Pass the TExES Life Science 8-12

FOR TEXAS TEACHERS
A test prep manual for the TExES Life Science exam #138 for grades 8-12
SEMINAR/TUTORING AVAILABLE!

First Edition

by Saba Sadiq, M.S.
with Mark Mentze, M.Ed., M.A.

Also available from Ed Publishing:
Pass the TExES PPR
Domain II:
Cell Structure and Processes

Competencies 4-7
(20% of the test)

Life Science Standard IX:
The science teacher knows and understands the science content appropriate to teach the statewide curriculum (Texas Essential Knowledge and Skills [TEKS]) in life science.
4. Biomolecules

Key Descriptors:

- The teacher explains how the essential chemical elements combine to form biologically important compounds.
- The teacher understands the importance of how the properties of water and carbon affect basic life processes.
- The teacher relates the shape of a molecule to its biological function.

Key Words:

- Organic
- Inorganic
- Hydrophobic
- Hydrophilic
- Hydrocarbon
- Isomers
- Polymers
- Monomers
- Phospholipids
- Lipids
- Carbohydrates
- Proteins
- Enzymes
- Coenzymes
- Substrate
- Active Site
- Amino Acids
- Polypeptides
- Nucleic Acids
- Hydrolysis
- Dehydration
- Synthesis

NOTE: Refer to the bullet points under each Competency in the ETS/SBEC study guide. Analyze each bullet point, and synthesize it down to a paraphrase that is meaningful to you, using no more than 5 words. List those phrases in order on the lines above. It may help to number the bullet points and the lines above. When complete, record them again on Worksheet 4 in Appendix I.
4. Biomolecules

Competency 4:
The teacher understands the structure and function of biomolecules.

1. Chemical Elements in Biology
   - The elements Hydrogen (H), Carbon (C), Oxygen (O), and Nitrogen (N) are extremely important to biology. These four elements make up 96% of living matter. A few other elements: phosphorus (P), sulfur (S), calcium (Ca) and potassium (K) make up most of the remaining 4%.
   - Chemical elements join together in different ways to form a range of molecules, from simple monomers to larger more complex polymers. These polymers and other large molecules make up the structures that eventually form living cells.
   - Cells are made up of small molecules like water; ions such as sodium and magnesium, and large organic molecules.
   - Many interactions important to cells involve bonds that are weaker than covalent bonds. The most important of these is the hydrogen bond. For example, in living things the weak forces contributed by hydrogen bonds stabilize the structure of large molecules such as DNA and proteins.
   - Inorganic compounds present in cells include water, mineral salts inorganic acids and bases. These are compounds that have no chemically combined carbon and hydrogen.
   - Organic compounds have carbon and hydrogen combined chemically. Examples of organic compounds present in cells include carbohydrates, lipids, proteins and nucleic acids.

2. Significance of Water and Carbon in Life Processes
   - Properties of Water
     - Water is the most common inorganic compound in living things. It makes up about 80-95% of living organisms.
     - The ability of ions and other molecules to dissolve in water is due to polarity. The tetrahedral shape of water and structure of its bonds makes water a polar molecule
     - It has unique hydration properties towards biological macromolecules (particularly proteins and nucleic acids) that determine their three dimensional structures, and hence their functions, in solution.
     - Water is a very important transport medium for living organisms because of its solvent properties.
     - This hydration forms gels that can reversibly undergo the gel-sol phase transitions that underlie many cellular mechanisms.
     - Water ionizes and allows easy proton exchange between molecules, so contributing to the richness of the ionic interactions in biology.
     - The hydrophobic effect, or the exclusion of compounds containing carbon and hydrogen (non-polar compounds), is another unique property of water caused by the hydrogen bonds. The hydrophobic effect is particularly important in the formation of cell membranes.
     - Water is a very thermally stable medium which helps living organisms resist changes in their environment. Compared to molecules of similar size and properties water has a very high melting point and boiling point.
   - Properties of Carbon
     - Because carbon has four valence electrons and makes covalent bonds, it can form molecules that are long chains and rings that serve as the backbones of organic molecules.
     - Carbon has the ability to form large, complex and diverse molecules. The cells and tissues of virtually all organisms are made up of the same basic carbon molecules: carbohydrates, lipids, proteins and the nucleic acids.

continued
• Carbon bonds covalently with other carbon atoms, as well as a number of other atoms, notably hydrogen, oxygen and nitrogen. In fact, the basic carbon compound is a hydrocarbon, formed from carbon and hydrogen.
• Hydrocarbon skeletons vary in length (number of carbons).
• Living systems make a variety of new chemicals by adding functional groups to hydrocarbon skeletons.
• Hydrocarbons vary in structure. Different structures with same chemical formula are isomers.
• Polymers are the chains that living systems assemble subunits into. Monomers are the subunits of polymers.

3. Biomolecules - How Shape Relates to Function
The structure of each type of macromolecules is what determines how the molecules function in our bodies.
• Receptor. A specialized molecule of a cell’s membrane that receives information from the environment and conveys it to other parts of the cell. The information is transmitted in the form of a specific chemical, neurotransmitter, which must fit the receptor like a key in a lock.
• Receptor Binding. Neurotransmitters will bind only to specific receptors on the postsynaptic membrane that recognize them.
• Neurotransmitters are made in the cell body of the neuron and then transported down the axon to the axon terminal.
• Communication of information between neurons is accomplished by movement of neurotransmitters across a small gap called the synapse.
• Lipids or fats can be considered to be biological molecules which are soluble in organic solvents.
• Phospholipids are a variation on the triacylglycerol theme in which one fatty acid is replaced with a phosphate group, which in turn is bound to additional functional groups.

• Structurally and functionally, the important thing about phospholipids is that these molecules are simultaneously hydrophobic (on the fatty acid end) and hydrophilic (on the phosphate end).
• Protein structure is critical for its function. Each protein has a unique shape or conformation. However, all proteins are composed exclusively of subunits of amino acids, which join together in long chains called polypeptides that fold or coil into the unique shape of the functional protein.
• The function of many proteins depends on a specific region of the protein that binds to another molecule. An enzyme binds to the substrate (the reactants) at a specific active site on the enzyme.
• Nucleic acids (polynucleotides) are formed when covalent linkages are made between the 3 carbons of one nucleotide’s sugar and the phosphate of the next nucleotide to form long chains. DNA forms double chains while RNA forms single chains.

4. Chemistry of Biomolecules
Cells use the following reactions to assemble and disassemble polymers. The reactions involve water. The methods of hooking the amino acids together, the sugars together, the nucleotides together, and the method of attaching each of the 3 fatty acids to the glycerol molecule are all the same.
• Dehydration synthesis is an exchange reaction in which two substances are joined such that a water molecule is lost. In other words, a reaction in which “Polymer + Monomer” yields “Longer Polymer + Water,” where monomers combine to form larger molecules. For example:
  A-OH + H-B → AB + HOH
• Dehydration synthesis allows for close packaging of complex molecules. An example is the process in which two single sugars combine to make the double sugar maltose.
• Hydrolysis is an exchange reaction in which
water is added to a molecule thus effecting its decomposition. It is a reaction in which “Polymer + Water” yields “Shorter Polymer + Monomer.” This is the way large macromolecules in food are digested into monomers small enough to enter our cells. For example: \( AB + HOH \rightarrow A-OH + H-B \).

5. Types of Biomolecules

**Carbohydrates**
- A carbohydrate is an organic compound that is composed of atoms of carbon, hydrogen and oxygen in a ratio of 1 carbon atom, 2 hydrogen atoms, and 1 oxygen atom.
- \( C_6H_{12}O_6 \), glucose, which is a monosaccharide, is the basic unit of all sugars and starches.
- The primary function of carbohydrates is for short-term energy storage. A secondary function is intermediate-term energy storage.
- Other carbohydrates are involved as structural components in cells, such as cellulose which is found in the cell walls of plants.
- Hooking two monosaccharides together forms more complex sugars called disaccharides (two sugars). Both monosaccharides and disaccharides are soluble in water.
- Polysaccharides are more complex carbohydrates that are formed by linking many shorter units together. Because of their size, these are often times not soluble in water. Many biologically important compounds such as starches and cellulose are Polysaccharides.

**Lipids**
- Each type of lipid has a slightly different structure, but they all possess a large number of \( C—H \) bonds which makes them a primarily non-polar group of molecules.
- There are three different functions for lipids in our bodies:
  - Energy storage
  - Forming the membranes around our cells.
  - Hormones and vitamins
- Lipids are made up of two basic units; an alcohol (usually glycerol) and fatty acids.
- Fatty acids are composed of a chain of methylene groups with a Carboxyl functional group at one end. The methyl chain is the fatty part, the Carboxyl, the acid.
- In triglycerides, a fatty acid is joined to each of the three carbons of glycerol by dehydration synthesis to form a molecule which stores a lot of calories in a small space. Triglycerides are energy-storage molecules.
- Phospholipids (P-lipids) serve an extremely important function in our bodies, they form the cell membrane. Phospholipids are very much like triglycerides but with one important difference. A phosphate functional group is substituted for one of the three fatty acids.
- The polar heads of the P-lipids turn toward the water molecules (Hydrophilic) while the non-polar tails hide from water molecules (Hydrophobic). When exposed to an aqueous (water) environment, phospholipids form unique assemblies called “bilayers.”
- The plasma or cell membrane is formed from a phospholipid bilayer. This structure is an important barrier and defines the boundaries of living and non-living portions of a cell.

continued
Proteins
- All proteins contain carbon, hydrogen, oxygen and nitrogen. Amino acids form the building blocks of a protein molecule.
- An amino acid is composed of a central asymmetrical carbon singly bonded to a hydrogen atom, a carboxyl group, an amino group, and a variable side chain that gives amino acids their unique properties.
- There are twenty different amino acids, each with a different side group.
- The carboxyl and amino groups of adjacent amino acids link together in a peptide bond, forming long polymers.
- Proteins function as enzymes or as structural units in cells. They do most of the work in the cells.
- The structure of a protein determines its function, and the order of amino acids determines the protein’s structure.
- **Primary Structure** is the sequence of amino acids in a protein.
- **Secondary structure** describes how the primary is folded into particular, localized configurations, the alpha helix and beta pleated sheets, which result from hydrogen bonding between peptide linkages.
- **Tertiary structure** describes the additional, less regular contortions of the molecule caused by the involvement of side groups in hydrophobic interactions, hydrogen bonds, ionic bonds, and covalent bonds called disulfide bridges.
- When a protein is subjected to very high temperature or extremes of pH, the well ordered tertiary structure is destroyed. When a protein loses its structural organization, it is said to be **denatured**. Most denatured proteins lose their function, and their properties can also change, they sometimes become insoluble or change their color.

Nucleic Acids
- Nucleic acids are polymers consisting of nucleotides, complex monomers consisting of a pentose (five-carbon sugar) covalently bonded to a phosphate group and to one of five different kinds of nitrogenous bases.
- The two kinds of nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are named on the basis of their characteristic pentoses: deoxyribose in DNA, and ribose in RNA.
- The five nitrogenous bases are members of two families, the **purines** and the **pyrimidines**, distinctive ring skeletons of carbon and nitrogen with various attached groups.
- The pyrimidines consist of cytosine (C) thymine (T) and uracil (U). The purines consist of adenine (A) and guanine (G).
- RNA is a single-stranded nucleotide polymer containing the bases A, G, C, and U.
- DNA is a helical, double-stranded polymer with bases A, G, C, and T projecting into the interior of the molecule. Since A always hydrogen bonds to T, and C to G, the nucleotide sequence of the two strands is complementary, and one strand can serve as a template for the formation of the other.
- The property of complementary strands gives DNA its unique ability to replicate itself and provides a mechanism for the continuity of life.
- Once replicated specific nucleotide segments of the DNA (genes) program the manufacture of an organism’s characteristic proteins. RNA functions in protein synthesis.

6. Enzymes and Biomolecules
Enzymes are reusable and are not consumed in a reaction. They act as organic catalysts for the thousands of biochemical reactions in our bodies. Living cells neither synthesize nor break down more material than is required for normal metabolism and growth. All of this necessitates precise control mechanisms for turning metabolic reactions on and off.
- Most biological enzymes are proteins. Some may have non-protein parts known as coenzymes. Vitamins frequently function as coenzymes.
- Enzymes have a definite three-dimensional
shape which is complementary to the material that the enzyme acts on, the *substrate*. A change in the shape of the enzyme can also prevent it from catalyzing reactions.

- The first step in any enzyme-catalyzed reaction is the formation of an enzyme-substrate complex.
- The substrate attaches to the region of the enzyme known as *active site*, where a reaction takes place, resulting in the formation of products.
- The enzyme is then free to react again with any available substrate.
- Three important characteristics of enzymes are important to the chemistry of cells:
  - Enzymes are deactivated by heat.
  - The action of enzymes can be blocked by certain compounds.
  - Enzymes are specific in their activity.
- Digestion of food is a disassembly process in which complex biopolymers are degraded to their simple monomer building blocks by *hydrolytic* (bond-breaking) *enzymes*.
- Genetic makeup can be analyzed using a technique called restriction mapping. In this process, strands of genetic material are first attacked by enzymes that cleave the DNA at specific sites. Restriction enzymes can be isolated and used in the laboratory to manipulate fragments of DNA. This makes them indispensable tools of recombinant DNA technology, or genetic engineering.
- Enzymes may be classified into 6 general groups.
  2. *Transferases* - catalyze group-transfer reactions.
  4. *Lyases* - catalyze addition groups to double bonds.
  5. *Isomerases* - catalyze isomerization reactions.
  6. *Ligases* - catalyze condensation of two molecules (coupled with cleavage of ATP, GTP etc.).
5. Cell Structure

Key Descriptors:

- The teacher knows the differences between viruses, prokaryotic and eukaryotic cells.
- The teacher understands and explains the structure and function of prokaryotic and eukaryotic cells.

Key Words:

- Virus
- Prokaryote
- Eukaryote
- Cell Membrane
- Cell Wall
- Cytoplasm
- Endoplasmic Reticulum
- Ribosomes
- Golgi Apparatus
- Mitochondria
- Nucleus
- Lysosomes
- Centrioles
- Centrosome
- Chloroplasts

NOTE: Refer to the bullet points under each Competency in the ETS/SBEC study guide. Analyze each bullet point, and synthesize it down to a paraphrase that is meaningful to you, using no more than 5 words. List those phrases in order on the lines above. It may help to number the bullet points and the lines above. When complete, record them again on Worksheet 4 in Appendix I.
5. Cell Structure

Competency 5:
The teacher understands that cells are the basic structures of living things and have specialized parts that perform specific functions.

1. Viruses, Prokaryotes and Eukaryotes
   
   **Viruses**
   - Viruses are not living since they cannot self-replicate.
   - They consist of just a protein coat for protection and a nucleic acid (RNA or DNA) for information how to make more copies of the same virus.
   - They are intracellular parasites, since they use cell machinery of a host cell to replicate and produce more viruses.
   
   **Prokaryotes**
   - Organisms whose cells lack a nucleus and other membrane-bound organelles are called prokaryotes. Examples include blue green algae and bacteria.
   - Prokaryotic cells lack mitochondria, an endoplasmic reticulum, Golgi bodies and lysosomes (lack membrane bound organelles).
   - The genetic material of a prokaryote cell consists of a large DNA molecule compacted in an area of cytoplasm called the nucleoid region.
   - Prokaryotes are asexual; the cell essentially replicates itself according to its own DNA and then divides itself from the newly created cell.
   - They are usually unicellular.
   - They have little to no internal compartmentalization.
   - Size range - 0.1 to 10µm diameter.
   
   **Eukaryotes**
   - Organisms whose cells contain a nucleus and other membrane-bound organelles are called eukaryotes. The cells are highly structured and tend to be larger than the cells of bacteria. Examples of eukaryotes are protozoa, higher plant and animal cells.
   - Eukaryotic cells generally have three main components: a cell membrane, a nucleus, and other organelles.
   - Genes in chromosomes contain more DNA than prokaryotes.
   - The presence of organelles indicates significant internal compartmentalization of function.
   - There are flexible cell walls.
   - Presence of cytoskeleton, which provides a framework to be larger.
   - They reproduce sexually.
   - Usually larger - cell volume 10X > than bacteria - size 5.0 to 20 µm diameter.
   - Extensive internal membranes.

2. Cell Structure - Prokaryotes and Eukaryotes
   
   **Cell membrane**
   - Also called the plasma membrane, it is a complex barrier of lipid molecules separating the cell from its external environment and encloses its contents.
   - These molecules can move apart to allow larger particles to move in or out of the cell. In other words, it is selectively permeable.
   - In prokaryotes and plants, the plasma membrane is the inner layer of protection, surrounded by a rigid cell wall which forms the outside boundary for the cell.
   - Eukaryotic animal cells have only the membrane to contain and protect their contents.

   **Cell wall**
   - It is found on the outside of some cells, bacteria and plants, and its main function is support and protection.
   - There are pores in the cell wall allowing substances to come in contact with the cell membrane.

   **Cytoplasm**
   - Cytoplasm comprises all of the living material of the cell outside the nucleus.

   continued
• It is packed with all the organelles and is structured and supported by a system of microtubules and microfilaments.

**Endoplasmic Reticulum**
- The endoplasmic reticulum is a network of sacs that manufactures, processes, and transports chemical compounds for use inside and outside of the cell.
- It is connected to the double-layered nuclear envelope, providing a connection between the nucleus and the cytoplasm.
- Rough endoplasmic reticulum is covered with ribosomes and is common in cells that export proteins and directs the flow of proteins.
- Smooth endoplasmic reticulum has few or no ribosomes and functions as a pathway for molecules.

**Ribosomes**
- All living cells contain ribosomes, tiny organelles composed of approximately 60 percent RNA and 40 percent protein.
- In eukaryotes, ribosomes are made of four strands of RNA.
- In prokaryotes, they consist of three strands of RNA.
- They are the protein production sites for the cell. Some of the proteins are synthesized for the cell's own use, particularly in single-celled organisms. In multicellular organisms, many of the proteins produced by a specialized cell are transported and used elsewhere in the organism.

**Golgi Body or Golgi Apparatus**
- It is a series of five to eight cup-shaped, membrane-covered sacs that look something like a stack of deflated balloons.
- It temporarily stores and transports materials synthesized in the cell to other parts of the body.
- Once the Golgi apparatus has enclosed the final product in a vesicle, the product is sent out through the cell membrane.

**Mitochondria**
- Large organelles scattered through most cells, they are most numerous in cells that use a lot of energy like liver and muscle cells.
- Mitochondria are the power generators of the cell, converting oxygen and nutrients into \( \text{ATP} \), which powers the cell in the process of aerobic respiration.
- They are the respiration centers of a cell.

**Nucleus**
The nucleus is a highly specialized organelle that serves as the information and administrative center of the cell.
- It has two major functions.
  - It stores the cell's hereditary material, or DNA.
  - It coordinates the cell's activities, which include metabolism, growth, protein synthesis, and reproduction.
- It is the cell's most prominent feature, and the spherical nucleus occupies about 10 percent of a cell's volume.
- Most of the nuclear material consists of chromatin (unstructured DNA) that organizes to form chromosomes during cell division.
- The nucleolus is also found inside the nucleus; it synthesizes protein producing ribosomes.

**Lysosomes**
- They are the digestive centers of a cell.
- They break down cellular waste products and debris from outside the cell into simple compounds, which are transferred to the cytoplasm as new cell-building materials.

**Centrioles**
- These are paired structures found inside the centrosome, lying just outside the nucleus of nearly all animal cells. The centrosome is an area where the microtubules are produced.

**Chloroplast**
- It is composed of a double layer of modified membrane (protein, chlorophyll, and lipid).
- Inner membrane forms layers called grana where chlorophyll is concentrated.
- It is the site of photosynthesis.
3. Differences in Cell Structure - Plant and Animal Cells
   - Plant cells have a cell wall, but animal cells do not. The cell wall is a non-living structure composed of cellulose. It forms a rigid boundary around the cell.
   - Plant cells have chloroplasts, but animal cells do not.
   - The centriole is unique to animal cells.
   - Plant cells generally have a more rectangular shape because the cell wall is more rigid.
   - Animal cells have a round or irregular shape because they do not have a cell wall.
   - Plant cells usually have one or more large vacuole(s), while animal cells have smaller vacuoles, if any are present. A vacuole is a space in the cytoplasm filled with water and dissolved substances. Cell sap in the vacuoles of some plants is responsible for the pigments that give color.

4. Specialized Cells
   The design and shape of a cell is dictated by its function and the conditions under which it works.
   - Cells of the nervous system carry information throughout the body. Consequently, they are very long and threadlike with branches that enable them to connect to other nerve cells.
   - Blood cells are shaped like round flattened disks. This shape gives them a maximum amount of surface area while still remaining smooth enough to slide through the smallest capillaries. Because red blood cells are manufactured for limited-time use, they have lost nearly all of their internal organelles, including nuclei.
   - Gland cells, like the cells found in the pancreas, are filled with Golgi apparatus.
   - Muscle cells, which must generate large amounts of force to move the body, have huge mitochondria and many microfibers. They are elongated and tapered at each end.
   - Skin cells are flat and thin, brick-shaped or honeycomb. They fit closely together to form a continuous protective layer.
   - Bone cells form a thick, mineral matrix, since the basic function is to provide support.

Plants
   - Protective tissue called epidermis covers the surface of leaves and the living cells of roots and stems. Its cells are flattened with their top and bottom surfaces parallel.
   - The cells of parenchyma are large, thin-walled, and usually have a large central vacuole. They are usually stuffed with plastids. In areas not exposed to light, colorless plastids predominate and food storage is the main function like in the potato. Where light is present, for example, in leaves, chloroplasts predominate and photosynthesis is the main function.
   - Collenchyma cells have thick walls that are especially thick at their corners. These cells provide mechanical support for the plant, for example, in the stalks of leaves.
   - Sclerenchyma is found in stems and also in leaf veins. The walls of these cells are very thick and built up in a uniform layer around the entire margin of the cell.