BIOL 1030
Introduction to Biology: Organismal Biology. Spring 2011
Section A

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Plant sex (or not)
Flowering plant reproduction and development, i.e. how plants do it. Sometimes they do it with others, sometimes on their own, sometimes they even do it without sex at all. How do they do that?
The ‘birds and the bees’ . . .

Nope, just the plants they pollinate . . . but they’ve been on a coevolutionary trajectory for a very, very long time!
Angiosperm reproduction

Angiosperms (flowering plants) have an extremely widespread distribution due to three key adaptations:

1) Pollen enables fertilization in the absence of free water; mosses and ferns require water for this (Gymnosperms ['naked seed' – conifers] also have this – e.g. down here in the Spring!).

2) Both Angiosperms and Gymnosperms have seeds that protect the embryo during dormancy and nourish the developing seedling; and . . .

3) Angiosperm flowers promote pollination and develop into fruits that aid in seed dispersal.
Asexual reproduction

- Many plants can form new individuals by mitotic cell division.
- Parent organism produces offspring that are genetically identical to it and to each other (clones).
- This is also called vegetative reproduction.
- It’s advantageous when environmental conditions are favorable and plants are well adapted to their surroundings. This can be seen in the giant Aspen clone forests out West.
- New plants can form from roots, stems, or leaves, depending on the plant.
- Lots of commercial applications – rooted cuttings propagate most nursery plants, grafting combines advantages of both “scion” and “root stock” for many fruit and nut trees, e.g. large seedless fruit on drought or pest tolerant root stock;
- Plus tissue culture in the laboratory can produce a whole plant!
Here's an example of plant tissue culture.

“Calli” give rise to plantlets given the right combination of hormones and nutrients.
An aspen clone in the Wasatch Mountains of Utah covering 100 acres is composed of 47,000 trunks of genetically identical aspen trees (Populus tremuloides), with a total weight of 6,500 tons.

But sexual reproduction . . .

- As we've seen, yields offspring with a mix of traits derived from parents due to random segregation and independent assortment during meiosis. The . . .

- Offspring are different from each other and from the parents. This is a nice advantage, and is . . .

- Adaptive in a changing environment.

- The basic plant life cycle has multicellular diploid and haploid stages (alternation of generation):
  - Sporophyte — diploid, produces haploid spores through meiosis.
  - Gametophyte — haploid, produces haploid egg and sperm by mitosis.
This “alternation of generations” is shown here.

Megaspores and microspores divide mitotically to produce female and male gametophytes, which produce gametes.
Flower structure

* Flowers are reproductive organs that bring plant eggs and sperms together.
* They protects seeds as they develop.
* Plus certain parts develop into the fruit.
* A flower begins to form on a mature sporophyte when the shoot apical meristem turns into floral meristem, due to particular physical transforming cues.
* Cues include day length, temperature, or even just the stage of the plant’s life.
The parts of a flower:

* Receptacle – the attachment point for all the other floral parts.

* All flowers have four whorls:
  1) Calyx – outermost whorl of sepals;
  2) Corolla – next, a whorl of petals; then the . . .
  3) Male reproductive parts – stamen, consisting of an anther (produces pollen) and a filament.
  4) Female reproductive parts – carpels, made up of the stigma, style, and ovary (encloses ovule).

* Monocots have multiples of three.

* Eudicots have multiples of four or five.
Those flower parts are shown here.

All flowers, no matter how big or small, or simple or complex, break down to four whorls.
Male and female gametophytes arise from two types of spores produced by the sporophyte.

- The anther has four pollen sacs. Inside that are...
- Diploid cells that divide by meiosis to produce four haploid microspores.
- Each microspore divides mitotically to form a two-celled thick-walled structure – this is the pollen grain, and is the young male gametophyte generation.
- Inside an ovule a diploid cell divides by meiosis, which...
- Produces four haploid megaspores.
- In many species only one megaspore persists.
- The megaspore undergoes three mitotic divisions to produce an embryo sac, which is the mature female gametophyte.
- Embryo sac – has eight haploid nuclei in seven cells – one is the egg itself. And the...
- Large central cell contains two polar nuclei.
The process is shown here.
And is lampooned in a great high-school claymation video.

http://www.youtube.com/watch?v=3EBfmZbqBc8

Also check out http://www.youtube.com/watch?v=6pHGN04CPEM for a surreal anthropomorphized version.
Pollination is the...

* Transfer of pollen from anther to stigma.
* Many modes of transfer exist, some are inanimate ones like rain and wind, others are animals, especially insects and birds.
* Flower color, shape, and odor are all used to attract pollinators. Pollination is...
* Mutually beneficial. And is a case of...
* Coevolution – where genetic change in one species selects for subsequent change in the genome of another species.
Many animals have evolved to pollinate specific plants. For example some bats only pollinate certain specific cacti.
Many plants use ultraviolet cues to attract insects. E.g. bees can see the dark patch in the middle of Black-eyed Susans because of the UV light they reflect. We can only see this with special photo equipment.
The pollen tube emerges from the pollen grain after it lands on the stigma of a receptive species.

* Two haploid sperm nuclei enter the tube.
* When the tube reaches an ovule it discharges the two sperm nuclei into the embryo sac. This is a . . .
* Double fertilization – the sperm nuclei fertilize the egg and the two polar nuclei. That is . . .
* One haploid sperm nuclei + the haploid egg nuclei forms the diploid zygote; the other haploid sperm + two haploid polar nuclei forms the triploid endosperm (food for developing embryo).
The endosperm is the starchy part of the grains we eat.
The seed develops, and . . .

* After fertilization, the embryo sac contains:
  * The diploid zygote, and the . . .
  * Triploid endosperm – this divides rapidly to form a large mass to supply nutrients to the developing embryo.

* The shoot and root apical meristems form at opposite ends of the embryo. The embryo also forms . . .

* The cotyledons (a.k.a. seed leaves);
  * Monocots have one; Eudicots have two.

* The embryo becomes dormant at some point.

* And the seed coat protects the dormant embryo and food supply until it’s ready to germinate.

* Seed = plant embryo, stored food, and seed coat.
Here's a diagram of seed development in a Eudicot.
And what a mature Monocot seed looks like, versus . . .
A mature Eudicot seed, where the cotyledons absorb most of the endosperm.
The flower plus the seed develops into the fruit.
The flower begins to change as seeds develop.

- The pollen tube produces ethylene that triggers unneeded flower parts to ripen and fall off.
- The developing seeds produce the hormone auxin that stimulates the fruit to form.
- The ovary grows rapidly to form a fruit with one or more seeds.
- Additional plant parts may also join in the fruit.
Fruits have two functions – protection and dispersal.

- Protection is obvious, dispersal not always quite so . . .
- Animals eat fruits carrying seeds to new locations where they can be passed on through defecation;
- Seeds may spread attached to fur or feathers;
- Wind or water may carry seeds far from the parent.
There are lots of types of fruits, and many things we consider vegetables are actually fruits, e.g. cucumbers, squash, chilies, tomatoes . . .

<table>
<thead>
<tr>
<th>Fruit Type</th>
<th>Characteristics</th>
<th>Example(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>Derived from one flower with one carpel</td>
<td>Olive, cherry, peach, plum, coconut, grape, tomato, pepper, eggplant, apple, pear</td>
</tr>
<tr>
<td>Aggregate</td>
<td>Derived from one flower with many separate carpels</td>
<td>Blackberry, strawberry, raspberry, magnolia</td>
</tr>
<tr>
<td>Multiple</td>
<td>Derived from tightly clustered flowers whose ovaries fuse as fruit develops</td>
<td>Pineapple</td>
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</tbody>
</table>
Germination is the...

- Resumption of growth and development after seed dormancy. It...
- Usually requires water, oxygen, and favorable temperatures.
- Rapidly dividing cells in the apical meristems add length to roots and shoots.
- By the time the seedling has used its food reserves, the young shoot is producing its own food through photosynthesis.
Monocot germination and development:

The coleoptile covers and protects the shoot's embryonic leaves.
Eudicot germination and development:

You saw this in lab. Notice the endosperm is largely missing.
Hormones matter to plants too. They are . . .

- Biochemicals synthesized in small quantities in one part of an organism and (often) transported to another, where they stimulate or inhibit a response from target cells. They . . .

- Interact with each other, and with the plant’s DNA, to regulate many aspects of the plant’s overall physiology.

- Complex interactions – each hormone has a variety of effects, and its action depends on both the concentration and the developmental stage of the plants; functions of hormones may overlap.

- There are five classic plant hormones . . .
Here they are:

<table>
<thead>
<tr>
<th>Class</th>
<th>Selected Actions</th>
<th>Synthesis Site(s)</th>
</tr>
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</table>
| Auxins      | • Elongate cells in seedlings, shoot tips, leaves, embryos (by triggering $H^+$ export to cell wall)  
                          • Control phototropism, gravitropism, thigmotropism  
                          • Promote growth of adventitious roots from stem cuttings  
                          • Inhibit growth of lateral buds (apical dominance) | Developing leaves and seeds, shoot tips                                           |
| Cytokinins  | • Stimulate cell division in seeds, roots, young leaves, fruits  
                          • Delay leaf senescence  
                          • Stimulate growth of lateral buds | Root tips                                                                      |
| Gibberellins| • Stimulate cell division and elongation in roots, shoots, young leaves  
                          • Break seed dormancy | Young shoot, developing seeds                                                    |
| Ethylene    | • Hastens fruit ripening  
                          • Stimulates leaf and flower senescence  
                          • Stimulates leaf and fruit abscission  
                          • Participates in thigmotropism | All parts, especially under stress, aging, or ripening                          |
| Abscisic acid| • Inhibits shoot growth and maintains bud dormancy  
                          • Induces and maintains seed dormancy  
                          • Stimulates protein storage in seeds  
                          • Stimulates stomatal closing  
                          • Promotes leaf, flower, and fruit abscission (perhaps by stimulating ethylene release) | Mature leaves, plants under stress                                               |
And in more detail – Auxins . . .

- From the Greek “to increase.” They . . .
- Promote cell elongation (not division) in stems and fruits.
- But they have the opposite effect in roots.
- They also control a plant’s responses to light and gravity.
- Indole-acetic acid (IAA) is the most active of them.
- The first plant hormones described were auxins. In the late 1870’s . . .
- Charles Darwin and his son discovered that ‘something’ caused plants to grow toward light.
Darwin's experiment demonstrated that something produced in the growing plant tip controlled the light response. That something turned out to be auxins.
Cytokinins...

- Stimulate cytokinesis (remember – the actual splitting of a cell after mitosis or meiosis).
- Their action is more pronounced in roots and other growing tissues. They also slow leaf senescence.
- The actions of auxins and cytokinins compete with each other.
- Cytokinins are more concentrated in the roots, auxins more so in shoot tips.
- Cytokinins move up the xylem to stimulate lateral meristem growth. In a counteracting action called...
- Apical dominance – terminal buds' auxins move down the plant to suppress lateral buds' growth.
- Cut the top off → less auxins coming down, more cytokinins coming up → a more bushy plant!
Gibberellins (have nothing to do with Gerbils).

- The name comes from a fungus (Gibberella fujikuroi) that infects plants and makes them long and spindly.
- You played with the hormone in lab. They...
- Were discovered in the 1920's while investigating "foolish seedling disease."
- Almost 100 different ones are found in nature.
- They’re multifunctional, causing shoot elongation in woody plants; and they...
- Promote cell division and elongation in all plants; and they...
- Stimulate seed germination in all plants.
Ethylene, more than just a flammable gas. It’s a . . .

* Gaseous hormone, that causes the old saying . . .
* “One bad apple, spoils the whole bushel!” This is . . .
* Because it ripens fruit. Therefore, . . .
* One overripe apple can hasten the ripening and spoilage of all the other nearby apples. It . . .
* Causes plant organs to fade, wither and fall. This . . .
* Helps prevent the damaged parts from spreading any infection to other parts of the plant.
* It is used commercially to ripen harvested, yet not-yet ripe, fruit.
Abscisic acid – ABA...

* Counters the growth-stimulating effects of many of the other hormones.
* It inhibits seed germination, ...
* Promotes abscission (plant part shedding), and ...
* Closes stomata to conserve water. It is ...
* Produced in response to stress like drought or freezing, and is used commercially to ...
* Inhibit growth in nursery plants.
A not so ‘classic’ but very interesting hormone...

Jasmonic acid is secreted by some plants like tomatoes to mount a defense against attack by caterpillars. It does this by both stimulating the production of protease inhibitors; And a gas that tells other plants to make more; And that attracts parasitic wasps that attack the caterpillars!

Courtesy University of California Statewide Integrated Pest Management Project, Photo by Jack Kelly Clark
The role of light – essential for photosynthesis. So . . .

* Photoreceptors in the plant perceive the quality and quantity of light.
* Light absorption triggers changes in these proteins, which, in turn promote the transcription of specific genes.
* This causes a change in phenotype.
* Phytochrome is a type of photoreceptor. It is a blue pigment molecule that can switch back and forth between red and far-red absorbance.
The phytochrome switching reaction

Red light (660 nm) → Pr

Far-red light (730 nm) → Pfr

Responses: seed germination, flowering

Slow spontaneous conversion in darkness
Some seeds germinate in total darkness. Others require light.

- The phytochrome system tells seed about sunlight. If a seed is buried too deeply, it will never germinate.
- After germination phytochromes and cryptochromes control early seedling growth by controlling tropism.
- Phototropism – the growth toward light. (Tropism is the orientation of a plant toward something.)
- This works through differential growth: Cells on the shaded side of a stem elongate more than the cells on the other side. The photoreceptors ‘tell’...
- Auxins to migrate to shaded side. This causes the...
- Cell walls to expand and elongate against turgor pressure.
These guys grew under a log and are, therefore, pale, long, and spindly. Asian bean sprouts are purposely grown this way for food.
These Crocus shoots are striving for the light – phototropism in action.
Here’s how it happens.
And in more detail.

1. Auxins stimulate proton pump in cell membrane to pump protons out of cytoplasm into the cell wall.

2. High acidity in cell wall loosens bonds between cellulose fibers.

3. Cell elongates as water moves in by osmosis and turgor pressure stretches the weakened cell wall.
Seasonal changes in photoperiod (i.e. the length of the day) . . .

- Can cause many seasonal plant changes, e.g. bud formation, leaf abscission, and dormancy all come on in the fall; whereas buds grow, and the plant comes out of dormancy in the spring.
- A complex interaction between environmental signals, hormones, and genes all controls this.
- Plants that flower in response to photoperiod can be divided into two categories:
  - The long-day plants flower when light periods are longer than a critical length (i.e. in spring or summer); versus the . . .
  - Short-day plants, which flower when light periods are shorter than a critical length (i.e. in late summer or fall).
- This requires a specific period of uninterrupted darkness, not light.
- Phytochromes measures the length of day and night.
Experiments confirm that they need uninterrupted darkness.

Long-day plants need a dark period shorter than some critical length.

Short-day plants need an uninterrupted dark period longer than some critical length.
The last flash matters.

Interrupting night with a short burst of red light shortens continuous darkness. A flash of far-red light right after cancels the effect. All comes down to the prevalent form of phytochrome.
Many things in plants respond to daily photoperiods.

- The Prayer plant folds its leaves up at night.
- Most plants close down their stomata at night (exception the CAM cacti).
- Some plants only bloom at night.
- These are all examples of circadian (daily) rhythms.
Plants respond to lots of other things too. Like…

* Higher carbon dioxide levels lead to fewer stomata;
* Higher nitrate levels lead to fewer lateral rootlets;
* Temperature may control when plants bud or flower.
* Most all work to conserve energy!
And gravity matters – gravitropism

This is a plant’s response to gravity.

The root cap cells have statoliths in them, which . . .

Sink to the bottom of the cells signaling “down.”
Here's a hypothesis of how the statoliths involved in gravitropism work.

Statoliths are starch filled plastids that may act as 'plumb-bobs.'
Another one is thigmotropism. This is a directional response to touch. It induces differential growth, as seen in vine tendrils. And is probably controlled by auxin and ethylene.
Finally . . . senescence.

- All plants age. Their . . .
- Metabolism switches from synthesis to breakdown. Annuals do it completely after a year and die. Perennials do it partially seasonally, but may not completely die for years and years.
- An example is changing leaf colors in the fall.
- The pigments masked by chlorophyll become visible – largely carotenoids and anthocyanin.
- The leaf separates from the plant at the abscission zone at base of the petiole.
- This prevents water loss from leaves in winter.
The abscission zone is seen here.
Dormancy (aren’t we all about now!)

* Those parts that aren’t lost often become dormant. They have a . . .
* Decreased metabolism. And . . .
* Antifreeze molecules (sugars and amino acids) minimize cold damage.
* Growth inhibitors accumulate in the buds, which cause the . . .
* Winter buds to get covered by protective scales. As seen in the following pic’ . . .
We’ll see you next time for the first installment of the Botany of Desire!