EEB 3240. LIFE CYCLES

Lab 1. Jan. 18, 2023

Purpose: This exercise is designed for you to develop a better understanding of the different stages of life cycles. This exercise consists in a purely theoretical approach to this objective. This exercise is a review of plant life stages, and of the fundamentals of genetics. It will allow you to become familiar with the terminology, and thereby follow the discussion on the evolution of life cycles, which is at the core of the evolutionary history of land plants, and also of the evolution of reproductive strategies, since this may be one of the drivers of plant evolution.

You should be able to complete this on your own; in fact, you would assess better your understanding, and hence learn more, working through it as it is. However, some questions (marked with an *) ask for particular terms and to answer these you would likely consult your intro biology text book.

NOTE: you should submit this assignment at the beginning of the lecture on Jan. 28. The quality of your presentation will matter: write clearly, and draw clean life cycles. DO NOT <u>draw any actual structures, such as a flower.</u>

A life cycle in sexual reproducing organisms is the complete sequence of phases in the growth and development of any organism from the zygote formation to the gamete formation.

The key words are: **zygote** and **gametes**, two stages characterizing any life cycle in sexual reproducing organisms. If you were given a cell, and asked whether this cell was a zygote or a gamete, what feature would you use to differentiate them?

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This difference is the key to understanding the concept of life cycles. Why? Well, imagine now a life cycle reduced to these two stages. How would these stages be connected in an organism undergoing <u>sexual reproduction</u>? In other words, what mechanisms account for the transition from one stage to the other? *No answer here, we will work through that.*

Let's start with the transition from "gamete" to "zygote". The zygote has twice the number of chromosomes found in each gamete. How is this achieved? Sexual reproduction involves the **fusion** of two cells. These cells are the *gametes*. "Gamete" is a generic term. An egg is a gamete and so is a sperm cell. Eggs and sperm cells are strikingly different in morphology (this is called **____________), but sometimes, the gametes cannot be told apart (**___________). The fusion of gametes, also called *___________, thus leads to a cell, which holds two sets of chromosomes, one from each gamete.

Remember that a life cycle is a "complete sequence of phases". It is thus necessary for the zygote-phase to be connected to the gamete-phase. A transition from a cell with two sets of chromosomes to one with a single set is thus needed. Simple! The zygote only has to be divided in two cells. In theory this is correct, but is practice, the mechanism is somewhat more sophisticated than a simple division.

Take a step back and think about the function of sexual reproduction. What are the advantages of sexual versus asexual reproduction? ____

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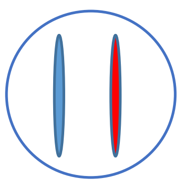
Exercise: draw two gametes each with two chromosomes, using red and blue to represent these chromosomes. Mark the chromosomes from gamete A by a median cross. In total you should have two red and two blue chromosomes, one of each in each cell.

A



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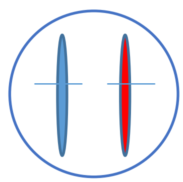
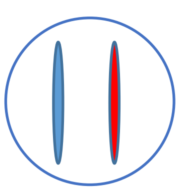


Syngamy occurs, and all four chromosomes occur in the diploid, forming a pair of red or blue chromosomes. These are pairs of homologues, each with an identical set of genes. Each pair has a chromosome inherited from the one of the parents. So you should have one red and one blue chromosome with and one without the median cross.

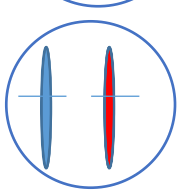
When both homologues are present in a cell, the cell is said to be diploid; when only one is present, the cell is haploid. So, the gametes are ___________, and the zygote is ____________.

For the diploid stage to yield a haploid stage, and hence complete the life cycle, the cell must divide. Draw two of these diploid cells. Each of these is dividing. Although in each case the daughter cells should have one red and one blue chromosome, the four daughter cells (two from each division) may not be the same. (so the zygote is undergoing meiosis; depending on how chromosomes aligned in Meiosis one, two outcomes are possible with regard to the distribution of parental gametes).

Parental gametes → Zygote → Possible daughter cells



A



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Chromosomes occur in complements in a **diploid** cell (e.g., a zygote). A "reductionnary" division would lead to the daughter cells holding one of two sets of chromosomes. The resulting cells may **not** be identical to the parental gametes, as chromosomes could be **reshuffled**: the red and blue chromosome of the gamete A may not be occurring in a single cell upon division of the zygote. Thus, how many different **genotypes** may you see among daughter cells? __________

As you know, characters (morphological or others) are defined by specific sequences of nucleotides in the DNA. These sequences may differ among cells of a same species. Imagine a haploid organism that could be characterized by two traits: shape of leaf (rounded or pointed) and length (short vs long). Consider two individuals, one sith short rounded leaves and the other with long point ones.

Imagine that these genes "shape and length" are on the same chromosome, for example the red chromosome in the example above. Would you ever expect to find a plant with long rounded leaves?
Explain: ____

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Consider the red chromosome of gamete A to bear the genes for yellow and round, and that of gamete B for red and wrinkled. How would you obtain a chromosome with red and round?

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A process similar to this occurs in cells undergoing **meiosis**, and is revealed by the presence of **chiasmata**. What are chiasmata?

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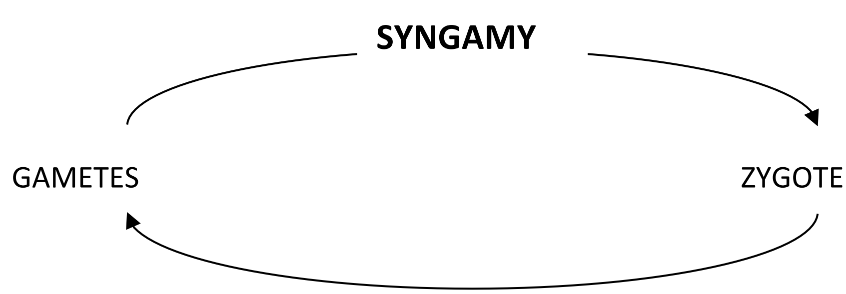
Meiosis is a set of **two successive divisions** in which the chromosome number is reduced from diploid (2N) to haploid (N). Meiosis thus differs from the simple division we imagined above, by the occurrence of one additional division. It is during this division that chiasmata are established between homologous chromosomes.

Because meiosis comprises 2 divisions, a zygote undergoing meiosis always yields 4 daughter cells. We have now linked two fundamental stages of a life cycle involving sexual reproduction:



MEIOSIS

Based on this life cycle, and try to only refer to this diagram and what was said before, how would you define zygote and gametes? Your definition should include cellularity, ploidy level, and process.

Zygote: ____

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Gametes: ____

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This is the simplest life cycle in which sexual reproduction occurs. A species characterized solely by these two phases would be a unicellular alga.

Many plants are, however, multicellular, that is their body is composed of numerous cells. Such multicellular body forms through the proliferation of cells. Imagine that the cells resulting from meiosis did not function as gametes, but instead remained **vegetative**. How would you develop a multicellular organism from these cells. If these cells merely aggregated, the result may seem like a multicellular organism, but would actually be a colonial organism composed of unicellular individuals. A multicellular organism starts out as a single cell that undergoes cell divisions.

Would meiosis be the mode of cell division? ______. Justify your answer: _______________

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The proliferation of cells relies on the duplication of the parental cell. What is needed for the daughter cells to be genetically identical to the parental cell, i.e., for them to have the exact same number of chromosomes as in the parent?

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How is this mode of cell division called? ____

For a cell to undergo mitosis, does it have to be a diploid cell? ___. Justify: ________________

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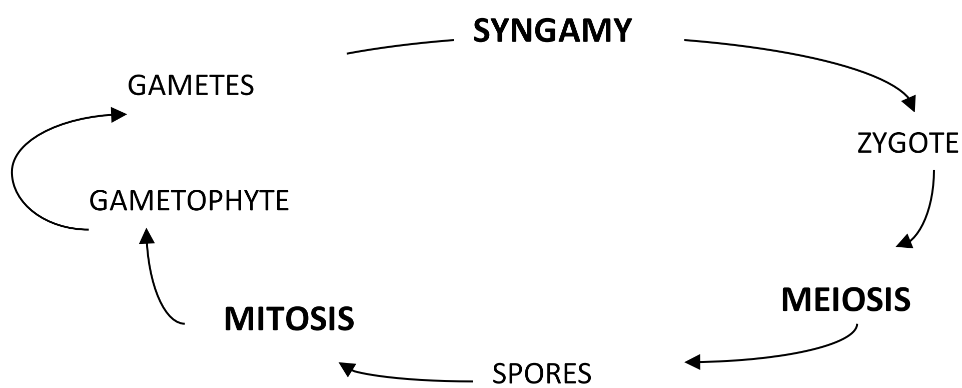
We could thus imagine that the cells produced through meiotic division of the zygote, undergo mitosis, thereby developing into a multicellular organism.



Since the term gamete is restricted to "*haploid reproductive cells*" a new term is needed for the cells derived from the zygote and developing into a gametophyte. These are called spores. A gametophyte is thus a haploid multicellular organism developed from a spore. If involved in sexual reproduction, this organism will have to develop reproductive cells (i.e., the gametes).

In land plants as well as some aquatic algae, the reproductive cells are developed in specialized tissues or organs. Such **gametangia** occur only in anisogamous plants. We can thus distinguish a male gametangium (antheridium) from a female gametangium (archegonium). Are gametangia haploid or diploid? ______________. Justify:

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Draw a life cycle with a multicellular gametophyte developing female and male gametangia:

Parallel to a multicellular gametophyte, we could imagine that the zygote develops into a multicellular phase prior to undergoing meiosis. The diploid stage emanating from the zygote is called a sporophyte.

Draw a life cycle with a multicellular gametophyte developing female and male gametangia and a multicellular sporophyte (basically take the one form the previous page and add any new stage):

Similarly, plants with multicellular sporophyte bear differentiated tissues wherein which spores are formed. These "organs" are called sporangia (one sporangium). Are sporangia haploid or diploid?____ Justify: ____

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In what stage of the life cycle is sex then expressed? ______________. Imagine that sexes are separated, and never occur on the same individual. Would a spore from such species carry the genes for one or two sexes?

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It is thus possible that spores come in two kinds, one that will give rise to male gametophytes, and the other to female gametophytes. In cases were spores are of two kinds, they could be produced in a single sporangium (e.g., in mosses), or be developed in two distinct sporangia, a microsporagium giving rise to the "male" spores, and a megasporangium holding the "female spores".

Draw a life cycle with a gametophyte developing female and male gametangia and a multicellular sporophyte with its two types of sporangia (basically take the one form the previous page and add any new stage):

When a single sporangium is involved in spore production, the plant is said to be **homosporous**; in contrast to a **heterosporous** plant, where two types of sporangia are differentiated. The most elaborate life cycle in terms of the diversity of stages is that heterosporous plants. Why is this important? Because all seed plants are heterosporous, and heterospory is undoubtedly a major innovation in the evolution and diversification of land plants.

However, as we will see, and perhaps you remember from your previous biology/botany courses, one more “invention” will be needed, for plants to be able to protect their embryo, and enhance its chances of survival. The origin of the seed, a structure we depend on daily as a food source (flour from grains, beans, corn,…). That story will be told in class, and now you should be prepared for it.

CONCLUDING REMARK. The evolution of the life cycle, how you developed a complex life cycle with many stages, starting from one that had only two stages, is a great example of the central theory of evolution, namely descend by modification: all innovations you developed during this exercise rest on the stages that were present. You should now see how life cycles with different complexities are connected through evolutionary time.