New Jersey Center for Teaching and Learning

Progressive Science Initiative

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AP BIOLOGY

Big Idea 1
Part B

August 2012

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Big Idea 1: Part B

Click on the topic to go to that section

Genes as Hereditary Units & Sexual Reproduction

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Heredity

All living things pass traits to their offspring. Heredity is the process that allows these traits to survive through many generations of ancestry.

Members of a species maintain their similarities and variations (differences) through this process.

Genes

Genes are:

- The basic unit of heredity. Each gene is the instructions for a whole trait or just part of a trait.

- Genes are made of deoxyribosenucleic Acid (DNA) and are part of a larger unit called a chromosome.

- The specific sequence of nucleotides (monomers of the DNA polymer) that makes up the functional gene is the code that produces a specific protein. The specific protein influences the expression of a trait.

Example of Gene Expression

Clasp your hands together

Note which thumb is on top

If you switch to the opposite way that you naturally clasped your hands together it should feel awkward.

1 Is your left thumb on top more comfortable?

- Yes
- No

Example of Gene Expression

A single gene causes you to feel more comfortable with your left thumb on top. If you are more comfortable with your right thumb on top then you do not have that gene.

About 60% of the US population has this gene.

Example of Gene Expression

If you have the "left thumb on top" gene you inherited it from your mother or your father. They inherited it from your grandmother or grandfather, and so on.

All traits are passed through a species from parent to offspring.

Alternate Versions of Genes Account for Most Variations

Many traits have multiple versions.
Some examples:

- Flowers of the same plant species are different colors
- Beaks of the same bird species are different sizes
- Bacteria are resistant to different forms of antibiotics

This is because the genes that produces the trait has different versions. These are called **alleles**.

The laboratory mouse, *Mus musculus*, also exhibits the extension series of alleles as noted in the chicken from L-R: black agouti and recessive yellow.

Different Ways to Pass Genes to Offspring

Although all species pass their alleles to their offspring, the way in which they are passed varies.

Some different ways include:

- Fission
- Budding
- Fragmentation
- Sexual reproduction

The first three are considered **asexual** reproduction because they don't involve mixing genes from more than one individual.

Fission

Fission is when the parent organism splits into "daughter" organisms. In other words the parent ceases to exist and is replaced by its offspring.

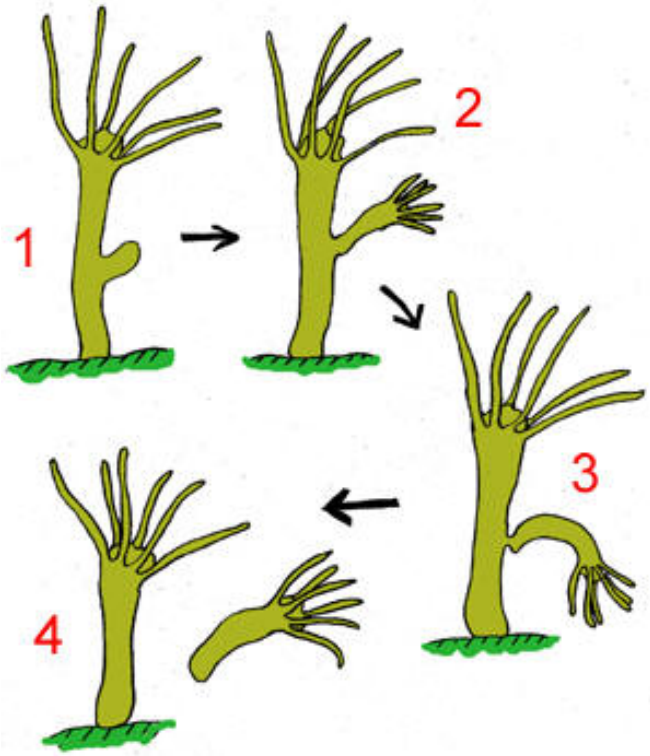
Bacteria divide by binary fission. One parent splits into two offspring.

The parents genes are copied and one copy is given to each of the offspring.

Rod-Shaped Bacterium, hemorrhagic, *E. coli*, strain 0157:H7 (division) (SEM x22,810). This image is copyright Dennis Kunkel at www.DennisKunkel.com

Budding

Budding is when a few cells from a parent organism grow into an adult offspring. This happens mostly in plants, unicellular organisms, or simple animals such as the hydra.



Animation of Hydra Budding

Click here

Fragmentation

Fragmentation passes alleles from parent to offspring by breaking a piece off of the parent. It is different from budding because the offspring begins to grow from a piece of the parent that has been removed.

Starfish can produce offspring by removal of an arm. The parent will grow back the removed arm and the offspring will grow a body from the parent's arm.

Sexual Reproduction

Sexual reproduction is unique to the other forms for several reasons:

- It requires two individuals, one male and one female.
- Genes from the participants are mixed together.
- Each parent contributes half their genes to the offspring.
- Each offspring is genetically unique from its parents and its siblings (brothers/sisters), with the exception of identical twins.

This process is considerably more complex, burns valuable energy and requires elaborate mating rituals in many species.
So...

Why Have Sex?

However asexual organisms can:

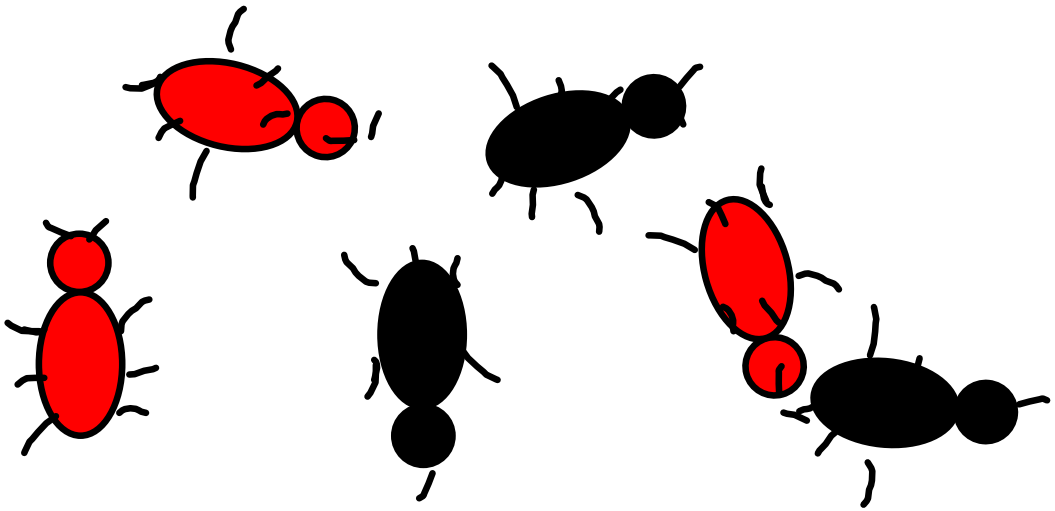
- reproduce faster
- pass all their genes to their offspring (not half)
- produce offspring with no need to find a mate
- spend no energy producing sex cells (egg/sperm)

We will revisit this question after some exploration of sexual heredity.

Sexually Reproducing Beetles

A researcher was curious about a new species of beetle. These beetles have two versions of the trait body color, black or red.

In other words, their body color **phenotype** can be black or red.



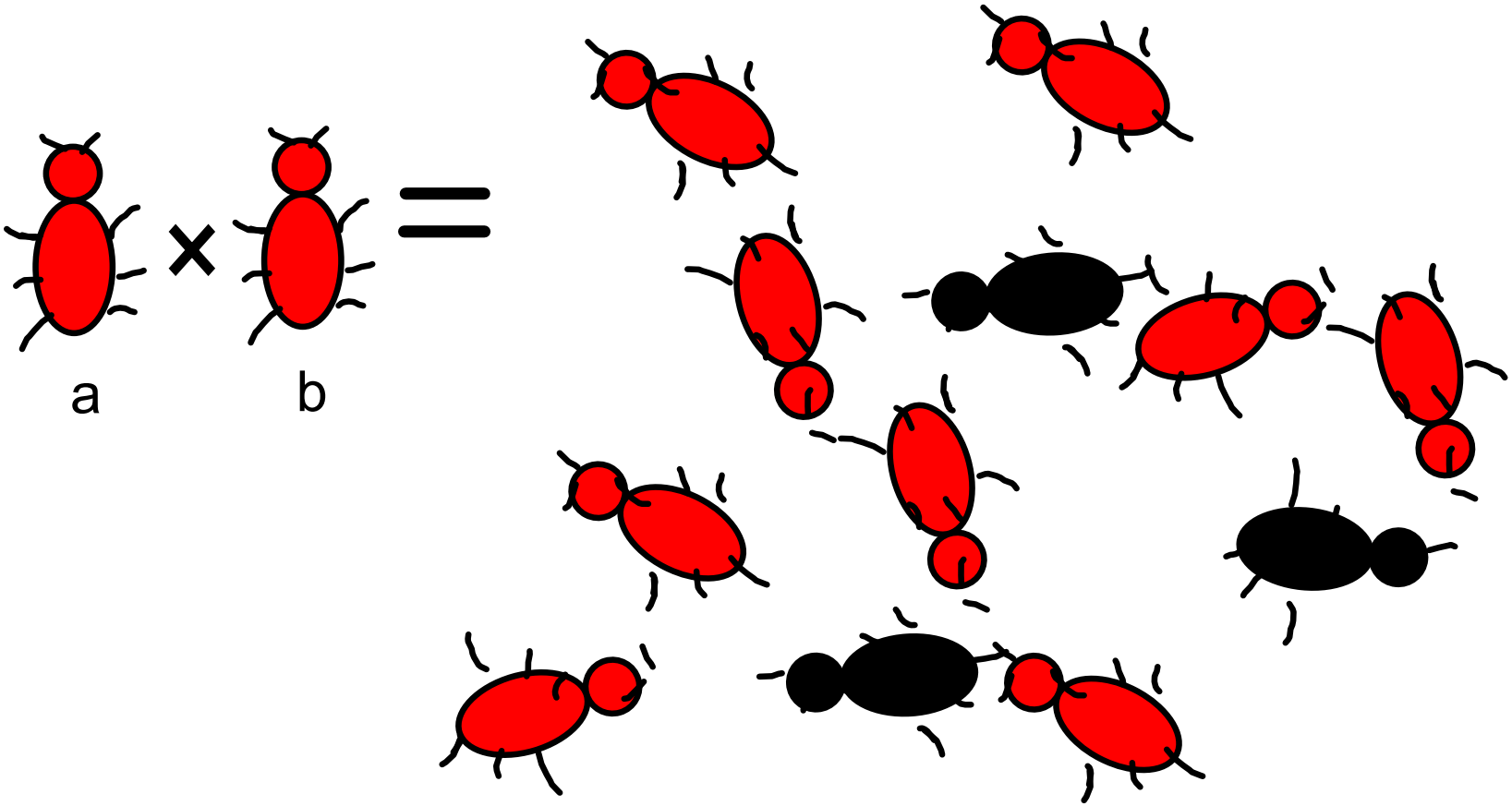
Sexually Reproducing Beetles

The researcher did some breeding experiments to try to determine how the alleles were passed from generation to generation. He wanted to know the **heredity pattern** of the phenotypes.

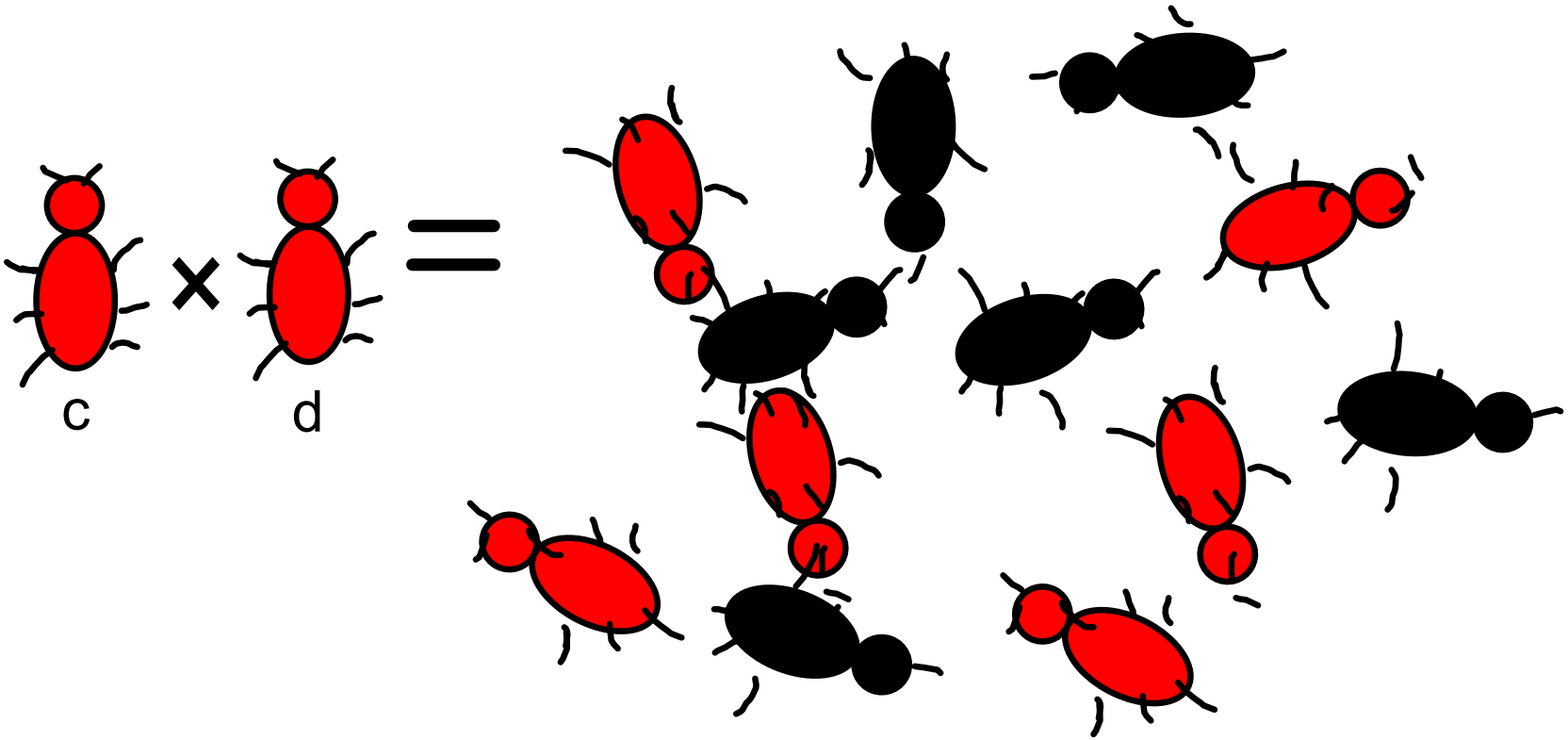
First he did crosses of red individuals and got 3 reoccurring outcomes (repeatable on numerous occasions).

Record the observations you see on the following slides in your notes.

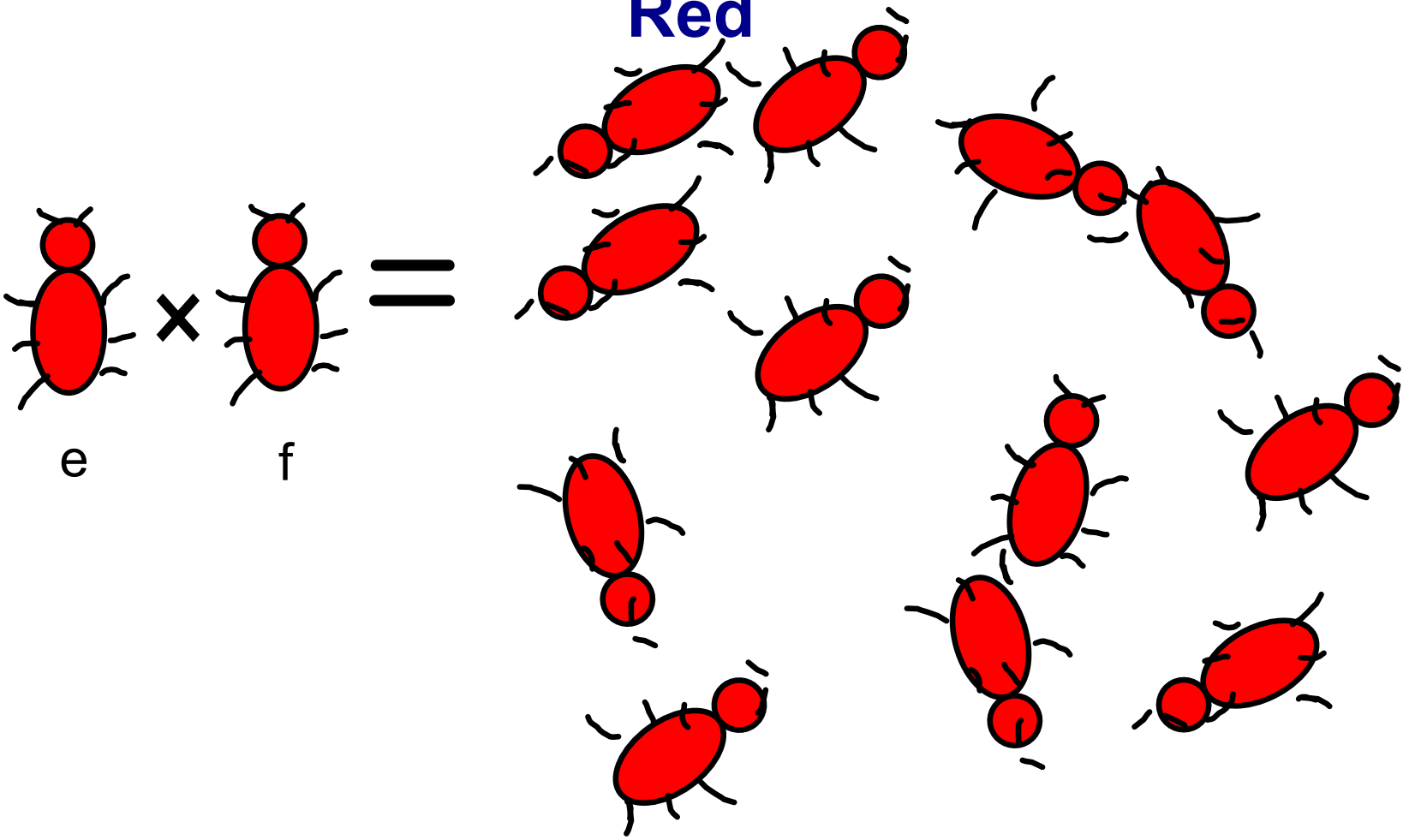
Outcome 1 of Red Crossed with Red



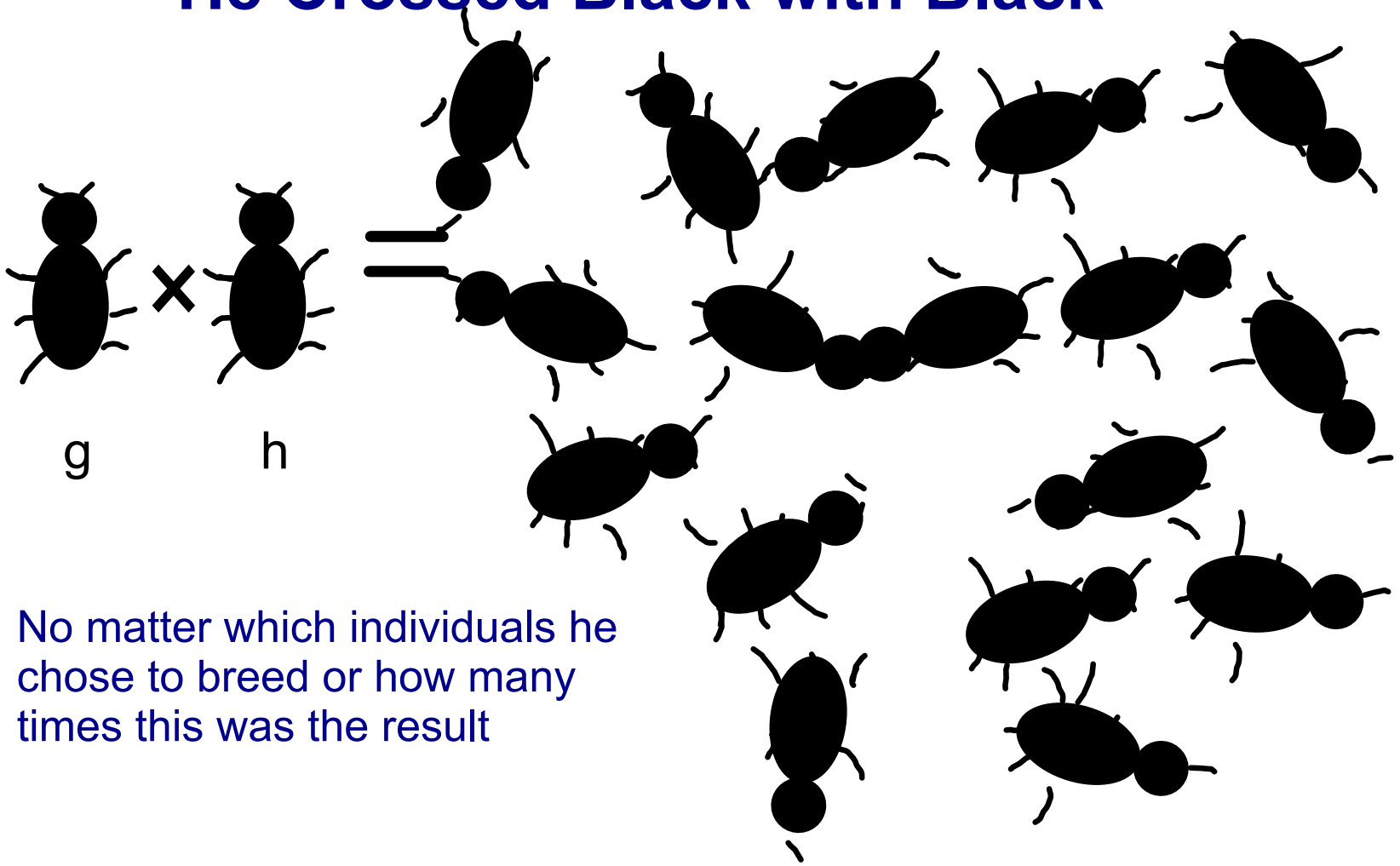
Outcome 2 of Red Crossed with Red



Outcome 3 of Red Crossed with Red

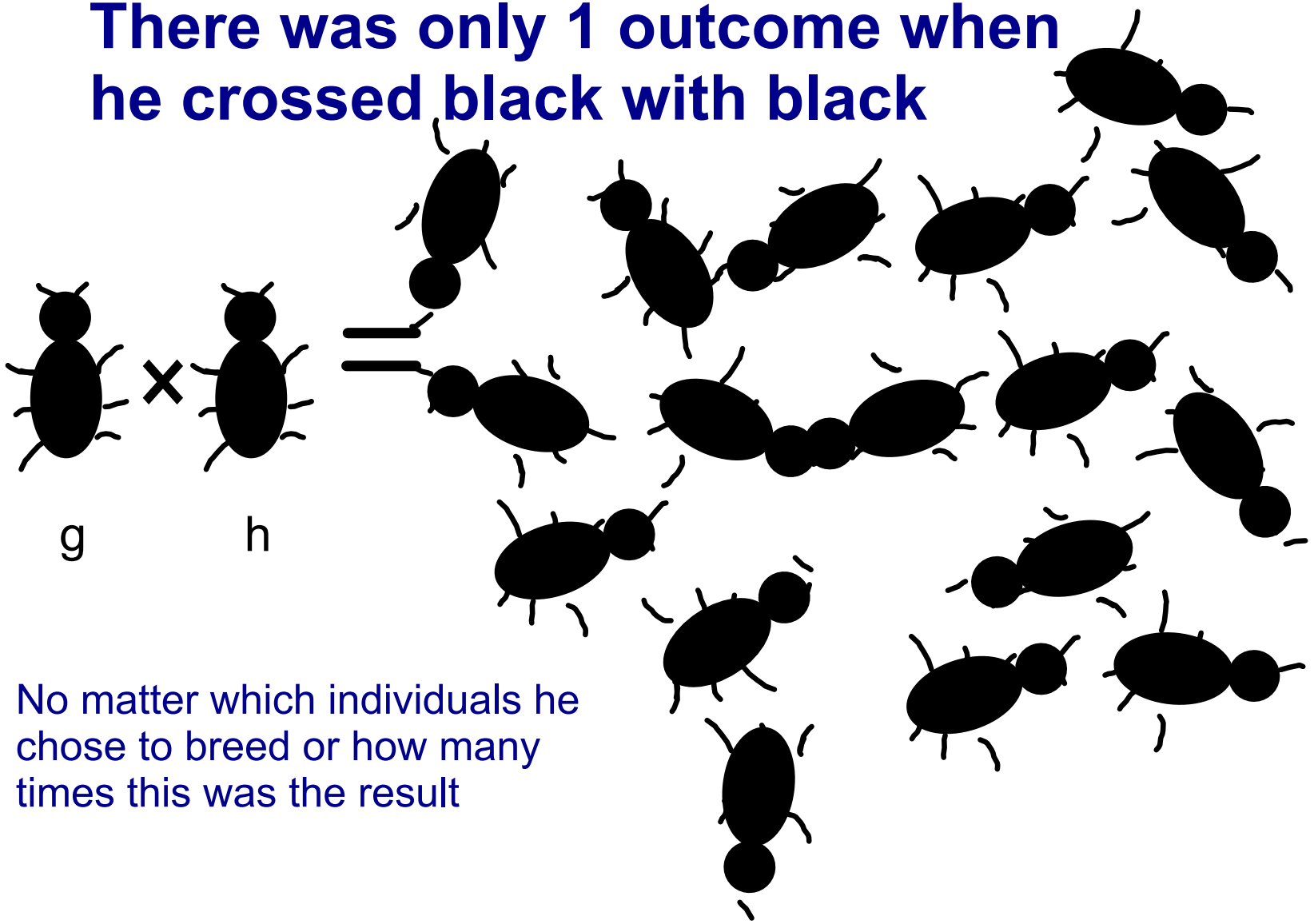


There Was Only 1 Outcome When He Crossed Black with Black



No matter which individuals he chose to breed or how many times this was the result

There was only 1 outcome when he crossed black with black



No matter which individuals he chose to breed or how many times this was the result

Sexually Reproducing Beetles

The question:

How is it genetically determined whether a beetle will be black or red?

Assuming that beetles always mix their genes the same way, describe a mechanism that can account for all the outcomes that the researcher observed. Use the numbers you recorded to hypothesize.

Suggest the alleles for body color that each of the parent beetles possess using your hypothesis. This is known as their **genotype**.

Sexually Reproducing Beetles

Individual beetle's genotype from the sample crosses:

a-

b-

c-

d-

e-

f-

g-

h-

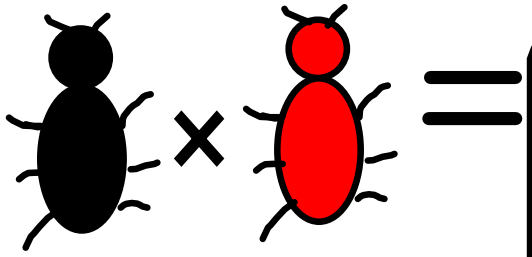
Sorry, this element requires Flash, which is not currently supported in PDFs.

Please refer to the original Notebook file.

Sexually Reproducing Beetles

The researcher recognized that the allele for black body color must be "hiding" in the genes of some of the red individuals but not all.

To further understand the inheritance of this gene he crossed a beetle that he knew didn't have a hiding black body gene (e or f) with a black beetle.



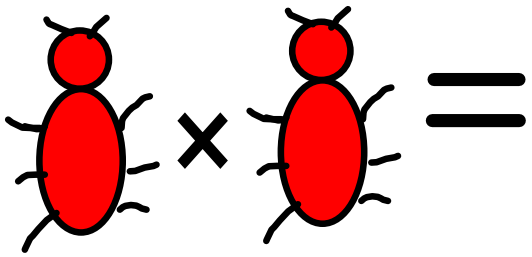
P generation

try to predict the result

Click to reveal result

Sexually Reproducing Beetles

The researcher was curious about the offspring of the red and black beetle cross. He took 2 of the offspring from that cross and then crossed them.



F1 generation

Predict the result

Do you want to revise any of your previous hypotheses?

Mechanism of Sexual Reproduction

The preceeding experiment was similar to how Gregor Mendel figured out his postulates (hypotheses) of sexual genetic heredity.

Compare your theories with his...

Mendel

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Mendel's Hypotheses

Hypothesis # 1: Alleles

There are alternative forms of genes that account for variations in inherited characteristics

For example- there are two different versions of the gene for flower color in pea plants: one for purple and one for white. These alternative forms are now called **alleles**.

Mendel's hypotheses

Hypothesis # 2: All Organisms have 2 alleles

For each characteristic, an organism inherits two alleles (one from each parent). The two alleles may be the same or they may be different.

An organism that has two identical alleles for a gene is **homozygous** for that gene.

An organism that has two different alleles for a gene is **heterozygous** for that gene.

Mendel's hypotheses

Hypothesis # 3: Dominant and Recessive

If the two alleles of a pair are different (heterozygous), one determines the appearance and is called the dominant allele.

The other allele has no noticeable effect on the appearance and is called the **recessive allele**.

Mendel's hypotheses

Hypothesis # 4: Law of Segregation

A sperm or egg carries only one allele for each trait because allele pairs separate from each other during sex cell formation (meiosis).

This became known as The Law of Segregation.

When sperm and egg unite at fertilization, each contributes its one allele, restoring the pair in the offspring.

Mendel's Experiments

Click here for a review of Mendel's Experiments

If further review is needed, please see NJCTL's first year biology course.

Genetics First Year Course

2 In a classic Mendelian cross, what would be the ratio of the offspring in the F1 generation?

- A 1:1
- B 2:1
- C 3:1
- D no ratio, only 1 kind

answer

3 In a classic Mendelian cross, what would be the ratio of the offspring in the F2 generation?

- A 1:1
- B 2:1
- C 3:1
- D no ratio, only 1 kind

answer

4 Aa x AA

If this cross produces 500 offspring what is the expected number of individuals who would have the dominant phenotype?

answer

5 Aa x aa

If this cross produces 500 offspring what is the expected number of individuals who would have the dominant phenotype?

answer

6 Aa x Aa

If this cross produces 500 offspring what is the expected number of individuals who would have the dominant phenotype?

answer

Law of Independent Assortment

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Mendel's Laws

As we have seen, the Law of Segregation is based on Mendel's **monohybrid** (single trait) crosses.

To understand his second law, the Law of Independent Assortment he had to look at 2 traits simultaneously, a **dihybrid** cross.

The following example will be used to demonstrate and practice the second law.

Study of Pond Life

While observing samples of pond water from a remote area of New Jersey, a researcher discovers a microbe. She determines that they are capable of sexual reproduction and devises a way to selectively breed individuals of the species.

Study of Pond Life

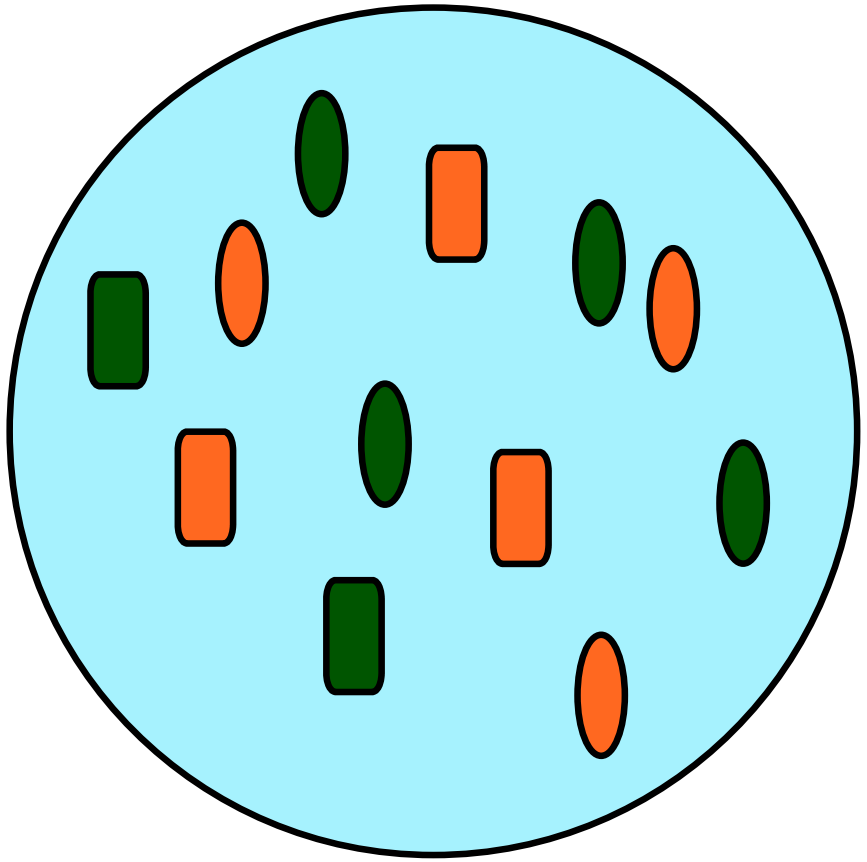
The researcher concentrates her study of their heredity pattern on two easily observable traits. Their color and their shape.

Fill in the data.

Possible colors:

Possible shapes:

Possible combinations of color and shape:

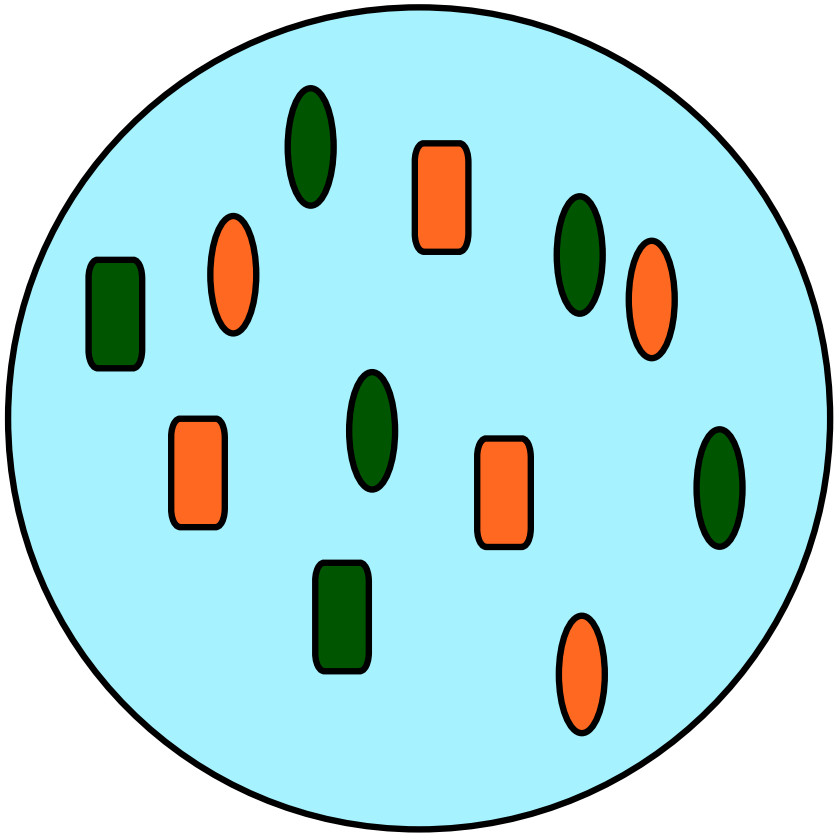


40X Magnification
Light Microscope

Study of Pond Life

First the researcher wants to determine which traits are dominant.

Suggest some tests that will help determine dominance for both of these traits.



40X Magnification
Light Microscope

Test 1:

Test 2:

Test 3;

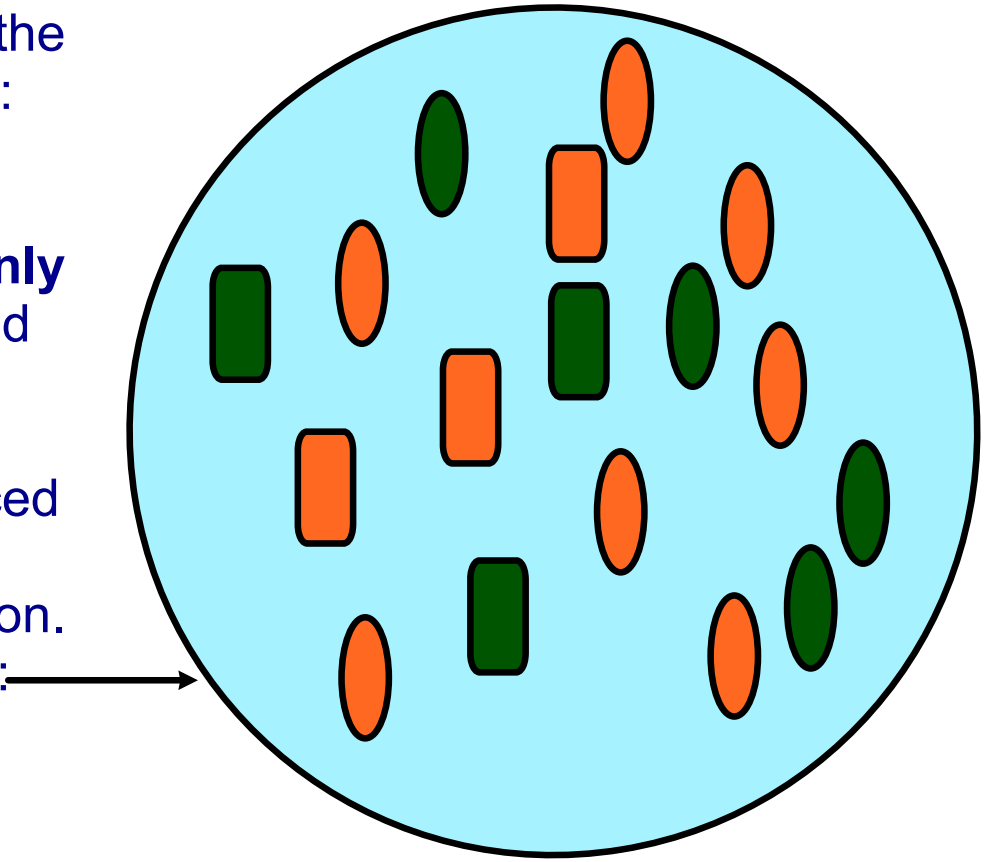
Test 4:

Test 5:

Study of Pond Life

The researcher does the following experiments:

She takes a pool of **only orange** individuals and isolates them. After enough time for offspring to be produced she samples and observes the population. This is what she sees:



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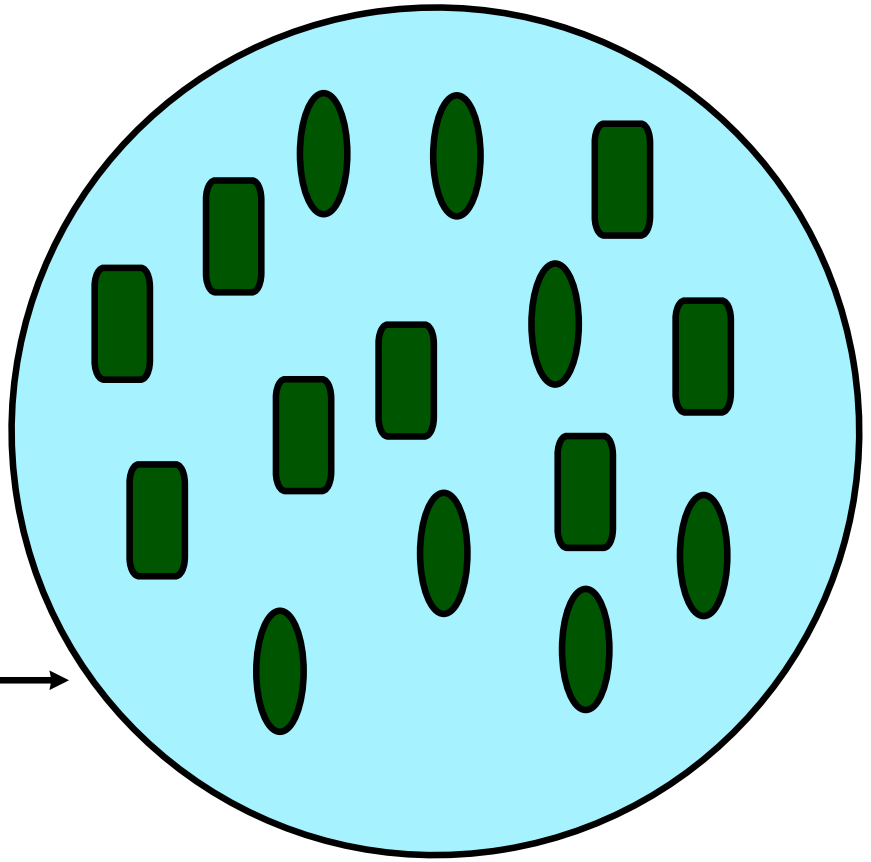
Light Microscope

Study of Pond Life

She then takes a pool of **only green** individuals and isolates them. After enough time for offspring to be produced she samples and observes the population. This is what she sees:

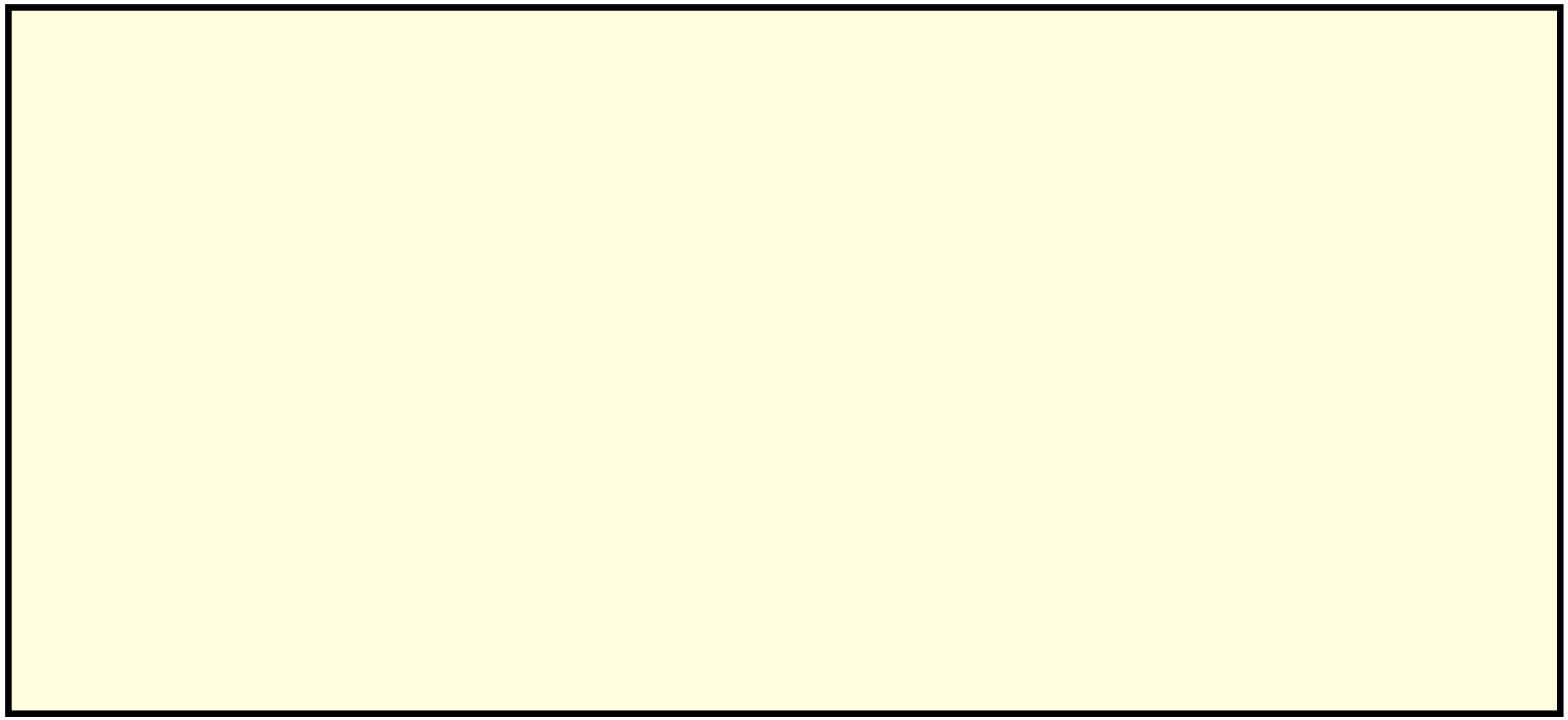


40X Magnification
Light Microscope

Study of Pond Life

Using what we learned in the beetle crosses, try to determine which color is dominant, green or orange.

Click below to see the researchers conclusion and explanation

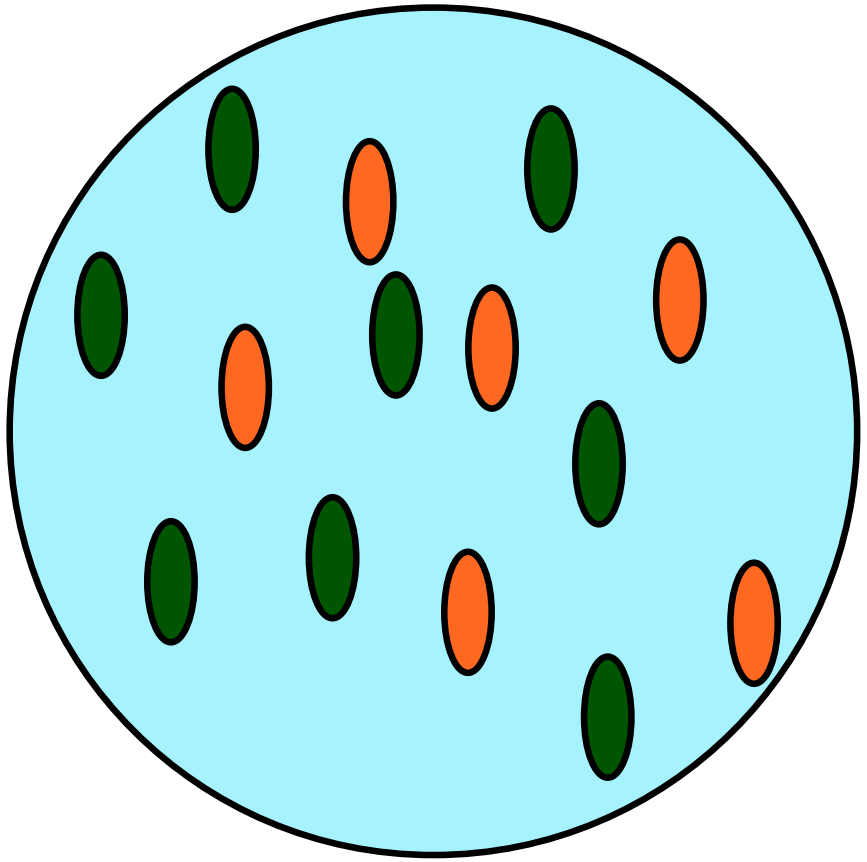


Study of Pond Life

The researcher does a similar experiment to determine shape.

Using the same logic she determines that rectangle is dominant to oval.

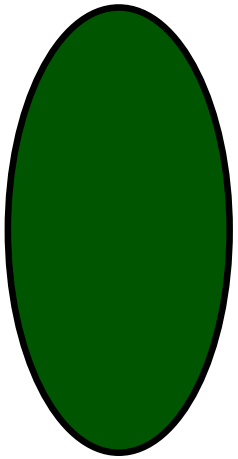
What was in the original pool that produced the results you see in this microscope field?



40X Magnification
Light Microscope

7 What is the genotype of the organism?

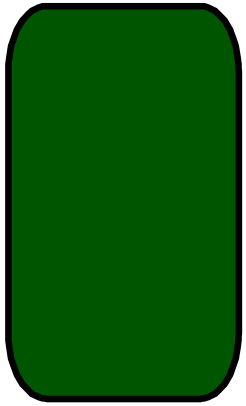
- A OoRr
- B ooRR
- C oorr
- D OORR



answer

8 What is the genotype of the organism?

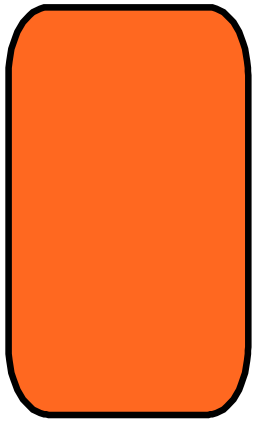
- A OoRr
- B ooRR
- C oorr
- D OORR



answer

9 What is the genotype of the organism?

- A OoRr
- B ooRR
- C oorr
- D OORR



answer

10 In order for the pond organism's phenotype to be orange their genotype must be:

- A heterozygous only
- B heterozygous or homozygous dominant
- C heterozygous or homozygous recessive
- D homozygous dominant only

answer

11 An organism with the genotype OOrr would appear to be:

- A Orange and Oval
- B Orange and Rectangle
- C Green and Oval
- D Green and Rectangle

answer

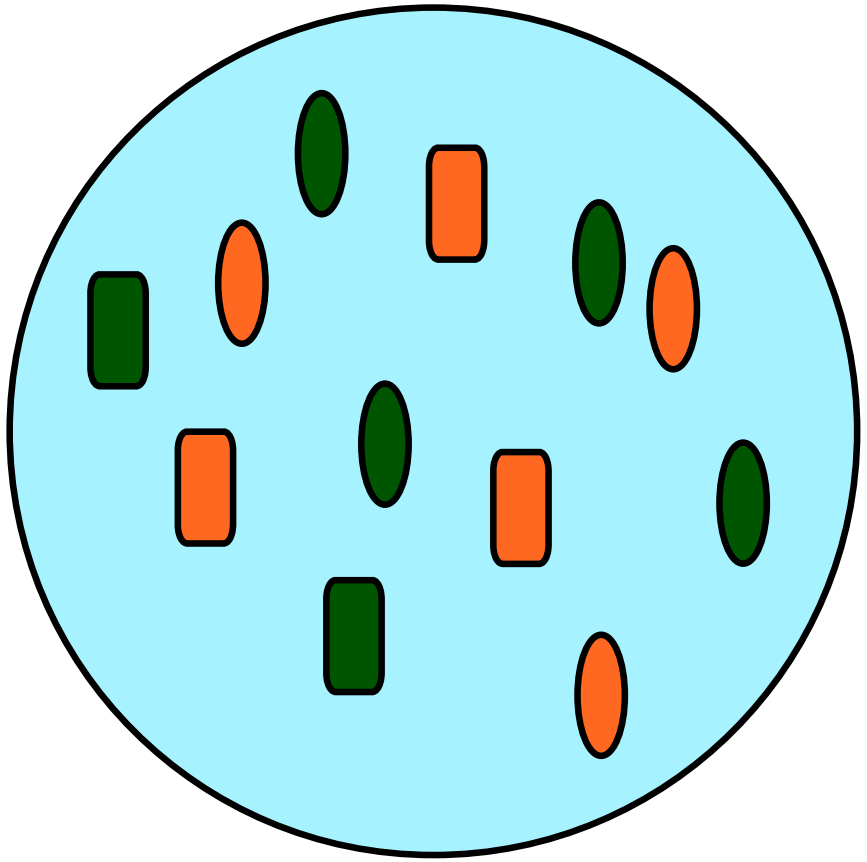
Study of Pond Life

Now that the researcher knows the dominance of these traits she can learn more by doing individual test crosses.

She wants to know:

Does the inheritance of color effect the inheritance of shape?

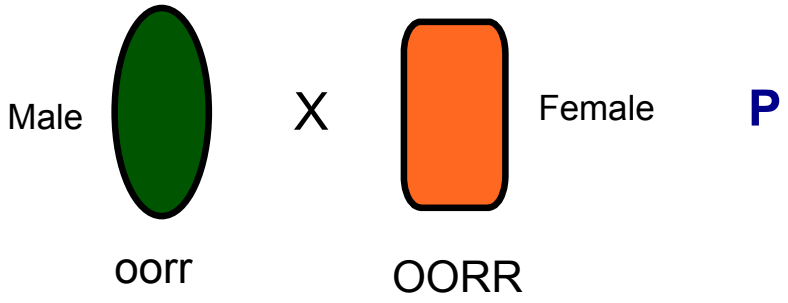
For example: If one is green, is it more likely to be oval? If one is orange is it more likely to be rectangular?



40X Magnification
Light Microscope

Study of Pond Life

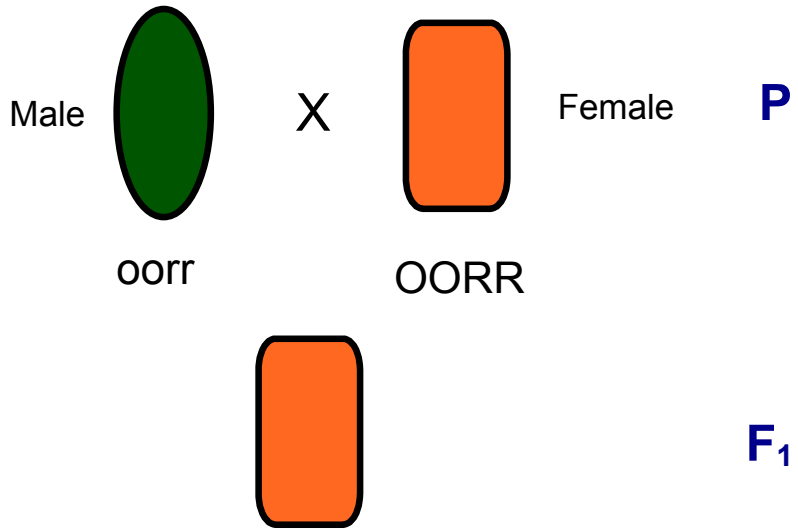
She isolates 2 individuals of known phenotype and genotype and crosses them. These will be the **parent (P) generation**.



Study of Pond Life

They produce thousands of offspring. All of them are the same: Orange and Rectangular.

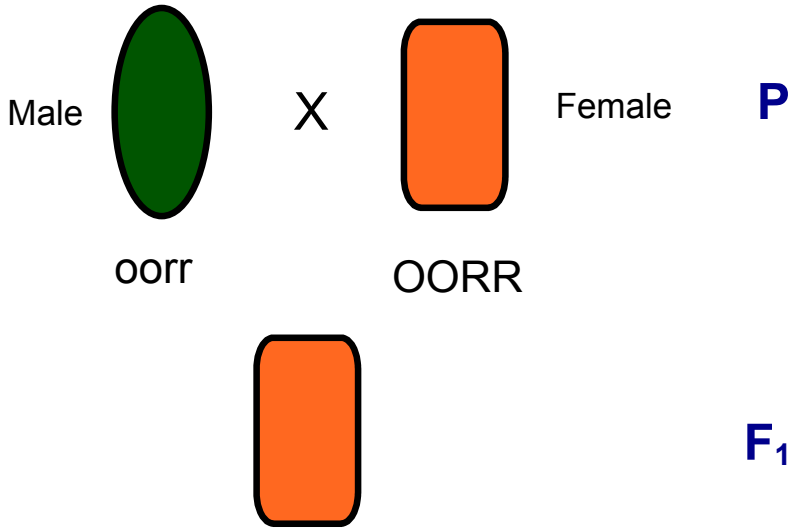
We will call all of their offspring the **F_1 Generation**



Study of Pond Life

To determine why all the F_1 generation are the same we need to consider the Mendelian Law of Segregation.

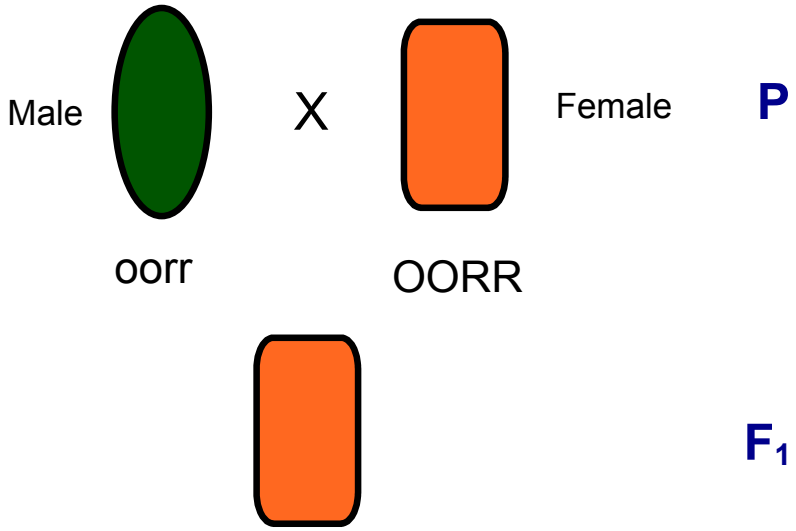
Alleles segregate from one another when sperm and egg are produced. So each sex cell only has **one allele for each trait.**



Study of Pond Life

If we look at the male in this cross we will see that he can only give the recessive allele for color (o) and the recessive allele for shape (r) to the offspring.

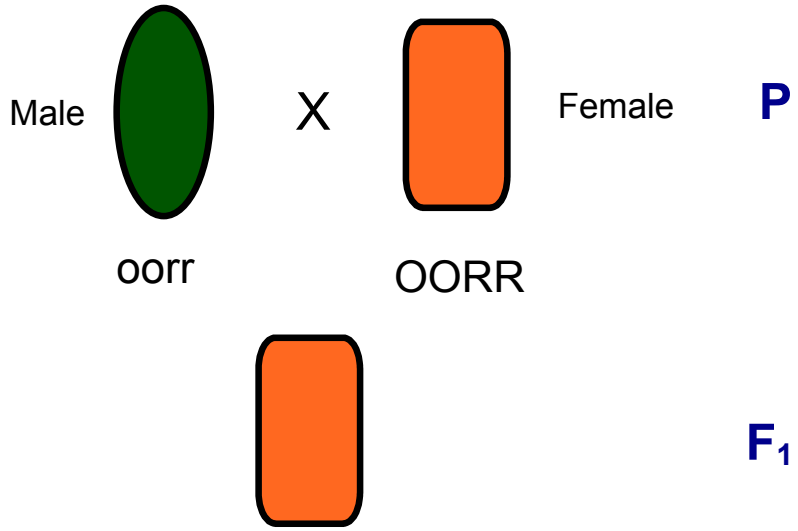
All of his sperm have the genotype: or



Study of Pond Life

For the female she only has the dominant for both traits so she can only give the dominant alleles to her offspring.

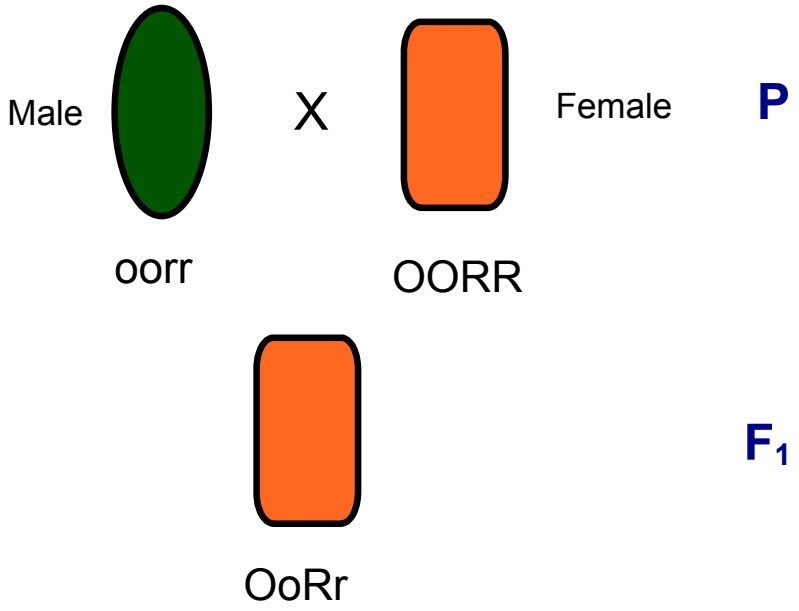
All of her eggs have the genotype: OR

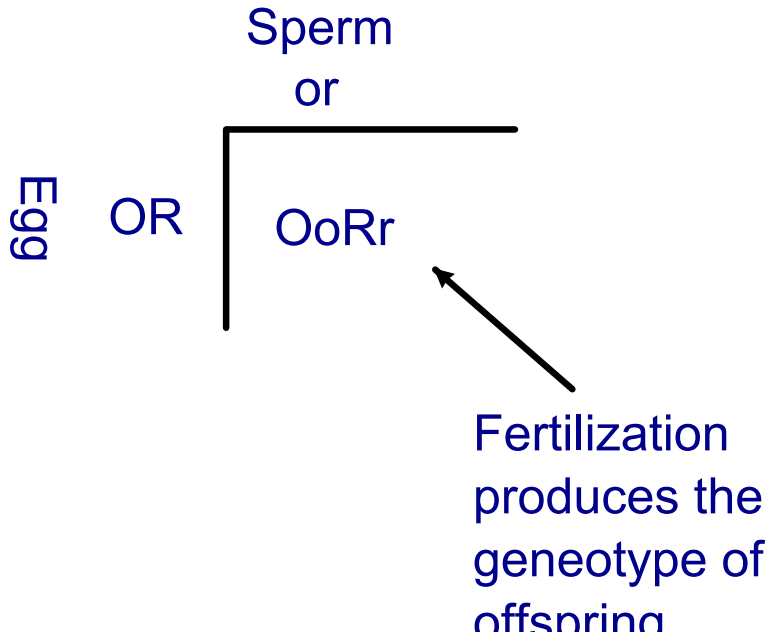


Study of Pond Life

Since the sperm and egg combine into one offspring there is only one possible result:

OoRr



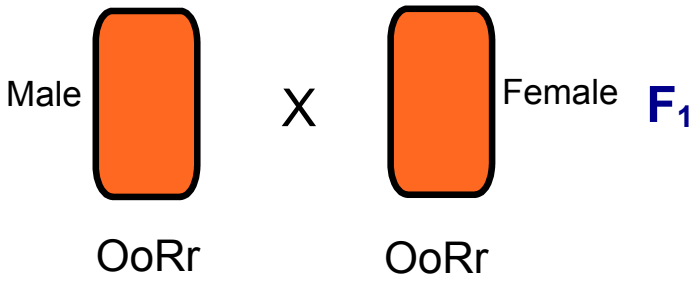


Fertilization produces the geneotype of offspring

Study of Pond Life

The next step for our researcher is to determine the expected result of a cross between 2 individuals from the hybrid (F_1) generation.

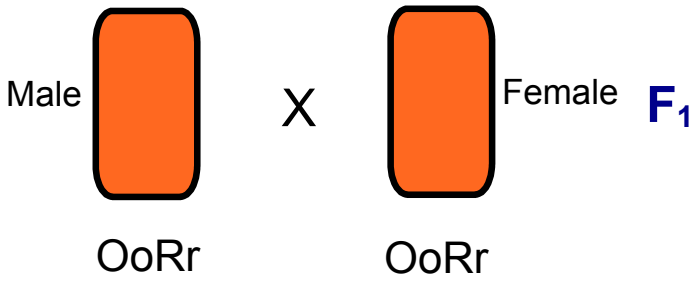
She hypothesizes that there is no connection between the 2 traits. She figures out the ratio of possible offspring that she should observe if this is true.



Study of Pond Life

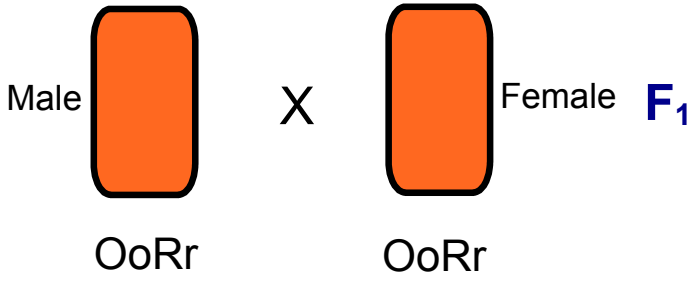
The next step for our researcher is to determine the expected result of a cross between 2 individuals from the hybrid (F_1) generation.

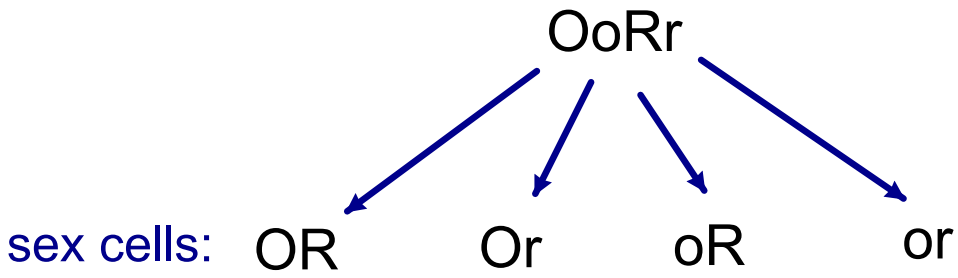
She assumes that there is no connection between the 2 traits. She figures out the ratio of possible offspring that she should observe if this is true.



Study of Pond Life

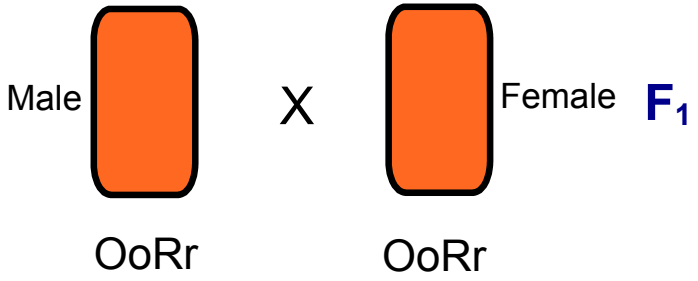
Since these individuals are heterozygous (hybrids) they are able to produce many different combinations of alleles in their gametes.

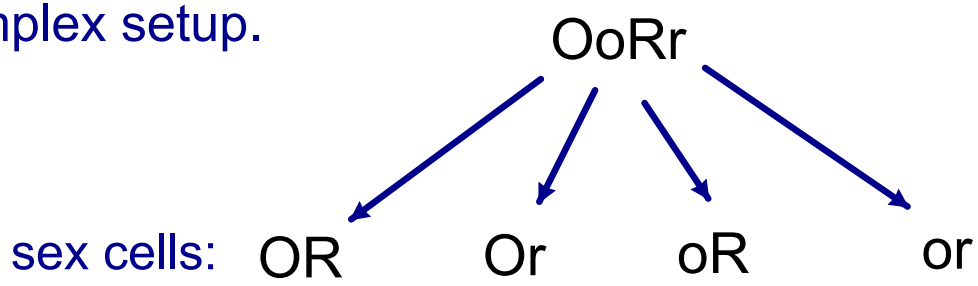




Study of Pond Life

To determine the ratio of offspring we need to compare the possibilities for combinations of sperm and egg in fertilization. We do this just like in the P generation, but it is a more complex setup.





Study of Pond Life

First put in all the possibilities for sperm above the top row

Sperm

OR	Or	oR	or

Study of Pond Life

Then put the possibilities for eggs along the side

Sperm

Egg	OR	Or	oR	or
OR				
Or				
oR				
or				

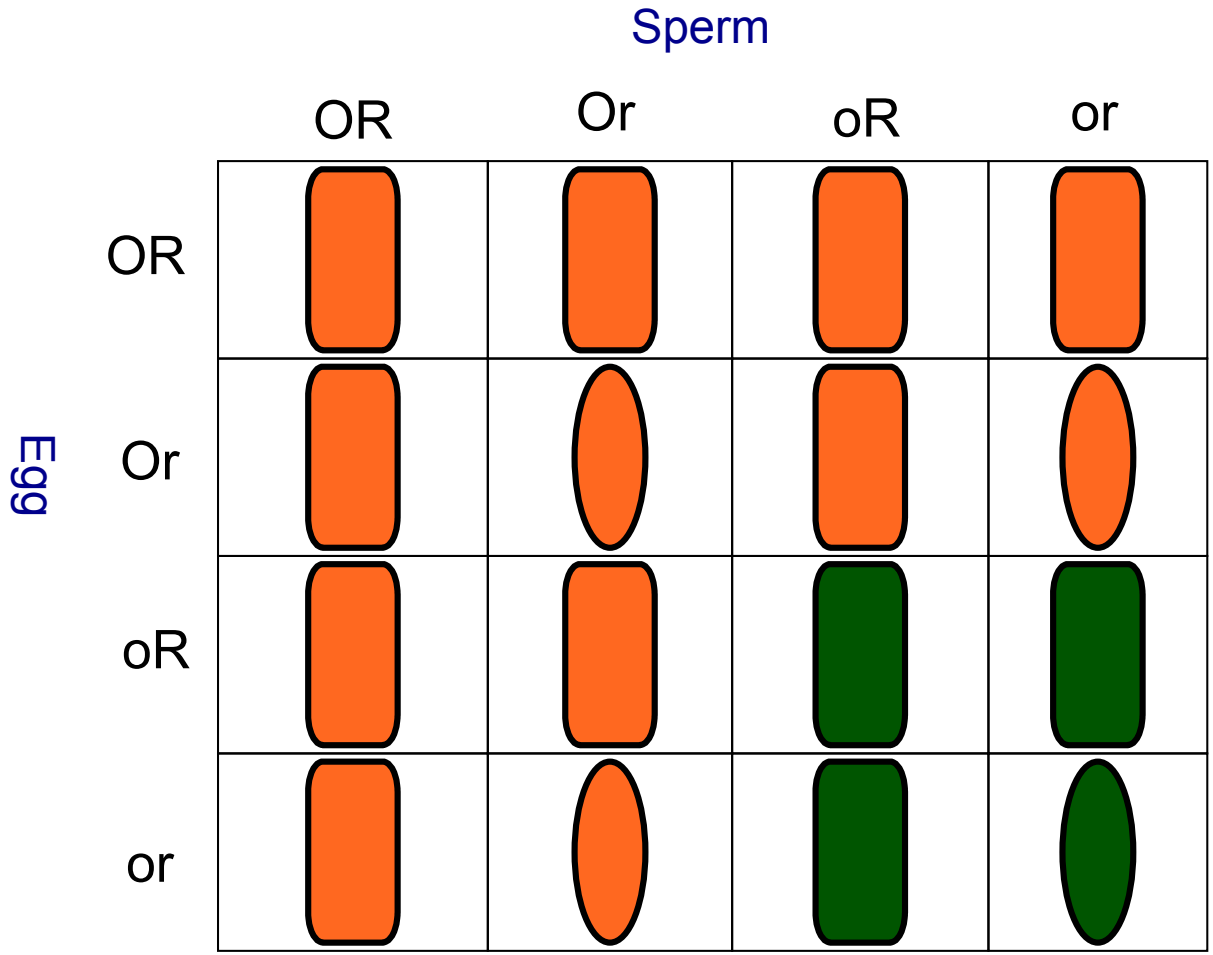
Study of Pond Life

Now fill in the table by combining each egg and sperm (**fertilization**) in the appropriate square. Click each to reveal the result.

Egg \ Sperm	OR	Or	oR	or
OR	OORR	OORr	OoRR	OoRr
Or	OORr	OOrr	OoRr	Oorr
oR	OoRR	OoRr	ooRR	ooRr
or	OoRr	Oorr	ooRr	oorr

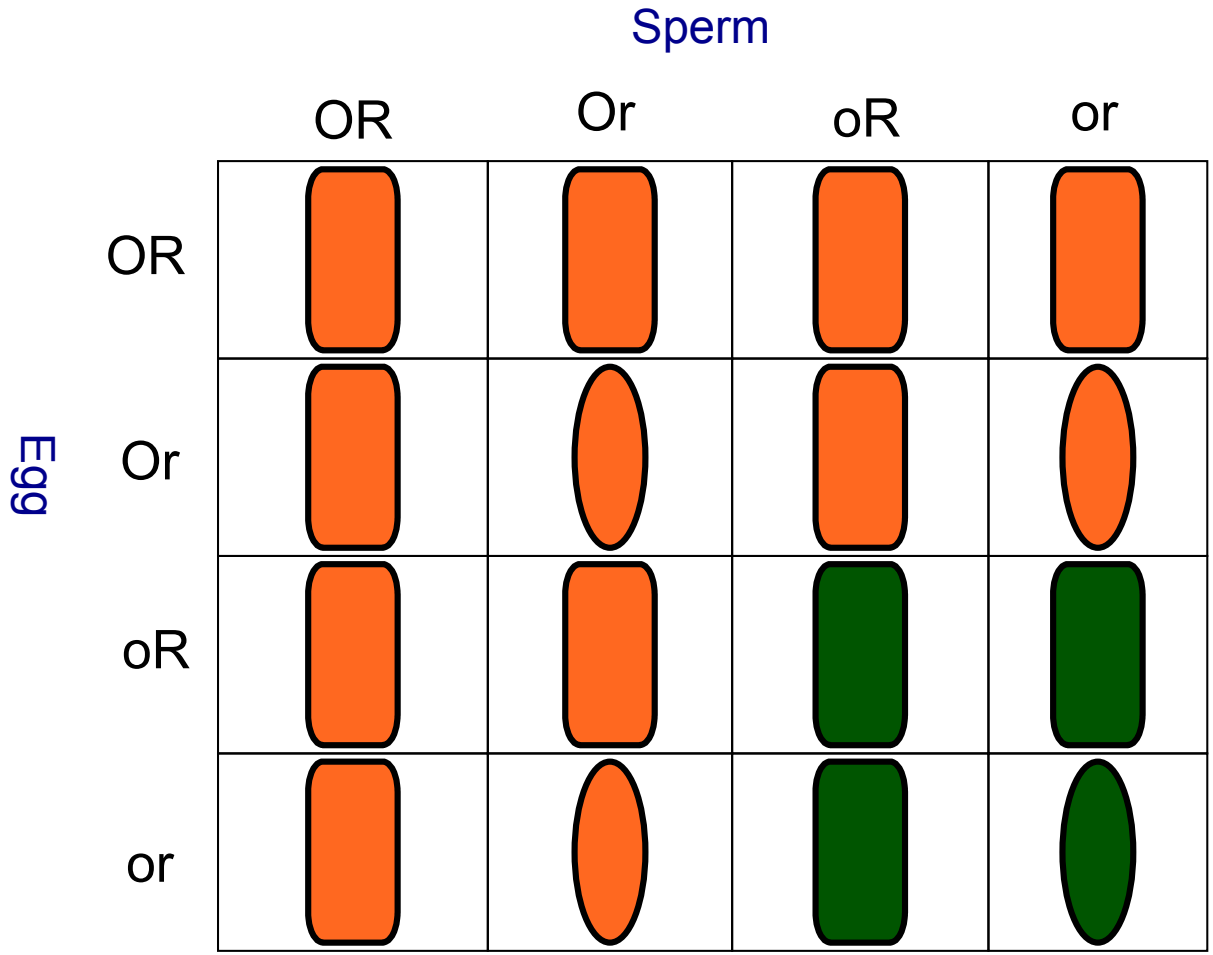
Study of Pond Life

Since we are comparing observable traits we need to convert each genotype into its phenotype.



Study of Pond Life

Finally we can count the possibilities and determine the expected ratio



9 Orange Rectangle

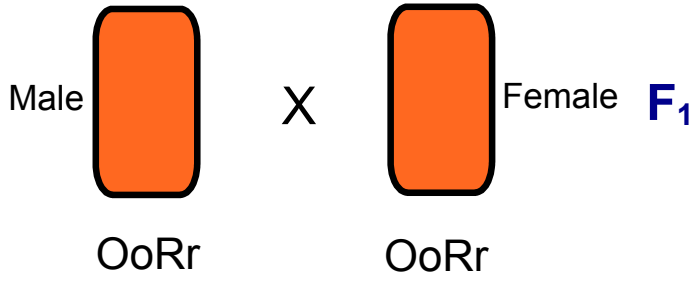
3 Orange Oval

3 Green Rectangle

1 Green Oval

Study of Pond Life

Now the researcher is ready to do the actual cross. She breeds 2 individuals from the F_1 and records the number of offspring. This is the **F_2 generation**.



Possible Phenotypes

F_2

number of offspring				
	5902	1966	1951	653

Does this fit with the expected ratio?

Study of Pond Life

Conclusion:
The original question was:

Does the inheritance of color effect the inheritance of shape?

If you discover observed results fit closely with the expected result then you should conclude that color does not effect shape and therefore these are **unlinked genes**. If they do not conform to your expected then they are **linked** and their inheritance is not independent.

Mendel's Laws

The preceding slides demonstrated Mendel's second law:

The Law of Independent Assortment states that separate genes for separate traits are passed independently of one another from parents to offspring.

The biological selection of one gene's allele pair for a particular trait has nothing to do with the selection of any other genes for any other trait.

Mendel's Laws

To demonstrate independent assortment lets look at 5 nondescript traits inside of one organism. Each has 2 alleles.

Trait 1: Allele A Allele B

Trait 2: Allele A Allele B

Trait 3: Allele A Allele B

Trait 4: Allele A Allele B

Trait 5: Allele A Allele B

Mendel's Laws

Just because allele A of trait 1 is selected in a particular **gamete** (sperm or egg) that does not mean it will be the same for the other traits. Each is selected independent of the others.

Trait 1: Allele A Allele B

Trait 2: Allele A Allele B

Trait 3: Allele A Allele B

Trait 4: Allele A Allele B

Trait 5: Allele A Allele B

12 AABB X aabb

What would be the expected number of offspring that have both dominant traits if the above cross produced 1000 offspring?

answer

13 AaBb X aabb

What would be the expected number of offspring that have both dominant traits if the above cross produced 1000 offspring?

answer

14 AaBb X AaBb

What would be the expected number of offspring that have both dominant traits if the above cross produced 1000 offspring?

answer

What Mendel Didn't Know

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What Mendel Didn't Know

Over the years since Mendel's discovery of genetics, modern science has discovered many traits that show exception to Mendel's Law. We can term these **Non-Mendelian Traits**.

For example, many traits are linked which means they do not follow the law of independent assortment. Like red hair and freckles.

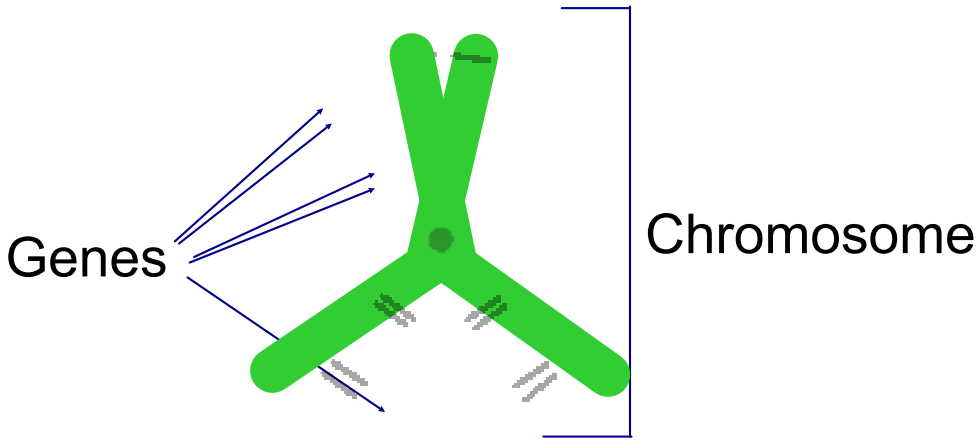
Molly Ringwald
http://xfinity.comcast.net/

What Mendel Didn't Know

The main new discovery that changed how we interpret Mendel's results is **chromosomal inheritance**.

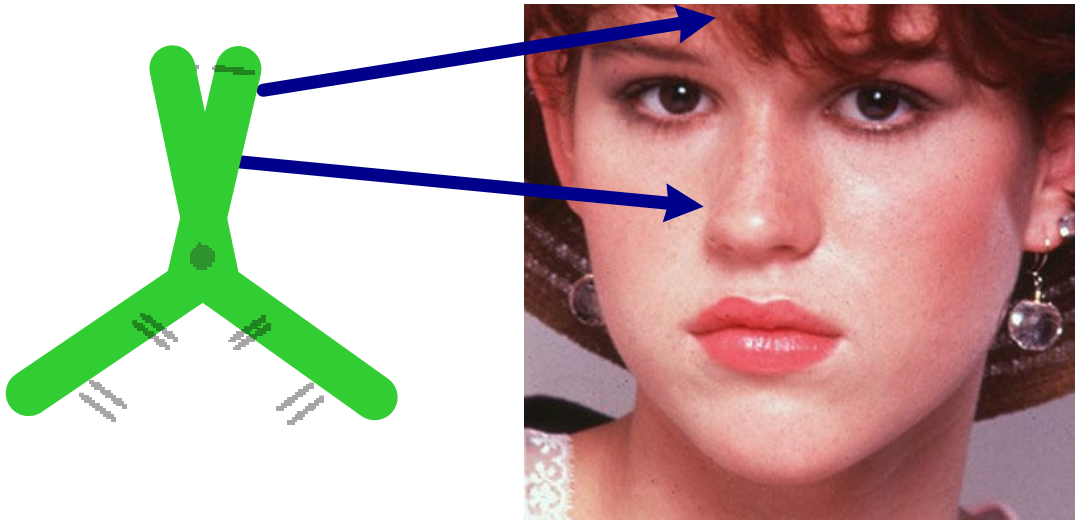
Sexual eeproducers pass their genes on small bundles of DNA called chromosomes. Each chromosome contains many genes. The chromosomes DO independently assort but the gene for a few, several, or many traits may be on the same chromosome.

These **linked genes** are inherited as a package.



What Mendel Didn't Know

Red hair and Freckles are on the same chromosome



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What Mendel Didn't Know

Click here for a review video of Non-Mendelian Genetics

If further review is needed, please see NJCTL's first year biology course.

Genetics First Year Course

15 ABO blood type is not a Mendelian "either /or" trait. Which of the following allelic relationships is responsible for this phenotype (trait)?

- A Codominance
- B Multiple genes
- C Incomplete dominance
- D Multiple Alleles

answer

16 Sickle-cell disease is caused by a single trait but causes multiple effects on its victim. This is an example of

- A Epistasis/Pleiotropy
- B Multiple genes
- C Incomplete dominance
- D Codominance
- E Multiple Alleles

answer

17 Skin color is an example of

- A Epistasis
- B Multiple genes
- C Incomplete dominance
- D Codominance
- E Multiple Alleles

answer

18 A white mouse and black mouse produce an offspring mouse that is grey. This is most likely due to

- A Epistasis
- B Multiple genes
- C Incomplete dominance
- D Codominance
- E Multiple Alleles

answer

19 A white mouse and a black mouse produce an offspring mouse with black and white spots. This is most likely due to

- A Epistasis
- B Multiple genes
- C Incomplete dominance
- D Codominance
- E Multiple Alleles

answer

20 Fur color of a particular organism could be orange, purple, green or blue. This is most likely due to

- A Epistasis
- B Multiple genes
- C Incomplete dominance
- D Codominance
- E Multiple Alleles

answer

21 A researcher does a cross to determine the heredity of a sexually reproducing organism. He uses 2 F_1 individuals (hybrids) that are heterozygous for 2 traits. He expects a 9:3:3:1 ratio. Out of 2,000 offspring he gets 800 individuals that are recessive for both traits. Does this fit his expected results of this dihybrid cross?

- Yes
- No

answer

22 In the previous question what would the expected number of homozygous recessive individuals be?

(2,000 offspring 9:3:3:1 ratio)

answer

23 What is the most likely reason for the inconsistency in the last example?

- A Multiple alleles
- B Incomplete dominance
- C Codominance
- D Linked genes

answer

Why Have sex?

Now that you have learned about Darwin's descent with modification and Mendel's patterns of inheritance, we can now combine the two and explore why sex, from a survival perspective, is worth the trouble.

Why Have Sex?

Discuss the pros of sex as a means of reproduction in comparison to asexual reproduction. Just to frame the discussion properly, do not think of human sex. Think of bees...

"Before mating, the new queen will need to kill off all of her sister siblings, ensuring she will remain the unchallenged monarch of the hive. Once that messy business is taken care of, the virgin queen will take a mating flight with about a dozen males. While the special mating males, selected from the tens of thousands of other male bees in the colony, might seem lucky at first, their luck is soon to change. That's because they die as their penises explode (audibly even) while inside the queen. She's then loaded up with all the sperm she'll need for the rest of her life, which entails laying up to fifteen hundred eggs per day for three full years."

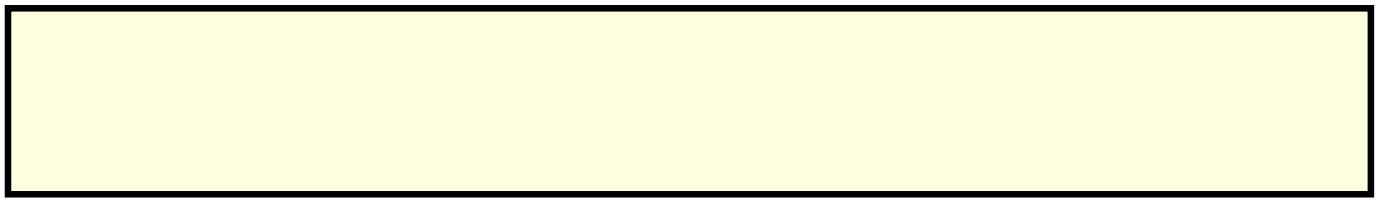
-Taken from 11 Horrifically Violent Animal Mating Rituals, Oddee.com

http://www.oddee.com/item_98073.aspx

SO... don't concentrate on the act, but the process of heredity.

What We Know Now...

Because of Darwin and Mendel we know that individuals are a conduit for population evolution. Individuals get their genes for ancestry, and pass their genes to the next generation in varying frequency based on their ability to survive. This makes the population stronger as a whole.



This is know as **population genetics.**