**Big Idea 1:** Synthetic biology is based on Engineering.

**Essential Question:** How does synthetic biology use engineering principles to create genetic systems that improve human lives?

**Enduring Understandings:**

1. Synthetic Biologists create genetic systems and alter cells to improve life and solve problems.
2. Synthetic Biologists apply engineering design principles in the design of their genetic systems.
3. Synthetic Biologists apply engineering principles such as abstraction, standardization, modularity, and modeling to the creation of genetic systems.

**Big Idea 2:** Synthetic biology is based on Biology.

**Essential Questions:** How does synthetic biology use biological principles to improve human lives? How does synthetic biology expand our understanding of biology?

**Enduring Understandings:**

1. Synthetic biology uses and expands on our understanding of molecular genetics.
2. Synthetic biology uses and expands on our understanding of cellular and molecular interactions.
3. Synthetic biology uses and expands on our understanding of evolution.

**Big Idea 3:** Synthetic biology research and implementation has societal implications.

**Essential Questions:** How do synthetic biologists balance risks with rewards in their research?

**Enduring Understandings:**

1. Synthetic Biologists must consider risk as well as reward offered by their designs.
2. Synthetic Biologists must use existing biosafety precautions as well as create new methods to maintain safety.
3. People will have to consider the extent to which they will use novel genetic systems and genetically modified organisms.

**Essential Knowledge:**

By the conclusion of this curriculum, the student will be able to:

* Explain how synthetic biology as an engineering discipline differs from genetic engineering.
* Explain the population growth curve of bacteria.
* Explain an abstraction hierarchy and apply it to the engineering of biology.
* Define and properly use synthetic biology terms: *part, device, inverter, measurement.*
* Define and properly use molecular genetics terms: *promoter, ribosome binding site ("RBS"), open reading frame ("ORF"),terminator, plasmid.*
* Explain the engineering paradigm and the role of tuning a system.
* Explain the functioning of the lac operon and how it can be used as a measurement tool.
* Define and properly use synthetic biology terms: *system, gain, tuning*.
* Define and properly use molecular genetics terms: *two component system, transcriptional activation, phosphorylation.*
* Relate the bacterial photography system to the two component signaling system.
* Explain the role that modeling can play in design, and name some ways that models differ from reality.
* Define and properly use synthetic biology terms: *chassis, system, device, minimal cell, sensor, color generator.*
* Define and properly use molecular genetics terms: *operon, gene expression, bacterial transformation.*
* Explain the role of chassis in synthetic biology and engineering.
* Discuss the risks associated with synthetic biology research and implementation.

**Essential Skills:**

By the conclusion of this curriculum, the student will be able to:

* Culture bacteria using proper microbiology methods.
* Measure the growth of a bacterial population.
* Measure a kinetic chemical reaction.
* Model a biological system using electronic parts and a computer program.
* Conduct and interpret the results of a bacterial transformation.
* Detail a project at the level of system(s), devices and parts.

**Big Idea 1:** The process of evolution drives the diversity and unity of life.

**Enduring understanding 1.A:** Change in the genetic makeup of a population over time is evolution.

* Essential knowledge 1.A.4: Biological evolution is supported by scientific evidence from many disciplines, including mathematics.
	+ Learning objective 1.9 The student is able to evaluate evidence provided by data from many scientific disciplines that support biological evolution. [See SP 5.3; Essential knowledge 1.A.4]
	+ Learning objective 1.10 The student is able to refine evidence based on data from many scientific disciplines that support biological evolution. [See SP 5.2; Essential knowledge 1.A.4]
	+ Learning objective 1.12 The student is able to connect scientific evidence from many scientific disciplines to support the modern concept of evolution. [See SP 7.1; Essential knowledge 1.A.4]
	+ Learning objective 1.13 The student is able to construct and/or justify mathematical models, diagrams or simulations that represent processes of biological evolution. [See SP 1.1, 2.1; Essential knowledge 1.A.4]

**Enduring understanding 1.B:** Organisms are linked by lines of descent from common ancestry.

* Essential knowledge 1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.
	+ Learning objective 1.14 The student is able to pose scientific questions that correctly identify essential properties of shared, core life processes that provide insights into the history of life on Earth. [See SP3.1; Essential knowledge 1.B.1]
	+ Learning objective 1.15 The student is able to describe specific examples of conserved core biological processes and features shared by all domains or within one domain of life, and how these shared, conserved core processes and features support the concept of common ancestry for all organisms. [See SP 7.2; Essential knowledge 1.B.1]
	+ Learning objective 1.16 The student is able to justify the scientific claim that organisms share many conserved core processes and features that evolved and are widely distributed among organisms today. [See SP 6.1; Essential knowledge 1.B.1]

**Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce, and to maintain dynamic homeostasis.**

**Enduring understanding 2.B:** Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments.

* Essential knowledge 2.B.3: Eukaryotic cells maintain internal membranes that partition the cell into specialized regions.
	+ Learning objective 2.14 The student is able to use representations and models to describe differences in prokaryotic and eukaryotic cells. [See SP 1.4; Essential knowledge 2.B.3]
* Essential knowledge 2.C.1: Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes.
	+ Learning objective 2.15 The student can justify a claim made about the effect(s) on a biological system at the molecular, physiological or organismal level when given a scenario in which one or more components within a negative regulatory system is altered. [See SP 6.1; Essential knowledge 2.C.1]
	+ Learning objective 2.16 The student is able to connect how organisms use negative feedback to maintain their internal environments. [See SP 7.2; Essential knowledge 2.C.1]
	+ Learning objective 2.17 The student is able to evaluate data that show the effect(s) of changes in concentrations of key molecules on negative feedback mechanisms. [See SP 5.3; Essential knowledge 2.C.1]
	+ Learning objective 2.18 The student can make predictions about how organisms use negative feedback mechanisms to maintain their internal environments. [See SP 6.4; Essential knowledge 2.C.1]
	+ Learning objective 2.19 The student is able to make predictions about how positive feedback mechanisms amplify activities and processes in organisms based on scientific theories and models. [See SP 6.4; Essential knowledge 2.C.1]
	+ Learning objective 2.20 The student is able to justify that positive feedback mechanisms amplify responses in organisms. [See SP 6.1; Essential knowledge 2.C.1]
* Essential knowledge 2.C.2: Organisms respond to changes in their external environments.
	+ Learning objective 2.21 The student is able to justify the selection of the kind of data needed to answer scientific questions about the relevant mechanism that organisms use to respond to changes in their external environment. [See SP 4.1; Essential knowledge 2.C.2]

**Enduring understanding 2.E:** Many biological processes involved in growth, reproduction and dynamic homeostasis include temporal regulation and coordination.

* Essential knowledge 2.E.2: Timing and coordination of physiological events are regulated by multiple mechanisms.
	+ Learning objective 2.35 The student is able to design a plan for collecting data to support the scientific claim that the timing and coordination of physiological events involve regulation. [See SP 4.2; Essential knowledge 2.E.2]
	+ Learning objective 2.36 The student is able to justify scientific claims with evidence to show how timing and coordination of physiological events involve regulation. [See SP 6.1; Essential knowledge 2.E.2]
	+ Learning objective 2.37 The student is able to connect concepts that describe mechanisms that regulate the timing and coordination of physiological events. [See SP 7.2; Essential knowledge 2.E.2]
* Essential knowledge 2.E.3: Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection.
	+ Learning objective 2.39 The student is able to justify scientific claims, using evidence, to describe how timing and coordination of behavioral events in organisms are regulated by several mechanisms. [See SP 6.1; Essential knowledge 2.E.3]
	+ Learning objective 2.40 The student is able to connect concepts in and across domain(s) to predict how environmental factors affect responses to information and change behavior. [See SP 7.2; Essential knowledge 2.E.3]

**Big Idea 3: Living systems store, retrieve, transmit, and respond to information essential to life processes.**

**Enduring understanding 3.A:** Heritable information provides for continuity of life.

* Essential knowledge 3.A.1: DNA, and in some cases RNA, is the primary source of heritable information.
	+ Learning objective 3.1 The student is able to construct scientific explanations that use the structures and mechanisms of DNA and RNA to support the claim that DNA and, in some cases, that RNA are the primary sources of heritable information. [See SP 6.5; Essential knowledge 3.A.1]
	+ Learning objective 3.2 The student is able to justify the selection of data from historical investigations that support the claim that DNA is the source of heritable information. [See SP 4.1; Essential knowledge 3.A.1]
	+ Learning objective 3.3 The student is able to describe representations and models that illustrate how genetic information is copied for transmission between generations. [See SP 1.2; Essential knowledge 3.A.1]
	+ Learning objective 3.4 The student is able to describe representations and models illustrating how genetic information is translated into polypeptides. [See SP 1.2; Essential knowledge 3.A.1]
	+ Learning objective 3.5 The student can justify the claim that humans can manipulate heritable information by identifying at least two commonly used technologies. [See SP 6.4; Essential knowledge 3.A.1]
	+ Learning objective 3.6 The student can predict how a change in a specific DNA or RNA sequence can result in changes in gene expression. [See SP 6.4; Essential knowledge 3.A.1]
* Essential knowledge 3.A.3: The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring.
	+ Learning objective 3.13 The student is able to pose questions about ethical, social or medical issues surrounding human genetic disorders. [See SP 3.1; Essential knowledge 3.A.3]

**Enduring understanding 3.B:** Expression of genetic information involves cellular and molecular mechanisms.

* Essential knowledge 3.B.1: Gene regulation results in differential gene expression, leading to cell specialization.
	+ Learning objective 3.18 The student is able to describe the connection between the regulation of gene expression and observed differences between different kinds of organisms. [See **S**P 7.1; Essential knowledge 3.B.1]
	+ Learning objective 3.19 The student is able to describe the connection between the regulation of gene expression and observed differences between individuals in a population. [See SP 7.1; Essential knowledge 3.B.1]
	+ Learning objective 3.20 The student is able to explain how the regulation of gene expression is essential for the processes and structures that support efficient cell function. [See SP 6.2; Essential knowledge 3.B.1]
	+ Learning objective 3.21 The student can use representations to describe how gene regulation influences cell products and function. [See SP 1.4; Essential knowledge 3.B.1]
* Essential knowledge 3.B.2: A variety of intercellular and intracellular signal transmissions mediate gene expression.
	+ Learning objective 3.22 The student is able to explain how signal pathways mediate gene expression, including how this process can affect protein production. [See SP 6.2; Essential knowledge 3.B.2]
	+ Learning objective 3.23 The student can use representations to describe mechanisms of the regulation of gene expression. [See SP 1.4; Essential knowledge 3.B.2]
* Essential knowledge 3.C.1: Changes in genotype can result in changes in phenotype.
	+ Learning objective 3.24 The student is able to predict how a change in genotype, when expressed as a phenotype, provides a variation that can be subject to natural selection. [See SP 6.4, 7.2; Essential knowledge 3.C.1]
	+ Learning objective 3.25 The student can create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. [See SP 1.1; Essential knowledge 3.C.1]
	+ Learning objective 3.26 The student is able to explain the connection between genetic variations in organisms and phenotypic variations in populations. [See SP 7.2; Essential knowledge 3.C.1]
* Essential knowledge 3.C.2: Biological systems have multiple processes that increase genetic variation.
	+ Learning objective 3.27 The student is able to compare and contrast processes by which genetic variation is produced and maintained in organisms from multiple domains. [See SP 7.2; Essential knowledge 3.C.2]

**Enduring understanding 3.D:** Cells communicate by generating, transmitting and receiving chemical signals.

* Essential knowledge 3.D.1: Cell communication processes share common features that reflect a shared evolutionary history.
	+ Learning objective 3.31 The student is able to describe basic chemical processes for cell communication shared across evolutionary lines of descent. [See SP 7.2; Essential knowledge 3.D.1]
	+ Learning objective 3.32 The student is able to generate scientific questions involving cell communication as it relates to the process of evolution. [See SP 3.1; Essential knowledge 3.D.1]
	+ Learning objective 3.33 The student is able to use representation(s) and appropriate models to describe features of a cell signaling pathway. [See SP 1.4; Essential knowledge 3.D.1]
* Essential knowledge 3.D.2: Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling.
	+ Learning objective 3.34 The student is able to construct explanations of cell communication through cell-to-cell direct contact or through chemical signaling. [See SP 6.2; Essential knowledge 3.D.2]
	+ Learning objective 3.35 The student is able to create representation(s) that depict how cell-to-cell communication occurs by direct contact or from a distance through chemical signaling. [See SP 1.1; Essential knowledge 3.D.2]
* Essential knowledge 3.D.3: Signal transduction pathways link signal reception with cellular response.
	+ Learning objective 3.36 The student is able to describe a model that expresses the key elements of signal transduction pathways by which a signal is converted to a cellular response. [See SP 1.5; Essential knowledge 3.D.3]
* Essential knowledge 3.D.4: Changes in signal transduction pathways can alter cellular response.
	+ Learning objective 3.37 The student is able to justify claims based on scientific evidence that changes in signal transduction pathways can alter cellular response. [See SP 6.1; Essential knowledge 3.D.4]
	+ Learning objective 3.38 The student is able to describe a model that expresses key elements to show how change in signal transduction can alter cellular response. [See SP 1.5; Essential knowledge 3.D.4]
	+ Learning objective 3.39 The student is able to construct an explanation of how certain drugs affect signal reception and, consequently, signal transduction pathways. [See SP 6.2; Essential knowledge 3.D.4]

**Enduring understanding 3.E:** Transmission of information results in changes within and between biological systems.

* Essential knowledge 3.E.1: Individuals can act on information and communicate it to others.
	+ Learning objective 3.40 The student is able to analyze data that indicate how organisms exchange information in response to internal changes and external cues, and which can change behavior. [See SP 5.1; Essential knowledge 3.E.1]
	+ Learning objective 3.41 The student is able to create a representation that describes how organisms exchange information in response to internal changes and external cues, and which can result in changes in behavior. [See SP 1.1; Essential knowledge 3.E.1]

**Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties.**

**Enduring understanding 4.A:** Interactions within biological systems lead to complex properties.

* Essential knowledge 4.A.1: The subcomponents of biological molecules and their sequence determine the properties of that molecule.
	+ Learning objective 4.1 The student is able to explain the connection between the sequence and the subcomponents of a biological polymer and its properties. [See SP 7.1; Essential knowledge 4.A.1]
	+ Learning objective 4.2 The student is able to refine representations and models to explain how the subcomponents of a biological polymer and their sequence determine the properties of that polymer. [See SP 1.3; Essential knowledge 4.A.1]
	+ Learning objective 4.3 The student is able to use models to predict and justify that changes in the subcomponents of a biological polymer affect the functionality of the molecule. [See SP 6.1, 6.4; Essential knowledge 4.A.1]
* Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.
	+ Learning objective 4.4 The student is able to make a prediction about the interactions of subcellular organelles. [See SP 6.4; Essential knowledge 4.A.2]
	+ Learning objective 4.5 The student is able to construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [See SP 6.2; Essential knowledge 4.A.2]
	+ Learning objective 4.6 The student is able to use representations and models to analyze situations qualitatively to describe how interactions of subcellular structures, which possess specialized functions, provide essential functions. [See SP 1.4; Essential knowledge 4.A.2]
* Essential knowledge 4.A.3: Interactions between external stimuli and regulated gene expression result in specialization of cells, tissues and organs.
	+ Learning objective 4.7 The student is able to refine representations to illustrate how interactions between external stimuli and gene expression result in specialization of cells, tissues and organs. [See SP 1.3; Essential knowledge 4.A.3]
* Essential knowledge 4.A.4: Organisms exhibit complex properties due to interactions between their constituent parts.
	+ Learning objective 4.8 The student is able to evaluate scientific questions concerning organisms that exhibit complex properties due to the interaction of their constituent parts. [See SP 3.3; Essential knowledge 4.A.4]
	+ Learning objective 4.9 The student is able to predict the effects of a change in a component(s) of a biological system on the functionality of an organism(s). [See SP 6.4; Essential knowledge 4.A.4]
	+ Learning objective 4.10 The student is able to refine representations and models to illustrate biocomplexity due to interactions of the constituent parts.[See SP 1.3; Essential knowledge 4.A.4]
* Essential knowledge 4.A.5: Communities are composed of populations of organisms that interact in complex ways.
* Learning objective 4.11 The student is able to justify the selection of the kind of data needed to answer scientific questions about the interaction of populations within communities. [See SP 1.4, 4.1; Essential knowledge 4.A.5]

**Enduring understanding 4.B:** Competition and cooperation are important aspects of biological systems.

* Essential knowledge 4.B.1: Interactions between molecules affect their structure and function.
	+ Learning objective 4.17 The student is able to analyze data to identify how molecular interactions affect structure and function. [See SP 5.1; Essential knowledge 4.B.1]

**Science properties:**

1.1 The student can create representations and models of natural or man-made phenomena and systems in the domain.

1.2 The student can describe representations and models of natural or man-made phenomena and systems in the domain.

1.3 The student can refine representations and models of natural or man-made phenomena and systems in the domain.

1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.

1.5 The student can re-express key elements of natural phenomena across multiple representations in the domain.

2.1 The student can justify the selection of a mathematical routine to solve problems.

2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

2.3 The student can estimate numerically quantities that describe natural phenomena.

3.1 The student can pose scientific questions.

3.2 The student can refine scientific questions.

3.3 The student can evaluate scientific questions.

4.1 The student can justify the selection of the kind of data needed to answer a particular scientific question.

4.2 The student can design a plan for collecting data to answer a particular scientific question.

4.3 The student can collect data to answer a particular scientific question.

4.4 The student can evaluate sources of data to answer a particular scientific question.

5.1 The student can analyze data to identify patterns or relationships.

5.2 The student can refine observations and measurements based on data analysis.

5.3 The student can evaluate the evidence provided by data sets in relation to a particular scientific question.

6.1 The student can justify claims with evidence.

6.2 The student can construct explanations of phenomena based on evidence produced through scientific practices.

6.3 The student can articulate the reasons that scientific explanations and theories are refined or replaced.

6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

6.5 The student can evaluate alternative scientific explanations.

7.1 The student can connect phenomena and models across spatial and temporal scales.

7.2 The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.