**Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Block: \_\_\_\_\_\_\_\_\_\_\_\_**

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**Using Punnett Squares to Predict the Outcomes of Crosses**

**(March 17, 2014)**

The possible gene combinations in the offspring that result from a genetic cross can be determined by drawing a diagram known as a Punnett square. A Punnett square shows the genes (represented by letters) in the parents’ gametes along the top and the left hand side of a square and the possible gene combinations in the offspring, within the square.

 A completed Punnett square gives the probable outcome of a given cross. However, actual results may vary from the probably results, especially if only a few organisms are considered.

**Monohybrid Crosses (looking at only one trait at a time)**

Crosses that involve one trait, such as seed coat color, are called monohybrid crosses. For the one-factor crosses in this activity we will use some of the traits Mendel observed in pea plants. The expressions of the dominant and recessive alleles for the genes controlling these traits are described in the following chart. The chart also assigns letters to represent the different alleles.

|  |  |  |
| --- | --- | --- |
| **Trait** | **Dominant Allele** | **Recessive Allele** |
| **Pod Shape** | **Smooth (N)** | **Constricted (n)** |
| **Pod Color** | **Green (G)** | **Yellow (g)** |
| **Flower Position** | **Axial (A)** | **Terminal (a)** |
| **Plant Height** | **Tall (T)** | **Short (t)** |

In the example that follows, we will predict the results of a cross between a plant that is heterozygous for green pods and a plant that has yellow pods.

**Sample Problem:**

***A plant that is heterozygous for green pods is crossed with a plant that has yellow pods. What are the probable genotypic and phenotypic ratios in the offspring resulting from this cross?***

Step 1: Choose

**Step 1**: **Choose a letter to represent the alleles in the cross**. In this case, the letters have already been selected (**G** for the dominant green allele, and **g** for the recessive yellow allele).

**Step 2**: **Write the genotypes of the parents**. Since the plant with the green pods is heterozygous for the trait, its genotype must be **Gg**. The problem does not state whether the plant with yellow pods is homozygous or heterozygous. But we know the yellow pods are a recessive character, and that recessive characters are expressed only in a homozygous recessive individual. Thus the genotype of this plant must be **gg**. The cross, therefore is

**Gg** x **gg**.

**Step 3:** **Determine the possible gametes (sperm or eggs) that the parents can produce**.

The two alleles of any gene are segregated during the fraction of gametes. Thus the green-pod parent (**Gg**) will produce two kinds of gametes: **G** and **g**. The yellow-pod parent (**gg**) will produce only **g** gametes.

**Step 4:** **Enter the possible gametes at the top and side of the Punnett square**.

At this point, the Punnett square for this problem would look like this:

|  |  |  |
| --- | --- | --- |
|  | **G** | **g** |
| **g** |  |  |
| **g** |  |  |

**Step 5: Complete the Punnett Square by writing the alleles from the gametes in the appropriate boxes**. This step represents the process of the fertilization, in which a male gamete from one parent combines with a female gamete from the other parent. To predict all possible offspring genotypes, each type of possible gamete from one parent is combines with each possible type of gamete from the other parent. The completed Punnett square for this problem would look like this:

|  |  |  |
| --- | --- | --- |
|  | **G** | **g** |
| **g** | **Gg** | **gg** |
| **g** | **Gg** | **gg** |

As you can see, ½ of the offspring are genotype **Gg** and ½ are **gg**.

**Step 6:** **Determine the phenotypes of the offspring**. Since green (**G**) is dominant over yellow (**g**), plants that have **G** in their genotypes have green pods. Only plants with genotype gg have yellow pods. In this example, ½ of the offspring have green pods and ½ have yellow pods.

**Step 7:** **Answer the questions posed (most of the time it will refer to genotype and phenotype ratios**). In this example, the genotypic ratio is **2Gg**:**2gg** or reduced to **1Gg**:**1gg**. The phenotypic ratio is **2 green:2 yellow** or reduced to **1 green:1 yellow.**

**Practice Problems:**

 For each of the following problems, fill-in the Punnett square provided and answer

the questions on the indicated lines.

 **Phenotype Description**

**1.**

**Nn** x **NN**

|  |  |  |
| --- | --- | --- |
| **Pod Shape** | **Smooth (N)** | **Constricted (n)** |

**Genotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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| --- | --- | --- |
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 **Phenotype Description**

**2.**

**Aa** x **aa**

|  |  |  |
| --- | --- | --- |
| **Flower Position** | **Axial (A)** | **Terminal (a)** |

**Genotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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| --- | --- | --- |
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 **Phenotype Description**

**3.**

**Tt** x **tt**

|  |  |  |
| --- | --- | --- |
| **Plant Height** | **Tall (T)** | **Short (t)** |

**a. Genotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**b. Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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| --- | --- | --- |
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**4.**

**Cross two plants that are heterozygous for green pods.**

 **Phenotype Description**

|  |  |  |
| --- | --- | --- |
| **Pod Color** | **Green (G)** | **Yellow (g)** |

**a. Genotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**b. Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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**5.**

**Cross a plant that is heterozygous for axial flowers with a plant**

**that has terminal flowers.**

 **Phenotype Description**

|  |  |  |
| --- | --- | --- |
| **Flower Position** | **Axial (A)** | **Terminal (a)** |

**a. Genotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**b. Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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| --- | --- | --- |
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**When a tall plant is crossed with a short plant, some of the offspring are short. What are the genotypes of the parents and of the offspring? What is the phenotype ratio in the offspring?**

**6.**

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

 **Phenotype Description**

|  |  |  |
| --- | --- | --- |
| **Plant Height** | **Tall (T)** | **Short (t)** |

**a. Parent’s Genotypes: \_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

 **Parent#1 Parent #2**

**b. Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Dihybrid Crosses (Investigating two traits at the same time)**

Crosses that involve two traits, such as pod color and pod shape, are called dihybrid or two-factor crosses. Predicting the outcome of two-factor crosses requires basically the same procedure as that for crosses involving one trait. Keep in mind that in two-factor crosses the genes controlling the two different traits are located on nonhomologous chromosomes. During meiosis, nonhomologous chromosomes assort independently. In other words, the chromosomes of any pair of homologous chromosomes has an equal probability of ending up in a gamete with either chromosome from any other pair of homologous chromosomes. Because of independent assortment, a plant that is heterozygous for two traits (genotype **AaBb**) will produce equal numbers of four types of gametes: **AB**, **Ab**, **aB**, and **ab**. In the example that follows, we will predict the results of a cross between two plants that are heterozygous for both pod color and pod shape.

**Sample problem:**

***What are the genotype and phenotype ratios in the offspring resulting from a cross between two pea plants that are heterozygous for pod color and pod shape?***

**Step 1:** **Choose letters to represent the alleles in the cross**:

 **(**e.g. **G** for green, **g** for yellow, **N** for smooth, and **n** for constricted).

**Step 2:** **Write the genotypes of the parents**. Since the parents are heterozygous for both traits, their genotypes must both be **GgNn**. The cross then is written like this

**GgNn** x **GgNn.**

**Step 3:** **Determine the possible gametes that the parents can produce**. Use F.O.I.L. to determine the gametes (**F**irst, **O**uter, **I**nner, **L**ast).

**GgNn GN GgNn Gn**

**GgNn gN GgNn gn**

Thus, these parent’s genotypes has the ability to produce four different types of gametes for these two traits - **GN**, **Gn**, **gN**, and **gn**.

**Step 4:** **Enter the possible gametes**. Place the first parent’s on the top of the Punnett Square, and put the second parent’s on the left side.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **GN** | **Gn** | **gN** | **gn** |
| **GN** |  |  |  |  |
| **Gn** |  |  |  |  |
| **gN** |  |  |  |  |
| **gn** |  |  |  |  |

**Step 5:** **Complete the Punnett square by writing the alleles from the gametes in the appropriate boxes**. Combine the gamete alleles at the top, with the gamete alleles on the left side. Write the capital letter first for each pair of alleles. The letters inside each box represent the probable genotypes of the offspring resulting from the cross.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **GN** | **Gn** | **gN** | **gn** |
| **GN** | **GGNN** | **GGNn** | **GgNN** | **GgNn** |
| **Gn** | **GGNn** | **GGnn** | **GgNn** | **Ggnn** |
| **gN** | **GgNn** | **GgNn** | **ggNN** | **ggNn** |
| **gn** | **GgNn** | **Ggnn** | **ggNn** | **ggnn** |

**Step 6: Determine the phenotypes of the offspring.** In this example, 9 offspring have green/smooth pods, 3 have yellow/smooth pods, 3 have green/constricted pods, and 1 has yellow/constricted pods.

**Step 7: Answer the questions that are asked.** It is important to read genetics problems carefully and make sure you answer the questions it asks. Many times that will include genotype ratio and phenotype ratio (but not always!).

**Practice Problems (Use the following information to answer questions**

**7-11)**

 ***In mice, the ability to run normally is a dominant trait. Mice with this trait are called running mice (R). The recessive trait causes mice to run in circles only. Mice with this trait are called waltzing mice (r). Hair color is also inherited in mice. Black hair (B) is dominant over brown hair (b). For each of the following problems fill in the Punnett square provided and fill in the answers on the indicated lines.***

**Cross a heterozygous running, heterozygous black mouse with a**

**homozygous running, homozygous black mouse.**

**7.**

**a. Parent’s Genotypes: \_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

 **Parent#1 Parent #2**

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**b. Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Cross a homozygous running, homozygous black mouse with a heterozygous running, brown mouse.**

**8.**

**a. Parent’s Genotypes: \_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

 **Parent#1 Parent #2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
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**b. Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Cross a waltzing brown mouse with a waltzing brown mouse.**

**9.**

**R=Running;**

**r=Waltzing;**

**B=Black;**

**b=Brown**

**a. Parent’s Genotypes: \_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

 **Parent#1 Parent #2**

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| --- | --- | --- | --- | --- |
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**b. Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**10.**

**Cross a homozygous running, heterozygous black mouse with a waltzing brown mouse.**

**a. Parent’s Genotypes: \_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

 **Parent#1 Parent #2**

|  |  |  |  |  |
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**b. Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Cross a heterozygous running, brown mouse with a heterozygous running, homozygous black mouse.**

**11.**

**a. Parent’s Genotypes: \_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

 **Parent#1 Parent #2**

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| --- | --- | --- | --- | --- |
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**b. Phenotypic Ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**