Sexual life cycles

Types of sexual life cycles: diploid-dominant, haploid-dominant, and alternation of generations.

Introduction

Do you ever wish you could clone yourself (for example, so you could get twice as much done in a day)? Because you're a human being, you can't just divide in two to make an extra you. If you were another type of organism, though – let's say a starfish, or maybe a cactus – cloning yourself might less of a big deal. Some starfish can make more genetically identical starfish simply by breaking off an arm, which will then regrow into a complete animal. Similarly, some cacti can clone themselves by dropping fragments of their branches, which take root and develop into new, genetically identical cacti.

These reproductive strategies are examples of **asexual reproduction**, which produces offspring genetically identical to the parent (that is, to the original starfish or cactus). In contrast, many plants, animals, and fungi produce offspring through **sexual reproduction**. In sexual reproduction, sex cells (**gametes**) from two parents combine in the process of fertilization, leading to the formation of a new, genetically distinct individual. Some organisms, including the starfish and cacti in the example above, can actually reproduce in either a sexual or an asexual mode.

All sexually reproducing species have certain key life cycle features in common, such as meiosis (the production of haploid cells from diploid ones) and fertilization (the fusion of haploid gametes to form a diploid cell called the **zygote**). Beyond these basic elements, however, there can be a lot of variation in sexual life cycles. In this article, we'll look at different types of sexual life cycles used by different organisms, from humans to ferns to bread mould.

A **haploid** cell has just one complete set of chromosomes. Human sperm and egg cells are haploid.

A **diploid** cell has two complete sets of chromosomes. Most cells of the human body, aside from sperm and egg cells, are diploid.

Types of sexual life cycles

Sexual life cycles involve an alternation between meiosis and fertilization. Meiosis is where a diploid cell gives rise to haploid cells, and fertilization is where two haploid cells (gametes) fuse to form a diploid zygote. What happens between these two events, however, can differ a lot between different organisms—say, between you and a mushroom or oak tree!
There are three main categories of sexual life cycles.

- In a **diploid-dominant** life cycle, the multicellular diploid stage is the most obvious life stage, and the only haploid cells are the gametes. Humans and most animals have this type of life cycle.
- In a **haploid-dominant** life cycle, the multicellular (or sometimes unicellular) haploid stage is the most obvious life stage and is often multicellular. In this type of life cycle, the single-celled zygote is the only diploid cell. Fungi and some algae have this type of life cycle.
- In **alternation of generations**, both the haploid and the diploid stages are multicellular, though they may be dominant to different degrees in different species. Plants and some algae have this type of life cycle.

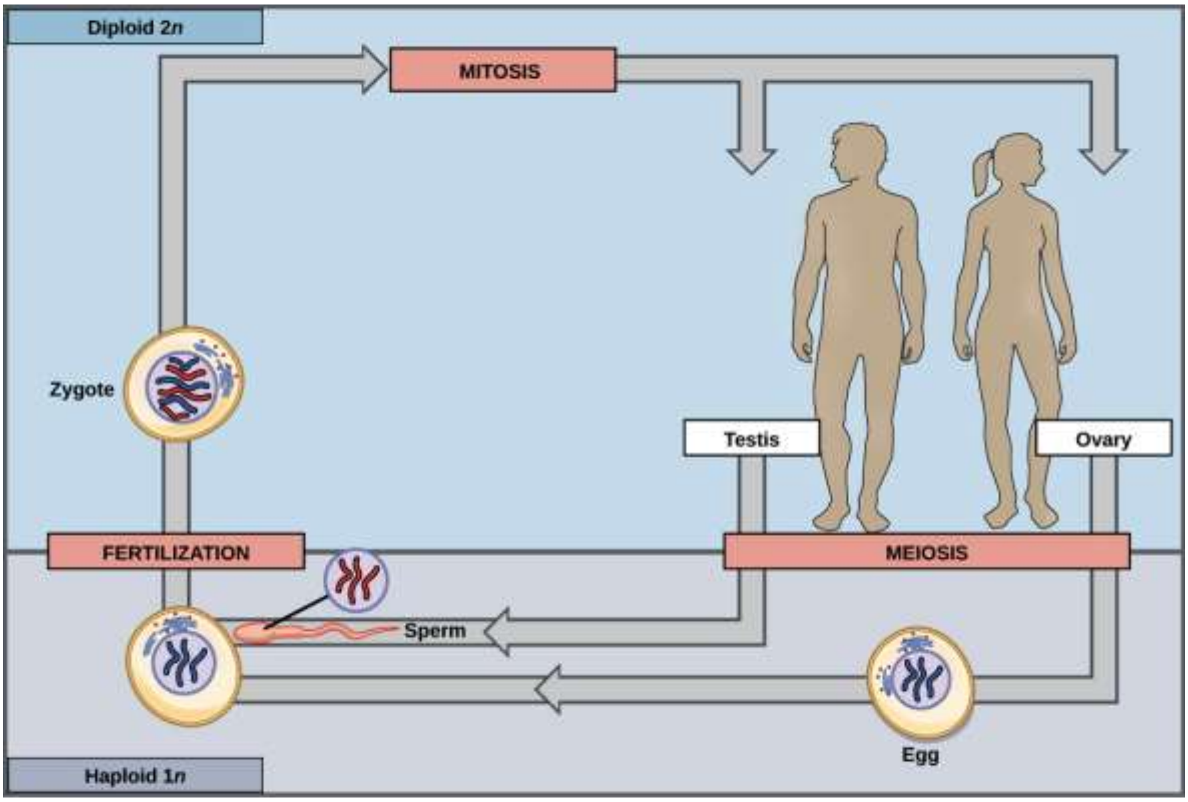
Let's make these ideas more concrete by looking at an example of each type of life cycle.

Diploid-dominant life cycle

Nearly all animals have a diploid-dominant life cycle in which the only haploid cells are the gametes. Early in the development of an animal embryo, special diploid cells, called **germ cells**, are made in the gonads (testes and ovaries). Germ cells can divide by mitosis to make more germ cells, but some of them undergo meiosis, making haploid gametes (sperm and egg cells). Fertilization involves the fusion of two gametes, usually from different individuals, restoring the diploid state.

Many species have separate male and female organisms. In these species, gametes must be contributed by two individuals of different sexes. However, some animal species are **hermaphroditic**, meaning that they have both male and female reproductive organs and can make both types of gametes.

Simultaneous hermaphrodites (organisms that have both male and female reproductive organs at the same time) may be able to self-fertilize, providing both sperm and egg to make a zygote. For example, banana slugs are simultaneous hermaphrodites and will self-fertilize if a partner is not available.

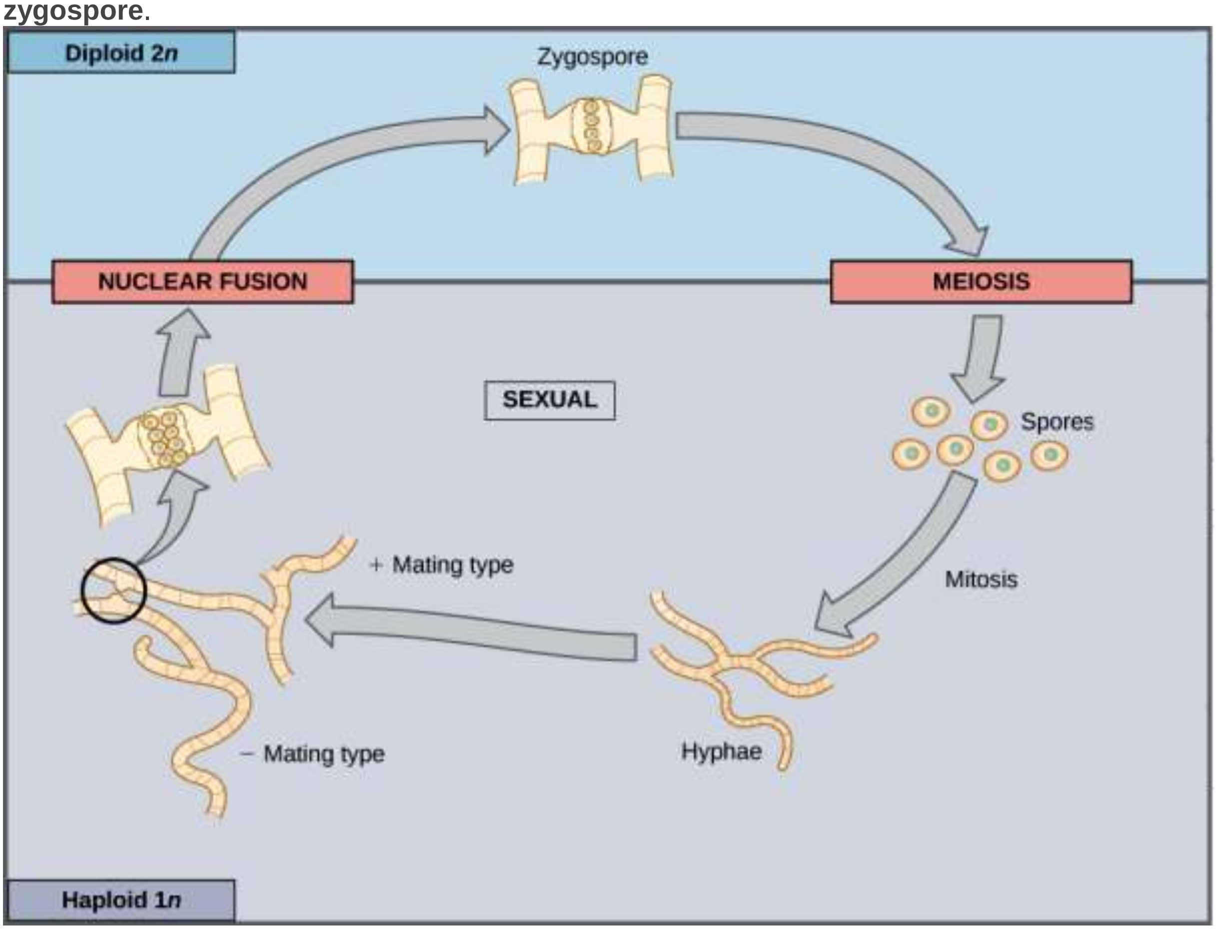


Example of a diploid-dominant life cycle: the human life cycle. In a mature human (2n), eggs are produced by meiosis in the ovary of a woman, or sperm are produced by meiosis in the testis of a man. The eggs and sperm are 1n, and they combine in fertilization to form a zygote (2n). The zygote divides by mitosis to produce a mature human.

Image modified from "Sexual reproduction: Figure 1," by OpenStax College, Biology (CC BY 3.0).

Haploid-dominant life cycle

Most fungi and some protists (unicellular eukaryotes) have a haploid-dominant life cycle, in which the "body" of the organism—that is, the mature, ecologically important form—is haploid.
An example of a fungus with a haploid-dominant life cycle is black bread mould, whose sexual life cycle is shown in the diagram below. In sexual reproduction of this mould, **hyphae** (multicellular, thread-like haploid structures) from two compatible individuals first grow towards each other.
Where the hyphae meet, they form a structure called the **zygosporangium**. A zygosporangium contains multiple haploid nuclei from the two parents within a single cell. The haploid nuclei fuse to form diploid nuclei, which are equivalent to zygotes. The cell containing the nuclei is called the **zygospore**.



Example of a haploid-dominant life cycle: black bread mould. A haploid spore (1n) undergoes mitosis to produce a multicellular individual (1n) with thread-like structures called hyphae. Two hyphae of compatible (+ and -) mating types extend protrusions towards one another, and where the protrusions meet, they form a zygosporangium with multiple haploid nuclei inside (some from both parent hyphae). Nuclear fusion then takes place, in which the haploid nuclei fuse to form diploid nuclei, and the cell containing the diploid nuclei is called the zygospore. The diploid nuclei in the zygospore undergo meiosis to produce haploid nuclei, which are released as unicellular spores (1n), and the cycle repeats.

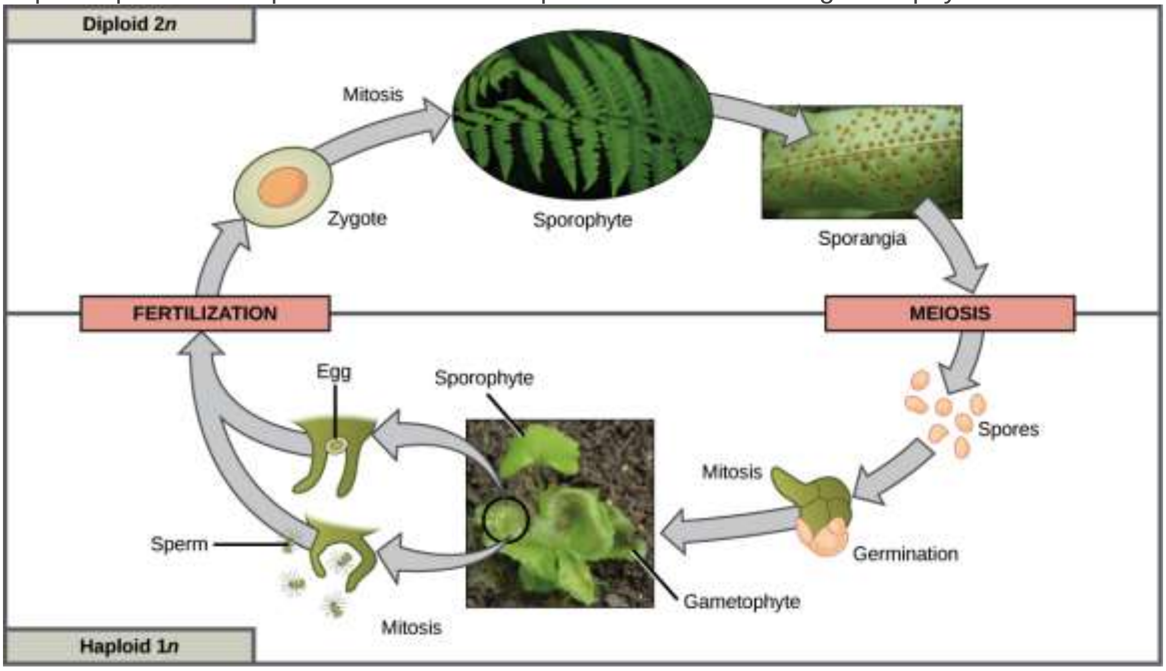
The zygospore may stay dormant for long periods of time, but under the right conditions, the diploid nuclei undergo meiosis to make haploid nuclei that are released in single cells called **spores**. Because they were formed through meiosis, each spore has a unique combination of genetic material. The spores germinate and divide by mitosis to make new, multicellular haploid fungi.

Alternation of generations

The third type of life cycle, alternation of generations, is a blend of the haploid-dominant and diploid-dominant extremes. This life cycle is found in some algae and all plants. Species with alternation of generations have both haploid and diploid multicellular stages.

The haploid multicellular plants (or algae) are called **gametophytes**, because they make gametes using specialized cells. Meiosis is not directly involved in making the gametes in this case, because the organism is already a haploid. Fertilization between the haploid gametes forms a diploid zygote.

The zygote will undergo many rounds of mitosis and give rise to a diploid multicellular plant called a **sporophyte**. Specialized cells of the sporophyte will undergo meiosis and produce haploid spores. The spores will then develop into the multicellular gametophytes.



Example of alternation of generations: life cycle of a fern. Haploid (1n) spores germinate and undergo mitosis to produce a multicellular gametophyte (1n).Specialized cells of the gametophyte under mitosis to produce sperm and egg cells (1n), which combine in fertilization to make a zygote (2n). The zygote undergoes mitosis to form a multicellular, diploid sporophyte, the frond-bearing structure that we usually think of a fern. On the sporophyte, specialized structures called sporangia form, and inside of them, haploid cells (spores, 1n) are formed by meiosis. The spores are released and can germinate, starting the cycle over again.

Although all sexually reproducing plants go through some version of alternation of generations, the relative sizes of the sporophyte and the gametophyte and the relationship between them vary among species.

In plants such as moss, the gametophyte is a free-living, relatively large plant, while the sporophyte is small and dependent on the gametophyte. In other plants, such as ferns, both the gametophyte and sporophyte are free-living; however, the sporophyte is much larger, and is what we normally think of as a fern.

In seed plants, such as magnolia trees and daisies, the sporophyte is much larger than the gametophyte: what we consider the “plant” is almost entirely sporophyte tissue. The gametophyte is made up of just a few cells and, in the case of the female gametophyte, is completely contained inside of the sporophyte (within a flower).

Why is sexual reproduction widespread?

In some ways, asexual reproduction, which makes offspring that are genetic clones of the parent, seems like a simpler and more efficient system than sexual reproduction. After all, if the parent is living successfully in a particular habitat, shouldn't offspring with the same genes be successful too? In addition, asexual reproduction only calls for one individual, removing the problem of finding a mate and making it possible for an isolated organism to reproduce.

Despite all this, few multicellular organisms are completely asexual. Why, then, is sexual reproduction so common? This question has been hotly debated, and there is still disagreement about the exact answer. In general, though, it's thought that sexual reproduction offers an evolutionary advantage – and thus, is widespread among organisms alive today – because it increases genetic variation, reshuffling gene variants to make new combinations. The processes that generate genetic variation in all sexual life cycles are: crossing over in meiosis, random assortment of homologous chromosomes, and fertilization.

Why is this genetic variation a good thing? As an example, let's consider the case where a population's environment changes, perhaps through the introduction of a new pathogen or predator. Sexual reproduction continually makes new, random combinations of gene variants. This makes it more likely that one or more members of a sexually reproducing population will happen to have a combination that allows survival under the new conditions (e.g., one that provides resistance to the pathogen or allows escape from the predator).

Over generations, beneficial gene variants can spread through the population, allowing it to survive as a group under the new conditions.