April 18 - Seed Adaptations and Ecology

Recall that pollination is the process by which pollen (produced in gymnosperms and angiosperms) is transported from the male anatomy of one plant to the female anatomy of another plant of the same species. After pollination, a pollen tube conveys sperm to ovules and the egg each contains, and fertilization occurs. (You should remember the details of pollination and where (i.e., the structure through which) the pollen tube grows in gymno- and angiosperms.

For organisms that are literally rooted in place, delivery of male gametes (sperm, in pollen) to the female gametes (eggs, in ovules) is only part of the challenge of reproducing sexually. The 2nd major challenge is maximizing potential success of a seed, which germinates into a seedling.

Seed germination: The beginning of growth by a seed, characterized by rupturing of the seed coat and growth of the embryo.

Seedling: Young sporophyte (2n!) developing from a germinated seed. (Typically the most sensitive period of a plant's life cycle!)

Within a plant's natural range (i.e., where it grows naturally), factors that are especially acute in limiting the survival and growth of a seedling/ plant include:
1) moisture; 2) nutrients; 3) temperature; 4) light; 5) space

If a seed is to succeed as a dispersal agent, it must germinate at a time and place in which conditions (moisture, nutrients, temperature, light, and space) are adequate for growth. This ensures (or maximizes) the odds of survival. Not surprisingly, seeds have many adaptations to ensure that they germinate under circumstances that maximize survival. We will focus on these adaptations today, thinking in an "evolutionary context" all the while (i.e., how do the adaptations discussed increase the S&R of these organisms…). In addition, we'll explore a couple of related and interesting stories along the way…

For this material, you will need to recall the three fundamental parts of a typical seed: 1) seed coat, 2) embryo, 3) endosperm.

Delayed germination

Most (nearly all?) seeds have delayed germination, which is an evolutionary strategy to synchronize germination with generally favorable growing conditions (such as those found during our springtime: i.e, wet, warmish, long photoperiod). Think about it: it would be disastrous to germinate in late fall/winter in, say, northern Canada – a seedling would freeze to death and there'd be little light to power the delicate first weeks/months of life! It would be similarly disastrous to germinate in August in Death Valley – a seedling would 'roast' and dehydrate!! Not surprisingly plants have evolved seeds that time their germination to favorable growing conditions. After all, the seedling stage is the most sensitive life stage of a plant – it is highly vulnerable to stresses such as cold, heat, and drought.

Delayed germination: Germination that occurs only in the presence of favorable environmental conditions (see quiescence) or specific germination cues (see dormancy).

Quiescence: Form of delayed germination in which a seed fails to germinate because the external environmental conditions are unsuitable (e.g., too dry, hot, or cold).

Dormancy: Form of delayed germination that can be broken (i.e., ended) only with specific environmental cues such as heat (e.g., fire), prolonged cold, light or long photoperiod, or chemicals. The requirement of these specific cues prevents breaking of dormancy EVEN during superficially favorable growing conditions that can break quiescence (e.g., a "false spring", early snowmelt, etc).

Remember the big picture here: all forms of delayed germination (both quiescence and dormancy) are adaptations that increase the odds that germination occurs when growth conditions are favorable for seedlings.

Adaptations we discussed for breaking quiescence and dormancy:
1) **Imbibition**. Absorption of water (here, by seeds). Typically precedes germination.
This alone (assuming reasonable temperatures etc.) can break quiescence, but NOT necessarily dormancy! Clearly, the presence of water is a reliable signal to a seed that water is indeed present…we diagrammed how water initiates germination in wheat (*Triticum* sp. (a grain)). Know this process, as well as its importance for brewing/distilling (i.e., understand malting).

Germination of wheat/grains
During (and due to) imbibition, the embryo produces the water-soluble hormone gibberellic acid (GA). Because imbibition causes water to be present in the seed, GA is able to diffuse to the aleurone layer, where it stimulates production of amylase. Amylase then diffuses into the endosperm (which is mostly starch) and catalyzes breakdown of starch into the sugars maltose (disaccharide) and/or glucose (monosaccharide). These sugars (maltose & glucose) are then used by the embryo to create ATP (via cellular respiration)! This process is a nifty and thrifty review of many concepts we've covered throughout the semester – and thus understanding this would make a great final exam question – don't ya' think?

Malting - used in brewing and for other food products
Brewers and distillers subject barley, or other grains, to this process because yeasts have a very limited ability (and often none) to chemically break down starch (the glucose subunits of which they convert to ethanol during alcohol fermentation). Thus, brewers must "pre-treat" barley and other grains by germinating the seeds such that the starch is converted to glucose and maltose that can be metabolized ("eaten") by yeast. Because this process yields the disaccharide maltose, it is referred to as malting.

Aleurone layer (a.k.a., aleurone): Outermost layer of the endosperm in wheat and other grains.
Gibberellic acid (a.k.a., gibberellin, GA): Plant hormone with many functions/effects on plant tissues. In germination of wheat (and other grains), imbibition triggers production of GA by the embryo, GA then diffuses (it is water soluble) to the aleurone layer and stimulates the production of the enzyme amylase.
Amylase: enzyme that converts starch to glucose or maltose.
Starch: Storage polysaccharide in plants, a long chain(s) of glucose molecules. The dominant component of grain endosperm.
Maltose: a disaccharide of two glucose molecules
Malting: A process in which grains (most often barley, but also wheat, rice, oats) are soaked in water and allowed to germinate, then dried using hot air (this arrests germination/development of the embryo). Malting thus converts starch (inedible to most yeasts) into maltose or glucose that yeast can use to make ATP via fermentation (or cellular

respiration when O_2 is initially present. Thus malting is a critical initial stage of brewing beer or producing hard alcohol made from grains - such as whiskey. “Smoky” or “peaty” whiskies are produced by arresting the malting process with hot smoky air produced by burning peat.

2) **Cold exposure**: many plants will not germinate without experiencing prolonged cold. This is an adaptation to avoid germination in late summer/fall (when many/most seeds are produced) and subsequent seedling death in winter! In horticulture, this dormancy trigger is simulated with stratification. **Stratification:** Horticultural practice of subjecting seeds to prolonged cold temps (temperature and duration vary by species) to imitate a cold period and break dormancy.

3) **Scarification:** Process of cutting or softening a seed coat to hasten germination.
(Scarification allows water, air, and/or light to penetrate the seed coat and initiate germination).

<u>There are many mechanisms of scarification:</u>

a) Heat (in nature, typically caused by fire). This adaptation synchronizes seed germination so that seedlings emerge after fire and therefore have reduced competition for water, light, space, and nutrients.

Examples of fire-scarified plants are well represented locally. Some species of *Ceanothus* in chaparral have seeds that must be scarified by fire. Other plants germinate almost exclusively after fires – these are known as **fire followers**. The genus *Phacelia* contains many such species.

b) Stomach acids of seed dispersers. Stop to think about how this developed through natural selection. Those seeds whose coats were scarified by stomach acids germinated after being dispersed (by an animal) and after being deposited in moist and nutrient-rich poop! Those seeds that didn’t scarify in the acids, or that germinated before being ingested, dispersed, and defecated in a nutrient rich poop would be at a distinct disadvantage – that is to say, they would have a much lower rate of survival. What a ‘clever’ and clear ‘signal’ that developed over evolutionary time! This thought exercise works equally well for heat (fire) scarification…and most other adaptations…I hope that you will continue to think about biology in this manner well after this class!

c) Physical tumbling etc. in soil.

4) **Chemicals**. Fascinating research has shown that the chemicals contained in ash can induce germination in many plants. This is an evolutionary cue to time germination to post-fire condition, just as with heat scarification.

This section covered very briefly in lecture…

5) **Orchid partnerships with mycorrhizal fungi**. Orchids have minute and dust-like seeds that have no (or virtually no) endosperm. Thus, they do not have adequate energy stores to fuel development from seed, through germination, and into a photosynthetic seedling. Instead, seeds germinate partially, and then their development stalls at stage called a **protocorm**. At this stage, the developing seedling is little more than a tiny seed with root-hair-like structures protruding (this is the protocorm). In order to continue developing, a **mycorrhizal fungus** must infect the seed/protocorm. Inside individual orchid cells, the fungal hyphae form small balls called **pelotons** (French for “little ball”). The fungus provides sugars and nutrients that fuel growth until the orchid can photosynthesize. At that time, the orchid then provides

sugars to the fungus (which, of course, is a heterotroph). (Note: in many cases the association breaks down or one member dies). This general situation, in which the plant provides sugars to the mycorrhizal fungus, is more typical – as we will learn in our fungus lecture next week. In return for sugars, mycorrhizal fungi enhance water and nutrient absorption of the plant's roots. Mycorrhizal fungi and their plant partners exemplify **mutualistic symbiosis** (more next lecture).

The mechanisms above are adaptations to ensure successful germination and seedling growth by maximizing the probability that adequate water, light, nutrients, and space is available. Another way to increase survival is through seed dispersal. We discuss this next – and we establish that seed dispersal has many benefits for long term survival of species.

Seed dispersal: The movement or transport of seeds away from the parent plant.
Dispersal away from the parent plant is important for a number of reasons:

1) <u>increase the survival of individual offspring</u>:
   1a) <u>Reduce competition with parent plant and among offspring</u>, and therefore greater rates of growth and survival [Ex from lecture – the *Cakile maritima* seedlings photographed at Ledbetter Beach, and competition for light, space, nutrients, etc.)]
   1b) <u>Provide an ideal microclimate for survival</u>. This is especially operative for animal – dispersed seeds that must be scarified by the digestive enzymes of the disperser; or the digestive enzymes may kill other potential competitors or pathogens (Ex: from lecture were the *Acacia* seedlings in elephant dung).
   {VIDEO: PLoP "Traveling" 34:45-37:40} - watch at end, if time permits!

2) <u>increases the overall number of individual plants</u> by spreading to other locations and habitats. Who knows, some other area or habitat might be superior for S&R!

3) <u>Reduce risk of extinction/population decline due to local disturbances</u> (landslide, fire, floods, volcanic eruption, etc) or disease (e.g., from oomycetes such as *Phytophthora*…which we'll study in our next lecture!) – if populations in one area go extinct, individuals farther away may survive and repopulate the area. [With regard to fire: beware that many plants and ecosystems are adapted to fire (we'll talk about this in great detail!)– but not all are, and there are other types of disturbance that can decimate local populations).

There are five major mechanisms of seed dispersal: 1) Gravity, 2) wind, 3) water, 4) ballistic/mechanical, and 5) animals

For each of the dispersal mechanisms above, fruits (which contains the seeds!) are distinctly different and adapted (through natural selection!) to facilitate dispersal. Think about it: what are the important differences between seeds (and fruits) that are dispersed via wind, water, gravity, or animals? Here, we emphasize fruits (but gymnosperms disperse seeds as well!!).

- **Gravity**: fruit is heavy so that it falls from tree/plant, and round to allow rolling. (Such fruits may be secondarily transported by animals or water after falling.)
  (Ex from lecture: *Couroupita guianensis* (cannonball tree), and close relative (same family = Lecythidaceae) *Bertholletia excelsa* (Brazil nut), *Malus* spp. (apples))

{VIDEO: PLoP "Traveling" 37:45-39:44} *This video includes caching – see below- show at end if time permits – did not show (no time)*

- **Wind**: fruit is light and with "wings" or "parachutes" to carry the seed a long distance (Ex: samara of maples (such as *Acer macrophyllum*), the pappus of dandelions and other Asteraceae).
  {VIDEO: PLoP "Traveling" 10:30-15:10}
- **Water**: Fruit is lighter than water (so that it is buoyant), with protective outer layer to guard against rotting (or salt if it is transported in seawater) as it is being transported (Ex: *Coco nucifera* - coconut as we saw in lab, *Entada phaseoloides* – sea bean (Fabaceae)).
  {VIDEO: PLoP "Traveling" 17:00-20:13}
- **Ballistic/mechanical**: Fruits are typically capsules (dehiscent fruits that open along 3+ sutures), legumes, or berry (as in squirting cucumber) that can burst open and "shoot" seeds. (Ex: from lecture: *Ecballium elaterium* - squirting cucumber, *Ceanothus megacarpus* - bigpod ceanothus).
  {VIDEO: PLoP "Traveling" 15:10-16:20}
- **Animals**: Fruits vary depending on the mechanism of animal dispersal:
  - **External:** fruits typically dry and with barbs, spines, or hooks to become entangled in fur or feathers and "hitch a ride" (Ex: *Xanthium strumarium* - cocklebur). Fruits may also be sticky (Ex. *Pisonia* spp. - catchbird trees).
    {VIDEO: PLoP "Traveling" 20:50-21:13} (did not show)
  - **Internal:** Fruits are designed to attract and/or reward the dispersers. This often includes bright colors, sweet flavors, soft and easily-chewed flesh (in fleshy fruits).
    {VIDEO: PLoP "Traveling" 23:55-27:10}

It is worthwhile at this point to review ripening in fleshy fruits, as we covered earlier and in lecture today. We identify three major events in a generic (representative) fleshy fruit as the seeds ripen and the plant makes the fruit more appealing to a potential disperser:

1) Acids that are sour (e.g., malic acid) are converted to sugars that make the fruit sweet. The acids likely deter premature dispersal.
2) Color changes from the relatively camouflaged green of an unripe fruit to the brighter colors such as reds, blue/purple, black (anthocyanins in cell vacuoles) or yellows, oranges, reds (carotenoids in chromoplasts).
3) Pectins that bind cells together (as well as hardening proteins that we did not discuss) that make flesh firm are broken down and the flesh becomes relatively soft and easily ingested.

What about seed eaters such as some jays (birds), ground squirrels, chipmunks, and others? If animals eat the seeds directly, how can that be of service to the plant? The answer lies in the fact that many of these animals cache the seeds, and later forget or otherwise do not rcover 100% or the seeds – leaving some partially buried away from the adult plant!
Caching: animal behavior in which food is stored in locations hidden from view, for later retrieval. (A Cache (pronounced CASH) is such a storage site.)
If time permits:
Brazil nut and Caching
{VIDEO: PLoP "Traveling" 37:45-39:44} * *note – this video includes gravity dispersal; didn't show*
Elephant video (microclimate:
{VIDEO: PLoP "Traveling" 34:45-37:40} - watch at end, if time permits!