Seed Physiology: A Brief Primer

I. Structure / Function

A. Seed Function

1. propagation of plant
2. mechanism for offspring dispersal
3. protect immature plant in adverse conditions

B. Definitions

- A fancy botanical definition for a seed: a ripened ovule
- Steve's simplistic definition: a baby in a suitcase carrying its lunch

C. Parts

1. The Baby = Embryo

- The embryo is essentially an immature, undeveloped plant
- derived from zygote
- The main parts of the embryo are the radicle (develops into the root), epicotyl (develops into the shoot), hypocotyl (embryonic stem connecting radicle and epicotyl), cotyledons (seed "leaves" - usually for food storage).

2. Suitcase = Seed coat. This represents the outer protective layer, derived from the integuments of the ovule.

3. Lunch = stored reserves

- provide nutrients for the germinating seedling
- various kinds of reserves depending upon the plant: starch (cereals), fats & oils (nuts, soybean), protein (legumes)
- amount of stored reserves varies (lots in cereals, legumes) to little (orchids provide virtually no reserves, which means the seedlings rely on a symbiotic relationship with fungi immediately on germination to support the seeds).

D. Seed Types - there are three major kinds based on embryo structure and how metabolize endosperm. Note that there are many variations and intermediate forms

- monocot (cereal)
- eudicot with endosperm
- eudicot without endosperm (endosperm is metabolized and stored in cotyledons, i.e., beans)

II. Seed Formation - Seed formation is initiated upon pollination/fertilization. The general pattern of activities: embryo formation → reserves stored → water loss

1. Embryo formation is the first stage. The zygote develops into the embryo. During this stage there is lots of cell division, synthesis of DNA, RNA and proteins, and endosperm formation.

2. Once the basic embryo forms, growth stops and then reserves accumulate. Growth inhibitors synthesized during latter part of the phase

3. Dehydration - seed looses water, mature seeds with less than 10% water; seed coat sclerifies (becomes hard & dry) for added protection

III. Dormancy

A. Definition

- **dormant** - suspended animation; won't germinate even if conditions are favorable (innate dormancy)
- **quiescence** (enforced dormancy) – doesn't germinate because conditions aren't favorable (i.e., missing one of the requirements for germination such as water).
- primary – dormant immediately at harvest
- secondary (induced dormancy) – can germinate initially, but if exposed to adverse conditions (cold, low oxygen, high temp) will become dormant

B. Are seeds alive?

- inactive metabolism, unable to detect
- viable vs. dead?
- Germination Percentage = # seeds germ/total * 100
- Germination Rate %germ vs. time (quicker better – sooner to photosynthesize, shorter growing time, uniform stand vs. uneven crop)
- Viability Tests: (a) sow, (b) tetrazolium, (c) float, (d) cut open embryo

C. Function

- withstand environmental extremes (*e.g.*, cold, heat, radiation, microwaves)
    - o loose water during development (dry to less than 10% moisture)
    - o prevents ice formation
    - o inactivates metabolism
- increase longevity - variable storage survival rates – few months to many years (10,000 arctic lupine); longest lived seeds with hard heavy coat or weeds; crops generally short viability
- provides time for dispersal
- key feature distinguishes plants and animals - animals have no dormant period, undergo continuous development
- viviparous – a few with no dormancy, uncommon (*i.e.*, mangrove), mutation in some

D. Dormancy Mechanisms

1. Mechanical *(heavy impervious seed coat)* – ***scarification*** to break (file), acid, rotating drum with sandpaper (e.g., honey locust, morning glory,)
2. Chemical (*inhibitors*) – removed by washing out, chilling (e.g., ABA in ash other seeds, citric acid in tomatoes)
3. After-ripening (*immature undeveloped embryos*) – require growth period after being shed from plant (e.g., carrots, parsnips, hemp).
4. Physiological inhibition
   (a) Light. Stimulates many (esp. small seeds) or inhibits (uncommon) or no effect. Acts via phytochrome, red light absorbing pigments, alternates between two forms)
   (b) Ethylene - larger seeds
   (c) Cold - ***stratification***, e.g., apples
   (d) Heat treatments for desert and winter annuals (germinate after warm summer)
   (e) Alternating temperatures - hot/cold; e.g., evening primrose, tobacco; mechanical

change in seed coat or other mechanism; epicotyl dormancy - root emerges in warm temp, epicotyl requires cold, gives time for root to develop before epicotyl, e.g., wild ginger, waterleaf

5. Fire - increases light by reducing competition, destroy inhibitors in soil, charred remains stimulate, smoke stimulates - habitats that are seasonally dry and adapted to periodic burning (e.g., chaparral in CA, prairie in MN)

IV. Germination

A. Requirements

1. Water
    - Absorption of water is called ***imbibition***. Seeds can absorb up to 200% of its weight and more than double its volume. Initially quick, slows, then followed by more rapid absorption; too fast damages cells, no time for 'repair'.
    - Embryo expansion provides force to rip open seed coat (which swells less). Generates lots of force (used to be used to quarry stone)
    - Water uptake is passive - due to affinity of water for seed components (adhesion/cohesion) and water potential gradients.
    - Function of water: (1) softens seed coat; (2) provides force to open; (3) activates dormant enzymes and stimulates synthesis of new ones; (4) solubilizes seed components; (5) dilutes inhibitors; (6) provides force for cell growth.

2. Oxygen

    - Oxygen uptake very slow initially, then rapidly after imbibition
    - required for oxidative reactions *(i.e.,* respiration & ATP production)
    - switch from anaerobic to aerobic metabolic key regulatory step during germination

3. Temperature

    - Affects rates of chemical reactions (recall the graph of reaction rate vs. temp for an enzymatic reaction)
    - Dry seeds withstand broad range of temperatures
    - Hydrated seeds (after imbibition occurs) can tolerate only a narrow range
    - Species vary in response to temp (minimal temp, maximal temp, optimal temp) for germination.
    - Temperature also influences things other than reaction rates. For example, if treat lima beans at 5 C for first half hour of imbibition, it depresses respiration and the embryo dies with 5 days - due to temp sensitivity of membranes. Cold makes them leaky, cold tolerant species don't leak.

4. Suitable stored reserves (foodstuffs)

    - provide (a) carbon skeletons, (b) fuel source for respiratory energy (ATP)
    - germination is initially heterotrophic. Consider graph of weight of seedling over time.
    - food reserves in polymeric form – requires conversion to monomeric form and then transported to sites of need
    - hydrolytic enzymes activated or synthesized

5. Dormancy broken (chemical treatments to encourage seeds; e.g., GA, potassium nitrate)

6. Suitable substrate - no inhibitors or *allelopathic* agents present; medium contains sufficient moisture, oxygen, etc.

B. Chronology of Events

1. Imbibition

2. Appearance of metabolic activity - early activities: primarily to get seed ready for metabolism & growth, later events involved in utilization of stored reserves for new synthesis

Table: Temperature Ranges for Germination of Various Seeds (data from Noggle & Fritz)

Species	Temperature (C)		
	Minimum	Optimum	Maximum
wheat	3-5	15-31	30-43
maize	8-10	32-35	40-44
cantelope	10-19	30-40	45-50
mustard	0.5-3	20-35	35-40

3. Radicle (root) emergence - now considered a seedling (germination starts at imbibition and ends at radicle appearance

IV. Molecular Biology of Barley Seed Germination

Gibberellic acid (GA), which is one of the plant hormones, is produced by the scutellum (cotyledon) of the embryo → stimulates the production of amylase by the aleurone layer → amylase hydrolyzes starch to simple sugars → absorbed by scutellum and translocated to embryo for growth.

The production of amylase occurs *de novo*. That is, gibberellin stimulates transcription. In short: GA → binds to membrane receptor → interacts with a protein complex (heterotrimeric G protein) that → activates a GA signaling intermediate →turns off a repressor → transcription of GA-MYB mRNA → translated in cytosol to make GA-MYB protein → returns to nucleus to bind to alpha-amylase gene promoter region → activates transcription of alpha-amylase mRNA → translated in ribosomes on RER → transported to golgi → secretory vesicles release alpha-amylase. This last step is apparently regulated by a calcium dependent mechanism that was also activated by the heterotrimeric G protein complex.

Brewers take advantage of GA's ability to stimulate germination and enzymes which are important in the brewing process.

see overhead

V. Planting seeds

1. Depth - no deeper than length or 3x the average diameter, shallower is better than deeper
2. Plant more than you think you need - not all will germinate (can't tell if dead, dormant or quiescent)
3. Thin as necessary - too much competition. Can you design an experiment to test the importance of thinning?
4. Methods - Petri dish, pots, rag dolls, germination paper
5. Timing – important
    a. Cool Season (40 – 55 F or 4.4. – 13 C) – radish, lettuce, spinach, Swiss chard, beet, carrot, onion, cauliflower, cabbage, broccoli, kohlrabi, kale, turnips, rutabagas, peas, snapdragons, pansies

    b. Warm season (> 60 F) - tomato, egg plant, pepper, cucumber, squash, watermelon, cantalope snap bean, lima bean, sweet corn, marigold, zinnia
6. Seed bed prep - uniform eliminate clods to get good contact between seed and soil, free from weeds
7. When to plant indoors - transplants put out after the average last killing frost (in late May). Tomato require about six weeks, annual flowers 6 – 8 weeks; cool season - sow outside as soon as work soil

VI . Seedlings

1. first leaves
2. hook vs. sheath (dicot vs. monocot)
3. adult vs. juvenile
4. epigaeous vs. hypogaeous
5. behavior - circumnutation