Build-a-Bird: The Pigeon Gene Shuffle

Student Instructions

Background
Animals that reproduce sexually make gametes, also known as eggs and sperm in most animals. Making gametes requires a special type of cell division, during which alleles are shuffled and recombined to make a nearly infinite number of allele combinations:

1. After the cell copies its DNA, the DNA coils up tightly, forming structures called chromosomes.
   - Each chromosome is made up of one very long DNA molecule.
   - A single chromosome can have hundreds or even thousands of genes.
   - Most sexually reproducing organisms have two copies of each chromosome.

2. Pairs of chromosomes swap large sections of DNA (called crossing-over or recombination). After crossing-over, each chromosome still has the same genes in the same order, but a new combination of alleles.

3. The cell divides to make gametes, each with only one copy of each chromosome. Each gamete has a different combination of alleles.

Which sperm collides with which egg is another roll of the dice. Offspring get a unique set of alleles from both mom and dad, and a unique set of traits. Between each generation, the process of allele shuffling increases genetic diversity within a population.

In this activity you’ll (1) recombine a pigeon chromosome, (2) make gametes, (3) combine gametes to make a pigeon offspring, and (4) determine what traits the offspring has—as you draw it.

The genes you’ll be working with are real-life pigeon genes but, for the sake of simplicity, they’ve all been placed on one chromosome. In reality, pigeons have 80 chromosomes (40 pairs).

Prepare your materials
- Cut out the Male Pigeon Chromosomes and Female Pigeon Chromosomes. Be careful to NOT cut along the center dashed line for each duplicated chromosome or the dashed lines in between genes. Those lines will be important later.
- We will start the activity with the cells having already gone through the process of DNA replication – so each chromosome is already attached to its copy.
Recombination

The chromosome pairs line up next to each other and become intertwined. Cellular machinery breaks the chromosomes at the exact same place, and it swaps the genetic material. This is called recombination or crossing over.

The longer the chromosome, the more places it can cross over. Most chromosomes cross over in at least one or two places.

1. Starting with the female chromosomes, choose two places on the F2 and F3 chromosomes to cross over.

   Carefully cut along the horizontal dashed lines in the same location on both chromosomes and swap them. Tape the exchanged material in place. Then do a crossover between F1 and F4 at a different horizontal dashed line.

2. Now do your crossing over on the male chromosomes. Choose two places on the M2 and M3 chromosomes to cross over.

   Carefully cut along the horizontal dashed lines in the same location on both chromosomes and swap them. Tape the exchanged material in place. Then do a crossover between M1 and M4 at a different horizontal dashed line.

3. Now each of the 4 chromosomes has a different combination of alleles. Next, the cell divides to make four gametes, each with only one copy of every chromosome.

   Carefully cut along the vertical dashed lines holding the chromosome copies together. Do this for both the female and male chromosomes.

   Each chromosome now represents an individual sperm (male) or egg (female) cell.
Fertilization
To make offspring, one sperm cell and one egg cell fuse to form a zygote. The female chromosome and male chromosome make a pair, creating a new combination of alleles different from both parents.

4. Make a pigeon zygote.

*Turn over your male and female chromosomes so you can’t see the genes, and shuffle them around.*

*Randomly select one female chromosome and one male chromosome. This is your zygote.*

5. What traits does your pigeon offspring have?

*Turn your selected chromosomes right-side up again and line them up together.*

*Use the Pigeon Traits Key to see what trait results from the allele combination for each of the five genes. Circle the results.*

*Draw the traits on your pigeon offspring.*

*Hint: Start with Spread and Recessive Red.*

*How does your offspring compare to others in your class?*
Draw Your Pigeon Offspring Traits

Pigeon Traits Key

<table>
<thead>
<tr>
<th>Gene</th>
<th>Representation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crest</td>
<td>C C C</td>
<td>no crest</td>
</tr>
<tr>
<td></td>
<td>C C C</td>
<td>crest</td>
</tr>
<tr>
<td></td>
<td>C C C</td>
<td>no crest</td>
</tr>
<tr>
<td></td>
<td>F F F</td>
<td>feathering</td>
</tr>
<tr>
<td></td>
<td>F f f</td>
<td>partial feathering</td>
</tr>
<tr>
<td></td>
<td>f f f</td>
<td>no feathering</td>
</tr>
<tr>
<td></td>
<td>S S S</td>
<td>spread</td>
</tr>
<tr>
<td></td>
<td>S s s</td>
<td>spread</td>
</tr>
<tr>
<td></td>
<td>s s s</td>
<td>no spread</td>
</tr>
<tr>
<td></td>
<td>R R R</td>
<td>not recessive red</td>
</tr>
<tr>
<td></td>
<td>R r r</td>
<td>recessive red</td>
</tr>
</tbody>
</table>

Wing Pattern

<table>
<thead>
<tr>
<th>Spread</th>
<th>Representation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-check</td>
<td>W W W</td>
<td></td>
</tr>
<tr>
<td>Check</td>
<td>W W W</td>
<td></td>
</tr>
<tr>
<td>Bar</td>
<td>W W W</td>
<td></td>
</tr>
<tr>
<td>Barless</td>
<td>W W W</td>
<td></td>
</tr>
</tbody>
</table>

Genes at each position along the chromosome

Crest

Foot Feathering

Wing Pattern

Recessive Red

Spread

Note: recessive red masks spread and wing pattern

Note: spread masks wing pattern