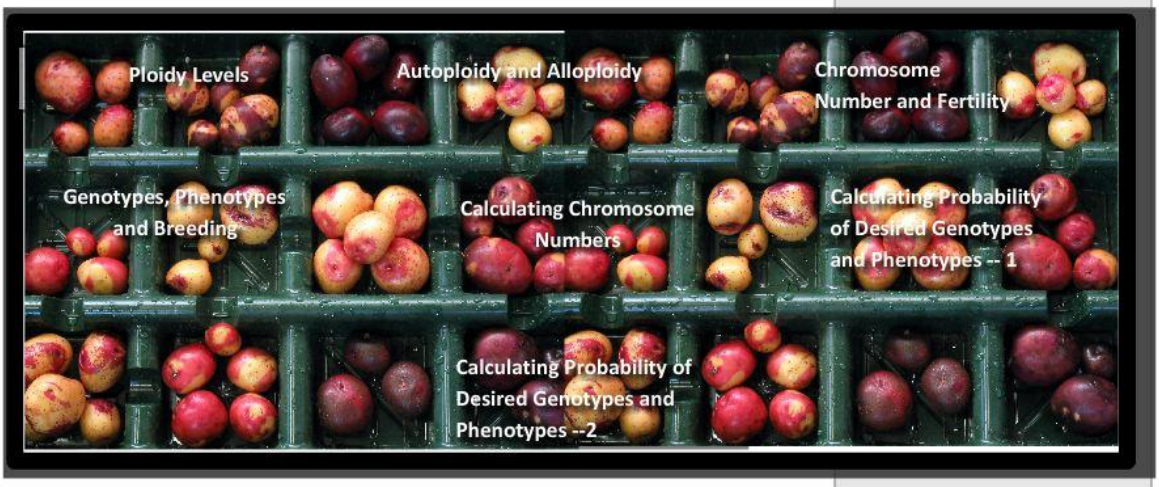
Introduction to Polyploidy: Potatoes

Click on any button to begin. Make sure to view all pages in the activity. Also take time to complete the review questions provided in the activity.

Acknowlegements



Information for Teachers

Polyploidy occurs when an organism has more than 2 sets of chromosomes. In plant breeding this can be both an advantage or a disadvantage, depending upon the goals of the program. This activity will use potato, as a case study to help demonstrate the unique

Additional Resources

Summary of Polyploidy

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Ploidy Levels

Potato, just like any other plant, has DNA that is condensed into structures called chromosomes. Living organisms differ from each other both in the numbers of chromosomes they have, as well as in the number of chromosome sets. Humans, for example, have two sets of 23 chromosomes. This means that humans have two copies of chromosome number four, two copies of chromosome number six, and so on. Having two complete sets of chromosomes makes humans diploid. In contrast, cultivated potatoes have four sets of 12 chromosomes, for a total of 48 chromosomes, and are said to be tetraploid (tetra means 4). Now, do all cells in potato contain 48 chromosomes? No. Just as in diploid species, sex cells in the potato (eggs and pollen) contain only half of the genetic information of somatic cells. So each pollen and egg cell has only 24 chromosomes. Each sex cell contains two copies of each of the 12 chromosomes.

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Ploidy Levels continued

There are certain advantages that come with polyploidy, i.e., having more than two sets of chromosomes). Polyploid plants tend to have more genetic diversity, larger flowers, and larger fruits. Carrying additional copies of each gene helps protect polyploids from the negative effects of mutation, and allows otherwise self-incompatible species (like diploid potato) to self pollinate (tetraploid potato can be selfed). Other examples of polyploids include wheat, strawberry, cotton, oats and sugar cane. Some animals and insects are also polyploid, such as bees, wasps and certain fish.

Wheat

Oats

Strawberries (Photo courtesy of Dr. Ellen Paparozzi and Liz Conley)

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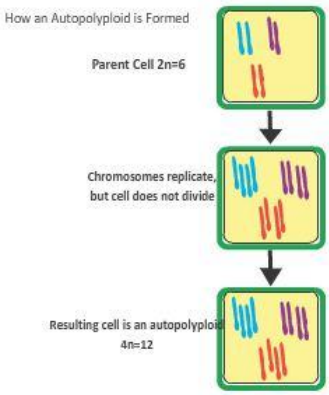
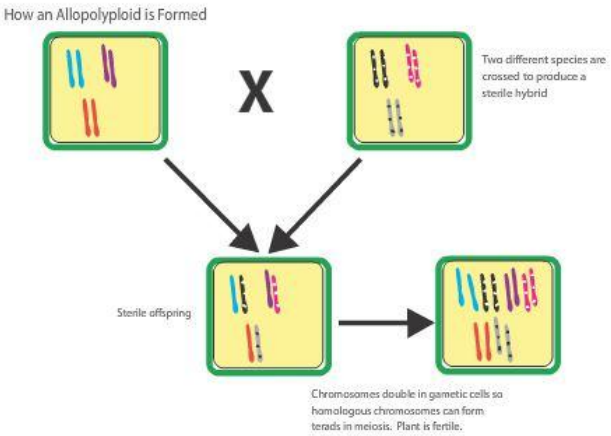
Autoploidy and Alloploidy

One question you may be asking is "how do organisms like potatoes end up with more than two sets of chromosomes?" There are two types of polyploids.: autopolyploids (autoploids) and allopolyploids (alloploids).

Autopolyploidy results when a cell fails to divide properly, so that the cell ends up with twice as many chromosomes as it had before. If this mistake in cell division happens during meiosis, the extra set(s) of chromosomes will be passed on to the offspring. Allopolyploidy can result from a cross between two different species. The resulting offspring is typically sterile because its chromosomes cannot pair to complete the process of meiosis. This is because there is only one set of chromosomes from each species, rather than two. If the chromosome number spontaneously doubles, however, perhaps because of a mistake in cell division, the chromosomes can pair to complete meiosis and the resulting allopolyploid is now fertile.

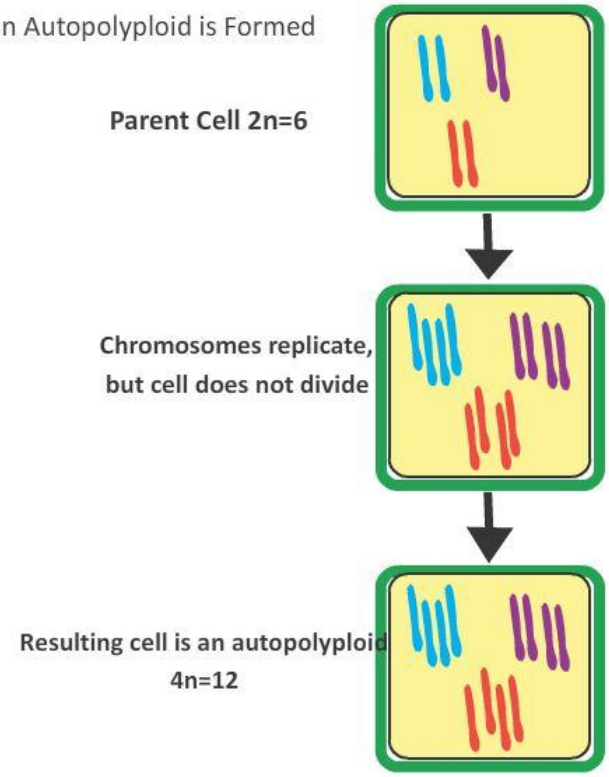




Introduction to Plant Breeding Learning Activity: Soybean

How an Autopolyploid is Formed

Go Back to Autoploidy and Alloploidy Page



Introduction to Plant Breeding Learning Activity: Soybean

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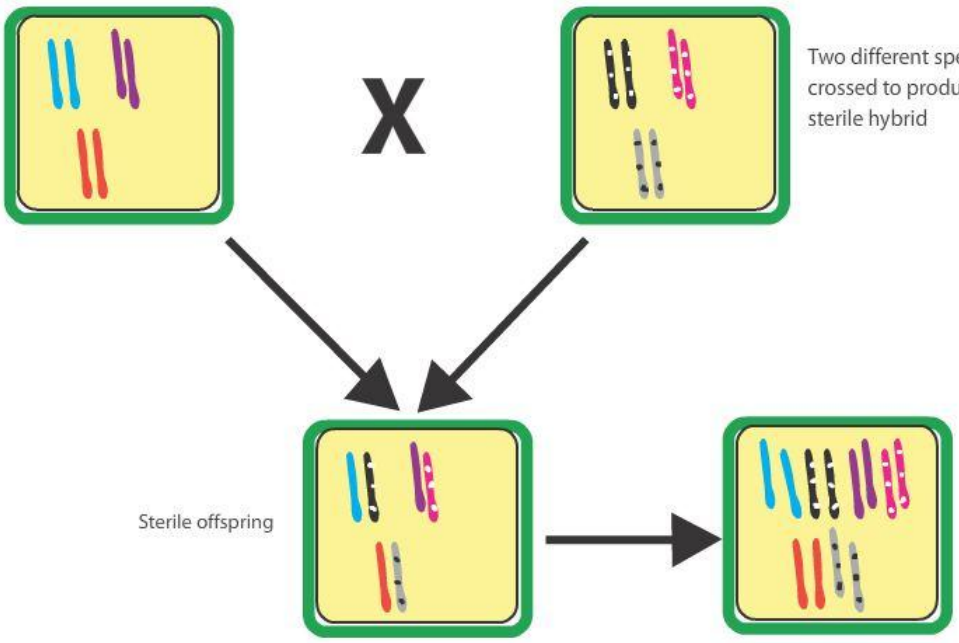
How an Allopolyploid is Formed



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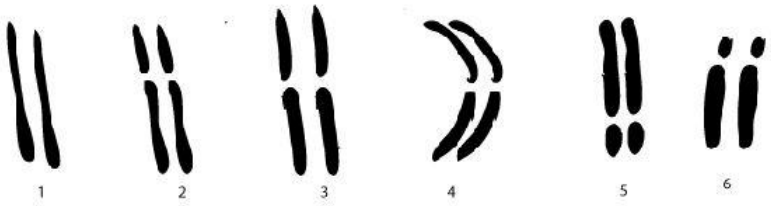
Chromosome Number and Fertility

Alloploid with one of each chromosome. No homologous chromosomes for pairing.



Diploid organism. Two of each of the chromosomes. Homologous chromosomes can pair.

As mentioned previously in the discussion of alloploids and autoploids, chromosomes must be able to make a "pair" in order to undergo meiosis. So does this mean that you just need an even number of chromosomes to have meiosis? Not quite.

Each individual chromosome needs to be able to "find its partner" or more accurately, pair with its homologous chromosome. So if a plant has 6 chromosomes all with different DNA sequences they will not be able to pair with each other. The plant would need to have 2 copies of each of the 6 chromosomes (diploid number of 12), because pairing during meiosis is based on the similarity of DNA sequences between homologous chromosomes.

When an organism has an odd number of chromosome sets (e.g., triploid or pentaploid) it is usually sterile, as chromosomes cannot pair properly during meiosis.

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Genotypes, phenotypes and breeding

"Genotype" is the term used to describe the actual genes a potato (or any organism) inherits from its parent and "phenotype" refers to its physical characteristic such as tuber color. Looking at potato tuber skin color, there are three possible phenotypes: red, purple or white.

Three unlinked genes - D (developer), R (red) and P (purple) - determine potato tuber skin color. To have red tuber skin, a potato needs dominant alleles at D and R. To have purple skin, a potato needs dominant alleles at D and P. Potatoes that have dominant alleles of all three genes are also purple, as the P gene is "epistatic" to R (presence of purple pigment masks presence of red pigment). If a potato has only recessive d alleles it will not be able to develop pigment, regardless of what alleles are present at R and P.

Because of the way these three genes interact, it is possible for a potato breeder to cross two white potatoes and end up with offspring that are red or purple. That is, if one parent has D but not P or R, it will be white. Cross it with a (white) potato that lacks D, but has R and/or P, and some of the progeny will end up with D and R (and thus be red), or D and P (and thus be purple).

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Genotypes, phenotypes, and breeding continued

Potato is an autotetraploid, which means that there are four copies of each gene. For example, a plant with a dddd RRrr Pppp genotype would produce tubers with white skin because it has four recessive d alleles. Although it has the necessary alleles to produce red and purple pigments, it cannot develop any color because it lacks the dominant D allele.

When developing red-skinned potatoes, breeders like to use parents that have many copies of D and many copies of R, e.g., cross DDDd RRrr pppp x DDdd RRRR pppp, because that way most offspring will receive at least one copy of D and one copy of R.

To revisit the information about polyploids **click here**.

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Calculating Chromosome Numbers

Understanding that polyploids have more than 2 sets of chromosomes in their somatic cells, let's practice some chromosome number calculations.

Q: We know that cultivated potatoes are tetraploid with a total of 48 chromosomes. How many chromosomes are in each set?

Click Here for Answer

Q: Now, how many chromosomes would be in a potato pollen cell? What would be its ploidy level?

Click Here for Answer

Q: Bread wheat is a hexaploid with 7 chromosomes in each set. How many total chromosomes does a somatic cell in a wheat plant have?

Click Here for Answer

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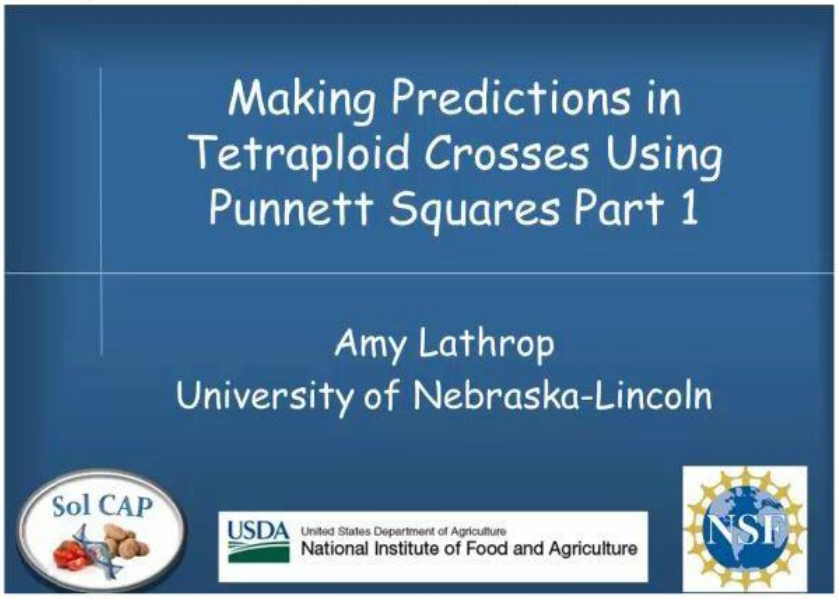
Calculating Probability of Desired Genotypes and Phenotypes



Click Here to View Video

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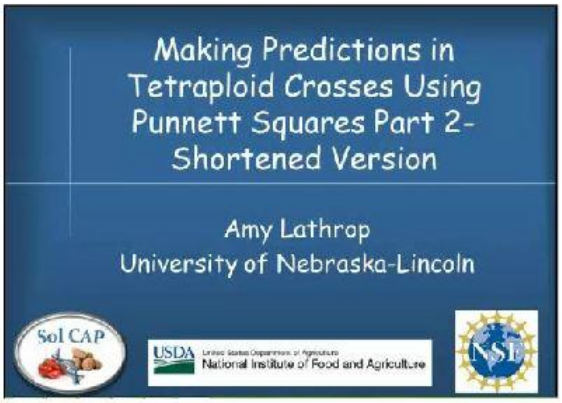
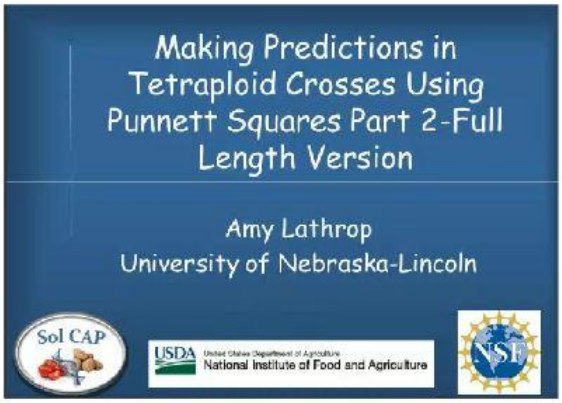
Calculating Probabilities of Desired Genotypes and Phenotypes--2

The shortened version of this video will introduce the problem to you and allow you to check your answer after trying the calculation on your own. The logner video will take you step by step through the calculation.



Click Here to View Shortened Video



Click Here to View Full Length Video

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Summary

Polyploid organisms have more than 2 sets of chromosomes. There are two types of polyploids: allopolyploids (alloploids) and autoployploids (autoploids). Ploidy levels can affect fertility. Polyploids with an odd number of chromosome sets, like triploids, are sterile, because their chromosomes are unable to pair properly during meiosis. Sterility can be advantageous in certain situations, such as developing seedless watermelons. Polyploid plants often have larger fruits, larger flowers and increased genetic diversity compared to their diploid counterparts. Nevertheless, the increased genetic variation in polyploids can make breeding difficult as it is more difficult to develop new varieties with desired combinations of alleles. Once a specific combination of genes is obtained, polyploids such as potato are often reproduced asexually in order to maintain that specific genotype. Making genetic predictions in autopolyploid crosses is also a bit more complicated than in diploids due to the larger number of possible gametes that can result.

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Additional Resources

Crossing Potatoes

http://www.youtube.com/watch?v=SQddcAiGBhE

http://www.youtube.com/watch?v=DXSPYFgJiRQ

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Acknowlegements

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