Below are the key learning objectives we expect students to be able to do at the college preparatory high school level before they enter our introductory biology courses for biology majors (BIO 1500 and BIO 1510). The objectives are organized by the five main themes of biology, which have been adopted by the Michigan K12 system and by postsecondary biology educators nationally. The five themes of biology are

Core Concepts
1. Pathways and transformation of energy and matter
2. Information flow, exchange and storage
3. Evolution
4. Structure and function
5. Complex systems

For any learning objective that you need to review, please refer to a high school or college introductory biology textbook for reference. It will be most efficient if you become familiar with the table of contents and index of the book you are using before you start studying.

1. **Information flow, exchange and storage.** Learning objectives are arranged in five clusters – transcription and translation, replication and mutation, regulation of gene expression, cell cycles, and inheritance. Students should be able to

**Transcription and Translation**
- Describe how genetic information is stored and used by living organisms.
- Describe how the genetic code in DNA determines the sequence of amino acids in proteins, and use a codon table to predict sequences of peptides from mRNA.
- Draw, label and explain the basic mechanism of transcription, and describe why it is important.
- Draw, label and explain the basic mechanism of translation, and describe why it is important. Include the role of tRNA, rRNA, tRNA synthetases and peptidyl transferase
- Compare how mRNA and proteins are processed depending on whether they are in a prokaryote or eukaryote; and, for eukaryotes, by whether they will end up in the cytosol, plasma membrane or secreted from the cell.

**Replication and Mutation**
- Draw, label and explain how DNA is replicated in a cell, and describe why DNA replication is important.
- Name, describe and solve problems related to what happens to the amino acid sequence when there is a nucleotide substitution that is a point mutation, a point mutation that is a deletion or a point mutation that is an addition.
• Predict and describe what happens to amino acid sequences what a frameshift mutation is, and when you do and when you do not get a frameshift mutation.

Regulation of Gene Expression
• Describe how DNA binding proteins bind to the DNA, and give examples of DNA-binding proteins and where they bind.
• Draw, label and explain how gene expression is regulated, comparing eukaryotes to prokaryotes.
• Draw, label and explain how the lac operon works and why it is important to bacteria.
• Describe how the DNA, mRNA and proteins present make one cell different from another in a multicellular organism.
• Predict the amount of mRNA if you know the amount of protein, and vice versa. Be able to explain the relationship between variations the amount of mRNA, protein and copies of a gene.

Cell Cycles
• Compare the purpose, mechanisms, and regulation of binary fission, mitosis, and meiosis.
• Describe the stages of the mitotic cell cycle including the major checkpoints. Draw, label and explain what is happening to the chromosomes, cytoskeleton and membranes at each stage of interphase and mitosis.
• Compare asexual and sexual reproduction, including their relative advantages and disadvantages.
• Describe how sexual reproduction leads to new combinations of alleles in offspring, and where new alleles come from.
• Draw, label and explain the structure and function of the phases and events of meiosis, including the chromosomes, membranes and cytoskeleton.

Inheritance
• Draw, label and explain the human life cycle and a plant life cycle.
• Describe how autosomal and sex-linked traits are inherited.
• Describe how a Mendelian monohybrid cross works. Describe how genotype relates to phenotype.
• Predict the genotype and phenotype ratios in the F1 and F2 generations of a Mendelian monohybrid cross. Explain the ratios using the concepts of meiosis, fertilization, mitosis and regulation of gene expression.
• Describe non-Mendelian inheritance. Compare Mendelian to non-Mendelian inheritance.
2. **Pathways and transformation of energy and matter.** Learning objectives are arranged in three clusters by scale – chemistry, cellular biology and ecosystems. **Students should be able to**

**Chemistry**
- Describe diffusion and osmosis.
- Describe kinetic and potential energy and give examples.
- Compare exergonic and endergonic (or exothermic and endothermic) reactions, and recognize the difference on graphs of the energies of the reactants and products of a reaction.
- Describe how reactions are coupled and why it is important.
- Describe redox (reduction oxidation) reactions.
- Describe enzymes, how they work, their effect on activation energies, and why they are important for biological organisms.
- Describe what a polymer is and how polymers are made and degraded, including nucleic acids, carbohydrates, lipids and proteins.

**Cellular Biology**
- Describe when, where and why glucose and ATP are each important.
- Describe cellular respiration and why it is important, including naming and describing the four major phases (glycolysis, pyruvate oxidation (or grooming), the Krebs cycle (or citric acid cycle) and oxidative phosphorylation), and where they occur. The MAJOR elements of each phase should be described, but it is NOT necessary to know the names and roles of every enzyme and intermediate.
- Compare the metabolism of a molecule of glucose by aerobic cellular respiration to the cellular metabolism of fatty acids and amino acids.
- Describe what fermentation is and why it is important.
- Describe photosynthesis and why it is important, including naming and describing the two major phases of photosynthesis (light-dependent reactions and the Calvin cycle or light-independent reactions), and where they occur. The MAJOR elements of each phase should be described, but it is NOT necessary to know the names and roles of every enzyme and intermediate.

**Ecosystems**
- Describe ecosystems and the roles of chemical cycling, energy flow and the organisms in ecosystems.
- Describe how energy flows through the trophic levels of food webs.
- Draw, label and explain a model of carbon cycling at the ecosystem scale as an example of chemical cycling. Explain how changes to these cycles by humans affect ecosystems, and how changes in the ecosystems affect humans.
3. **Evolution.** Learning objectives are arranged in three clusters – natural selection, macroevolution, and evolution of biodiversity. Students should be able to

**Natural Selection**
- Compare artificial selection and natural selection.
- Describe the history of how humans have changed allele frequencies of other species to meet our own needs.
- Describe and apply Darwin’s theory of natural selection and how it provides a mechanism for evolution.
- Describe and calculate allele frequency and phenotype frequency of a population and how these frequencies change when there is genetic drift, gene flow or selection.
- Describe biological fitness and how it is related to natural selection.

**Macroevolution**
- Describe how reproductive isolation and hybrid zones are changing populations and species over time.
- Describe the evidence for macroevolution from a single common ancestor, and how it explains the current diversity of organisms on Earth.
- Draw, label and explain the major differences between prokaryotes and eukaryotes.
- Explain why people have different genotypes and phenotypes from each other.

**Evolution of Biodiversity**
- Describe the eight basic taxa of classification of living organisms, from most inclusive to least inclusive and give an example of the types of organisms found in each eukaryotic domain.
- Describe plant adaptations to life on land, and compare nonvascular plants to vascular seedless and seed plants.
- Describe general characteristics that distinguish animals from other organisms.
- Describe key transitions in animal evolution: tissues, symmetry, body cavity, development, and segmentation.
4. **Structure and function** of biological elements are related. Learning objectives are arranged in three clusters by biological scale – cellular and molecular, organismal, and population and organismal. Students should be able to

**Cellular and Molecular Level**
- Be able to draw, label and explain polar covalent bonds and hydrogen bonds and describe why these bonds are important for the properties of water and other molecules in biological systems.
- Draw label and explain how the structure of the four major macromolecules (nucleic acids, proteins, carbohydrates and lipids), membranes, enzymes, and cytoskeleton proteins relates to their function.
- Draw, label and explain the structures, relationships and functions of a nucleotide, gene, molecule of DNA, chromosome, a pair of homologous chromosomes, pair of sister chromatids and karyotype.
- Describe and predict the relationship among the sequence of amino acids, the location of a protein, the shape of a protein and the function of a protein.
- Draw, label and explain the structures and functions of the organelles of cells.

**Organismal Level**
- Describe what a tissue is.
- Describe how the structures of tissues and the major organs determine their functions.
- Describe and apply the relationship of surface area and exchange of molecules or heat across the surface.

**Population and Ecosystem Level**
- Describe how natural selection has favored structures that improve the function in a specific environment.
5. Biology is a set of complex systems at many scales. Learning objectives are arranged in three clusters by biological scale – cellular and molecular, organismal, and population and organismal. Students should be able to

**Cellular and Molecular Level**
- Describe how DNA replication, transcription and translation are a complex molecular system that determines the function of a cell.
- Describe how cellular respiration and photosynthesis are complex molecular systems that affect the function of cells.
- Describe and compare how a single-celled organism and a cell within a multicellular organism respond to their environments.
- Describe how multicellular organisms receive information about their environment and respond to it.

**Organismal Level**
- Describe homeostasis and how it is maintained by the endocrine, renal and nervous systems.
- Describe and compare generally how the organ systems work together to allow humans and other animals to move. Include the musculoskeletal system, nervous system, respiratory system, cardiovascular system, and digestive system.
- Draw, label and explain the structures and functions of the parts of the female and male human reproductive systems. Describe the human life cycle, including fertilization, pregnancy and childbirth.
- Describe the importance and major structures and functions of the parts of the immune system, including antibodies. Describe how vaccines (immunizations) work.

**Population and Ecosystem Level**
- Compare species, populations, communities, ecosystems and the biosphere.
- Describe the complex system of a food web in terms of chemical cycling and energy flow. Describe how humans’ changes to chemical cycles affect ecosystems, and how changes in the ecosystems affect humans.
- Describe how ecosystems change over time, and the effect of availability of biotic and abiotic resources on these dynamic changes.
- Describe how biodiversity impacts ecosystems.

6. A biology education requires skills as well as understanding concepts. Some of the necessary skills are encompasses in the previous objectives. They include the use of quantitative reasoning, communication across disciplines, modeling, understanding that biology is an interdisciplinary field of study, and understanding the relationship between science and society. In addition to the skills in the previous learning objectives, students should be able to
- Describe and apply the process of scientific inquiry.