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| **Phenomena** |
| The processes of cellular division, together with the influence of the environment, determine how heritable traits are passed from one generation of cells or organisms to the next during sexual and asexual reproduction. |

**ASSESSMENT ITEM SET: MEIOSIS, MITOSIS, AND REPRODUCTION**

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| **Performance Expectation** | **SEP** | **DCI** | **CCC** |
| **HS LS3-2**: Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. | **SEP 7 HS-5**: Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. | **LS3.B HS-1**: In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.  **LS3.B HS-2**: Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors. | **CCC 2 HS-1**: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |
| **HS LS1-4**: Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. | **SEP 2 HS-3**: Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. | **LS1.B HS-1**: In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. | **CCC 4 HS-3**: Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales |

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| **Stimulus #1** |
| **Sexual Reproduction and Inheritance in a Species of Rodent**  All species of rodent reproduce by way of a sexual process. In a species of rodent, fur color may be either black or white. The “A” allele for black fur is dominant to the “a” allele for white fur. A second gene determines eye color, which may be black or red. For eye color, the “B” allele for black eyes is dominant to the “b” allele for red eyes. The genes for fur and eye color are located on the same chromosome.  A researcher studying the inheritance of these characteristics obtains the following information about two rodents he will use in a breeding experiment:  Rodent #1 Genotype and Chromosome Maps  Rodent #1 Diploid Genotype: AaBb  Rodent #1 Chromosome Maps (only relevant chromosome pair shown)    Rodent #2 Genotype and Chromosome Maps  Rodent #2 Diploid Genotype: aabb  Rodent#2 Chromosome Maps (only relevant chromosome pair shown)    Additionally, the scientist analyzes the haploid gametes produced by the two rodents and determines the frequency each occurs. Their data is shown in the table below.   |  |  |  | | --- | --- | --- | |  | Frequency of Gamete Genotype, Rodent #1 | Frequency of Gamete Genotype, Rodent #1 | | AB | 0.49 | 0.00 | | Ab | 0.01 | 0.00 | | aB | 0.01 | 0.00 | | Ab | 0.49 | 1.00 | |
| **Stimulus #2** |
| **Asexual Reproduction of Strawberries (*Fragaria ananassa*) by Vegetative Propagation**  Strawberries, like many species of plant, can reproduce sexually or asexually. In strawberries, asexual reproduction is accomplished by the growth of structures called runners. At the growing end of a runner there is a structure called a node. Node cells can differentiate into different cell types to produce a clones of the parent plant, as shown in the diagram below.  strawberry-plant.jpg (336×252)  A model of the cell division and differentiation process that gives rise to new strawberry plants through the asexual reproduction of node cells is shown below. |
| **Stimulus #3** |
| **How is the gender of some reptiles determined by temperature?**  Adapted from Scientific American.  https://www.scientificamerican.com/article/experts-temperature-sex-determination-reptiles/  Sex-determining mechanisms in reptiles are broadly divided into two main categories: genotypic sex determination (GSD) and temperature-dependent sex determination (TSD).  Species in the genotypic group, like mammals and birds, have sex chromosomes, which in reptiles come in two major types. Many species—such as several species of turtle and lizards, like the green iguana—have X and Y sex chromosomes (again, like mammals), with females being "homogametic," that is, having two identical X chromosomes. Males, on the other hand, are "heterogametic," with one X chromosome and one Y chromosome. Other reptiles governed by GSD have a system, similar to one found in birds, with Z and W sex chromosomes. In this case—which governs all snake species—males are the homogametic sex (ZZ) and females are the heterogametic sex (ZW).  In temperature-dependent sex determination, however, it is the environmental temperature during a critical period of embryonic development that determines whether an egg develops as male or female. This thermosensitive period occurs after the egg has been laid, so sex determination in these reptiles is at the mercy of the ambient conditions affecting egg clutches in nests. For example, in many turtle species, eggs from cooler nests hatch as all males, and eggs from warmer nests hatch as all females. In crocodilian species—the most studied of which is the American alligator—*both* low and high temperatures result in females and intermediate temperatures select for males.    A widely held view is that temperature-dependent and genotypic sex determination are mutually exclusive, incompatible mechanisms—in other words, a reptile's sex is never under the influence of both sex chromosomes *and* environmental temperature. This model indicates that there is no genetic predisposition for the embryo of a temperature-sensitive reptile to develop as either male or female, so the early embryo does not have a "sex" until it enters the thermosensitive period of its development.  This paradigm, though, has been recently challenged, with new evidence now emerging that there may indeed be both sex chromosomes and temperature involved in the sex determination of some reptile species. Apparently, in animals where both occur, certain incubation temperatures can "reverse" the genotypic sex of an embryo. For example, there is an Australian skink lizard that is genotypically governed by X and Y sex chromosomes. A low incubation temperature during the development of this lizard's egg reverses some genotypic females (XX) into "phenotypic" males—so that they have only functioning male reproductive organs. Therefore, in this species, there are both XX and XY males, but females are always XX. A slightly different example of this temperature-induced sex reversal is found in an Australian dragon lizard, which has the ZW system of sex chromosomes. In this species, high incubation temperature during egg development reverses genotypic males (ZZ) into phenotypic females; so females can be ZZ or ZW, but males are always ZZ.  Reptiles in which both incubation temperature and sex chromosomes interact to determine sex may represent "transitional" evolutionary states between two end points: complete GSD and complete TSD. It is quite possible that there are other species of reptiles with more complicated scenarios of temperature reversal of chromosomal sex. There are certainly many known examples of fish and amphibians with GSD, in which both high and low incubation temperatures can cause sex reversal. In these cases, all genotypes (from ZZ and ZW to XX and XY) are susceptible to reversal by extremes of incubation temperature. |

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| **Items** | | | |
| **Item Description** | **DCI**  **Element** | **SEP**  **Element** | **CCC**  **Element** |
| 1. Why are gametes with the haploid genotypes AB and ab produced by rodent #1 more frequent than the genotypes Ab and aB?  A. Because gamete genotypes are determined by the random assortment of chromosomes during mitosis.  B. Because gamete genotypes are determined by the random assortment of chromosomes during meiosis.  C. Because the two genes are located on the same chromosome.  D. Because the two genes are located on different chromosomes.  E. Because the genotypes Ab and aB have lethal mutations. | **LS3.B HS-1** | SEP 2 HS-3 | CCC 4 HS-3 |
| 2. What cell process is represented by two arrows leading from one diploid (2n) cell to two different diploid (2n) cells? in the model of strawberry reproduction?  A. meiosis B. mitosis C. crossing-over D. fertilization E. pairing of homologous chromosomes | LS1.B HS-1 | **SEP 2 HS-3** | CCC 4 HS-3 |
| 3. What evidence is provided in the article “How is the gender of some reptiles determined by temperature?” that the “widely held view” of GSD and TSD being “mutually exclusive” is incorrect?  A. Some reptiles, such as snakes, use a system of Z and W chromosomes like the GSD system of birds.  B. In some species of fish and amphibians, differences in incubation temperature can cause sex reversal.  C. In birds and some species of reptile, females are heterogametic (ZW) and males are homogametic (ZZ), which is the opposite of the mammal system.  D. In the American Alligator, both high and low incubation temperatures produce female offspring, with males being produced only from moderate incubation temperatures.  E. Some reptile species, such as the Australian skink lizard, have been identified where incubation temperature can produce offspring with a sex phenotype different from their genotypic sex. | LS3.B HS-2 | **SEP 7 HS-5** | CCC 2 HS-1 |
| 4. Which of the following occur during the sexual reproductive process in rodents but **NOT** in the asexual reproductive process of strawberries? **SELECT ALL THAT APPLY**  A. meiosis B. mitosis C. recombination of alleles D. cell division E. binary fission | **LS3.B HS-1** | SEP 2 HS-3 | CCC 4 HS-3 |
| 5. If a new species of reptile is discovered, which of the following sets of data could be used to determine if the sex of offspring is genotype-dependent or temperature dependent for that species?  A. a data set showing the frequency of haploid genotypes produced by parents at different temperatures  B. a data set showing the sex genotype, sex phenotype, and incubation temperature of offspring  C. observations of the mating rituals and processes of the new species  D. observations and descriptions of parthenogenesis (asexual reproduction) in the new species  E. observations and descriptions of temperature dependent sex reversal in the new species | LS3.B HS-2 | SEP 7 HS-5 | **CCC 2 HS-1** |
| 6. **CR**. Is the reproductive process of reptile species with temperature-dependent sex determination more like the sexual reproductive process of rodents or the asexual reproductive process of strawberries? Identify similarities and differences about the types of cell division that occur during the three processes, and describe the genetic relationship between parent(s) and offspring in each case. | LS3.B HS-1 | **SEP 7 HS-5** | CCC 4 HS-3 |

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| **CR Rubric – 4 points** |
| Award 2 points for correctly identifying reptile reproduction as being more similar to rodent reproduction because it is a sexual process.  Award 1 point for identifying and distinguishing mitosis from meiosis as asexual cell division and a component of sexual reproduction, respectively.  Award 1 point for describing the offspring of asexual reproduction as being genetic duplicates (i.e. “clones,” “copies,” “identical,” etc.) of their parents and the offspring of sexual reproduction as being genetically unique from parents. |