Biological concept list: March 2005
Bioliteracy project http://bioliteracy.org

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Course: _____ Institution: _____

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❏ you may contact me ❏ please, do not contact me

Survey instructions: For each course you teach, please indicate which concepts are emphasized, covered, or not covered and whether you consider them critical, important or marginal - you can also let us know if you think the concept statement itself is incorrect (wrong).

Science and its methods:

1. Science is a social endeavor, and as such depends upon a community of scientists who accepts its "rules".

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2. The preparation of results for publication, their review, and the response of the scientific community is an integral part of the scientific process.

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3. To be valid, an experiment generally must include both positive and negative controls.

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4. A positive control checks to see whether reagents and methods used produce the expected effects – whether they work. A negative control checks to see of the experimental effect observed are due to a specific change in the system.

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5. Scientific questions are generally based on a working hypothesis. The question is framed to provide, if possible, an unambiguous yes/no answer.

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6. If a question cannot be answered unambiguously, it needs to be reformulated. Often it must be simplified.

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7. To be useful, it must be possible to accurately describe the conditions under which an experiment was carried out, the reagents used, etc., so that other can, if they desire, repeat and extend the observation.

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8. Fruitful hypothesis are either revised or extended, they rarely remain constant.

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9. As a hypothesis gains confirmation and is extended, it may become a well-established theory. Theories may be modified, or subsumed by other more generally applicable or accurate theories, but are rarely abandoned *in toto*.

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10. The more accurately measurements can be made, the more rigorously a hypothesis can be tested.

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Experimental Savvy

1. Without positive and negative controls, experimental results are almost always uninterpretable.

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2. A well-designed hypothesis leads to clear and distinct predictions that can be validated or disproven by experimental observation.

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3. Unconscious bias can enter many types of experiments; it can be best controlled for through the use of "double-blind" experimental protocols and placebo-controls.

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4. The ability to reproduce an experiment is key; an experiment that cannot be reproduced cannot be interpreted.

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5. Investigators must honestly report their methods, observations and interpretation so that other can reproduce them.

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6. Keeping of a legible, well-dated, and complete record of experiments is important not only in terms of enabling others to reproduce or reconstruct previous experiments, but in establishing the priority of specific discoveries.

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7. Work performed in a lab, either University, public or private sector, is the property of the lab, not the investigator (this needs to be stated more accurately).

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8. To withhold information that clearly argues against the conclusions of an experimental study is as dishonest as fabricating data that supports the desired conclusion.

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9. Failure to acknowledge the contributions of others, whether past workers or co-workers is plagiarism.

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Origins and ancestors

1. There is a continuous uninterrupted line of descent from the first organisms that arose ~3.5-billion years ago, and all currently living organisms.

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2. The spontaneous generation of organisms does not occur in the modern world, but did occur on the early earth.

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3. Based on a number of structural and molecular traits, organisms can be divided into three distinct "kingdoms": bacteria, archaea and eukarya.

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4. All modern organisms shared a common ancestor that lived some billions of years ago.

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5. Modern eukarya are hybrid organisms, formed by the combination of a bacterial and a non-bacterial cell.

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6. Modern multicellular plants (metaphyta), fungi, and animals (metazoa) arose independently from eukaryotic ancestors.

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7. All metazoa appear to share a common ancestor that lived around ~1.5 billion years ago.

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8. The original hierarchical classification system of organisms (the Linnaean system) was based on structural similarities, not evolutionary relationships.

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9. Evolutionary theory explains the relationships between organisms, based on common ancestry.

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Bioenergetics

1. The cell is the basic unit of life. The free form of viruses, virions, are not alive, they are ametabolic. To replicate a virus must invade and parasitize a cell.

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2. Cells are bounded systems of interacting chemical reactions. The rates of these reactions are controlled by catalysts (enzymes and ribozymes).

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3. Cells are non-equilibrium systems that depend upon the continual influx of energy and the export of entropy.

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4. Living organisms obey all of the laws of thermodynamics.

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5. When a molecule is reduced, electrons are added to it. Oxidation is the opposite, it involves the removal of electrons.

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6. The addition of electrons to a molecule increases its free energy.

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7. Under the conditions that normally exist within a cell, energy can be stored by reducing molecules and released upon their oxidation.

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8. The rate of a reaction reflects the step in the reaction with the highest activation energy. This step is the rate-limiting step.

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9. Catalysts act to reduce the activation energy of a reaction.

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10. It is possible to couple, through common intermediates, reactions that are energetically favorable with those that are energetically unfavorable, so that energetically unfavorable reaction occurs to a significant extent.

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11. The equilibrium constant of a reaction reflects the concentration of reactants and products when the reaction reaches equilibrium. The equilibrium constant does not provide an estimate for the time it takes for the reaction to reach equilibrium.

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12. Biological catalysts are either proteins (enzymes), RNAs (ribozymes) or macromolecules complexes (e.g. the ribosome and the splicesome) that contain both polypeptides and RNAs.

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13. The energy of visible light can be captured by cells using pigments, associated with proteins, that absorb these wavelengths of light.

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14. When light is absorbed by a molecule, an electron moves into a higher energy state. The electron is said to be excited. When the electron relaxes, this energy can excite an electron in another molecule, be emitted as a photon (fluorescence) or transformed into molecular motion (heat).

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15. An electron transport chain (ETC) is a series of membrane proteins.

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16. As an excited electron moves through an electron transport chain, the components of the electron transport chain undergo sequential oxidation and reduction.

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17. As electrons move through an electron transport chain, H+s are pumped across a membrane, generating a H+ gradient.

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18. Adenosine triphosphate (ATP) is a major storage form of chemical energy within cells.

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19. ATP can be generated from adenosine diphosphate (ADP) and phosphate as H+s move through the membrane-protein ATP synthase, an enzyme.

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20. The hydrolysis of ATP into ADP and phosphate can be used to generate ion gradients across membranes.

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21. A non-equilibrium situation, for example the existence of a high concentration of protons on one side of a membrane and a low concentration on the other, provides an opportunity for cells to capture energy to do metabolic work.

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22. Metabolism is the sum of all of the chemical reactions that occur within a particularly living system.

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Evolution Basics

1. The fossil record provides direct evidence for the evolution of life on earth.

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2. Evolution occurs most rapidly in populations of interbreeding organisms; in asexual (clonal) organisms, evolutionary change is slower (as measured in life cycle times).

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3. A molecular analysis of the genomes (genetic material) of organisms provides evidence for the evolutionary relationships between organisms.

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4. The establishment of barriers to interbreeding can produce a selective advantage by preserving adaptations.

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5. Speciation occurs when members of two populations can no longer interbreed successfully.

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6. Evolution is based on genetic variation and superfecundity, which leads to changes in genetic composition over time.

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7. Without mutations there would be no evolution.

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8. Random events, such as genetic drift, founder effects and genetic bottlenecks, can influence evolutionary change.

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9. Non-random mating behavior, known as sexual selection, can influence evolutionary change.

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Water and Membranes:

1. Hydrogen-bonding between water molecules is the cause of water's unique physiochemical properties. A water molecule can interact with four neighboring water molecules.

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2. Molecules that cannot make H-bonds are insoluble in water; the larger such a molecule, the more insoluble. Such molecules are termed hydrophobic; hydrophilic molecules can make H-bonds.

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3. Lipids are a diverse class of molecules grouped based on their insolubility in water. Of particular importance in biology are the amphipathic lipids, which contain two domains, one capable of making H-bonds, the other not.

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4. When dispersed into aqueous solvent, amphipathic lipids can self-assemble into higher order structures such as micelles and bilayers. In these states, the lipid's hydrophilic domain interacts with water while its hydrophobic domain(s) are removed from contact with water.

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5. The primary boundary layer of a cell, the plasma membrane, is based on the ability lipids to self-assemble.

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6. The plasma membrane poses a barrier to the movement of hydrophilic molecules into and out of the cell.

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7. Proteins within the plasma membrane regulate molecular movements into and out of the cell.

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8. Within the plasma membrane is a concentrated solution of proteins and other small and macromolecules, the cytoplasm.

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9. Energy can be stored in the form of chemical gradients across the membranes.

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10. The high concentration of cytoplasmic components leads to osmotic effects across the plasma membrane.

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Polypeptide basics:

1. A polypeptide is a linear polymer of amino acids, linked together by peptide bonds.

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2. Proteins are functional entities composed of polypeptides, and in some cases non-polypeptide cofactors. A protein without its co-factors is known as an apoprotein.

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3. All terrestrial organisms use the same set of 19 L-form amino acids and 1 imino acid, proline.

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4. Translation is the process by which polypeptides are synthesized based on information carried in an mRNA and using a tRNA adaptors. This reaction is catalyzed by the ribosome.

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5. All terrestrial organisms, with a few minor exceptions, use exactly the same the genetic code to specify polypeptide sequences synthesized by the process of translation. The exceptions primarily involved the use of stop codons to encode amino acids and the reassignment of a few codons to different amino acids.

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6. The ubiquity of the genetic code indicates that it was a trait present in the last common ancestor of all organisms.

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7. The presence of minor variations in the genetic code suggests that it is not a predetermined, obligate feature of the translation process, but an inherited trait.

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8. Amino acids are linked together in a condensation reaction that leads to the formation of a peptide bond.

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9. During translation, new amino acids are added to the –COOH (C) terminus of the growing polypeptide chain.

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10. A functional protein can consist of one or more polypeptides.

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11. A specific polypeptide can be part of more than one protein.

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12. Amino acids are distinguished by the "R" groups, which attach to the alpha C. These R groups of different sizes: some are hydrophobic, hydrophilic, positive or negatively charged at physiological pH.

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Protein activity

1. Protein function or activity can be regulated by the binding of other polypeptides or small molecules; this binding leads to a change in protein structure.

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2. Protein function or activity can be regulated by post-translational modifications that lead to changes in protein structure.

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3. Protein function or activity can be regulated by interactions between proteins.

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4. Most post-translational modifications are reversible and regulated.

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5. Some proteins are post-translationally modified by coupling to a lipid molecule -- such modifications regulate a protein's localization within the cell.

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6. Post-translational addition of the small polypeptide ubiquitin is often used to target proteins for proteolytic degradation by the proteosome.

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7. The concentration and net activity of the protein can be regulated by both the rate of its synthesis, assembly and degradation.

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8. Allostery involves the regulation of protein function by molecules that bind to sites other than the protein's active site.

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Protein folding

1. In aqueous solution, polypeptides will fold to minimize the interactions between their hydrophobic R-groups with water.

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2. Generally, this folding leads to a compact globular, rather than an extended, structure.

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3. Generally, the native (functional) state of a protein is the state of lowest free energy.

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4. Chaperones facilitate the process by which a polypeptide folds into its native state, primarily by unfolding incorrectly folded polypeptides.

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5. Chaperones recognize incorrectly folded polypeptides by the fact that they have display hydrophobic R-groups on their surface.

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6. Some chaperones catalyze proline-peptide bond isomerization or break cysteine disulfide bonds, thereby facilitating correct polypeptide folding.

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7. Some chaperones can mediate the assembly of multipolypeptide proteins by binding and stabilizing polypeptides prior to their assembly with the 'final' partners.

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8. The process of protein folding begins as the newly synthesized polypeptide emerges from the ribosomal tunnel; before that folding is sterically suppressed.

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9. H-bonds that form between the -C=O and -NH groups of the peptide bond are responsible for the common secondary structural motifs of proteins, α-helices and β-sheets.

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10. In an α-helix, the R-groups of the amino acid residues point outward, perpendicular to the helix axis. In a β-sheet, the R-groups alternate in pointing above and below the plane of the sheet.

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11. The synthesis of all polypeptide begins in the cytoplasm. For many proteins that are inserted into the plasma (or internal cellular membranes), translation is regulated by specific signals.

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12. Polypeptides and proteins are targeted to specific cellular compartments by signals encoded in their structure. In some cases these signals are cleaved away once the polypeptide reaches its target.

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Nucleic Acids and Genes:

1. All organism store genetic information in molecules of double-stranded deoxyribonucleic acid (DNA).

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2.Some viruses use single stranded DNA, single- or double-stranded ribonucleic acid (RNA) rather than double-stranded DNA to store genetic information.

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3. DNA differs from RNA in that the hydroxyl group on the C2 carbon of ribose is replaced by a -H. Instead of uracil (in RNA), DNA contains thymine.

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4. In both DNA and RNA, information is stored in the sequence of the nucleotides along the length of the molecule.

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5. Each strand of a DNA double helix is a polynucleotide molecule, composed of deoxynucleotide subunits.

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6. A deoxyribonucleotide consists of a phosphate group, attached to the 5' carbon of the sugar deoxyribose. One of four nitrogenous 'bases', either a purine (cytosine or thymine) or a pyrimidine (guanine or adenine), is attached to the 1' carbon of the sugar. In a ribonucleotide, the sugar ribose is used and the purine uracil is used instead of thymine are used)

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7. The chains in a double stranded DNA molecule are anti-parallel and complementary. If there is an adenine residue on one chain, there is a thymine residue on the other. Similarly, if there is a cytosine on one chain, the other chain contains a guanine residue.

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8. These base pairs interact through hydrogen bonds, three between C and G, two between A and T.

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9. Both DNA and RNA are synthesized using nucleotide triphosphates. These are added the 3' OH group of the sugar (deoxyribose or ribose), creating a phosphodiester bond and releasing pyrophosphate

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10. The enzymes that mediate DNA synthesis require a pre-existing nucleic acid primer to add on to.

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11. Both DNA and most RNA polymerases use a nucleic acid template to determine the sequence of nucleotides in the newly synthesized molecule. An exception, polyA polymerase, mediates the addition of AAA(n) to mRNAs.

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12. During DNA replication and RNA transcription, the two strands of a double-stranded DNA molecule must separated so that they can be used as the templates for the synthesis of a new nucleic acid strand. Replication uses both strands, transcription one.

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13. DNA is used only to store information, RNA can both store information and perform structural/catalytic functions.

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14. The information stored in DNA is used in two distinct ways. First, sequences along the DNA are recognized by regulatory factors, mostly proteins, that bind to specific nucleotide sequences and determine which regions of the DNA are transcribed into RNA. Second, sequences of DNA are transcribed into RNAs.

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15.A gene can be defined as the region of DNA that contains the sequences transcribed to produce the gene product together with the regulatory sequences that control transcription.

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16. Changes in the nucleotide sequence of a gene can change when, where, how much, and the type of gene product produced.

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RNA:

1. To be used by the cell, DNA is transcribed into ribonucleic acid (RNA).

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2. RNA is synthesized by a DNA-dependent RNA polymerase using ribonucleotides.

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3. A ribonucleotide consists of a phosphate group, attached to the 5' carbon of the sugar ribose. One of four nitrogenous 'bases', either a pyrimidine (cytosine or uracil) or a purine (guanine or adenine), is attached to the 1' carbon of the sugar.

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4. RNAs can perform many functions: structural, catalytic, informational and regulative. Translation involves mRNA, tRNA and the RNAs of the ribosome.

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5. The enzymes that mediate RNA synthesis can synthesize RNA *de novo*, that is without a pre-existing primer.

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6. After their synthesis (transcription), RNA can be modified in various ways, for example by splicing, 5' inverted G cap addition, RNA editing and post-transcriptional modification of the nucleotide bases.

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7. Given their ability to both template their own replication and to act as catalysts, RNAs are often assumed to have played a key roll in the origins of life. This is so-called RNA world hypothesis.

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8. A ribosomal RNA catalyses peptide bond formation during mRNA/tRNA-based translation on ribosomes.

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Cellular basics:

1. Cells are bounded by a plasma membrane, composed of lipids and proteins.

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2.Within the boundary defined by the plasma membrane, there is a concentrated solution of macromolecules (RNAs, proteins), macromolecular complexes (ribosomes, proteosomes) and organelles (in eukaryotes - mitochondria, endoplasmic reticulum, Golgi apparatus, peroxisomes, lysosomes | in plants - chloroplasts).

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3. The cytoplasm is the site of protein synthesis (via ribosomes, tRNAs and mRNAs) and a wide array of basic metabolic reactions.

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4.As polypeptides are synthesized, they often interact with cytoplasmic factors (chaperones) that facilitated their correct folding.

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5.Chaperones can also facilitated the correct folding of proteins that become unfolded.

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6. Without further information, a newly synthesized polypeptide will end up in the cytoplasm. In most cases, specific 'targeting' sequences are used to direct a polypeptide other cellular targets (for example the nucleus, mitochondria, endoplasmic reticulum).

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7. Without further information, a newly synthesized polypeptide will end up in the cytoplasm. In most cases, specific 'targeting' sequences are used to direct a polypeptide other cellular targets (for example the nucleus, mitochondria, endoplasmic reticulum).

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8. Aberrantly folded polypeptides are degraded by specific proteolytic complexes, for example proteosomes.

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❑ critical ❑ important ❑ marginal ❑ wrong

9. Controlling the life time of an RNA or polypeptide is an important regulatory mechanism. polypeptides. Specific signaling within RNAs and polypeptides are used to target these macromolecules for degradation.

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10. Whether a macromolecule is stable or degraded can be regulated, as can its location within a cell.
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11. Proteins that are secreted by the cell are first targeted to membranes.
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12. Cells internalize extracellular macromolecules through the process of endocytosis.
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13. Lysosomes are intracellular organelles that contain hydrolases that function in the degradation of extracellular macromolecules that have been endocytosed.
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Cell division, differentiation and death

1. All cells are derived from preexisting cells by the process of cell division. Cells die either because they are damaged (necrosis) or by the active process of programmed cells death (apoptosis).
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2. During typical cell division, the two daughter cells can receive the same number of chromosomes as were present in the mother cells (mitosis) or half the number of chromosomes (meiosis).
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3.In eukaryotic cells, the processes of chromosome segregation (mitosis and meiosis) are mediated by a macromolecular machine, the spindle. The spindle is composed of microtubules, microtubule-associated and chromosome-associated proteins.
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❑ critical ❑ important ❑ marginal ❑ wrong

4.In eukaryotic cells, the process of cell division (cytokinesis) is mediated by a macromolecular machine, the cleavage furrow in animal cells and the phragmoplast in plants. In prokaryotes, the formation of a septum divides cells.
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5. In multicellular eukaryotes, cells can be part of the body (somatic cells) or the germ line. Most somatic cell can divide only a limited number of times before they senesce; the exceptions are stem cells, which can divide in an apparently unlimited manner.
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6. Stem cells often divide asymmetrically, one daughter remains a stem cell and the other goes on to differentiate.
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7. Cellular differentiation is associated with changes in gene expression, that is which genes are transcribed and which gene products (RNAs and polypeptides) accumulate and are active.

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8. Cellular differentiation is often associated with changes in the organization of the chromatin, so that these changes may be effectively irreversible.

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9. To survive and differentiate correctly, cells depend upon external signals. Generally these include secrete factors made by neighboring cells.

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10. In the absence of the appropriate external signals, a normal cell will undergo programmed cell death (apoptosis).

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11. While the death of a damaged (necrotic) cell leads to inflammation, apoptotic cell death does not, and the cell corpse is rapidly engulfed by neighboring cells.

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12. S phase (DNA replication) and M phase (mitosis) are temporally distinct stages of the cell cycle.

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Life cycles

The life cycle of an organism begins with its appearance and ends with its death.

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2. The simplest of life cycles are asexual and involve a process of fission, budding or fragmentation such that each offspring receives a complete copy of the genome plus necessary cytoplasmic organelles, such as the chloroplasts and mitochondria of eukaryotes.

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3. A version of an asexual life cycle involves the formation of alternative vegetative state, such as a spore. Spores are passive (non-reproducing) but under appropriate conditions can give rise to normally dividing organisms.

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4. In an asexual organism, changes to the genome can occur only through mutation or horizontal gene transfer.

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5. The process of sex involves genetic recombination between two (or more) distinct organisms. In the most common form, sex involves the fusion of gametes from two distinct individuals.

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6. Gametes are haploid cells; typically gametes can fuse through the process of syngamy/fertilization to form a diploid cell.

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7. In organisms with a haplontic life cycle, the diploid (sporophytic) phase is transient and mitosis only occurs in the haploid (gametophytic) phase.

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8. In organisms with a haplodiplontic life cycle, mitosis can during either the haploid or the diploid phase of the life cycle.

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9. Most animals are diplontic. Mitosis occurs only in the diploid phase of the life cycle and the haploid gametophytic phase is transient ending in fertilization or death.

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10. The germ line of an organism gives rise to germ cells, which in turn produce the gametes and supporting cells.

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11. In many animals, the germ cells arise in one location and migrate to the male (testes) and female (ovary) sexual organs. Testes produce sperm while ovaries produce eggs, both of which produce haploid pronuclei, which fuse to form a diploid nucleus.

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12. Gametes can be similar in size (isogamous organisms) or very different (anisogamous). It is conventional to call the individual that produces the larger gametes (eggs) female and the smaller gametes (sperm) male.

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13. The egg contains the bulk of the cytoplasm present in the new diploid organism formed upon fertilization. In particular, it is common that mitochondria are supplied only by the egg.

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14. Eggs are typically non-motile, sperm motile.

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15. A number of different mechanisms are used to insure that an egg is fertilized by only a single sperm; fertilization of an egg by multiple sperm generally leads to severe developmental abnormalities.

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Gene regulation basics:

1. A gene consists of DNA sequences that are transcribed and those that are not. Both transcribed and non-transcribed sequences are used to regulate gene expression. The sequences of DNA that make up a gene need not occupy a single continuous stretch of DNA.

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2. The final products of genes can be RNAs or polypeptides. For genes that encode polypeptides a transitional (mRNA) RNA is produced through the processing of the primary transcript RNA.

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3. Gene expression refers to the level of the final gene product that a gene produces.

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4. The first step in the regulation of gene expression is the control of the number of copies of the gene's transcribed region that are synthesized. This synthesis is catalyzed by RNA polymerases.

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5. A gene has at least one, and may have more than one, distinct transcription start site. Each transcription start site is defined by a distinct promoter.

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6. A gene's promoter is the region of DNA that, through interactions with regulatory proteins (transaction or transcription factors), determines the binding site, binding affinity and enzymatic activity of RNA polymerase.

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7. Promoters can be (semi-arbitrarily) divided into proximal and distal elements. The proximal promoter is located near the transcription start site. Distal elements are located further away from the transcription start site. In humans, promoter elements can occupy many hundreds of kilobases of DNA both 'upstream' and 'downstream' of the transcription start site.

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8. It is possible that more than one gene can be present within a specific region of a DNA molecule; in fact more than one gene can use a specific DNA sequence.

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9. The ability of transcription factors to recognize and bind to DNA is regulated by the binding of other transcription factors and the packing of the DNA into chromatin.

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10. Once transcription begins, the amount of the final transcript that accumulates is a function of transcription, processing and degradation rates. Particularly in eukaryotes, transcript processing can be quite complex and include 5' cap addition, 3' polyadenylation, RNA splicing, RNA editing, RNA modification and RNA transport/localization within the cell.

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11. Differential splicing can generate different final RNA transcripts from a single gene. If the RNA is used to direct polypeptide synthesis, different transcripts can produce related by distinct polypeptides. The pattern of splicing can itself be regulated.

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12. Some transcripts are rapidly degraded, others are relatively stable. Transcript stability directly impacts gene expression.

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13. mRNAs can differ in the efficiency with which they engage the translational machinery. The efficiency of an mRNA's translation can be regulated

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14. Once a polypeptide is synthesized, the efficiency with which it folds or assembles into a functional protein through interactions with other polypeptides and co-factors can be regulated. Misfolded proteins are often rapidly degraded.

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15.The activity of a protein can be regulated directly, through interactions with allosteric effectors, competitive inhibitors and cooperative interactions. It can be regulated indirectly by controlling the cellular localization and stability.

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Alleles, mutations and phenotypes:

1. Genes can exist in different versions, which differ in the nucleotide sequence; these versions are known as alleles.

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2. The complete set of genes carried by an organism is its genome; the specific set of alleles it carries is known as its genotype.

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3. The specific features of an organism are known as its phenotype.

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4. The phenotype is a function of the genotype and environmental and molecular events that occur during embryonic development and thereafter.

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5. Some phenotypic traits are due to the allelic composition of a single gene, most are based on a large number of different genes.

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6. During meiosis the process of recombination can lead to the formation of new alleles and new combinations of alleles along a chromosome.

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7. The process of sexual reproduction can generate vast numbers of possible genotypes.

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8. All alleles have their origins as a mutation or a recombination event. The original version of the gene, before the mutation, is known as the wild type allele.

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9. A specific gene is also known as a genetic locus (position). In a particular population of organisms, the number and frequency of alleles of a specific genetic locus will be determined by various factors, including founder effects, genetic drift and natural selection. Generally the most frequent allele will be considered the wild type, but this is an artificial convention.

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10. Genes produce products, either RNAs or (indirectly) polypeptides (proteins).

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11. A mutation can alter either the gene product itself, its regulation (when, where and how much is produced).

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12. We can classify mutations formally, without even knowing what the gene products do or how the mutation alters them in the following terms. A mutation can be amorphic (no gene product produced), hypomorphic (the gene product has the same function, but is less active than the wild type), hypermorphic (the gene product has the same function, but is more active than the wild type), antimorphic (the mutant gene product antagonizes the function of the wild type product) or neomorphic (the gene product has a new function, different from the wild type gene produce).

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13. Haploid organisms have a single copy of each genetic locus. Diploid organisms have two copies (one inherited from the maternal parent the other from the paternal parent). In a diploid organism, if a phenotypic trait is determined by one allele, irrespective of the nature of the other allele at the genetic locus, the determining allele is said to be dominant, the other allele(s), recessive.

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14 Most alleles are neither strictly dominant nor recessive, but interact in complex ways with each other and the rest of the genotype to determine phenotype.

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Developmental basics:

1.The generation of distinct cell types requires the generation of molecular and cellular asymmetries. A single cell can be asymmetric or polarized.

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2. Cytoplasmic asymmetries can be in the form of differentially distributed RNAs or proteins, and usually both.

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3. Cytoplasmic asymmetries lead to differential patterns of gene expression in the cells that come to reside in different regions of the embryo.

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4. In some species, where a sperm enters the egg is predetermined. In other species, the site of sperm entry serve to establish asymmetry.

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5. Asymmetries can be generated by the relative positions of cells within an embryo; surface cells can differ from internal cells.

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6. Differential gene expression in turn leads to altered cytoplasmic and nuclear composition. It is this process that generates differentiated cells, that is, cells with distinct morphologies and functions within the organism.

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7. Changes in chromatin organization occur during the process of differentiation are involved in the stability of the differentiated state. These are an example of epigenetic changes.

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8. Cellular asymmetries can lead to asymmetries in intercellular interactions, which in turn can stabilize or direct further cellular asymmetries.

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9. Inductive interactions between cells can involve juxtacrine (direct contact, surface-mediated), paracrine (short range secreted factor-mediated) and endocrine (long range secreted factor-mediated) signaling events between cells.

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10. Often interactions between groups of cells are required in order to respond to an inductive signal. Rarely do individual cells differentiate independently of their neighbors, rather groups of cells differentiate to form a tissue. This is known as the community effect.

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11. Cells can respond differently to differences in level of inductive signals. This behavior underlies morphogenic/inductive gradients. These gradients can lead to new cell types and new inductive signals.

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12. The regulated movement of cells and changes in cellular morphology are critical to both the patterning of inductive interactions and the process of morphogenesis during development and organ formation.

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13. The timing of inductive events is critical to normal developmental events.

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14. Inductive signaling is mediated by secreted factors and cell surface ligands, membrane and intracellular receptors, and the intracellular signal transduction pathways that they regulate.

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15. For each positively acting factor there are generally antagonists and co-factors that modulate 'signal strength' and specificity.

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16. Signal transduction pathways often regulate gene expression by regulating the activity of transcription factors. Signal transduction pathway can also regulate protein activity involved in cell morphology, movement, division or survival.

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17. It can be assumed that a number of inductive events underlie each aspect of embryonic development. These are not necessarily additive; they can involve complex and non-linear interactions.

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18. The formation of organs, and the tissues that compose them, is based on a similar process of inductive interactions.

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Tissue and organ basics

1. An organ is a functional and anatomically distinct component of a multicellular organism.

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2. Organs are often integrated into larger systems. For example, the heart is a critical component of the cardiovascular system, while the stomach is part of the gastrointestinal system (alimentary canal).

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3. Glands are organs that secrete one or more substance. Endocrine glands secrete directly into the blood stream while exocrine glands secrete onto an epithelium via a duct.

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4. Organs are generally composed of one or more cell types or tissues.

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5. Organ function is regulated and coordinated directly by neural signals via the autonomous nervous system and by hormones secreted by glands, which are themselves often under neural control.

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6. Organ function can in turn influence the nervous system.

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7. Normally the interactions between organ systems leads to homeostasis that is the body's ongoing adaptation to changes in its internal and external environment.

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Physiology basics:

1. All animal cells have an electrical potential across their plasma membrane; this is known as the resting potential. It arises from the concentration gradients of Na+ and K+ across the membrane, established and maintained by the action of the Na+, K+ ATPase, and the plasma membrane's differential permeability for Na+ and K+

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2. Excitable cells, such as neurons and muscle cells, have voltage-gated ion channel proteins in their plasma membrane. Activation and inactivation of these channels gives rise to a traveling wave of potential change across the plasma membrane called the action potential .

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3. Action potentials have a constant amplitude. The cells of the nervous system (neurons) encode and transmit information primarily through the frequency and patterns of action potentials, not in terms of action potential size .

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4. Action potentials move along neurons with a distinct directionality. They generally arise in the region adjacent to the neuronal cell body (the soma) known as the axonal hillock. They pass down the axon.

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5. Neurons interact with one another, or with muscle or gland cells, through structures known as synapses. At a chemical synapse a chemical neurotransmitter is released by the presynaptic cell and binds to neurotransmitter receptor proteins on the surface of the post-synaptic cell. At an electrical synapse, the electrical wave in the presynaptic cell is directly passed to the post-synaptic cell through gap junction-like membrane proteins.

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6. The binding of the neurotransmitter to neurotransmitter receptor can either induce (excite/depolarize) or inhibit (hyperpolarize) the generation of action potentials or other response (contraction of muscle cells, release of hormones by exocrine cells) in the post-synaptic cell.

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7. The activity of a synpase is determined by the rate of transmitter release and removal, by either uptake or destruction, as well as the responsiveness of the receptor that interacts with the transmitter.

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8. Typically, synapses are made on the non-axonal parts of a neuron, known as the dendrites and soma. Generally these regions cannot generate action potentials. The activity of the synaptic neuron will be determined by whether the net synaptic inputs lead the depolarization of the hillock region above a 'threshold'. In this way, a neuron acts to integrate the incoming signals that impinge upon it.

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9. Complex behaviors, including memory and consciousness, are generated through the electrical and chemical activities of networks of neuronal interactions.

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Cardivascular and respiratory systems:

1. The heart is a muscular pump whose periodic contraction (beat) causes blood to flow through the circulatory system.

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2. Within the circulatory system, blood carries oxygen O2 and carbon dioxide CO2 (the respiratory gases), nutrients, waste products, and hormones to and from every cell in the body.

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3. The respiratory gases are exchanged (uptake of oxygen, release of carbon dioxide) within the lungs.

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4. Vertebrates have a closed circulatory system, consisting of a heart, arteries, capillaries and veins.

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5. The amount of blood leaving the heart each minute (cardiac output) is the product of the heart rate (number of beats/minute) and the amount of blood pumped with each beat (ml/beat).

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6. The pressure in the aorta (just outside the heart) is determined by the product of the cardiac output and the total peripheral resistance.

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7. Peripheral resistance is a function of arterial diameter, which can be controlled by smooth muscle cells that surround these vessels; their state of contraction is controlled by the autonomic nervous system.

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8. The pressure at any point in the circulatory loop is determined by the volume of blood that is contained there and the compliance at that point.

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9. The pressure gradient across an organ or tissue and the resistance to flow (a function of vessel diameter) determines the flow/minute through the organ or tissue (the perfusion rate)

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10. The cardiovascular system is homeostatic. It acts to hold constant the pressure in the aorta (mean arterial pressure) by controlling the function of the heart (heart beat rate, contraction strength) and the circulatory resistance.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

11. The resistance to blood flow in an organ or tissue is determined by the local metabolic activity and blood vessel diameter; signals from the autonomic nervous system regulate blood vessel diameter.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

12. Most animals are aerobic. To survive they require molecular oxygen (O2), which they use as an electron acceptor (producing water) during respiration. O2 is obtained from the atmosphere. Its presence in the atmosphere is due to its release as a waste product during photosynthesis.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

13. Aerobic organisms produce carbon dioxide as a waste product, it must be disposed of into the atmosphere.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

13. O2 is captured from the atmosphere in the lungs and carried to the tissues (where it is used by the cells). Carbon dioxide (produced in the cells) is carried from the tissues to the lungs, where it is released, by the circulatory system.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

14. Air, which consists of ~20% O2 and little (~0.035%) carbon dioxide, is brought into the lungs by the contraction of the inspiratory muscles. This leads to a sub-atmospheric pressure in the lungs. Air flows in through the respiratory tree driven by the resulting pressure gradient.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

15. Air leaves the lungs (containing much less O2 and significantly higher levels carbon dioxide) when the inspiratory muscles relax; elastic recoil of the lungs creates a pressure greater than atmospheric and the resulting pressure gradient drives flow.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

16. O2 diffuses from the air in the lungs into the blood, carbon dioxide diffuses from the blood into the air in the lungs, and both gases move down their respective partial pressure gradients.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

17. The partial pressure of O2 in the lungs is directly determined by alveolar ventilation and inversely determined by the rate of O2 consumption. The partial pressure of carbon dioxide in the lungs is inversely determined by alveolar ventilation .

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

18. O2 is transported in the blood bound to the protein hemoglobin, which is present within red blood cells. Carbon dioxide is transported predominately as bicarbonate ions.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

19. The respiratory system is homeostatic. It regulates the partial pressure of O2 and carbon dioxide in arterial blood.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

Gastrointestinal systems:

1. The GI system is NOT homeostatically regulated: it absorbs everything that it can digest that is presented to it.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

2. Movement of material through the GI tract occurs because of the presence of pressure gradients created by the coordinated contraction of the smooth muscles that in the walls of the tract (stomach, small and large intestine).

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

3. Digestion involves the enzymatic breakdown of food into monomers (amino acids, simple sugars, fatty acids).

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

4. The products of digestion (monomers) are absorbed by passive diffusion (fats) or by active transport processes (carbohydrates, proteins, nucleic acids, minerals, vitamins).

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

5. The enzymes required for digestion are produced in exocrine organs and released into the GI tract. They are not derived from the food itself.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

6. The motility and secretory activities of the GI tract organs are controlled by the intrinsic (enteric) and extrinsic (autonomic) nervous systems and by hormonal signals.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

Endocrine systems:

1. Hormones are chemical messengers, produced by gland (exocrine and endocrine) cells. Hormones can alter the metabolism of target cells.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

2. For a hormone to alter a cell's function, that cell must have (express) receptors for the hormone. Hormone receptors are proteins.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

3. Every cell has a subset of hormone receptors, and every cell responds to a number of different hormones.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

4. Hormones alter cell function by altering the activity of a specific sets of cellular enzymes. Hormones act through a number of different mechanisms. They can regulate protein activity or gene expression, or both.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

5. Hormones play major roles in sexual reproduction, energy metabolism, water and electrolyte balance, growth and development, and stress response and immune function.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

6. Hormones generally reach their target cells by transport in the blood and thus affect cells throughout the body.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

7. The storage and utilization of energy substrates – glucose, fatty acids, and amino acids – are controlled by hormones. Storage of energy substrates is controlled by insulin; by its actions promoting glucose storage, insulin is the primary regulator of blood glucose concentration. Utilization of energy is controlled by glucagons, epinephrine, cortisol and growth hormone.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

8. Reproductive functions – generation of gametes (eggs and sperm) and the production of the sex hormones (testosterone and estrogen) – is controlled by hormonal feedback between the hypothalamus, the anterior pituitary, and the gonads (ovaries and testes) .

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

9. Na+ and K+ balance is regulated by the rennin-angiotensin II-aldosterone system acting on the kidneys.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

10. Body fluid osmolarity is regulated by antidiuretic hormone, related from the posterior pituitary, acting to control water readsorption by the kidneys.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

11. Reproductive behavior is generated by the interaction of the nervous system (CNS, ANS and hypothalamus) and the endocrine system.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

12. Ca2+ balance is regulated by parathyroid hormone and calcitonin.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

13. Gametes (sperm and eggs are haploid cells produced in the gonads (testes and ovaries, respectively) under the control of the hypothalamic-pituitary-gonadal axis.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

Ecology basics

1. Ecology is the study of the inter-relationships between organisms and their environment. It includes how organisms are impacted by their environment and how they, in turn, impact their environment.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

2. The major source of energy that flows through ecological systems is the sun. This energy is captured primarily through photosynthesis. Additional sources of energy are found in chemicals.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

3. A number of different approaches are used to characterize ecological processes. The trophic-dynamic concept tracks energy flow through populations, communities, ecosystems and the entire globe.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

4. The biogeochemical cycle concept, tracks materials and elements through populations, communities, ecosystems and the entire globe.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

5. Ecological interactions can occur at the level of individuals, populations and communities. Such interactions include symbiosis, competition, predation, succession, and stability.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

6. Population dynamics are a complex function of environmental factors, organismic behavior and fecundity, predation, pathogenesis, and cooperation (interorganismic and intrapopulation interactions).

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

7. Much of what is meant by the term natural selection can be best understood in terms of ecological interactions and principles.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

Carbon cycles:

1. Carbon moves through and between ecosystems as CO2 (low energy) and reduced (high energy) organic (carbon-containing) molecules.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

2. One class of organisms, known as primary producers or autotrophs, transform CO2 into reduced organic molecules; this process requires energy.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

3. Energy enters ecosystems primarily as sunlight (electromagnetic energy). The process by which autotrophs use light is used to generate reduced CO2 is known as photosynthesis.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

4. The most common form of photosynthesis, the form used by most photosynthetic bacteria and plants, involves the light-driven extraction of electrons from water; these electrons are used to generate reduced CO2. A by-product of this reaction is O2.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

5. Organisms that cannot use energy to generate reduced CO2 are known as heterotrophs. Heterotrophs require a source of reduced CO2 to survive and grow. They obtain this reduced CO2 by eating other organisms or the by-products of other organisms.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

6. During aerobic respiration energy is extracted from reduced CO2 by the removal of elections; these electrons are delivered to O2 to form H2O.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

7. Aerobic heterotrophs (animals, fungi, non-photosynthetic, non-autotrophic bacteria and archaea) take in organic molecules and O2 and release CO2.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

8. Methanogenic heterotrophs (archaea) take in organic molecules and release CH4; Methanotrophic heterotrophs oxidize CH4 to form CO2.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

9. Aerobic autotrophs perform both photosynthesis in the light and respiration (all the time).

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

10. Reduced organic molecules. ATP and related molecules carry energy around within the cell.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

11. Carbon moves between organisms and between the cells within an organism (via the circulatory system if an organism has one) as CO2 or organic molecules (food and to a lesser extent, waste).

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

12. The total amount of reduced organic molecules present within organisms is know as biomass.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

13. Autotrophs move carbon in and out of the biomass (with generally a net increase), while heterotrophs move it out (with a net decrease).

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

14. The atmosphere and oceans contain pools of CO2, pools of reduced carbon are found in buried sediments, in rocks, dissolved in the ocean, and as methane hydrates.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

Symbionts and pathogens:

1. There is a multidimensional continuum between organisms. It varies from organisms that live in close proximity but have no discernable effect on one another, to organisms that benefit or suffer as a result of their interactions.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

2. Some interactions between organisms are transient, for example predator/prey or host/pathogen. Other relationships are permanent or prolonged; these are known as symbiotic or parasitic relationships.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

3. Symbiotic relationships can be characterized in terms of benefit and cost to each of the organisms involved. Mutualism indicates that both organisms benefit; Commensalism involves benefit to one but no serious harm to the other; Amensalism involves harm to one but no significant benefit to the other while Parasitism involves benefit to one and significant harm to the other.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

4. We can think of the pathogen/host relationship as an extreme form of parasitism, cut short by the death of the host or the elimination of the pathogen by the host's immune system.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

5.There are many modern examples of endosymbiosis, in which one organism lives within the confines of the cells of another.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

6. The function of the immune system is to recognize foreign organisms and viruses and to eliminate them from the host's body.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong

7. The immune system does not always function perfectly, or it may over-react to a benign organism or situation -- this can lead to autoimmune disease.

❑ emphasized ❑ covered ❑ not covered
❑ critical ❑ important ❑ marginal ❑ wrong