**Polyploidapalooza**

**Module 2: Mitosis and Meiosis in polyploid species**

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**Abstract**

Polyploidy plays an important role in the evolution of life but is often overlooked in undergraduate classrooms. In this series of modules, we explore how polyploid species are formed, how they evolve and adapt, and their economic and conservation importance. Module 2 explores cell division in polyploid animals, focusing on the differences between allopolyploids and autopolyploids, as well as odd versus even ploidy levels.

**Objectives**

* Review diploid cell division (mitosis and meiosis)
* Identify the key differences between allopolyploid and autopolyploid cell division
* Identify the key differences between cell division in diploids, triploids, and tetraploids

**Logistics**

Department: Biology

Level: Upper undergraduate

Prep time: 0 hours

Class time: 1-2 hours

**Pre-module preparation**

List of terms - come back to these terms if you need to while reading the text.

**Mitosis**—cell division that results in a clone of the original cell

**Meiosis**—cell division that results in gametes (eggs, sperm, spores)

**Homologous chromosomes**—chromosomes that share the same genes at the same loci positions

**Polyploidy**—having more than one pair of homologous chromosomes

**Autopolyploid**—polyploid formed through genome duplication within a species

**Allopolyploid**—polyploid formed through hybridization between two species

**Diploid**—containing two complete sets of chromosomes (one from each

parent)

**Triploid**—containing three complete sets of chromosomes (one from one

parent

and two from the other)

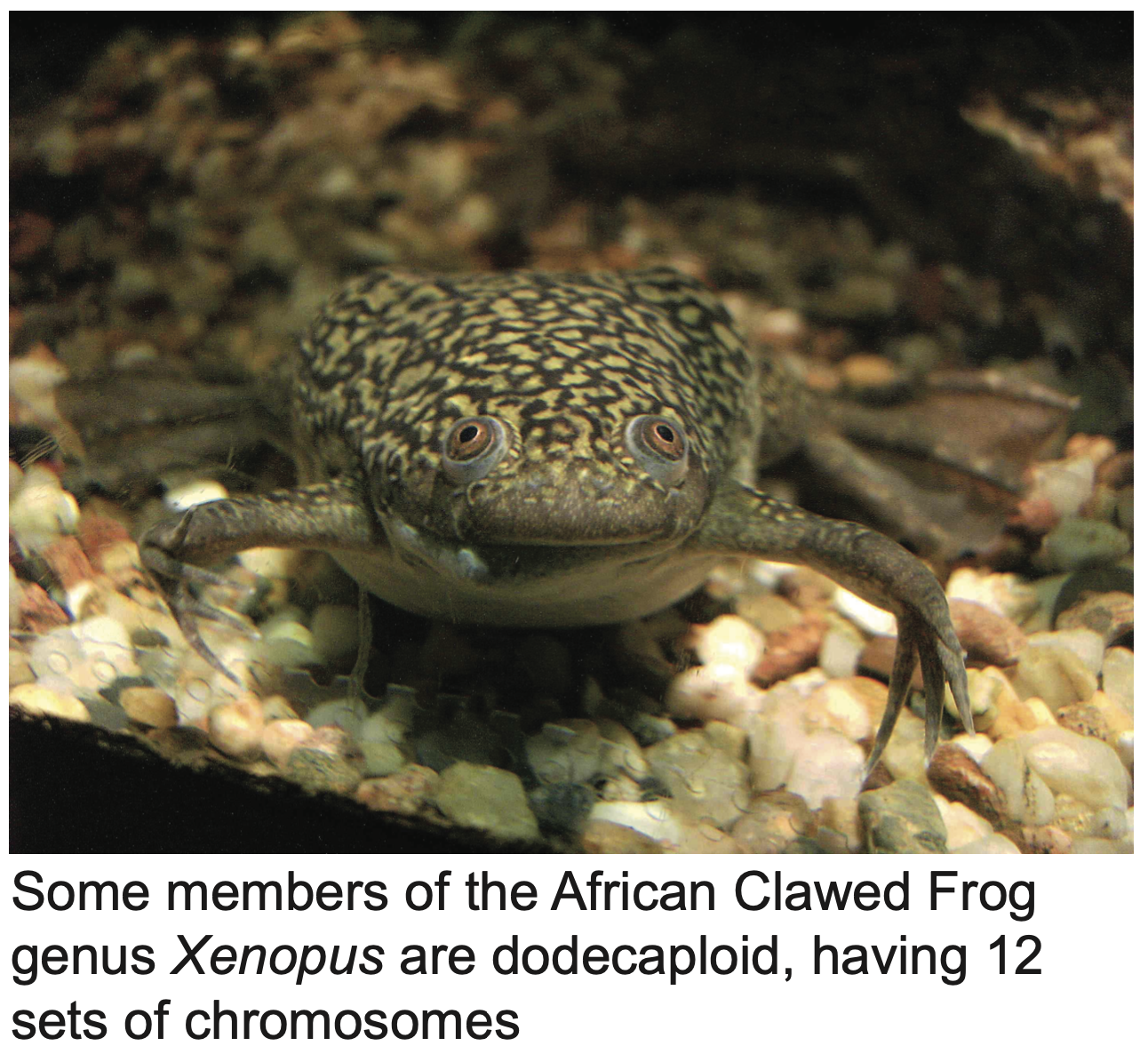
**Tetraploid**—containing four complete sets of chromosomes (two from each

parent)

**Sub-genome**—one full genome that is part of a duplicated polyploid genome

**Introduction**

Cell division is crucial to the survival and reproduction of eukaryotic organisms. Throughout the body, cells multiply every day by dividing and creating copies of themselves. This process, called **mitosis**, allows the organism to grow and replace old cells that are no longer functional. In reproductive organs, cells divide through **meiosis** to create gametes (i.e., egg and sperm cells). During meiosis, an extra round of division takes place so that only half of the original DNA remains in each cell.

Humans, along with many other animals, are **diploid**, meaning that they have two sets of DNA (one from each parent). These sets of DNA take the form of pairs of **homologous chromosomes**, each with a version of the DNA from the egg cell or sperm cell. During metaphase of mitosis and metaphase 1 of meiosis, homologous chromosome pairs line up at the metaphase equatorial plate to be divided into two newly formed, duplicated cells. 

But what happens if there are more than two homologous chromosomes? This is a problem that polyploid species, which inherit more than one copy of DNA from each parent, must deal with every time they go through cell division. Different kinds of polyploid organisms (i.e., **allopolyploids** and **autopolyploids**) have solved the problem in different ways. It’s even more complicated if there is one set of homologous chromosomes from one parent and two or more from the other, leading to an uneven number of chromosomes in each set. In this module, we will learn about how cell division occurs in polyploid species and the effects that even and odd ploidy levels have on mitosis and meiosis.

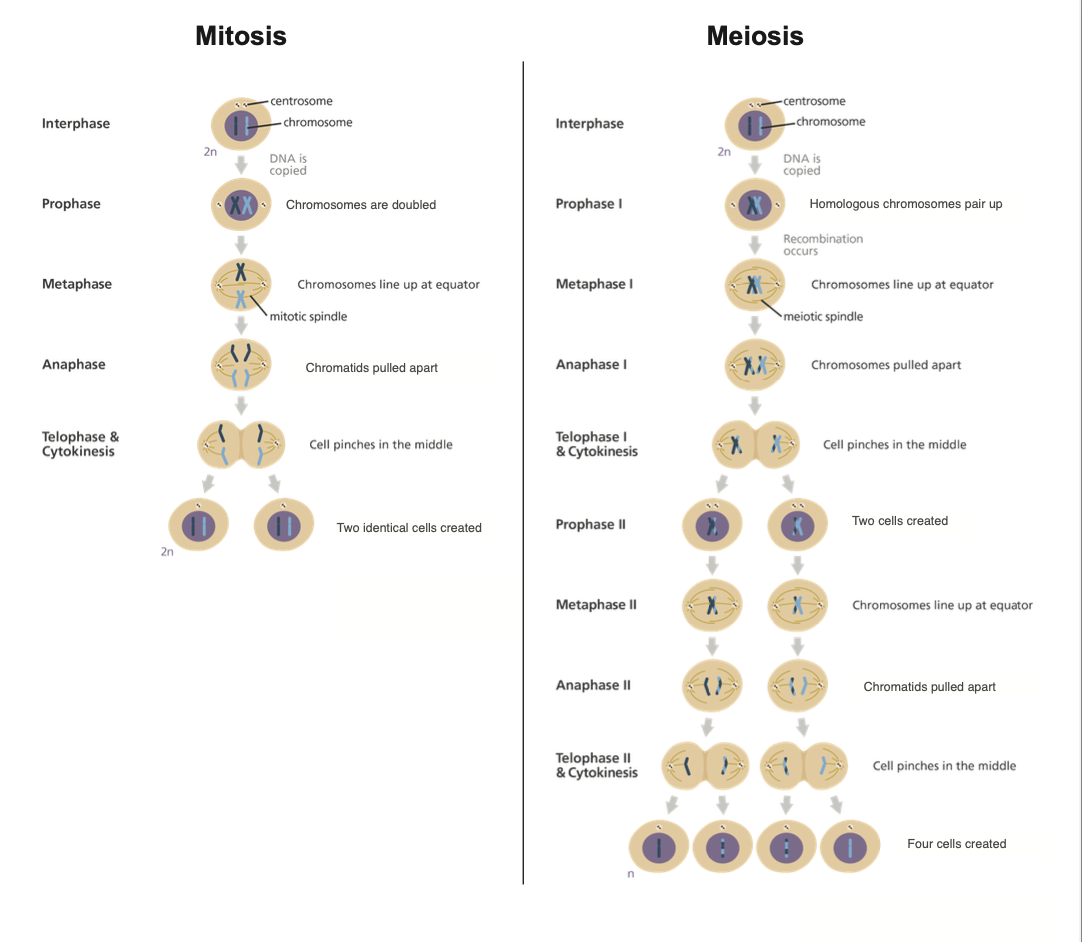
**A brief review of diploid cell division**

You probably remember many of the details of mitosis and meiosis from your introductory biology classes. We will review the steps of each for diploids to facilitate the comparison to polyploids in the rest of the module.

***Mitosis*** – Used for the duplication of somatic cells resulting in organism growth and cell replacement. The end result of mitosis is two cells that are identical to the original parent cell.

***Meiosis*** – Used to create gamete cells such as eggs and sperm. The cell goes through two rounds of division, resulting in four cells, each with half the amount of DNA that was in the parent cell.

Below is a diagram of mitosis and meiosis. Please take a look at the diagram and answer the questions that follow.



Please answer the following four (4) questions related to the Introduction and figure above:

1. The chromosomes that pair up in prophase I of meiosis are (circle one):

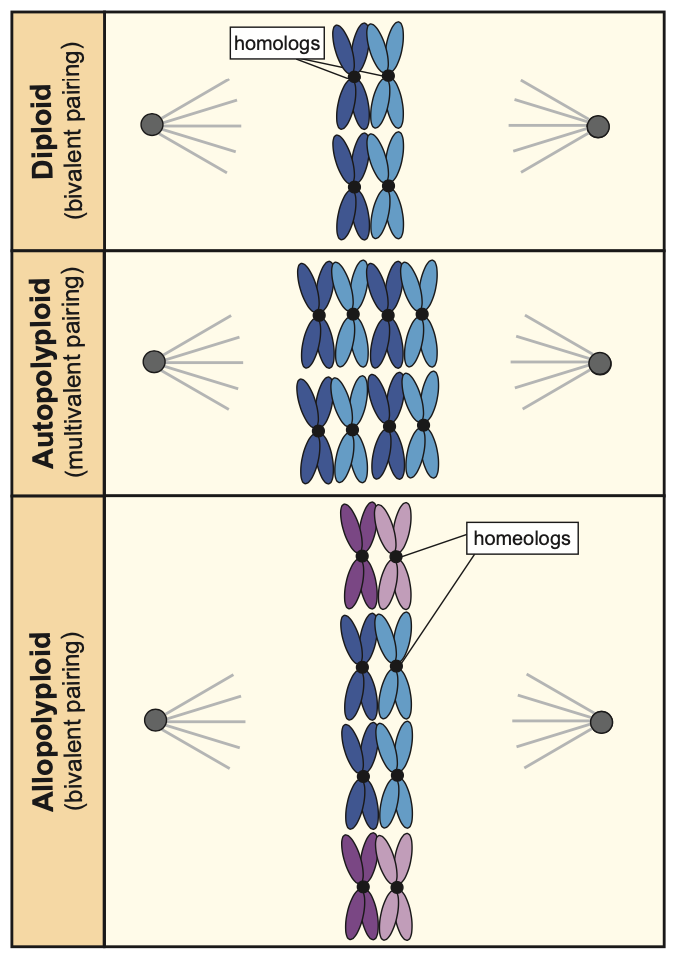
Homologous Non-homologous

1. Provide a definition of the word homologous as it relates to chromosomes.
2. At what stage in the cell division process do homologous chromosomes pair up?
3. At what stage in the cell division process do homologous chromosomes line up at the equatorial plate?

**Polyploid cell division**

Polyploid species have more than two copies of their DNA and must navigate the cell division process differently than diploid species. There are two main categories of polyploids. **Autopolyploids** are formed through duplication of the genome within a species, meaning that all of the homologous chromosomes are highly similar to each other. **Allopolyploids** are formed through duplication of the genome during a hybridization event between two different species, meaning that some of the homologous chromosomes come from different species and can be very different from each other. Because of these differences, the two categories of polyploids approach cell division differently, which we discuss below.

While this module focuses on cell division in established polyploid species, it is interesting that many polyploids are formed through errors during meiosis. These errors cause the final products of meiosis to be unreduced (i.e., having more than one entire copy of the parental DNA), meaning that this extra copy of the genome is passed on to the offspring. This is covered in detail in Module 1: The formation of polyploid species.

***Autopolyploids*** –Because autopolyploids have identical pairs of genomes (**sub-genomes**) that are duplicated within the same species, it is often the case that all of the highly similar homologous chromosomes pair up together during meiosis. This is called multivalent pairing and can be seen in the middle panel on the right, with the diploid version displayed above for comparison. Multivalent pairing can be disadvantageous because it can lead to a high rate of error during cell division, occasionally leading to cells with too many or too few chromosomes. Over a long period of evolutionary time, many autopolyploids will develop bivalent chromosome pairing similar to a diploid organism. 

***Allopolyploids*** – Because allopolyploids have sub-genomes that come from two distinct species, they are much more likely to form bivalent pairs during cell division, similar to a diploid. This is a result of the higher number of differences between homologous chromosomes from the two parental species (called homoeologs in a polyploid organism). This can be seen in the figure to the right, where homoeologous chromosomes in blue come from one parental species, and those in purple come from the other parental species.

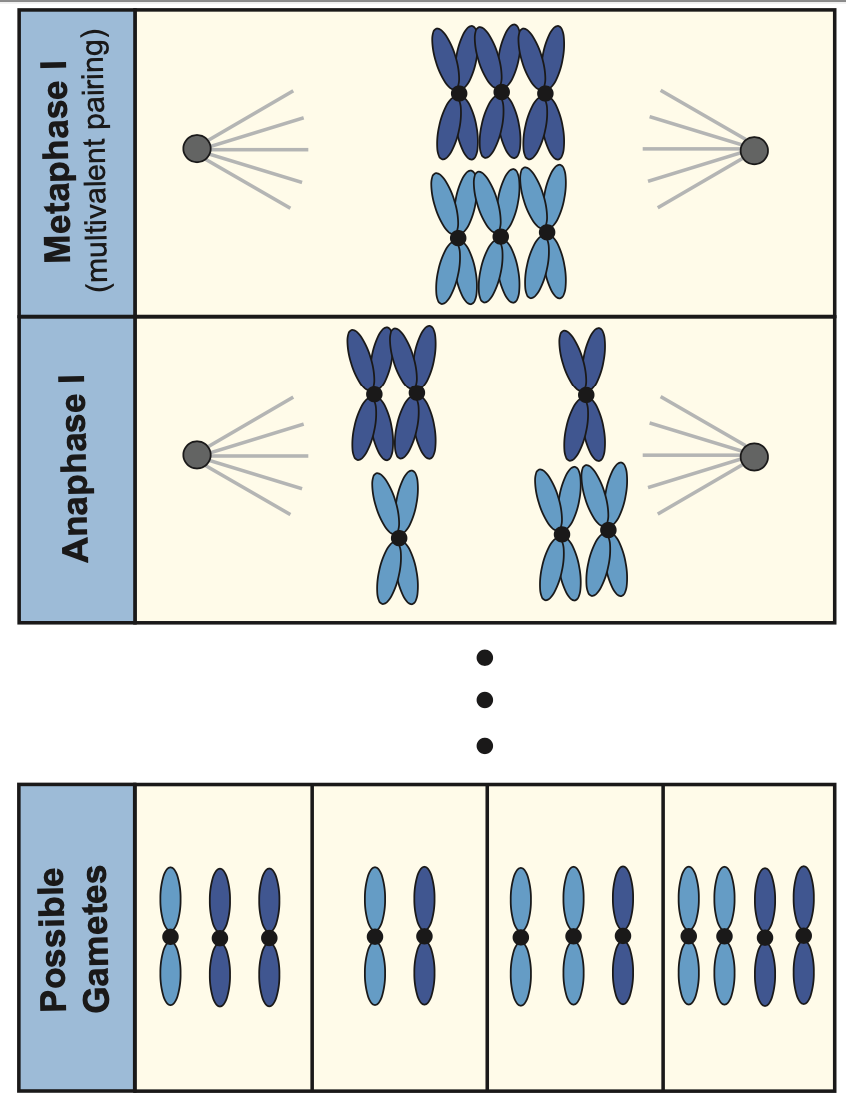
Please answer the following four (4) questions related to what you just read:

1. What stage of mitosis/meiosis does the figure above represent?

Interphase prophase metaphase anaphase

1. What are the benefits of bivalent vs multivalent pairing during cell division?
2. What is the difference between a homologous and a homoeologous chromosome?
3. Draw the stages of meiosis from prophase I to anaphase I for an autopolyploid and an allopolyploid, making sure to label the homologous and homoeologous chromosomes.

**Effect of Triploidy**

In Module 1, we learned that **triploids** are often either partially or wholly sterile due to difficulty pairing during meiosis. As you can see in the diagram to the right, the three homologous chromosomes of the triploid undergo trivalent pairing during prophase and metaphase of meiosis I. As these chromosomes are pulled apart during anaphase I, one or two of the homologs are pulled to one side of the other. However, the number going to each side is completely random so that the final gametes may have three copies of one chromosome and zero of another. If you extrapolate this across the entire set of an organism's chromosomes, the likelihood of having gametes that have an even distribution of all of their chromosomes is extremely small. This is why triploids are rare in the wild, however, some plants and animals have found ways to work with this unusual number of chromosomes, for instance, through parthenogenesis (i.e. reproduction without fertilization) or vegetative reproduction (i.e. cloning in plants). 

Fun fact: While the likelihood of viable gametes formation in a triploid organism is low, the gametes that do make it play a surprisingly important role in the formation of **tetraploid** organisms. This process is called the “triploid bridge” and occurs when triploid gametes that have two copies of every chromosome (like in the fourth panel of possible gametes in the figure above) combine to create a tetraploid zygote.

Please answer the following two (2) questions related to what you just read:

1. How many homologous chromosomes does a diploid have? A triploid? A tetraploid?
2. What makes triploid meiosis so much more complicated than diploid or tetraploid?

**Acknowledgments**

We would like to thank Makenzie Mabry, Michelle Gaynor,, Libby Ellwood, and Alva Mihalik for their thoughtful feedback on these modules.

**References**

Mitosis and Meiosis figure adapted from:

<https://www.yourgenome.org/facts/what-is-mitosis>

<https://www.yourgenome.org/facts/what-is-meiosis>

Homeolog and possible gamete figures created by Kaitlin Allen

Xenopus: "[File:Gemeiner Krallenfrosch - Xenopus laevis - aus Afrika.jpg](https://commons.wikimedia.org/w/index.php?curid=57190789)" by Benedikt Rauscher is licensed under [CC BY-SA 3.0](https://creativecommons.org/licenses/by-sa/3.0/?ref=openverse).

Autopolyploid, allopolyplod, diploid figure: Adapted from ​​Otto, S. P. (2007). The evolutionary consequences of polyploidy. *Cell*, *131*, 452–462.