Workshop on Alternation of Generations

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Introduction

For students new to the study of Kingdom Plantae, the life cycle of plants--in which a diploid generation alternates with a haploid generation--can be difficult to understand. The purpose of this workshop is to allow the student to better relate to the phenomenon of Alternation of Generations by (1) examining the details of plant gametophyte and sporophyte structure and function, and (2) creating an animal analog to this type of life history.

In today's workshop, your goals will be to

1. Understand the alternation of haploid and diploid individuals in the plant life cycle.
2. Understand the terminology used to describe parts of the life cycle, and recognize what each life cycle stage looks like in the major plant taxa.
3. Acquire a more "personal" understanding of how the alternation of generations works by designing an imaginary animal that goes through this type of life cycle.

I. Alternation of Generations in Plants: Processes and Terminology

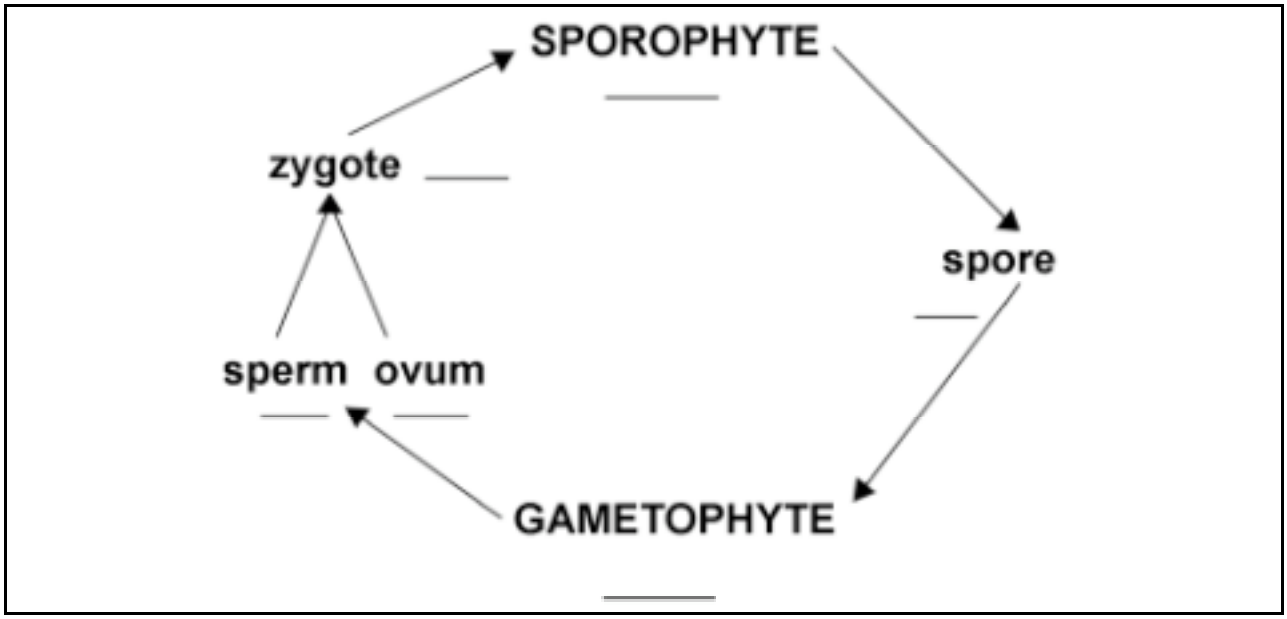
The painful part comes first: knowing the general course of events, and what each life cycle stage and structure is called.

A. An Overview of Alternation of Generations

The plant life cycle, unlike that of animals, consists of alternating generations of individual organisms that are haploid (the **gametophyte**) and diploid (the **sporophyte**). Specialized diploid cells in the sporophyte undergo meiosis to produce haploid spores (hence the name "sporophyte"). Each spore grows mitotically to become the new gametophyte, which then produces **gametes** (hence, the name "gametophyte") which fuse to form a **zygote**. This grows into the sporophyte, and the cycle continues, as shown in the diagram below.

In the diagram

1. Indicate the ploidy (n for haploid, 2n for diploid) of each life cycle stage or structure.
2. Over each of the five arrows, indicate which of the following processes is taking place:
   mitosis **meiosis** **fertilization**



B. Terminology

Part of learning a new subject is learning its vocabulary and terminology. So here we go!

1. In the sporophyte, what is the name of the structure within which diploid cells undergo meiosis to become haploid spores? _____

Describe what this structure looks like and where it is found in:

a. a moss (or other bryophyte)

b. a fern (or other seedless tracheophyte)

c. a pine (or other gymnosperm)

d. a flowering plant (any of the angiosperms)

2. If the spore-producing structures you just named are found on a leaf specialized to bear those structures, that leaf is called a _____

Describe what this structure looks like in:

a. a moss (or other bryophyte)

b. a fern (or other seedless tracheophyte)

c. a pine (or other gymnosperm)

d. a flowering plant (any of the angiosperms)

3. A spore that develops into a female gametophyte is called a _____

Describe where this is found in:

a. a liverwort

b. a fern

c. a pine

d. a flowering plant

4. A spore that develops into a male gametophyte is called a _____

Describe where this is found in:

a. a liverwort

b. a fern

c. a pine

d. a flowering plant

5. A sporophyll that bears megaspores is called a _____

Describe what this structure looks like in:

a. a liverwort or moss

b. a fern

c. a pine

d. a flowering plant

6. A sporophyll that bears microspores is called a_____

Describe what this structure looks like in:

a. a liverwort or moss

b. a fern

c. a pine

d. a flowering plant

8. Describe the appearance of the mature male gametophyte in

a. a liverwort or moss

b. a fern

c. a pine

d. a flowering plant

9. Describe the appearance of the mature female gametophyte in

a. a liverwort or moss

b. a fern

c. a pine

d. a flowering plant

10. In the female gametophyte, what is the name of the structure within which haploid cells develop into ova? _____

Describe what this structure looks like in:

a. a liverwort or moss

b. a fern

c. a pine

d. a flowering plant

11. In the male gametophyte, what is the name of the structure within which haploid cells develop into sperm? _____

Describe what this structure looks like in:

a. a liverwort or moss

b. a fern

c. a pine

d. a flowering plant

12. What does it mean if a plant is **dioecious**?

13. What does it mean if a plant is **monoecious**?

II. Creating an Animal Analogy

Understandably, it's sometimes difficult for animals like us to easily relate to the plant life cycle, as ours is so dissimilar. In an attempt to make the Alternation of Generations a little bit more "real" to us, let us engage in a bit of fantasy.

A. Creating an Imaginary Animal Species that undergoes Alternation of Generations

Don't get your hopes up too high. We are merely going to mimic the life cycle stages as one typically sees them in a SEEDLESS TRACHEOPHYTE. The sporophyte produces spores in sporangia on sporophylls, then releases the spores to the environment. A spore germinates into a free-living gametophyte that produces gametes in gametangia (analogous to testes and ovaries). Fertilization occurs when sperm travel from the male gametophyte to the female, enter her gametangium and fertilize her ovum to produce a zygote. The zygote grows into the new sporophyte, obliterating the female gametophyte. The male withers and dies shortly after the sperm are released. Keep this cycle in mind when you design your animal model.

1. As a group, create an animal (it can be an existing animal, or something similar to a species with which you are already familiar) that is diploid. This animal will be your sporophyte generation, and you should decide in advance whether it will be dioecious or monoecious.
   Does this animal have gonads (ovaries or testes)? Explain.
   Briefly describe your animal sporophyte.

2. Next, choose an area on the animal where specialized diploid cells will undergo meiosis to produce spores. Remember that this should be an external area, since the spores will be released to the environment. Also remember to create the areas on your animal as appropriate to dioecy or monoecy, whichever you have chosen your animal to be.

3. Release the spores! What happens to the spores that land in an area appropriate to germination? Describe the resulting organism (the gametophyte generation of this species), and again note whether it is monoecious or dioecious, since this will be important in the next few steps. Be sure to note this animal's ploidy, and whether it has gonads (testes and/or ovaries).

4. If your gametophyte is bisexual, describe how and in what anatomical locations it will produce sperm and ova. How will sperm reach the ova? Describe the process.

5. If your gametophyte animal is male, describe how and in what anatomical location it will produce sperm. How will these gametes reach the female gametophyte's ova? Describe the process.

6. If your gametophyte animal is female, describe how it will produce ova, and where. Will these gametes be released into the environment, or will they remain inside the female? If they remain inside the female, describe where they will be found.

7. Describe fertilization between the male and female gametophytes of your species (if the species is monoecious) or how fertilization takes place in your individual bisexual gametophyte (if the species is dioecious). What is the result of fertilization? Where would you find it if you were to dissect your gametophyte animal?

8. What will now happen to the fertilized ovum (zygote)? Describe how it grows, and where. What happens to the gametophytes once fertilization is complete?

9. Describe the mature result of growth of the zygote. What will be the next step in this life cycle?

B. Thought Questions

1. Do any other organisms alternate haploid and diploid conditions? If so, how--and at what point in the life cycle--does this occur in each group you have named?
2. What is the significance of alternating haploid and diploid conditions in any organism?
3. How is the alternation of haploid and diploid conditions in plants different from that seen in most other types of organisms?
4. Are there any other organisms that have an alternation of generations similar to that seen in plants? If so, what are they?
5. If you answered "yes" to the questions above, how is the alternation of generations in plants different from that seen in the organism(s) you named in the previous question?
6. How does the alternation of generations cycle differ among plant taxa? How does the cycle differ between the taxa considered to be more primitive, and those considered more derived?
7. Do you believe that the alternation of generations seen in plants and a few other taxa are synapomorphic, or convergent? How would you test your hypothesis?
8. What do you suppose might be the evolutionary significance of a heteromorphic alternation of generations?