Hand-out 1: The life cycle (due next Tuesday)

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. Although the exercises may at times seem repetitive, you are encouraged to proceed through all of them, as this will allow you to become familiar with the terminology

A life cycle 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 of any life cycle. How would you define these terms?

Zygote: first diploid cell resulting from the fusion of a sperm cell and an egg (or following sexual reproduction)

Gametes: **haploid cells generated via mitosis in sex organs (gametangia) that will be dispersed and will fuse to form the zygote**

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? **their ploidy (haploid or diploid)**

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 sexual reproduction? In other words, what mechanisms account for the transition from one stage to the other?

Let's start with the transition from "gamete" to "zygote". The zygote has twice the number of chromosomes than the 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. Eggs and sperms are strikingly different in morphology (this is called **anisogamy**), but sometimes, the gametes cannot be told apart (**isogamy**). The fusion of gametes, also called **syngamy**, thus leads to a cell that bears two sets of chromosomes, one from each gamete.

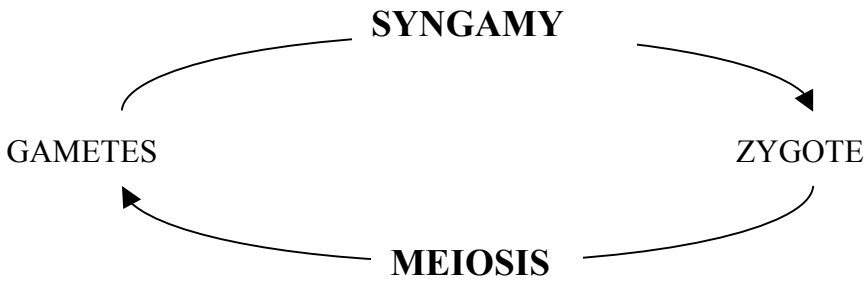
Remember that a life cycle is a "complete sequence of phases". It is thus necessary for the zygote-phase to be connected to the gamete-phase. A transition from a cell with two complements to one with a single set of chromosomes is thus needed. Simple! The zygote only has to be divided in two cells. In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

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 there are two divisions in meiosis, a zygote undergoing meiosis always yields four daughter cells.

If the parents are genotypically distinct (i.e., not clones), it is highly likely that none of the daughter cells is genetically identical to either parent, and that any two daughter cells are identical (this is why, from an evolutionary point of view, sexual reproduction is "better" than asexual [clonal] reproduction).

We have now linked two fundamental stages of a life cycle involving sexual reproduction:



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

Many plants are, however, multicellular, that is their body is composed of numerous cells. Such multicellular organism 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 organim, but would actually be a colonial organism composed of unicellular individuals. A multicellular organism is obtained by the cells undergoing cell division.

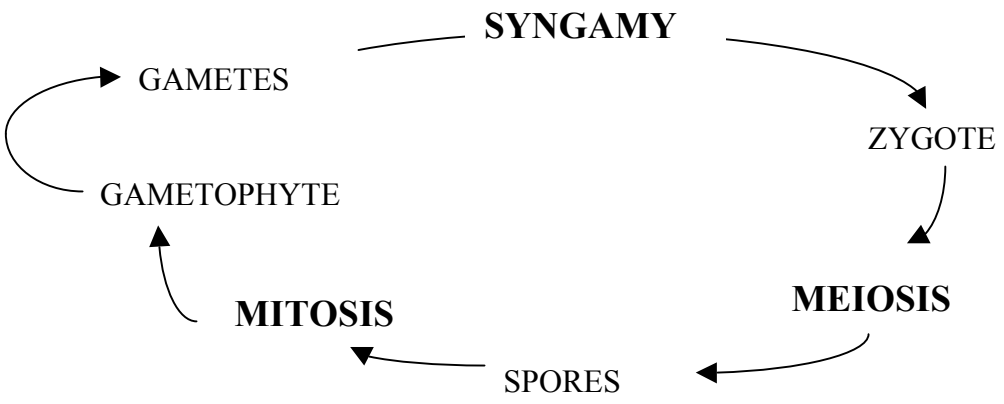
Would meiosis be the mode of cell division? **NO**. Justify your answer: **Meiosis results in the halving of the number of homologs (chromosomes that carry the identical set of genes) following each set of divisions; haploid cells cannot undergo meiosis. A multicellular body is born through mitotic divisions of cells, whereby identical cells are being generated and added to the body.**

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? **The genome has to be copied and then divided, whereby the same set(s) of homologs is/are transmitted to the daughter cells.**

How is this mode of cell division called? **Mitosis**

For a cell to undergo mitosis, does it have to be a diploid cell? **No**. Justify: **Since the chromosomes are first replicated and the two copies then sorted between the daughter cells, it does not matter if the mother cell is haploid or diploid; following mitosis the chromosome number per cell has not changed.**

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: the gametophyte. A gametophyte is thus a haploid multicellular organism. If involved in sexual reproduction, this organism will have to develop reproductive cells (i.e., the gametes).

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 and sporophyte:

Same as above but with mitosis following the zygote stage, whereby a multicellular diploid structure/body is formed prior to meiosis

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? **haploid** Justify: **Gametangia are always formed by the gametophyte, which is developed via mitotic divisions from a spore, which results from meiosis and hence is always haploid. Therefore gametangia are always haploid**.

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

Same as above but with the gametophyte developing male ad female sex organs, inserted in the life cycle between the gametophyte and gamete stages.

Similarly, plants with multicellular sporophyte bear differentiated tissues wherein spores are formed. These "organs" are called sporangia (one sporangium). Are sporangia haploid or diploid? **diploid**. Justify: **Sporangia are always formed by the sporophyte, which is developed via mitotic divisions from a zygote, which results from the fusion of a sperm cell and an egg cell and hence is always diploid. Therefore gametangia are always diploid**

In what stage of the life cycle is sex expressed? **Sex is always expressed by the gametophytes (as the name indicates the gametophyte is the plant [-phyte"] bearing the gametes..**