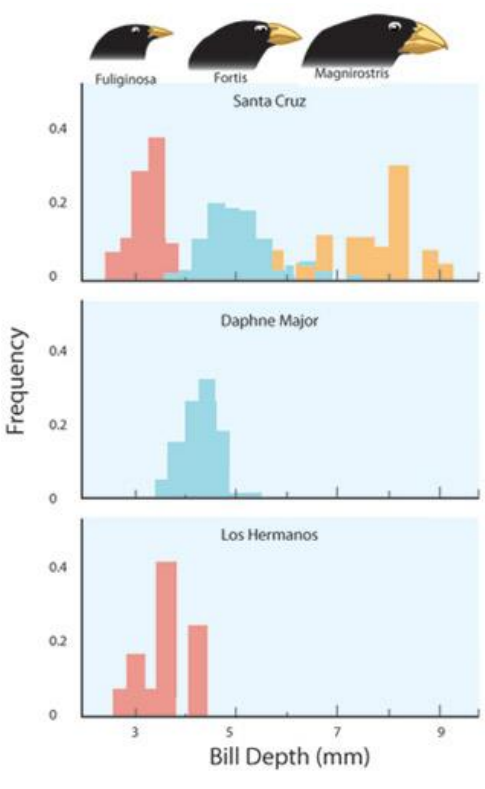


53. D. Because of very long life span and sharp decrease of individuals who reached old age.

One of the biggest factors that affect populations is life history, or the sequence of events in an organism's life that relate to its survival and reproduction. An organism's life history includes factors such as number of offspring produced, frequency of reproduction, amount of care and resources dedicated to offspring and what kind of survivorship curve the organism exhibits. A

survivorship curve is a graph of the number of individuals still alive at each age.
Here is an example of the survivorship curves for three animals with three different life histories. Let's start with the curve for humans. Humans display a type I survivorship curve, which means that humans have low death rates in the younger and middle age groups and high death rates in the oldest age groups. The low death rate in the younger age groups is due to the fact that humans invest a lot of resources, care and protection into their offspring, which gives each individual a very high probability of surviving to adulthood. The low death rate in the middle age groups is due to the adaptability and resiliency of humans and the lack of predation. And the high death rate in the oldest age groups reflects the human life span as defined by physiological limitations of age and accumulated damage. Other organisms that display a type I survivorship curve include elephants, gorillas and annual grasses. Although annual grasses have a much shorter lifespan, a relatively high number of offspring survive to adulthood compared to other plants due to the relatively large size of their seeds compared to their mass and their ability to grow back even after most of their mass has been eaten by herbivores. The highest death rates occur at the end of their life span, usually when water in the upper soil levels is all used up at the end of the growing season.
Songbirds display a type II survivorship curve, with a relatively steady death rate throughout their lifespan. Songbirds invest a lot of energy and care into their offspring, which helps survivorship at the beginning of their life. However, predation, disease and lack of resources are all causes of mortality that are always present for songbirds of all ages, which causes the death rate to remain relatively steady throughout their life history.
Most frog species display a type III survivorship curve, where the death rate is very high early in life and much lower in the middle and older age groups. This reflects a very high death rate for tadpoles mostly due to a high rate of predation. Frogs compensate for the high death rates by producing a very large number of offspring each breeding season, and for the tadpoles that do survive to become adults, the adult frogs can use camouflage, their terrific jumping ability and their swimming ability to avoid predators. The key hallmarks of species with type III survivorship curves are the production of very large numbers of very small offspring with little parental investment in each offspring. Most insects have type III survivorship curves. It should also be noted here that not all frogs display a type III survivorship curve. Some poison dart frogs lay only a few eggs at a time and then carry the eggs and tadpoles on their backs, investing a lot of parental care in each offspring. These species have much lower death rates for their offspring, and because they have poisons that protect them from predation throughout their adult lives, they display a type I survivorship curve similar to that of humans.

54. B. Statement B is false because intense competition may occur between distantly related species which occupy the SAME territory and use the SAME resources.
Statement A is true because two species cannot coexist together in the same niche due to competition. The competitive exclusion principle, sometimes referred to as Gause's Law of competitive exclusion or just Gause's Law, states that two species that compete for the exact same resources cannot stably coexist.



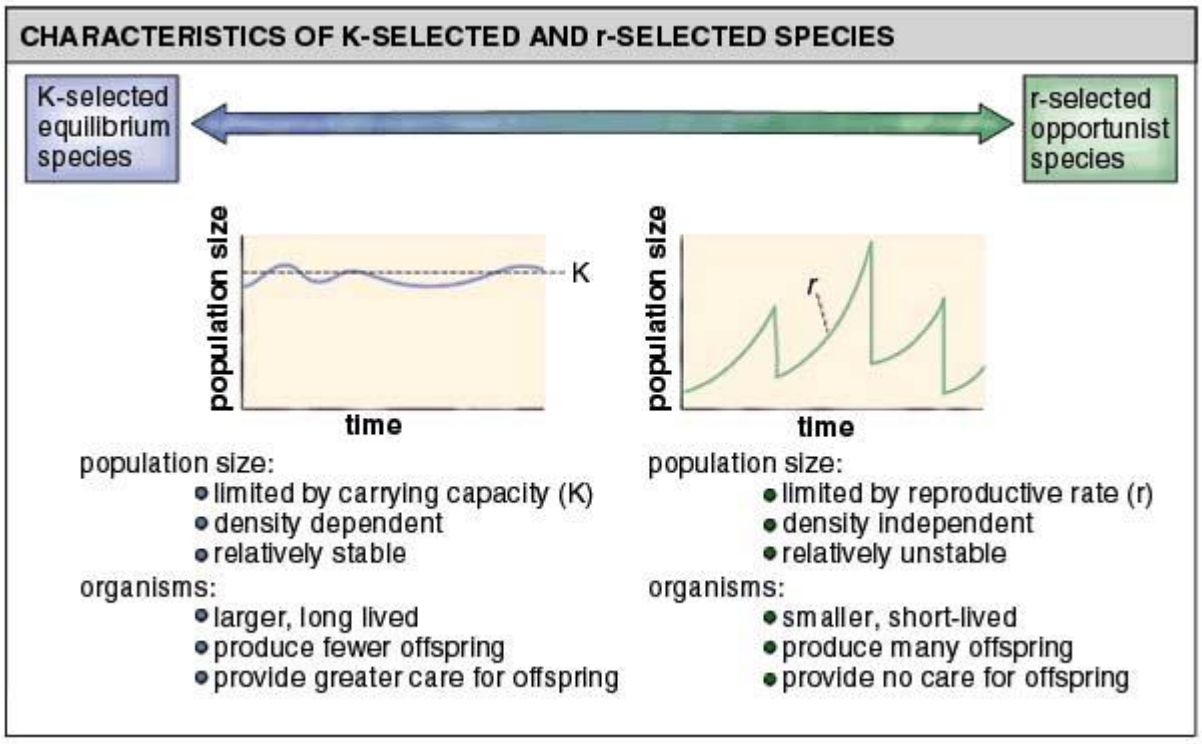
Statement C is true because competing related species often evolve distinguishing characteristics in areas where they both coexist. Remember beak shapes of the finch.

Statement D is true because one of the two competitors will always have an ever so slight

advantage over the other that leads to extinction of the second competitor in the long run (in a hypothetical non-evolving system) or (in the real world) to an evolutionary shift of the inferior competitor towards a different ecological niche.
Statement E seems very similar to A just put in other words.

55. C. If you remember that placental mammals all bear live young, which are nourished before birth in the mother's uterus through a specialized embryonic organ attached to the uterus wall, the placenta, you could guess that drought might not put much influence on carrying capacity.
The carrying capacity of a biological species in an environment is the maximum population size of the species that the environment can sustain. There are four variables which govern changes in population size. births; deaths; immigration; emigration.
Statements A, B and E all have profound effects on the number of birth and death, thus, they have a significant effect on carrying capacity.
Statement D has a significant effect on carrying capacity because as population density increases, birth rate often decreases and death rate typically increases.

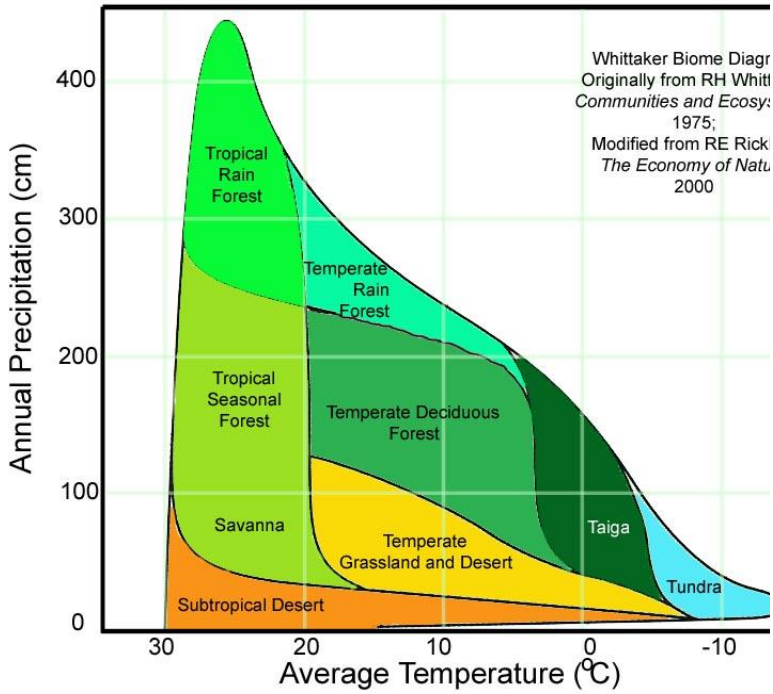
56. C. The size of the R-selected species population depends on density-independent factors that are abiotic, like the weather. Animals with short life spans, early reproduction and high reproductive rates represent r strategy. In unstable or unpredictable environments, r-selection predominates as the ability to reproduce quickly is crucial. There is little advantage in adaptations that permit successful competition with other organisms, because the environment is likely to change again.



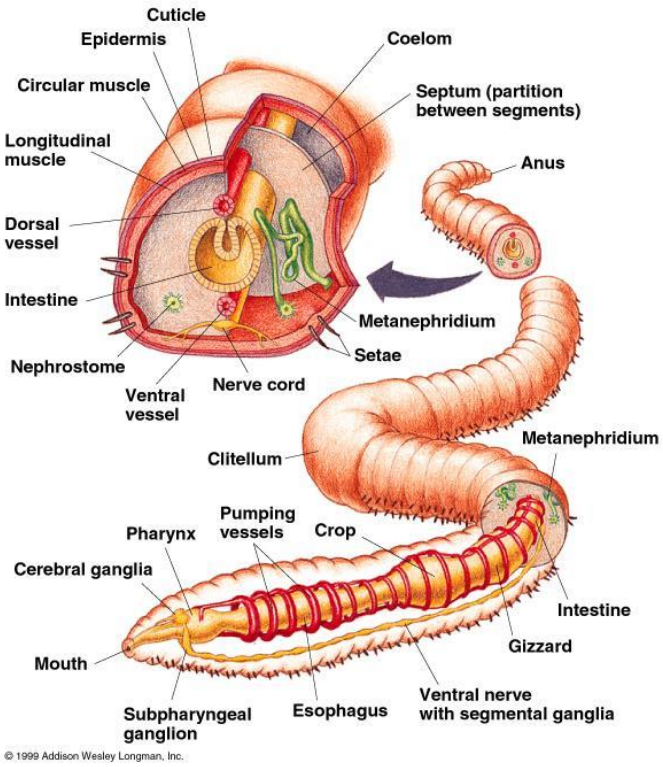
R strategists usually create an abundance of offspring in the hopes that a few will make it. These species usually have a very short maturation time, often breed at a very young age, have a short lifespan, produce many offspring very quickly, have young with high mortality rates and invest relatively little in parental care. The parents do not focus on passing down memes, units of cultural information, to their young. Instead the behavior of the young is determined by their genes. The young are precocial, meaning that they often can make it on their own without any instruction from their parents. Examples of r-selected species include bacteria, insects, and fish.

K strategists are very different in that they attempt to ensure the survival of their offspring by investing time in them, instead of investing in lots of them. It is a reproductive strategy that focuses on quality over quantity. K strategist have relatively few offspring and make an effort at being good parents. Their young are altricial meaning that they cannot survive on their own until they reach adulthood. This extended period of maturation is used for memetic transference- the parents teach the young so that they can go on to reproduce themselves. K strategists are known to have a relatively long life span, produce relatively few offspring, the offspring have low mortality rates and the parents provide extensive parental care. The offspring are also relatively intelligent so that they can internalize the lessons from their parents. K-selected species include elephants, apes and whales. Humans are perhaps the most K-selected because their young are truly helpless- they necessitate a full two decades of parental care and tutelage and the parents usually only produce one offspring at a time.

57. A. Remember the picture from Campbell:



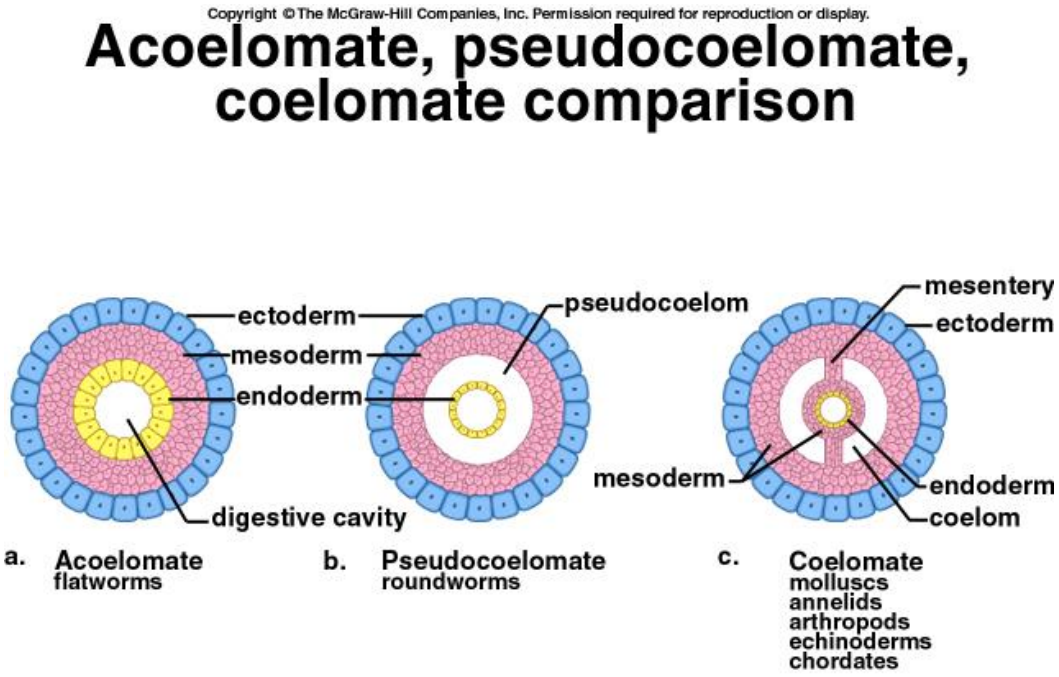
58. A. is correct because earthworms do have a series of single-chambered pumping hearts as well as a closed circulatory system.
B is incorrect because vertebrates do not have multiple hearts. They have a multi-chambered heart. Earthworms have a closed circulatory system.
C is incorrect because an earthworm has purely closed circulatory system.
D is incorrect because earthworms, molluscs and vertebrates all of them have coelom with organs suspended in celomic cavity.
E is incorrect because mollusc has open circulatory system.



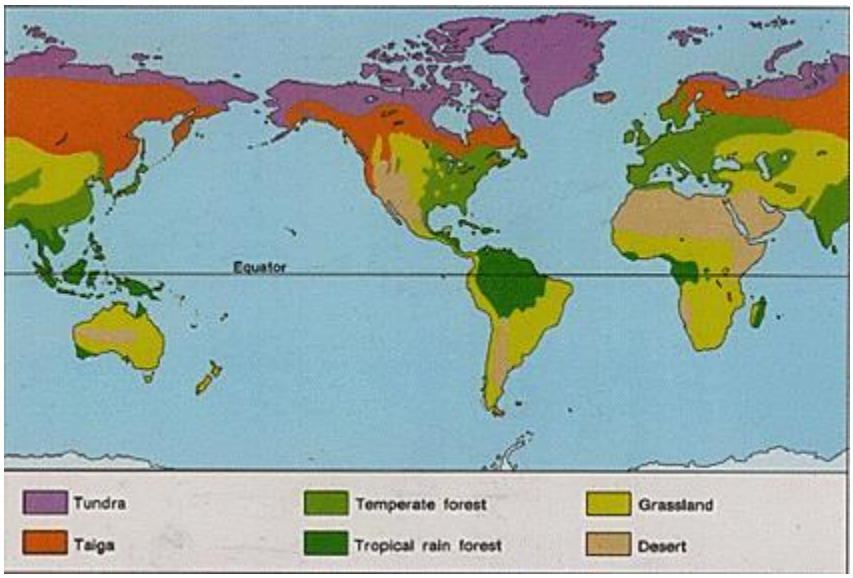
The open circulatory system is common to molluscs and arthropods. Open circulatory systems (evolved in

crustaceans, insects, mollusks and other invertebrates) pump blood into a hemocoel with the blood diffusing back to the circulatory system between cells. Blood is pumped by a heart into the body cavities, where tissues are surrounded by the blood.

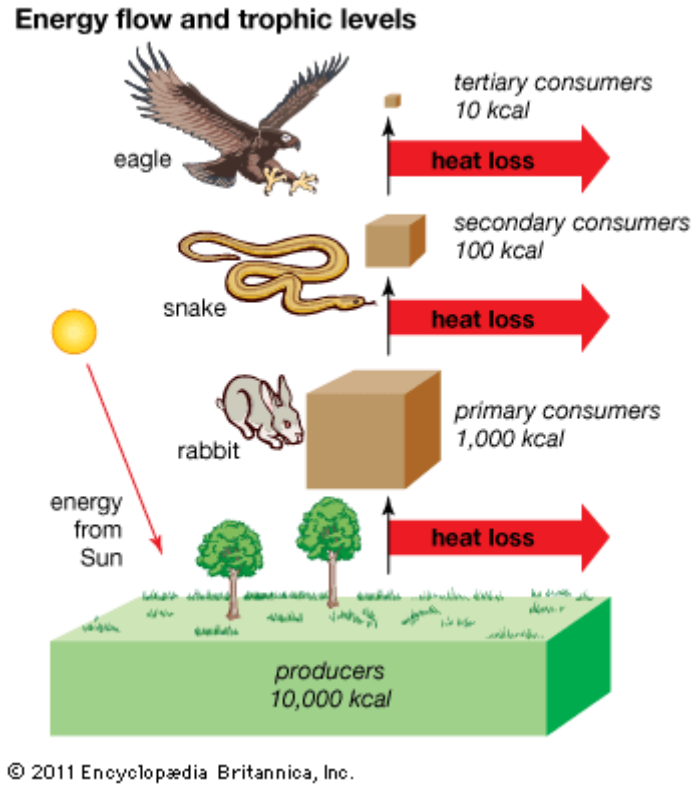
Vertebrates, and a few invertebrates, have a closed circulatory system. Closed circulatory systems have the blood closed at all times within vessels of different size and wall thickness. In this type of system, blood is pumped by a heart through vessels, and does not normally fill body cavities.



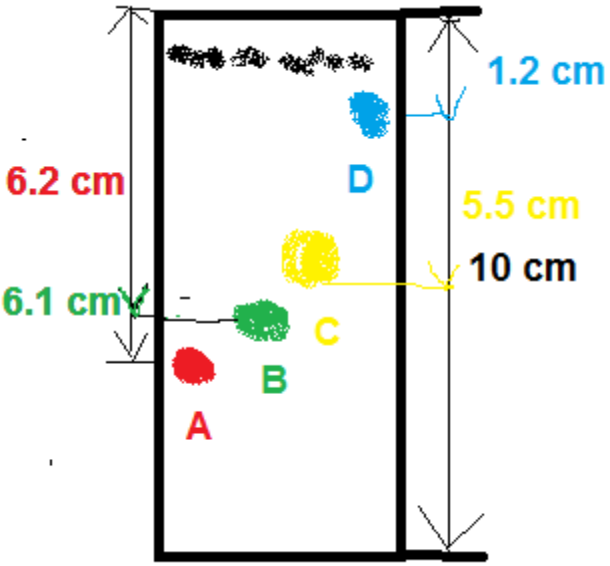
59. A.



60. D. The amount of energy at each trophic level decreases as it moves through an ecosystem. As little as 10 percent of the energy at any trophic level is transferred to the next level; the rest is lost largely through metabolic processes as heat. If a grassland ecosystem has 10,000 kilocalories (kcal) of energy concentrated in vegetation, only about 1,000 kcal will be transferred to primary consumers, and very little (only 10 kcal) will make it to the tertiary level. Energy pyramids such as this help to explain the trophic structure of an ecosystem: the number of consumer trophic levels that can be supported is dependent on the size and energy richness of the producer level. The general formula for energy transfer is as follow: 0.1^{n-1}, where n is the trophic level number.



61. B. I recommend to sketch this quick diagram:
Your are told that polar molecules travel slowly, thus their path will be shorter. This means:
More polar → smaller length
Thus you can arrange your dots in order of increasing polarity
A->B->C->D
Now, you should take a look at the choices and classify amino acids:
Non-polar: A, C and E.
Polar: B and D.
Basic: D.



Amino acids groups

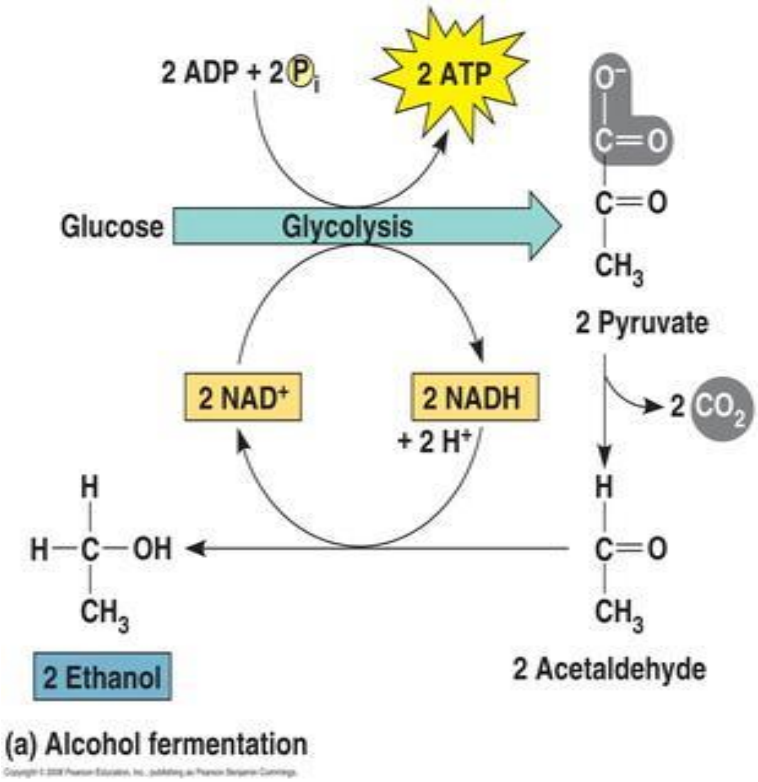
Group	Characteristics	Names	Example (-Rx)
non-polar	hydrophobic	Ala, Val, Leu, Ile, Pro, Phe Trp, Met	Leu
polar	hydrophilic (non-charged)	Gly , Ser, Thr, Cys, Tyr, Asn Gln	Thr
acidic	negatively charged	Asp, Glu	Asp
basic	positively charged	Lys, Arg, His	Lys

Total = 20

Only three amino acids absorb UV light and those are with heterocylic side group: tyrosine, tryptophan, phenylalanine. So you rule out answers A and D. As we mentioned above, phenylalanine and tryptophan are both nonpolar therefore they will travel longest distance and should be A and B spots. You are left with tyrosine which both absorbs UV and is highly polar. Note that spot D may represent a small polypeptide because it's path is shortest and very different from three other spots.

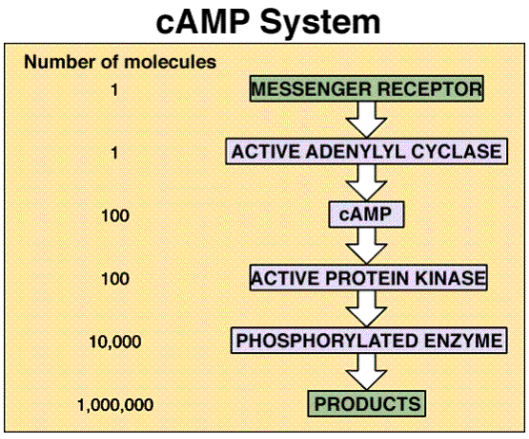
62. B. This problem is from the IBO 2007 so do not forget to cover all past IBO papers. The reaction of alcoholic fermentation is as follows:
$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2 + 2ATP$
Below you will find a picture which shows that during glycolysis 4ATPs are synthesized, but 2 ATPs are used, as well as 2 NAD+ are needed to produce ethanol. As you notice from the diagram NAD+ and NADH are recycled, therefore, their amounts are not taken into account. We have loads of glucose but limited amount of

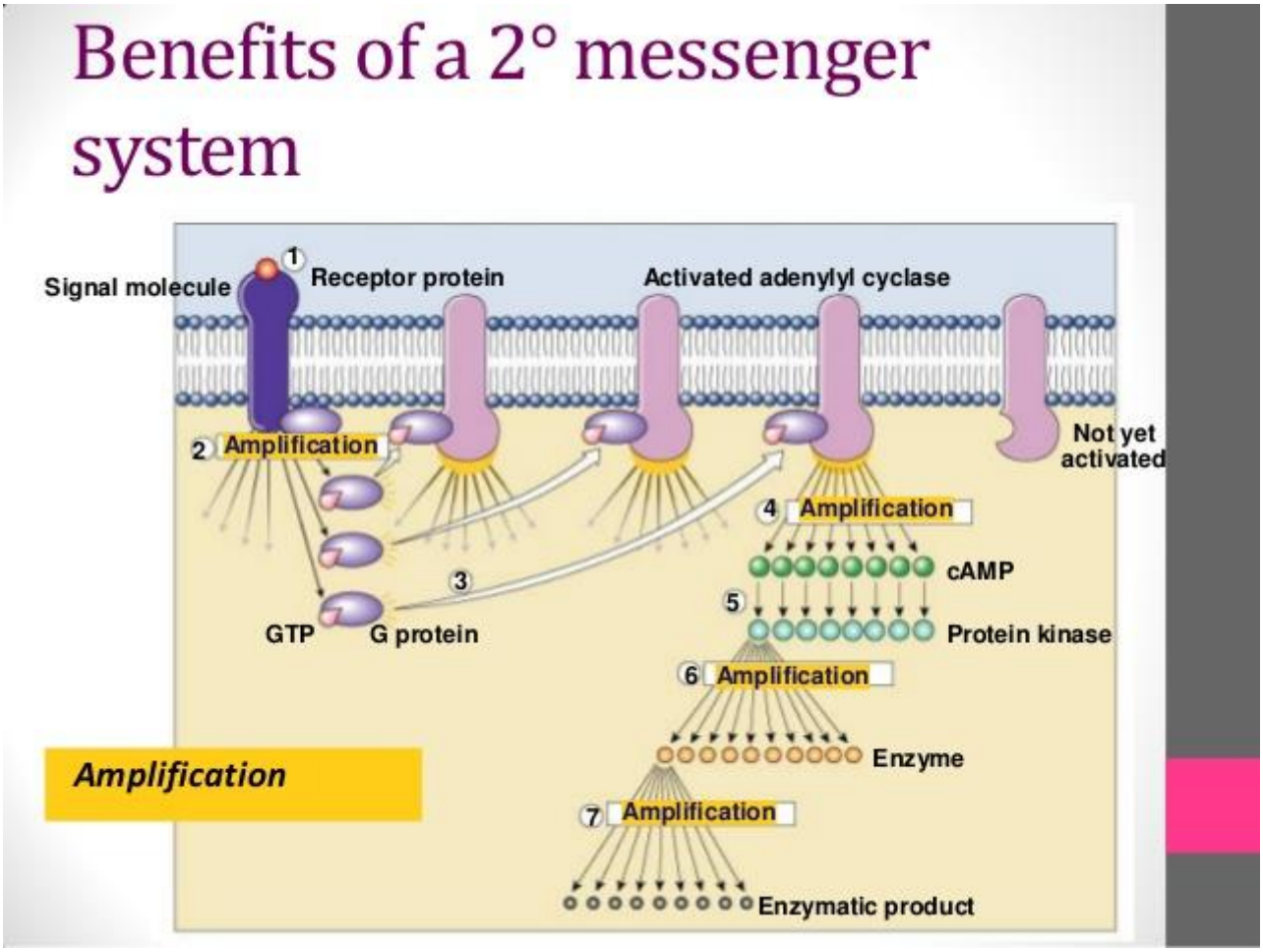
ADP and inorganic phosphate. Therefore, their concentration is what determines the maximum amount of ethanol. From 20 mM ADP and 20 mM Pi we can get 20mM of ATP. As we know that to convert 1 glucose to 2 ethanol molecules we need to use 2 ATPs:
1 mmol of glucose → 2 mmol of ethanol →2 mmol ATPs, then if we have 20 ATPs :
X mmol of glucose → x mmol of ethanol → 20 mmol ATPs, from this:
X=20 mmol ATPs x 2 mmol of ethanol / 2 mmol ATPs = 20mM of ethanol.



(a) Alcohol fermentation

63. B, C, D, E. In this cascade the first enzyme is adenylyl cyclase, therefore, it is adenylyl cyclase →cAMP conversion that amplifies the signal (because enzymes are very efficient and work on many substrates). I cannot even think of any enzyme that produces only one molecule of a product.

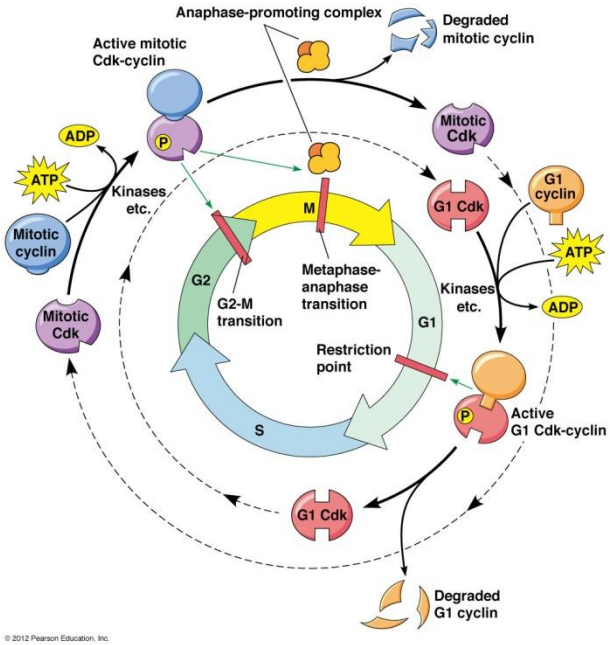




64. FALSE (B), because growth factors PROMOTE cell division, not stops growth.

65. TRUE (A)

Remember that more active cyclin means more active cyclin-cdk complexes which in turn lead to more active division. If we degrade cyclin, no cyclin-cdk complexes will form, thus cells cannot undergo mitosis.



66. FALSE (B). Cancer is a disease characterized by abnormality of mitosis. More mitosis → more uncontrolled divisions →cells more prone to developing cancer.

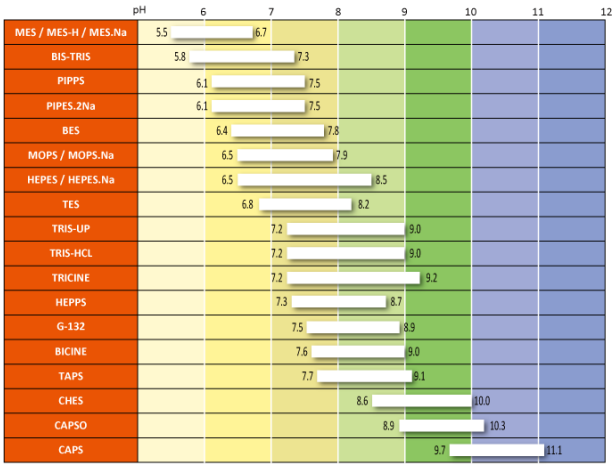
67. FASLE (B) As mentioned in 65, more cyclin-cdk complexes mean more divisions which mean more cells that may become cancerous.

68. TRUE (A) If a cell does not enter G2 phase, it cannot proceed to M phase and this restricts growth and cancer formation.

69. B. It is well established that fat serves as the primary fuel for migratory flight in birds. The fatty acids made available from lipolysis are more highly reduced than glycogen and yield more energy per unit mass when oxidized to CO2 + H2O. Unlike glycogen, which is stored in hydrated form in muscle and liver as glycogen particles, fats are stored as lipid droplets in these organs as well as in adipose tissue. The combination of these factors endows a unit mass of fat with close to 8 times more energy than a unit mass of hydrated glycogen.

70. D. It is because of changes of concentrations of donor and acceptor forms buffers are so good at maintaining pH. If no change occurred, then what's the point of the buffer?

Statement A is correct because this is a function of a buffer. Many chemical reactions are affected by the acidity of the solution in which they occur. In order for a particular reaction to occur or to occur at an appropriate rate, the pH of the reaction medium must be controlled. Such control is provided by buffer solutions, which are solutions that maintain a particular pH. Biochemical reactions are especially sensitive to pH. Most biological molecules contain groups of atoms that may be charged or neutral depending on pH, and whether these groups are charged or neutral has a significant effect on the biological activity of the molecule.



Statement B is correct because each buffer is made up of different substances which have different properties. At the right you will find a diagram of pH ranges of different buffers used in a laboratory.

Statement C is correct because it is exactly what happens:

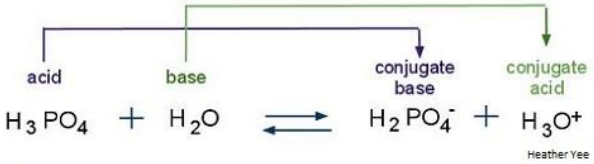


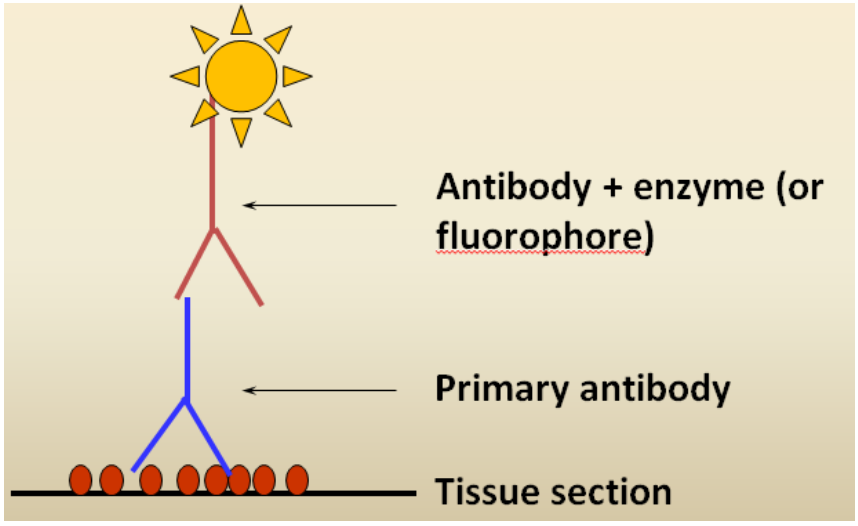
Figure 1. This reaction shows the dissociation of a weak acid. Image created by Heather Yee

Statement E is definitely true. By far the most important buffer for maintaining acid-base balance in the blood is the carbonic-acid-bicarbonate buffer. The simultaneous equilibrium reactions of interest are:

$$H^+(aq) + HCO_3^-(aq) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H_2O(l) + CO_2(g)$$

71. D.

This is what is happening in this procedure:



I. is probable because harsh treatment may denature proteins and thus antibodies will not recognize those denatured proteins because of their altered structure.

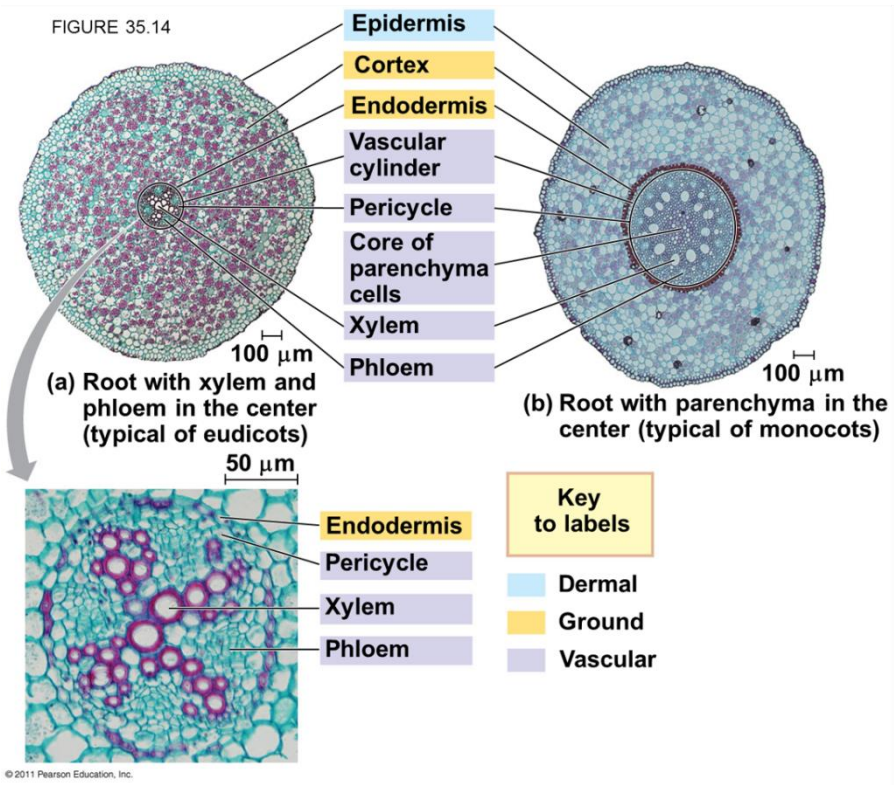
II. is not probable because primary antibodies can recognize only one type of antigen. If there is no antigen (for example, all proteins were denatured during cell preparation procedure), no antibody will be bound.
III. is possible because chromatin attaches to the internal membrane of nuclear envelope and thus may hinder binding of antibodies to lamins.
IV. It might be probable. Without secondary antibody which has a fluorophore, the scientist could not see any fluorescence.
V. Is unlikely. Secondary antibody carries fluorophore, so if too much antibody was present, she should have seen loads of fluorescence, which she has not.
We have I, III and IV which leads to choose D as a correct one. Therefore, chromatin may not bind to the same site as antibodies. So this third statement is improbable.
72. A and D. Note, that we should look at only Case 2 results which indicate that we see clumped uneven stain and the we should choose more than one answer as we are asked: 'which of the following ARE..'.
Statement A seems correct because if different types of lamin A mutations indeed occur, we should notice UNEVEN staining, that is, different in various regions of the nuclear envelope.
Statement D seems correct because we notice uneven staining and this may be caused by uneven distribution in the nuclear envelope.
Statement B seems incorrect because we proteins will not be recognized by antibodies and this should produce results similar or exactly the same like the control cells as in Case 1.
Statement C seems incorrect because if the mutation alters the binding site, we would observe no staining, which explains Case 3.
73-75 To answer this section you need to remember differences between monocots and dicots. Please find three tables below which will help you distinguish between these two groups.
73. C for monocot stem (note absence of pith and scattered vascular bundles) and D for dicot root (note small tetrarch xylem in the centre and absence of pith in the centre).
74. A for monocot root (note large pith at the centre and xylem/phloem circular arrangement) and B for dicot leaf (note differentiated mesophyll which is composed of palisade and spongy parts).
75. E (note centrally placed pith and circularly arranged vascular bundles with sclerenchyma being the outermost layer).

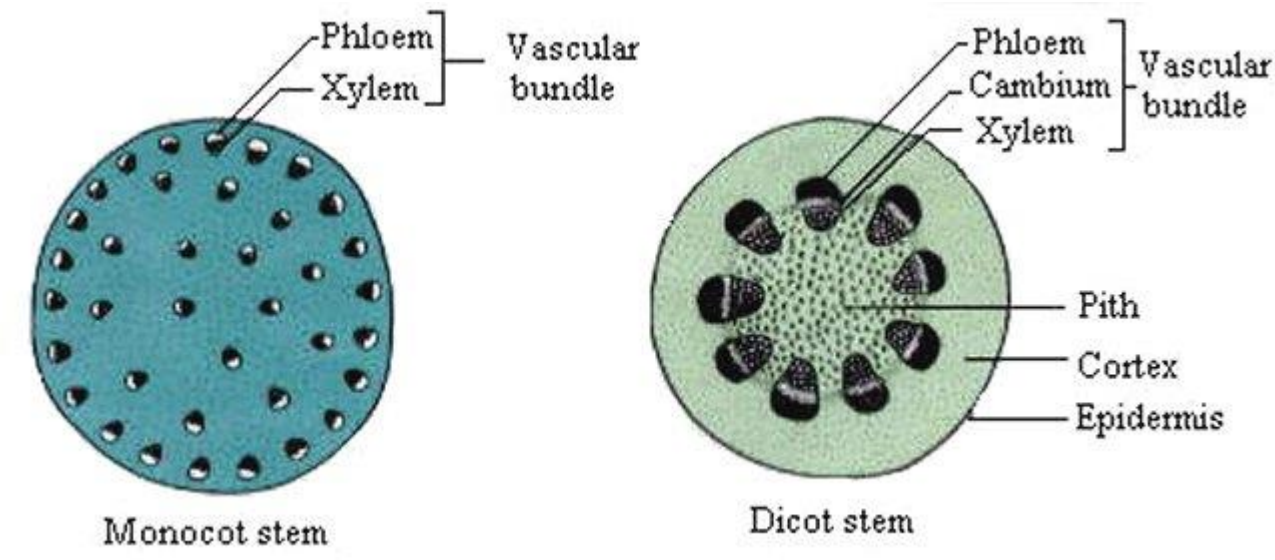
CHARACTERS	DICOT STEM (e.g., Sunflower)	MONOCOT STEM (e.g., Maize)
1. Epidermis a) Trichomes b) Cuticle	 Present Present	 Absent Present
2. Hypodermis	Made up of collenchyma	Made up of sclerenchyma
3. Ground tissue	Differentiated into cortex, endodermis, pericycle, medullary rays and pith	Undifferentiated
4. Vascular bundles a) Number b) Arrangement c) Bundle Cap d) Bundle Sheath	 Eight In the form of a broken ring Present Absent	 Numerous Irregularly scattered Absent Present
5. Nature of the vascular bundles	Conjoint, collateral and open with endarch xylem	Conjoint, collateral and closed with endarch xylem
6. Xylem vessels	Many protoxylem and meta-xylem vessels in each bundle	Only two protoxylem vessels in each bundle

Characters	Dicot leaf	Monocot leaf
1. Nature of orientation	Typically dorsi-ventral	Typically iso-bilateral
2. Stomata	Hypostomatic	Amphistomatic
3. Motor cells	Absent	Present in the upper epidermis
4. Mesophyll	Differentiated into palisade and spongy parenchyma	Undifferentiated
5. Veins	Irregularly scattered	Parallely arranged
6. Xylem vessels	Many protoxylem and metaxylem vessels in each bundle	Two protoxylem and two metaxylem vessels in each bundle
7. Bundle sheath extensions	Made up of collenchyma	Made up of sclerenchyma

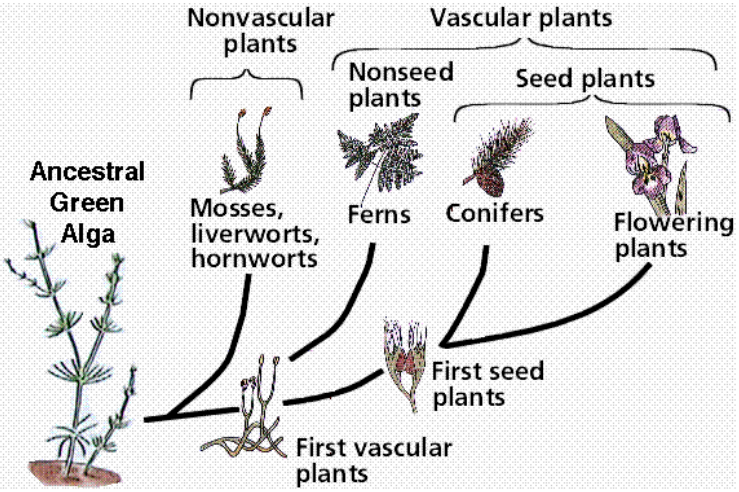
Difference between monocot and dicot root

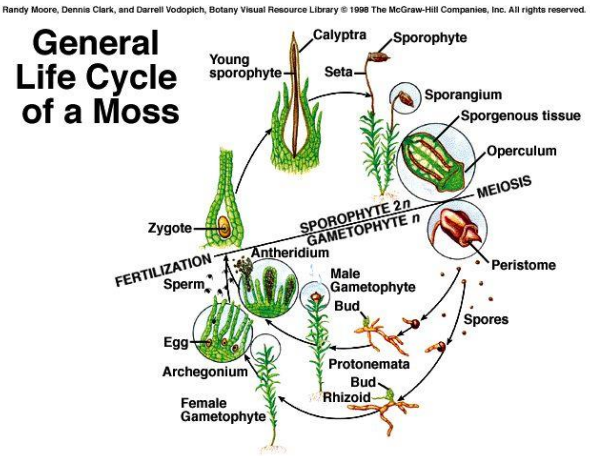
Monocot roots	Dicot roots
1. Xylem is **polyarch**.	1. Xylem is usually **tetrarch.**
2. Pith is usually large at the centre.	2. Pith is usually absent.
3. Metaxylem vessels are generally **circular** in cross section.	3. Metaxylem vessels are generally **polygonal** in cross section.
4. Conjunctive tissue is sclerenchymatous in Maize.	4. Conjunctive tissue is usually parenchymatous.
5. There is no secondary growth.	5. Secondary growth is generally present.





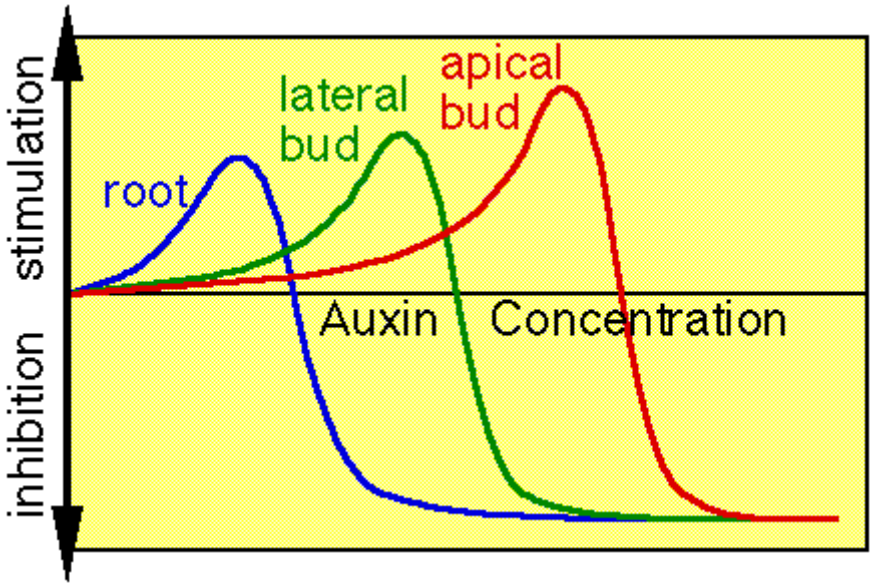
76. A. No xylem means that this organism is avascular, therefore, you can rule out B, C and D which are all vascular plants. No seeds mean that this plant is neither a conifer nor a flowering plant (so rule out B and D again). Multicellular reproductive organs should help you rule out E. Spirogyra which are a genus of filamentous charophyte green algae. Bryophytes, on the contrary, have multicellular sex organs, i.e. the gametes are enclosed by a sterile jacket of cells (http://ecflora.cavehill.uwi.edu/bio_courses/bl14apl/bryo1.htm). Also note that early embryonic development of a moss occurs in archegonia (see the picture on the right-hand side below).



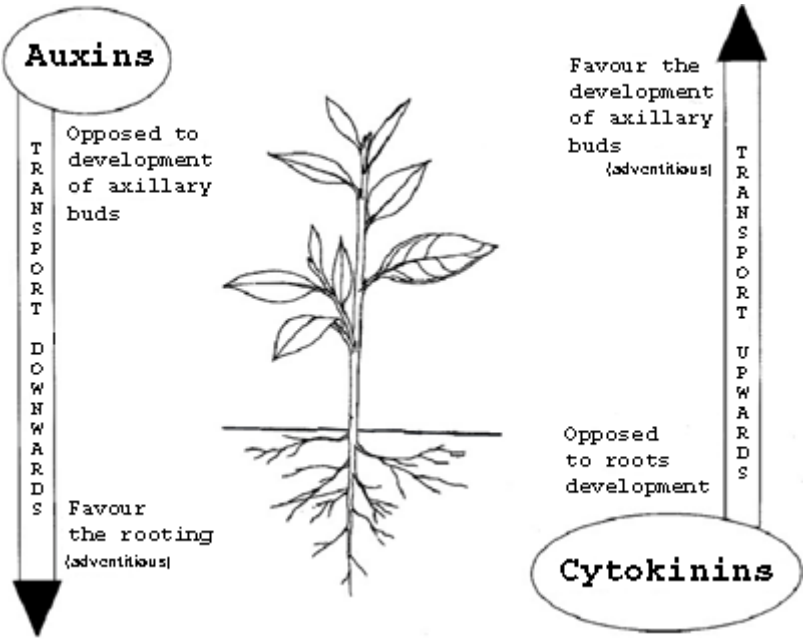


STREPTOPHYTES: THE GREEN PLANTS							
Charophytes	Embryophytes: The Land Plants						
	Non Vascular			Vascular			
	Seedless Plants Bryophytes			Seedless Plants		Seed Plants Spermatophytes	
				Lycophytes	Pterophytes		
	Liver-worts	Horn-worts	Mosses	Club Mosses	Whisk Ferns	Gymno-sperms	Angio-sperms
				Quillworts	Horsetails		
				Spike Mosses	Ferns		

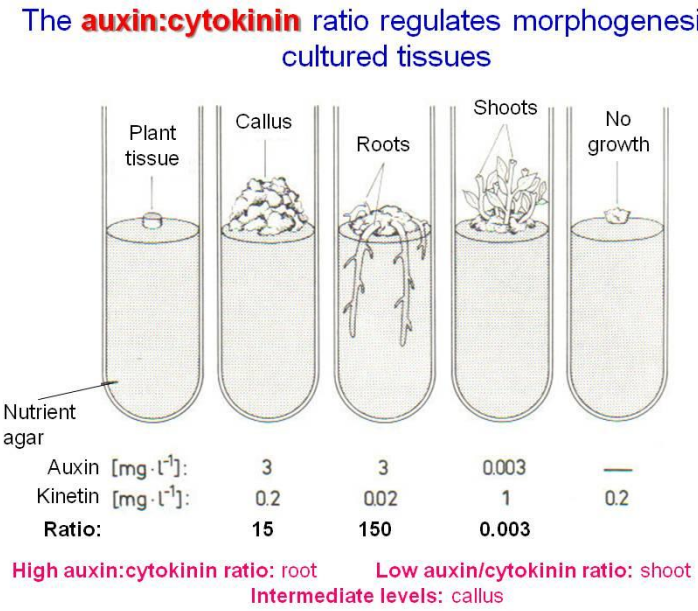
77. C. This statement is correct because auxins regulate apical dominance. The auxin causes the lateral buds to remain dormant. When the apical bud is removed, the source of IAA is removed. Since the auxin concentration is much lower, the lateral buds can now grow.
The difference in response between the two kinds of buds is explained in their sensitivity to the auxin concentration. Clearly the lateral buds are more sensitive to auxin than the apical bud. There is a concentration of auxin at which the apical bud is stimulated to grow while the lateral buds are inhibited. That concentration would be near the letter "C" of "Concentration" in the graph below.



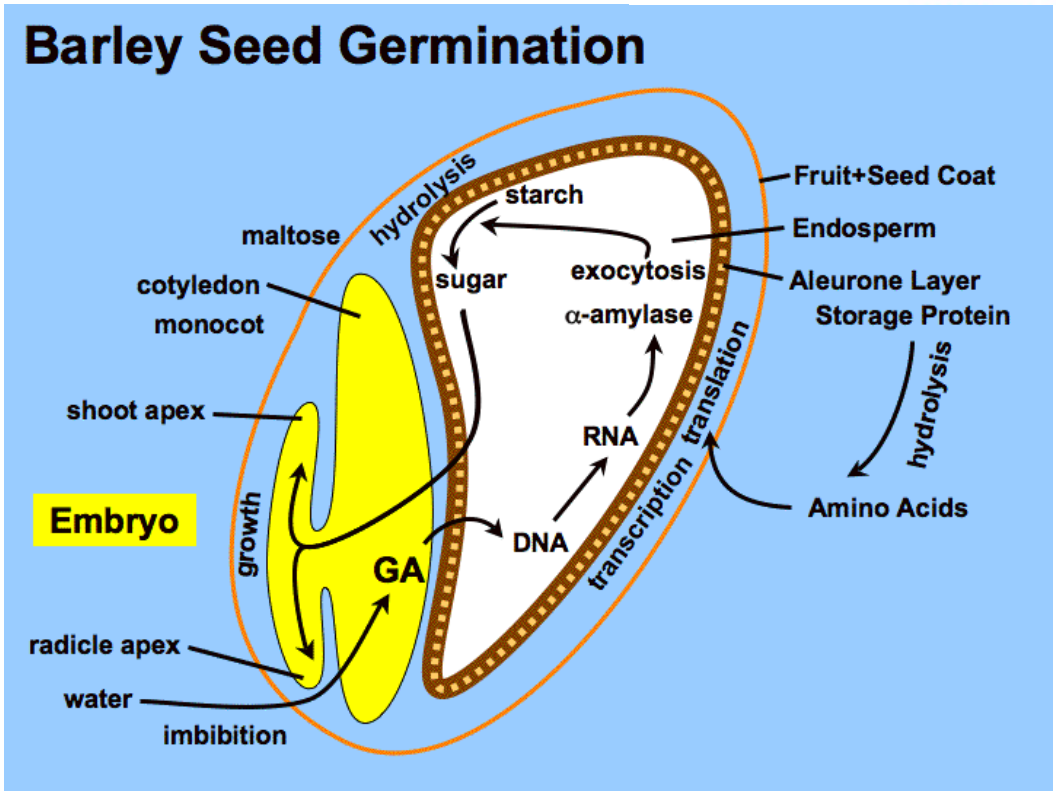
Remember that mainly auxin and cytokinin are involved in regulating bud formation. Thus, statement D should be the first to be ruled out.
Statement B does not support the changes of concentrations because if it moves upward, then what prevents from reaching upper buds?
Statement A is incorrect because most of the cytokinins required for the plant body are synthesized in the root tips, and then they are translocated to different regions particularly to meristematic and expanding tissues; transportation is through xylem stream.
Statement E is incorrect because if you have bigger concentration of cytokinin low on a tem, this means that you need LESS receptors to achieve the same effect compared to when you have lower concentration.



78. B. Kinetin is a type of cytokinin, a class of plant hormone that promotes cell division. Cytokinins are most abundant in growing tissues, such as roots, embryos, and fruits, where cell division is occurring. Cytokinins are known to delay senescence in leaf tissues, promote mitosis, and stimulate differentiation of the meristem in shoots and roots. While auxins promote root growth, cytokinins influences shoot growth. Thus it would be probable that new shoots will grow in the area.



79. D. You should remember that gibberellin initiates arousal from dormancy. As seed plants disperse by SEEDS which contain no female gametophyte anymore, it is embryo that produces this hormone. See picture below.



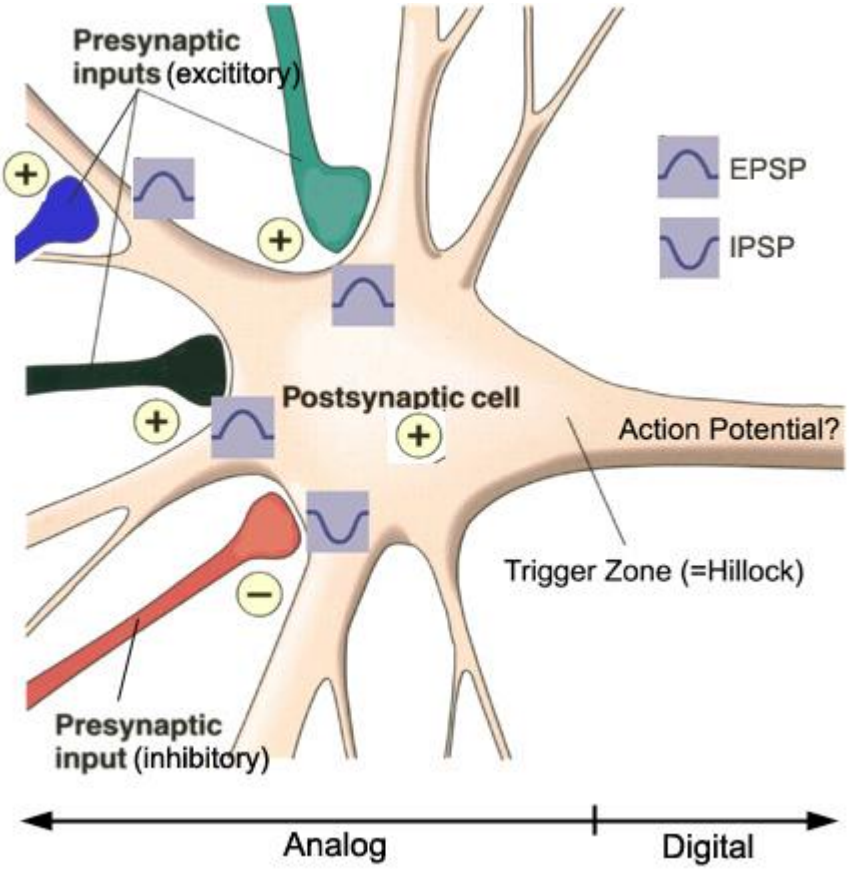
80.C. Every plant for which flower initiation is light-dependent (and not all plants are) has a critical day-length associated with it. The term long-day describes plants that begin forming flower buds when the days are longer than their critical day length. The term short-day, on the other hand, describes plants that begin flowering when the days are shorter than their critical day length. Day-neutral plants form flowers independent of day length. Generally, long-day plants flower in summer; short-day plants flower in spring or fall. As poinsettias are available to buy in shops only during Christmas, we can conclude that it is a short-day plant.
Classification of plants based on response to day length for flowering:
Short-Day Plants - plants that initiate flower buds when the day length is shorter than the critical day length or when the night length is longer than the critical night length. Day lengths longer than critical result in vegetative growth.

Long-Day Plants - plants that initiate flower buds when the day length is longer than the critical day length or the night length is shorted than the critical night length. Day lengths shorter than critical result in vegetative growth.
Day-Neutral Plants - plants that initiate flower buds over a wide range of photoperiods. Generally, these plants form flower buds after the plant reaches specific size or stage of development.
Short-Long Day Plants - plants that initiate flower buds only when a sequence of short days are followed by long days.
Long-Short Day Plants - plants that initiate flower buds only when a sequence of long days is followed by short days.

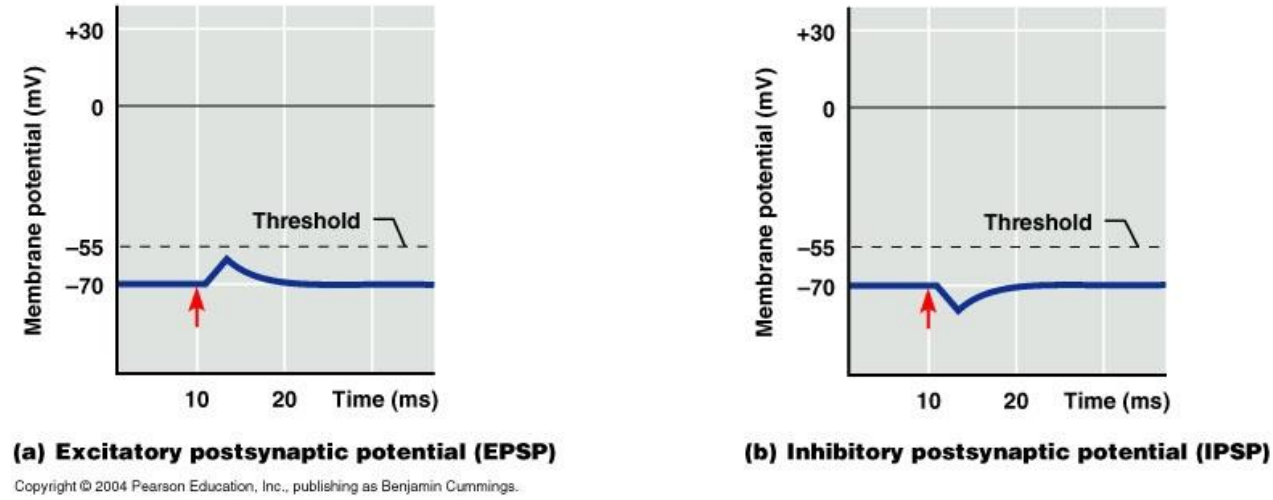
One important point about these classifications is that there is no mention of the number hours of light that constitutes a long or short day. Only that the day length must be longer or shorter than a critical day-length for the plant in question to flower. Each plant has its own specific critical day length!

It is even possible for a short-day and long-day plant to flower at the same photoperiod. Example, Cocklebur are short-day plants with a critical day length of 15 hours, it flowers at day lengths less than the critical. Spinach is long day plants with a critical day length of 13 hours, they flower when the day length is longer than critical. A day length greater than 13 and less than 15 hours will cause both plants to flower. Therefore, you should choose the answer which include word 'CRITICAL' not some kind of fixed time.

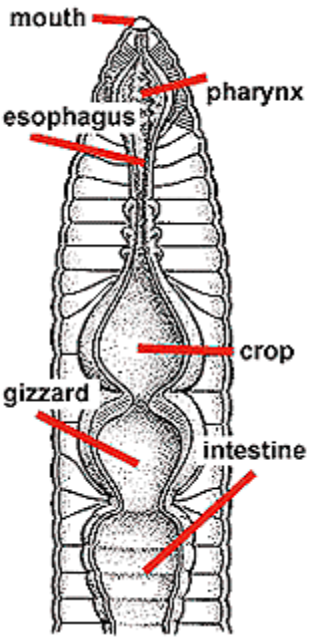
81-84. Note that an inhibitory postsynaptic potential (IPSP) is a kind of synaptic potential that makes a postsynaptic neuron less likely to generate an action potential due to hyperpolarization.
81. True, because inhibitory neurotransmitter binds to receptors on post-synaptic cell and causes either positive charges to leak out of the cell or negative charges to leak into the cell. This causes graded inhibitory postsynaptic potential which may be recorded.



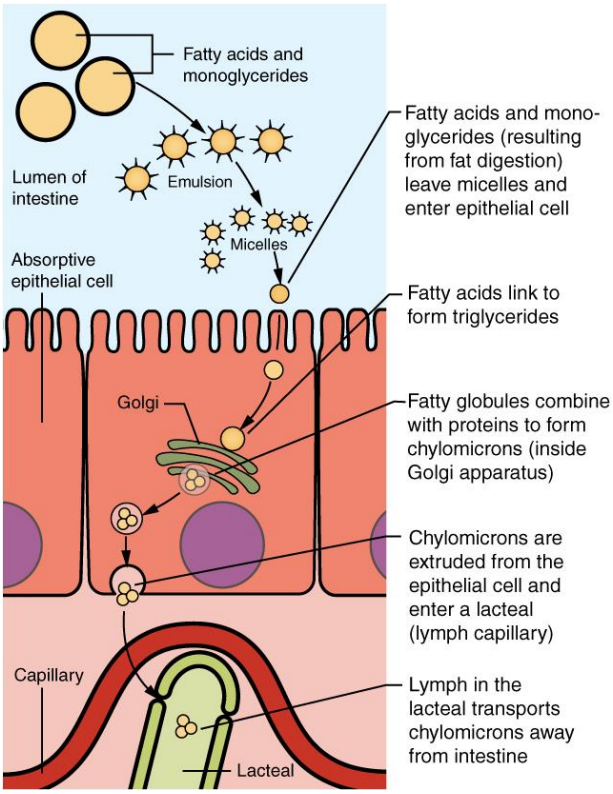
82. False, because IPSP causes a hyperpolarization, not depolarization.



83. False, because if positive charges flow into the cell, the cell depolarizes and this causes excitatory post-synaptic potential, not inhibitory.
84. True, because negative charge in the post-synaptic cell makes it less likely to fire action potentials and results in inhibitory postsynaptic potential.
85. E. Look at the diagram on the right.



86. C.
Note that fatty acids and cholesterol are both hydrophobic and lipophilic, therefore, they easily dissolve in the plasma membrane. Thus, youkan rule out A, D and E. Don't forget that fats are packed into chylomicrons and enter lymphatic system, not blood. Statement B is incorrect because fatty acids are monomers and they cannot be cleaved (but lipids, fats, etc. can be cleaved into monomers because they are polymers).
Take a look at fatty acid transportation through the intestinal wall.



87. B.
The key male reproductive organs include the testes, epididymis, urethra, vas deferens, prostate gland, seminal vesicle, and penis. The testes are composed of coiled structures called seminiferous tubules, which are the sites of sperm production. The structure on top of the seminiferous tubules in the testes is the epididymis. The sperm migrate from of the seminiferous tubules to the epididymis. Within the epididymis, the sperm mature while they are stored in this structure. The ejaculation process begins as the penis fills with blood and becomes erect. With sufficient stimulation, mature sperm travel from the epididymis through the vas deferens, a muscular tube,

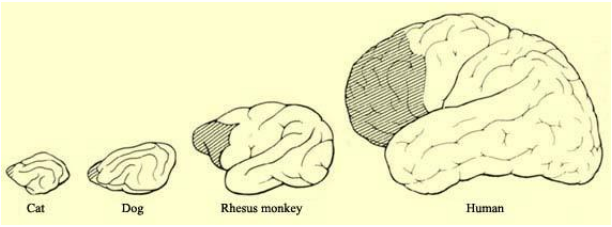
which propels sperm forward through smooth muscle contractions. The sperm arrive first at the ampulla, where secretions from the seminal vesicle are added. From the ampulla, seminal fluid is propelled forward through the ejaculatory ducts toward the urethra, passing first by the prostate gland, where a milky fluid is added to form semen. Finally, the semen is ejaculated through the far end of the urethra into the vagina. From there, it reaches female uterus and then goes to oviducts where conception may occur. OVIDUCT is the place where fertilization occurs.

88. B. All neurons carry information in one direction only: from dendrites to axons. This is mainly because of the absolute and less importantly relative refractory periods.

Statement A is correct because compare *Hydra* nerve net which does not form any nerves and human sciatic nerve, the largest nerve cord in our body.

Statement C is correct because remember spinal reflexes and compare monosynaptic and polysynaptic.

Statement D is true because rostral means anterior part and this constitutes the majority of cerebrum. We can easily notice an increase in brain size over many species as in picture below.



Statement E is correct because again remember for example a *Hydra* which does not have any smell organs and sharks which do have acute smell organs, both of which live in water.

89. D and E.

A is incorrect because Bacteria do not have cytoskeleton, therefore, they do not have any cilia, only flagella made of different protein flagellin.

B is incorrect because fungi are immobile and only some have flagella like chytrids. Chytrids have flagellated gametes -- their reproductive cells have a flagellum that allows them to swim. No other fungi have flagella, which suggest that the other fungi lost this trait at some point in their evolutionary history.

C is incorrect because plants are immobile and only some species of seedless nonvascular plants have flagella in their gametes.

D is correct. Some protists that belong to phylum Ciliophora are ciliated. Others such as Chlamydomonas and Euglena and colonial algae (Volvox) use flagella for locomotion.

E is correct because in humans, for example, motile cilia are found in the lining of the trachea (windpipe), where they sweep mucus and dirt out of the lungs. In female mammals, the beating of cilia in the Fallopian tubes moves the ovum from the ovary to the uterus.

In humans, primary cilia are found on nearly every cell in the body. In comparison to motile cilia, non-motile (or primary) cilia usually occur one per cell; nearly all mammalian cells have a single non-motile primary cilium. In addition, examples of specialized primary cilia can be found in human sensory organs such as the eye and the nose:

The outer segment of the rod photoreceptor cell in the human eye is connected to its cell body with a specialized non-motile cilium.

The dendritic knob of the olfactory neuron, where the odorant receptors are located, also contains non-motile cilia (about 10 cilia per dendritic knob).

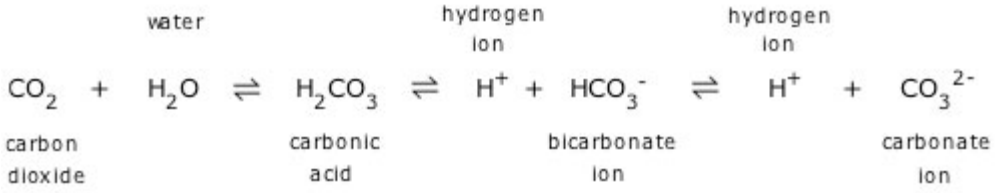
90. D. The physiological changes characterize the fight-or-flight reaction. To produce the fight-or-flight response, the hypothalamus activates two systems: the sympathetic nervous system and the adrenal-cortical system. The sympathetic nervous system uses nerve pathways to initiate reactions in the body, and the adrenal-cortical system uses the bloodstream. The combined effects of these two systems are the fight-or-flight response.

When the hypothalamus tells the sympathetic nervous system to kick into gear, the overall effect is that the body speeds up, tenses up and becomes generally very alert. If there's a burglar at the door, you're going to have to take action -- and fast. The sympathetic nervous system sends out impulses to glands and smooth muscles

and tells the adrenal medulla to release epinephrine (adrenaline) and norepinephrine (noradrenaline) into the bloodstream. These "stress hormones" cause several changes in the body, including an increase in heart rate and blood pressure.

91. C. In freshwater, the inside of the fish is "saltier" than the surrounding environment. Water moves into the fish by osmosis, passively, through the gills and the skin and the stomach. Fish have to eliminate all this excess water by peeing dilute urine. And NOT drinking water in order to maintain more concentrated composition of body fluids. In saltwater (marine environments), the environment is saltier, the fish loses water passively, so it has to drink. It eliminates excess salt using specialized cells; the excess salt is excreted primarily in highly concentrated urine or through the gills.
All fish have thick, waterproof skin to protect from water-immersion wrinkling (remember your skin after long stay in the shower or sea/lake/etc.).

92-94
92. True (A) because a decrease of oxygen levels are detected by chemoreceptors in carotid bodies. Carotid bodies are sensory receptors that detect changes in the oxygen level in the arterial blood, and the sensory information is relayed to brain stem neurons that regulate breathing. It is appreciated that oxygen sensing by the carotid body is crucial for life in mammals and, in fact, may play a life-or-death role in situations involving acute hypoxia. Signals from the chemoreceptors reach the hypothalamus, and this structure activates diaphragm and increase breathing rate. As the girl shows rapid breathing, this indicates increased contractility of the diaphragm and this means that oxygen levels are diminished.
93. False (B) because the penny not only prevents oxygen from coming into the airways but at the same time inhibits the expiration of carbon dioxide and this results in increased levels of CO_2.
94. True (A) because as we said in 93., carbon dioxide levels are higher than normal and CO_2 reacts with water in this reaction:



Notice a hydrogen ion released in this reaction. Actually, the girl is experiencing respiratory acidosis. Respiratory acidosis is a medical emergency in which decreased ventilation (hypoventilation) causes increased blood carbon dioxide concentration and decreased pH (a condition generally called acidosis).
Carbon dioxide is produced continuously as the body's cells respire, and this CO2 will accumulate rapidly if the lungs do not adequately expel it through alveolar ventilation. Alveolar hypoventilation thus leads to an increased PaCO2 (called hypercapnia). The increase in PaCO2 in turn decreases the HCO3−/PaCO2 ratio and decreases pH.
95. False (B) because with reduced amount of available oxygen, circulatory system must be activated to supply the cells with as much oxygen as it has at this time.
96. B.I would consider this statement as a correct one because if you take a look at humans, we have different faces whereas insects are almost all look the same. That means that vertebrates rely on more individual recognition whereas insects on species recognition.
Statement A is incorrect because remember grasshoppers and their serenades during summer nights.
Statement D is incorrect because it is all about the family we love and care for. As a humans (also vertebrates) we usually try to make benefit for our family while ignoring non-related people wishes.
Statement C is incorrect because we are not as bad as we may think of ourselves. We also engage in altruistic behaviours as insects.

Statement E is incorrect because remember yellow spots on winter snow in your street left by dogs to indicate their territory boundaries to other dogs. As we know, urine stinks quite a bit and this is a form of chemical communication.
97. D. This statement is incorrect because remember workers in ant population which are infertile and sacrifice their lives to helping queens to reproduce and bring up the offsprings.
Eusociality, an extensively studied social system, is displayed in three main insect orders: Hymenoptera-ants, bees, wasps, Isoptera -termites, and Homoptera -aphids. Eusocial insects are recognized by three main characteristics:

1. The mother, along with individuals that may or may not be directly related, conducts cooperative care of young.
2. A reproductive division of labor evolves from sterile castes which often have certain propensities or characteristics associated with helping behavior.
3. There is an overlapping of generations which allows for the older generations of offspring to help related, younger generations.
98. D. Remember the key rule of Olympiads: whenever you find words such as all, always, none, no and the like, be very suspicious. In this case, if subordinates did not have any contribution to reproductive success, then they will become extinct and only superior individuals would dominate. But this is not the case. Indeed, subordinate individuals may help protect superior individuals from predators, may provide them with more food or may get rid of competitors and thus increase the likelihood to attract potential female mates.
99. B, D.
A is incorrect because animals are diploid and haploid animals are inviable.
B is what actually happens because females have two X chromosomes, one of which is inactivated during lyonization and converted into Barr body. This means that genes found on that chromosome are also silenced and thus various patterns of fur are observed.
C seems to be incorrect because both somatic and germ cell come from the same zygote. Not all somatic cells are identical because of X-chromosome inactivation and not all germ cells are identical because due to haploid nature, alleles may be segregated differently in the cells (that is an allele for blue eyes might be in one population of germ cells, but the allele for brown eyes might be in the other population of germ cells, making them different from each other).
D seems correct because epigenetics may make one cells express one set of genes but other cells to express different setoff genes. In biology, epigenetics is the study of cellular and physiological traits that are heritable by daughter cells and not caused by changes in the DNA sequence; epigenetics describes the study of stable, long-term alterations in the transcriptional potential of a cell. These alterations may or may not be heritable, although the use of the term epigenetic to describe processes that are not heritable is controversial. Unlike simple genetics based on changes to the DNA sequence (the genotype), the changes in gene expression or cellular phenotype of epigenetics have other causes.
Statement E is not correct because cloning was performed which involves somatic cells which reproduce by mitosis, not meiosis.

100-103.
100. True (A). Since F(Bb)>F(Aa), having b helps a lot more (F(Bb)=F(bb)=1+s) than having a because a works only in homozygous combination (F(aa)=1+s), so it takes longer for allele a to reach frequency 0.05.

101. False (B). While Aa soon disappears (F(Aa)=1) in the group, Bb would not disappear soon as Bb is as strong as bb (F(Bb)=F(bb)=1+s) so t1(a)-t0.95(a)<t1(b)0t0.95(b).

102. False. The more a the group has, the more aa individuals the group has, so a will increase faster, it will take less time so the third one is false.

When frequency of a is small, it is really rare to have a combination of aa because only F(aa)=1+s could have high relative fitness.
When number of a is large, it is easy to get a combination of aa because F(Aa)=1 comes into play which have one recessive allele. Thus a increases faster when there is many a (frequency of a is at least 0.5), so the time should be shorter.

103. False. Note that both F(Bb) and F(bb) which have recessive alleles come into play during fixation and they have the biggest relative fitness - 1+s. In the case for a allele fixation, only genotype aa has high relative fitness 1+s, but F(Aa) which contains only one recessive allele has a fitness of only 1. When b frequency is small, b increases faster than a because bb and Bb has bigger relative fitness than BB (this was the case of 100.). But when the proportion of b got larger, b becomes slow to increase in frequency because Bb has B in it and it has the same relative fitness as bb. At the same time, when the frequency of a increases, mainly aa genotypes are favoured due to the highest relative fitness (1+s) as compared to F(AA) and F(Aa)(1). Therefore, a reaches fixation quicker, that is:
t1(a)<t1(b).

104. E. Here you do not need to make big Punnett square. Consider individual crosses:
Aa x Aa gives you ¼ probability to get aa.
Bb x Bb gives you ¼ probability to get bb.
CC x Cc gives you 0 probability to get cc. This leads to answer E.

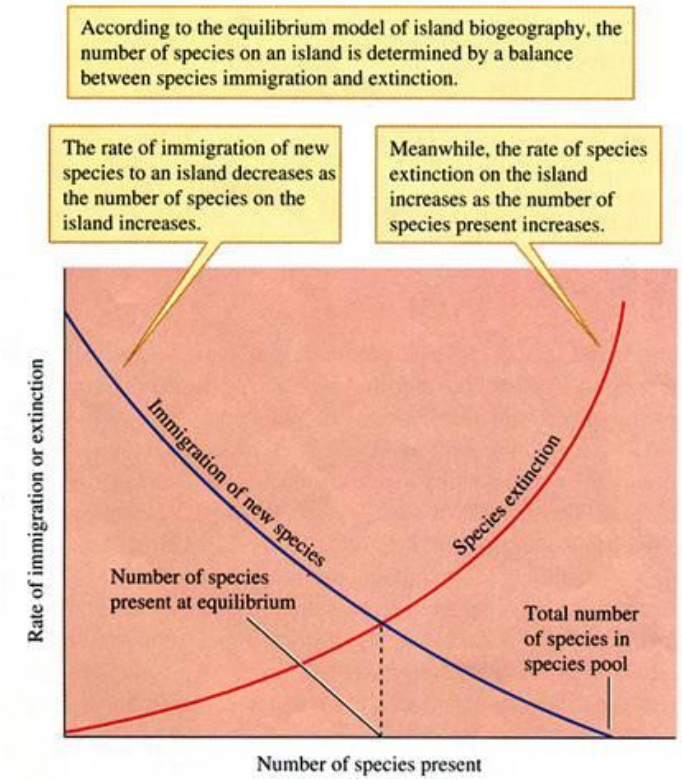
105-108. Very useful guide about this topic: http://www.jrss.in/data/35.pdf
Sensitivity and specificity are the statistical measures of performance of a binary classification tests. The sensitivity measures the proportion of actual positive which are classified as such (e.g. the percentage of sick people who are identified as having the condition); and specificity measures the proportion of negatives who are correctly identified (e.g. the percentage of well people who are identified as not having the condition). In short, sensitivity refers the probability of true showing up true and specificity to the probability of false showing up false. Sensitivity and specificity are usually expressed in percentage

105. False (B). Specificity and sensitivity affect the error rate of SNP detection technology
106. True (A).
Sensitivity is defined as:

$$\text{Sensitivity} = \frac{\text{Number of true positives}}{\text{Number of true positives} + \text{Number of false negatives}}$$

Therefore, we should look at both results.
107. True (A) A sensitive test have a fewer Type II error. Type II error, is also known as “error of second kind” or “beta” error or a “false negative”, the error of accepting null hypothesis when alternative hypothesis is true.
108. True (A) Increasing the specificity of the test lower the probability of type I error. Type I error is known as error of first kind, or “alpha” error, or a false positive”, the error of rejecting null hypothesis when it is actually true. A false positive normally mean that a test claims something to be positive when that is not the case. Thus, specificity is a statistical measure how well a binary classification test correctly identifies the negative cases.
109-112. Secondary succession refers to the concept of an ecosystem reviving itself after all or a portion has been destroyed. The concept refers primarily to plant life and can be the result of a natural or man-made event. The primary concept is that the life was previously on the soil, eliminating the need for deposition of new seeds or soil. Secondary succession is a much more rapid process than primary succession because the soil and nutrients are already available.
109. False (B) because secondary succession occurs when soil is already present.
110. False (B) because early-arriving species make the environment better for incoming species. They increase nutrient availability and promote colonization of the area by other species. If this were not true, we would see

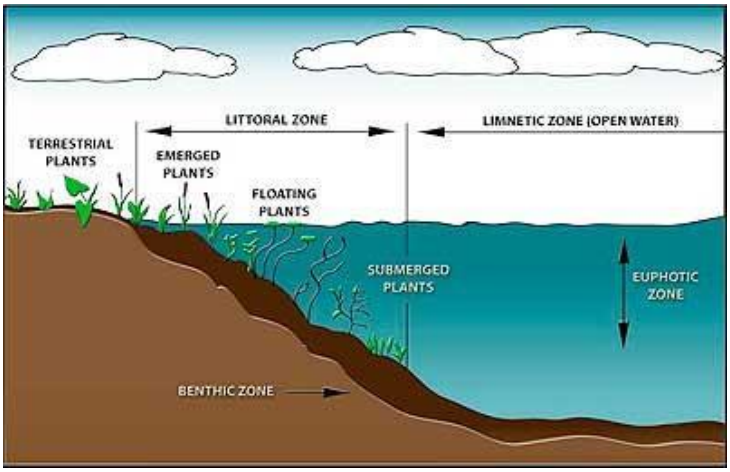
bare areas all around us where volcanos erupted or where ice has retracted. Instead we see fully functional ecosystems in such areas of secondary succession.
111. False (B) because again the word ALL does not make sense because some of the trees may survive the fire due to thick bark.
112. True (A) The Proteaceae are a family of flowering plants predominantly distributed in the Southern Hemisphere. Some are resprouters, and have a thick rootstock buried in the ground that shoots up new stems after a fire, and others are reseeders, meaning the adult plants are killed by the fire, but disperse their seeds, which are stimulated by the smoke to take root and grow. The heat was previously thought to have stimulated growth, but the chemicals in the smoke have now been shown to cause it.
113. D. It would be illogical to fly with other moths because it would make a moth more noticeable for a bat.
Statement A is correct because fleeing from predator is the most commonly used tactic to protect from predators.
Statement B is also correct because this will confuse a bat tremendously.
Statement C is correct because who would like to eat somebody who is (or pretends to be) dead???
Statement E is quite correct, I do not know explanation based on physics but this seems probable.
114. E. As we know, lichens are made up of algae and fungi living together. These are one of the oldest kingdoms so this would satisfy the condition 'one of the oldest'.
C and D seem to be predator and prey relationships.
Statement B is not the oldest as snails evolved after algae and fungi did. The same is true about animals in statement A in which case I think they are related by parasitic interactions.
115. B. The picture bellow explains this.



116. C. Most solar energy occurs at wavelengths unsuitable for photosynthesis. Between 98 and 99 percent of solar energy reaching the Earth is reflected from leaves and other surfaces and absorbed by other molecules, which convert it to heat. Thus, only 1 to 2 percent is available to be captured by plants. The rate at which plants photosynthesize depends on the amount of light reaching the leaves, the temperature of the environment, and the availability of water and other nutrients such as nitrogen and phosphorus. The measurement of the rate at which organisms convert light energy (or inorganic chemical energy) to the chemical energy of organic compounds is called primary productivity. Hence, the total amount of energy assimilated by plants in an ecosystem during photosynthesis (gross primary productivity) varies among environments.
117. E. Water lilies are autotrophs, they float in the littoral zone and they have CONSPICUOUS flowers.

A typical lake has three distinct zones (limnetic, littoral and the benthic zone; Fig. 11) of biological communities linked to its physical structure. The littoral zone is the near shore area where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow. The 1 % light level defines the euphotic zone of the lake, which is the layer from the surface to the depth where light levels become too low for photosynthesis. In most lakes, sunlit euphotic zone occurs within epilimnion. In transparent lakes, photosynthesis may occur well below the thermocline, into the perennially cold hypolimnion. The higher plants in littoral zone, in addition to being a food source and a substrate for algae and invertebrates, provide habitat for fish and other organisms different from the open waterzones.

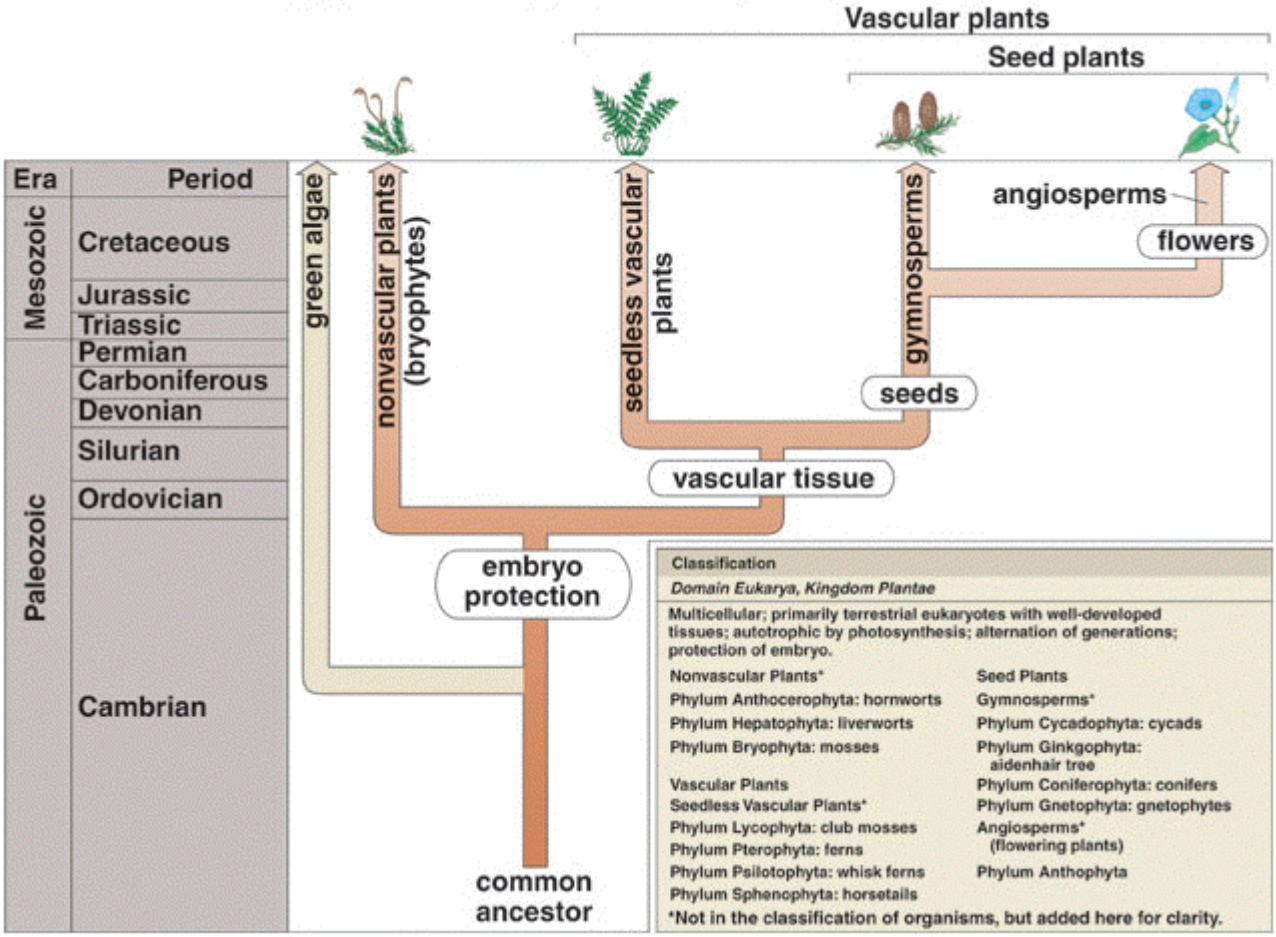
The limnetic (pelagic) zone is the open water area where light does not penetrate to the bottom. The third component of the lake habitat is benthic zone (the bottom of the lake), covered by fine layers of mud in which animals live. In the littoral zone, there is enough light for rooted plants to grow, but beyond this zone, there are no rooted plants as the water is too deep for light to reach them. The deepest part of the open water forms profoundal zone, but this is relevant only in extremely deep lakes.



Pelagic zone is the home of plankton and nekton. They are distinguished based on their swimming ability. Planktons are suspended in water whereas nektons are active swimmers. The phytoplankton consists of algae ranging in cells from 10 mm in diameter such as Chlorella to clusters of cells (Volvox). Several major groups of algae occur the world over, although the species vary. Majority of the planktonic animals (zooplankton) are herbivores feeding on algae, but there are also carnivores. The most important species are crustaceans of two major groups: cladocera (eg., Daphnia) and copepoda. They range in size from 0.2mm to about 4mm long, with exceptional species reaching 1-2 cm. These animals are an important link between the algae and much larger creatures such as birds and fish. Fish are the most obvious predators of zooplankton. Most fish start feeding on rotifers and move on to cladocerans.

The term benthic applies to flora and fauna living at the bottom and those species that live by burrowing in it. Benthic organisms can live in the substrate (in mud and sand), move on the substrate surface, grow attached to the surface or move freely in the bottom. Benthic primary producers include cyanobacteria, all higher taxa of eukaryotic algae and flowering plants. Algae attached to a substrate are called as benthic, to distinguish them from phytoplankton, which live floating in water. In some shallow lakes, benthic algae may be an important source of food but most benthic animals beyond the littoral zone derive their food from detritus raining down from the open water.

118. D. Because D has the highest number of different amino acids from species X.
A has the same sequence. B has 1 alteration. C has 1 alteration. D has 2 alterations. E has 1 alteration.
119. A. Take a look at the image.



120. B. That seems to me to be a gonad. Sea cucumbers are echinoderms and do not have circulatory system which could deliver O2. Oxygen diffuses across the surface, thus rule out D and C. However, like all echinoderms, sea cucumbers possess both a water vascular system that provides hydraulic pressure to the tentacles and tube feet, allowing them to move, and a haemal system. Digestion occurs in widely extended intestine (which I would guess is the mass reminiscent of spaghetti in the picture). Like all echinoderms, sea cucumbers possess pentaradial symmetry. However, because of their posture, they have secondarily evolved a degree of bilateral symmetry. For example, because one side of the body is typically pressed against the substratum, and the other is not, there is usually some difference between the two surfaces (except for Apodida). Like sea urchins, most sea cucumbers have fivestrip-like ambulacral areas running along the length of the body from the mouth to the anus. The three on the lower surface have numerous tube feet, often with suckers, that allow the animal to crawl along :it is called trivium. The two on the upper surface have under-developed or vestigial tube feet, and, in some species, lack tube feet altogether ; this face is called bivium. But tube feet are on the outside, so rule out E.