Workshop on Alternation of Generations by Dana Krempels

Introduction
If you have never studied plants before, the alternation of generations—in which a diploid generation alternates with a haploid generation—can be a bit confusing. In this workshop, you will (1) examine the details of plant gametophyte and sporophyte structure and function, and (2) create an animal analog to this type of life history. Your goals:

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 names of the structures and processes.

A. An Overview of Alternation of Generations
In the plant life cycle, generations alternate between a

- DIPLOID (2n) SPOROPHYTE and a
- HAPLOID (n) GAMETOPHYTE

The sporophyte bears gametophyte offspring, and the gametophyte bears sporophyte offspring.

Plants alternate ploidy (haploid to diploid) in each generation. The sporophyte and gametophyte generations look completely different from one another, as you can see in the diagram below.

1. In the diagram below, use the following terms to label the organisms/structures marked a – e.

   - gametophyte
   - spore
   - zygote
   - sporophyte
   - gamete

   ploidy on this side: ____________  ploidy on this side: ____________
2. In the spaces labeled 1 – 5, insert the appropriate cellular event, choosing from these three: meiosis, mitosis, fertilization.

3. All structures on the grey side of the diagram are the same ploidy as each other, and all structures on the white side of the diagram are the same ploidy as each other. Which side is diploid and which is haploid? Label appropriately on the top of the diagram.

B. Terminology
The diploid SPOROPHYTE bears structures devoted to generating spores. Use the list of terms below to correctly identify these fantastic plant parts!

- microsporophyll
- microspore
- microsporangium
- sporophyte
- megasporophyll
- sporophyll
- megaspore
- megasporangium
- spore
- sporangium
- zygote

1. A sexually mature diploid plant is called a __________________. It bears small, “boxlike” structures inside of which diploid cells undergo meiosis to become __________________.

2. The boxlike ________________, where meiosis takes place, is borne on a specialized leaf called a __________________.

3. The haploid reproductive cell made by a sporophyte is called a ________________. If this cell is a __________________, it will grow into a female gametophyte. If this cell is a __________________, it will grow into a male gametophyte.

4. Female spores are formed via meiosis inside the ________________, which is borne on the female spore-bearing leaf, known as the __________________.

5. Male spores are formed via meiosis inside the ________________, which is borne on the male spore-bearing leaf, known as the __________________.

The haploid GAMETOPHYTE, like its sporophyte mother and daughter, has specialized structures devoted to reproduction. Use the following terms to fill in the blanks.

- gamete
- gametophyte
- antheridiophore
- ovum
- sperm
- antheridium
- archegoniophore
- archegonium

1. A sexually mature haploid plant is called a ________________. It bears multicellular organs that produce gametes. The female sex organ, analogous to an ovary, is called a(n) ________________. The male sex organ, analogous to a testis, is called a(n) ________________.

2. In some species, such as liverworts, the female sex organs are borne on a stalk called an __________________________, and the male sex organs are borne on a stalk called an __________________________.

3. Inside the archegonium, haploid cells undergo mitosis to make __________________________.

4. Inside the antheridium, haploid cells undergo mitosis to make __________________________.

C. Morphology: Recognizing What You See in a Plant
In Bryophytes (non-vascular plants such as mosses, liverworts, hornworts), the gametophyte is the more conspicuous life cycle stage than the ephemeral sporophyte. (Look up ephemeral.) In Tracheophytes (vascular plants, such as ferns, conifers, anthophytes), the sporophyte is the more conspicuous life cycle stage than the ephemeral gametophyte. Can you recognize them?
1. **Describe or draw the male gametophyte of…**
   a. a liverwort (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. **Describe or draw the female gametophyte of…**
   a. a liverwort (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. **Describe or draw the sporophyte of…**
   a. a liverwort (or other bryophyte)
   b. a fern (or other seedless tracheophyte)
   c. a pine (or other gymnosperm)
   d. a flowering plant (any of the angiosperms)

4. **Describe or draw the sporophyll of…**
   a. a liverwort (or other bryophyte)
   b. a fern (or other seedless tracheophyte)
   c. a pine (or other gymnosperm)
   d. a flowering plant (any of the angiosperms)

5. What does it mean if a plant is **dioecious** (die-ee'-shus)?

6. What does it mean if a plant is **monoecious** (mo-nee'-shus)?

**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. Discussion 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 think that the alternation of generations seen in plants and a few other types of organisms (algae) are synapomorphic, or convergent with each other? How would you test your hypothesis?

8. What do you suppose might be the evolutionary significance of a heteromorphic alternation of generations?