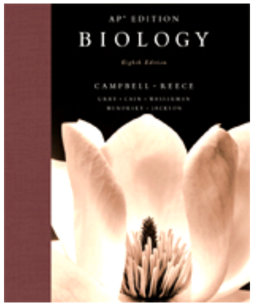
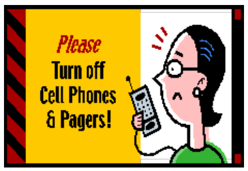




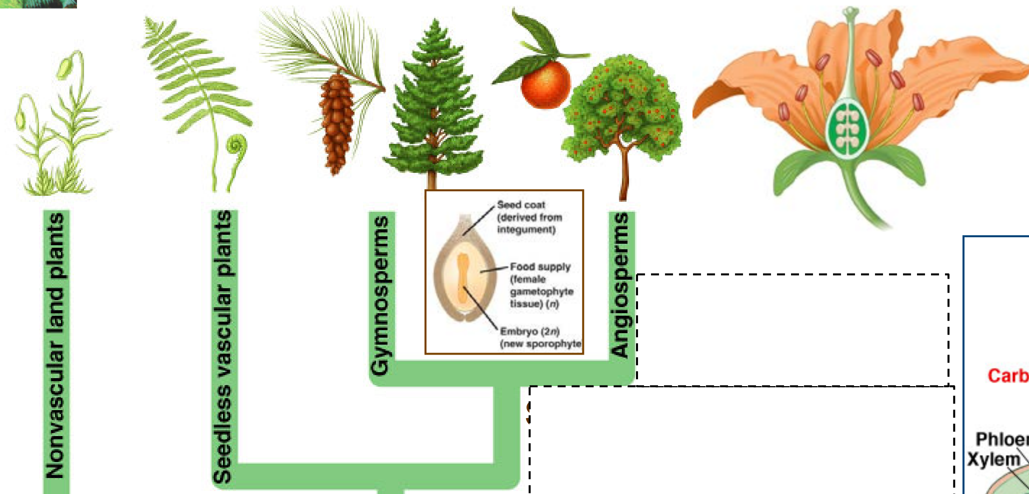
Overview of Lecture: Plants

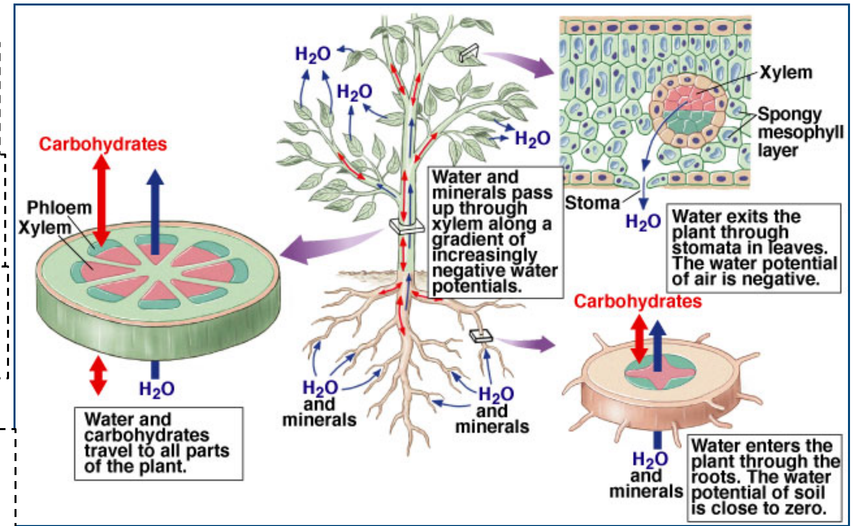
Read: Text ch 29 & 30

Bullet Points:

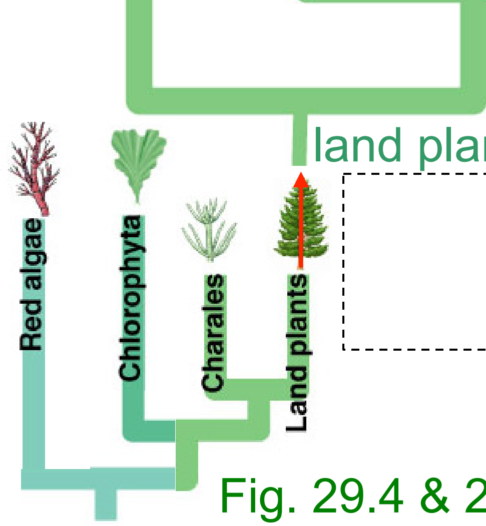
- plant phylogeny & diversity
- photosynthesis
- light spectral sensitivity
- alternation of generations
  multicellular gametophyte (n)
  & sporophyte (2n)
- nonvascular mosses etc.
- vascular ferns etc
- seed plants
- flowering plants - sex
- fruit and seed dispersal
- chemical defenses
  ... and offenses!

Plant Diversity: Land plants evolved from freshwater green algae
w/ many shared, derived traits - adaptations to life in land-air environment





land plants



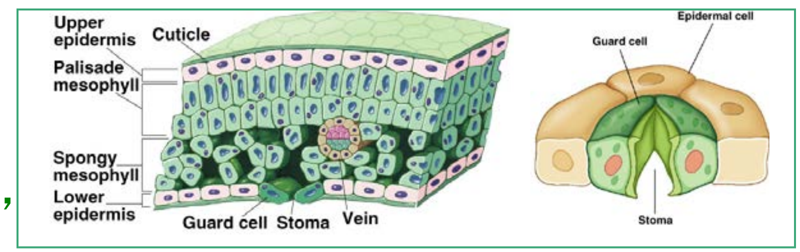


Fig. 29.4 & 29.7. The 'Kingdom Plantae' has been revised into a sister clade of the chara pond weed clade (Fig 29.4)

modern *Chara*
- a pond weed

The **mitochondrial genome** of Chara vulgaris:
Insights into the mitochondrial DNA architecture
of the last common ancestor of green algae and land plants
Turmel M, et al. PLANT CELL 15 (8): 1888-1903 AUG 2003

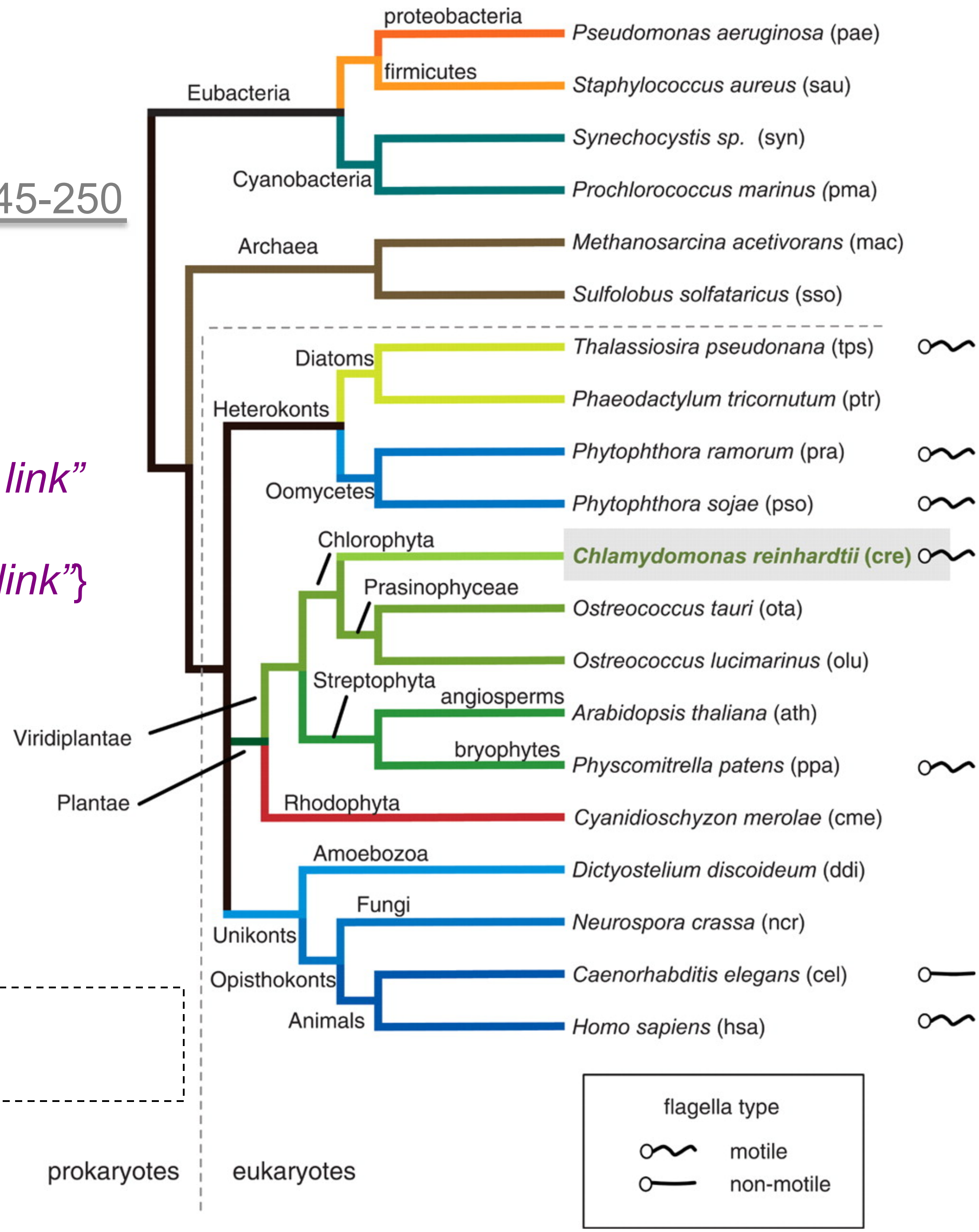
The Chlamydomonas Genome Reveals the Evolution of Key Animal and Plant Functions

Merchant et al. 2007 Science 318:245-250

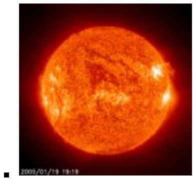
… **the Chlamydomonas genome sheds light on the nature of the last common ancestor of plants and animals**

{the common ancestor is a "missing link" between plants and animals; Chlamydomonas is not a "missing link"}

Genes shared by Chlamydomonas and animals are derived from the last plant-animal common ancestor and **many of these have been lost in angiosperms,**

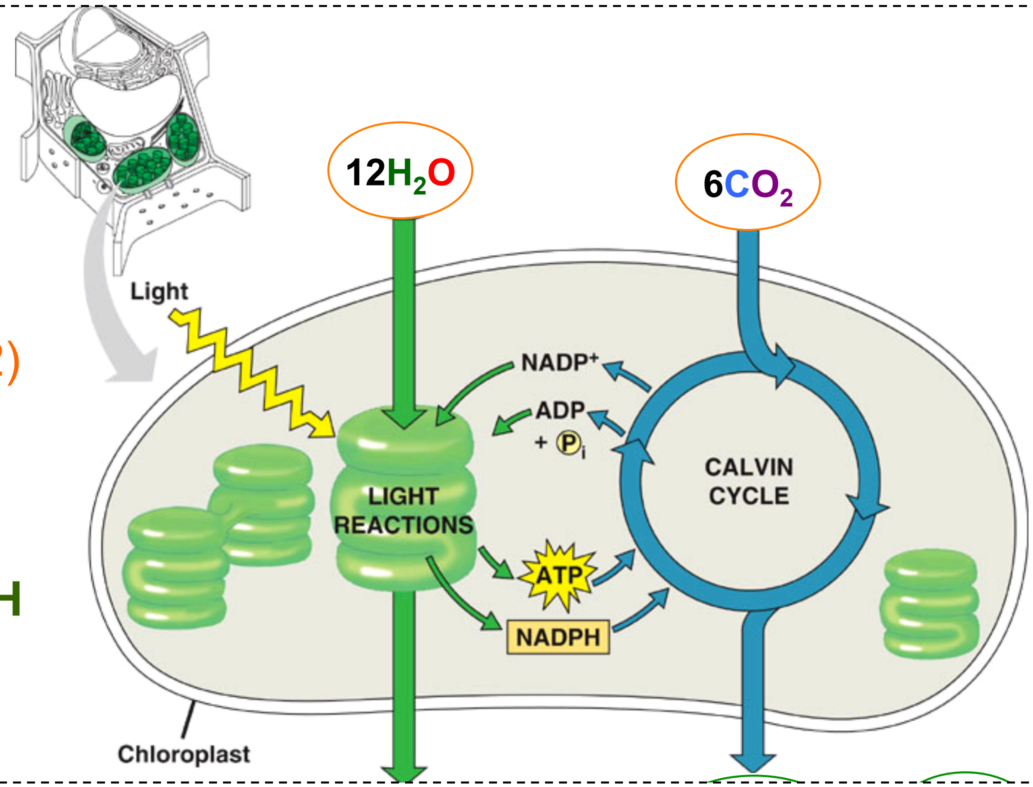


Photosynthesis (ch 10): Life is powered by sunshine.
Every molecular O_2 that we breath
was once part of two H_2O molecules, liberated by photosynthesis.
The captured energy is released from our food and fuel.



Photosynthesis occurs in many bacteria

Photosynthesis uses light energy to
- split H_2O, release O → O_2,
- make ATP & NADPH, and
- put the 'hydrate' in carbo**hydrate**.



2 stages:

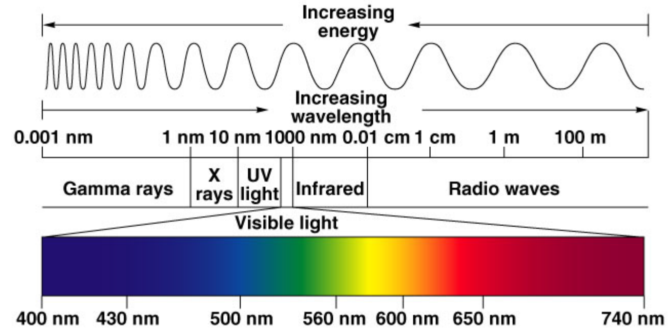
1a capturing energy from light (ch 10.2)
  w/ photopigment molecules:
    chlorophylls & carotenoids

1b using the energy to make
  reducing (electron accepting) NADPH
  energy-storing ATP

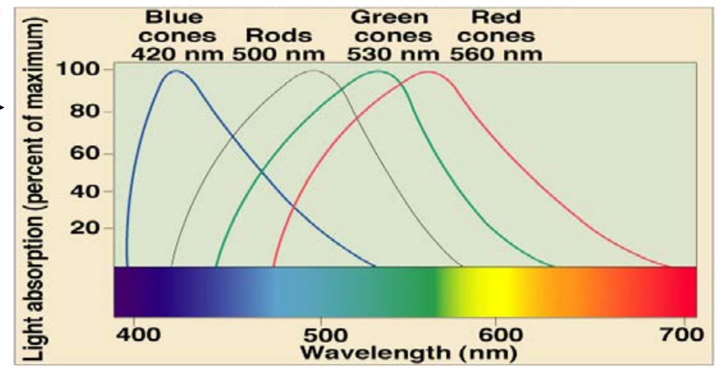
2 the Calvin cycle (ch 10.3):

What is in sunlight plants can use? (sec 10.2)

Light is electromagnetic energy,
'conveniently thought of as' a wave.
Shorter wavelengths carry greater energy
Fig 10.6



Light visible to human retinal pigments
is a small portion of the solar spectrum.
{birds & insects see down into UV}



Cyanobacteria, green algae & plants
use **chlorophyll a** as main photopigment
& chlorophyll b as an accessory
Carotenoids absorbs blue-green – inefficeintly.

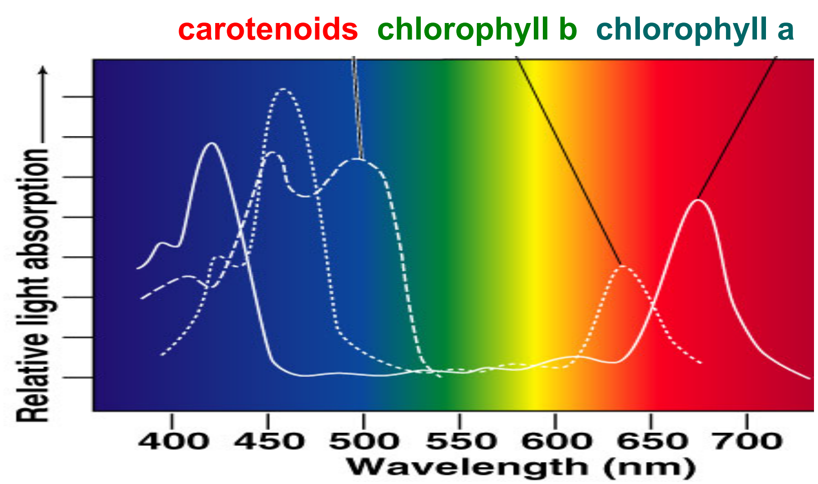
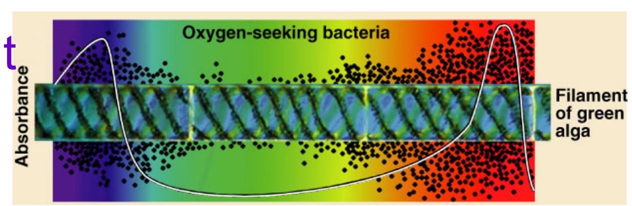


Fig 10.9 Englemann's brilliant 1882 experiment
w/ aerobic bacteria distributing themselves
along spyrogyra algae behind a prism



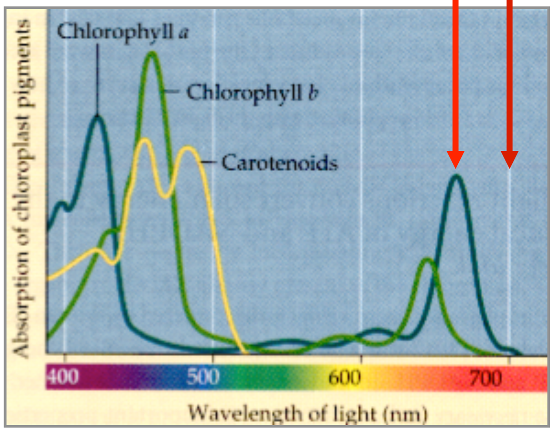
Plants have sensory systems and "behavioral" responses: to crowding

Plant sensory systems (ch 39); red-light sensitive **phytochrome** (Fig 39.4, Fig 39.19) exists in interconvertible forms: when Pr absorbs red (~660nm), switches to Pfr

when Pfr absorbs far-red (~730nm), switches to Pr

The concentration of Pfr influences stem elongation (etiolation) in shade.

Note low ratio of red/far-red left in light passed through leaves (shade).



Manipulative approaches to testing **adaptive plasticity**: **Phytochrome-mediated shade-avoidance responses** in plants. *{text ch 39.3}*

Schmitt et al. 1999. AM NAT 154:S43-S54.

Because chlorophyll selectively absorbs red wavelengths, the ratio of red (R) to far-red (FR) wavelengths is an accurate signal of vegetation shade ...

Many plants respond to **low** R:FR with a suite of photomorphogenic changes such as stem elongation, suppression of branching, altered biomass allocation, and accelerated flowering, commonly referred to as **the "shade avoidance syndrome".**

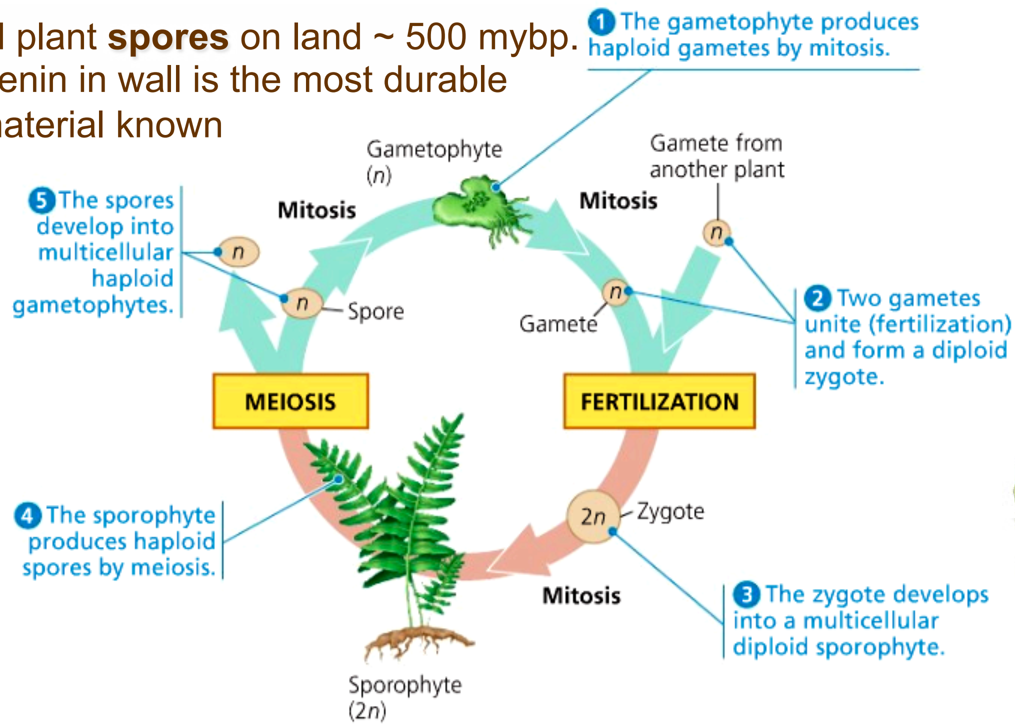
Such responses are often elicited by FR reflected

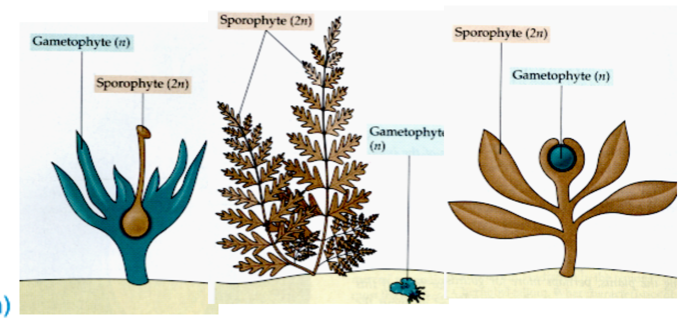
All plants undergo mitosis *{cell multiplication}* after meiosis *{formation of haploid spores}* resulting in

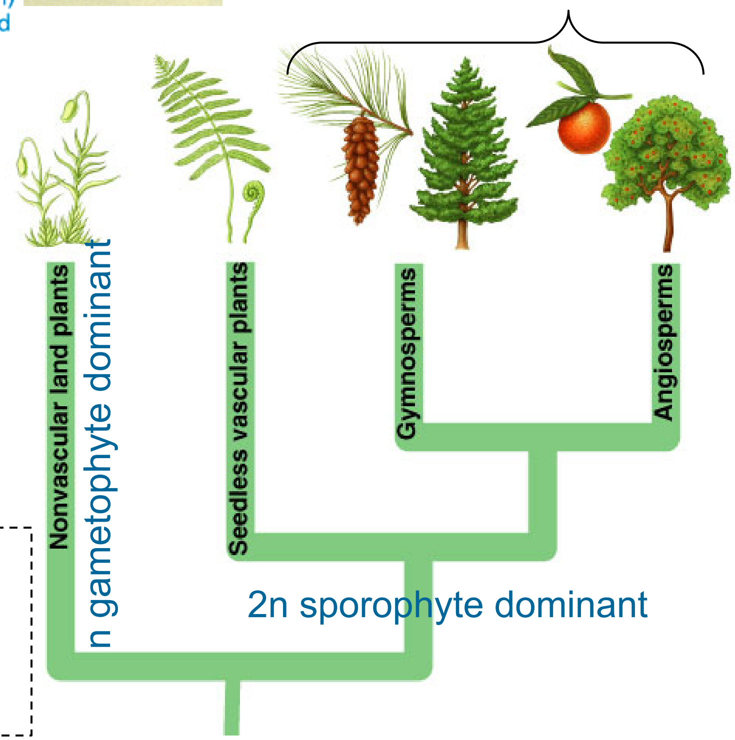
as well as a multicellular diploid stage *{as in animals}*: **sophyte** (2n)

- called 'haplodiplotonic' **alternation of generations** (Fig 29.5)

Fossilized plant **spores** on land ~ 500 mybp.
Sporopollenin in wall is the most durable organic material known







The multicellular **diploid sporophyte** produces haploid spores not gametes, by meiosis.

{if you were a plant, would you be a sporophyte, gametophyte or both?}

REPORT

KNOX2 Genes Regulate **the Haploid-to-Diploid Morphological Transition in Land Plants**

K Sakakibara et al. Science 1 March 2013: Vol. 339 no. 6123 pp. 1067-1070

Unlike animals, **land plants undergo an alternation of generations, producing multicellular bodies in both haploid (1n: gametophyte) and diploid (2n: sporophyte) generations.**

In mosses,

in vascular plants—including ferns, gymnosperms, and angiosperms—

The closest living relatives of land plants are green algae that lack an alternation of generations.

Their only organismic {*multicellular*} generation is a haploid gametophyte; after fertilization and the formation of a diploid zygote, meiosis creates haploid propagules that reestablish new gametophytes.

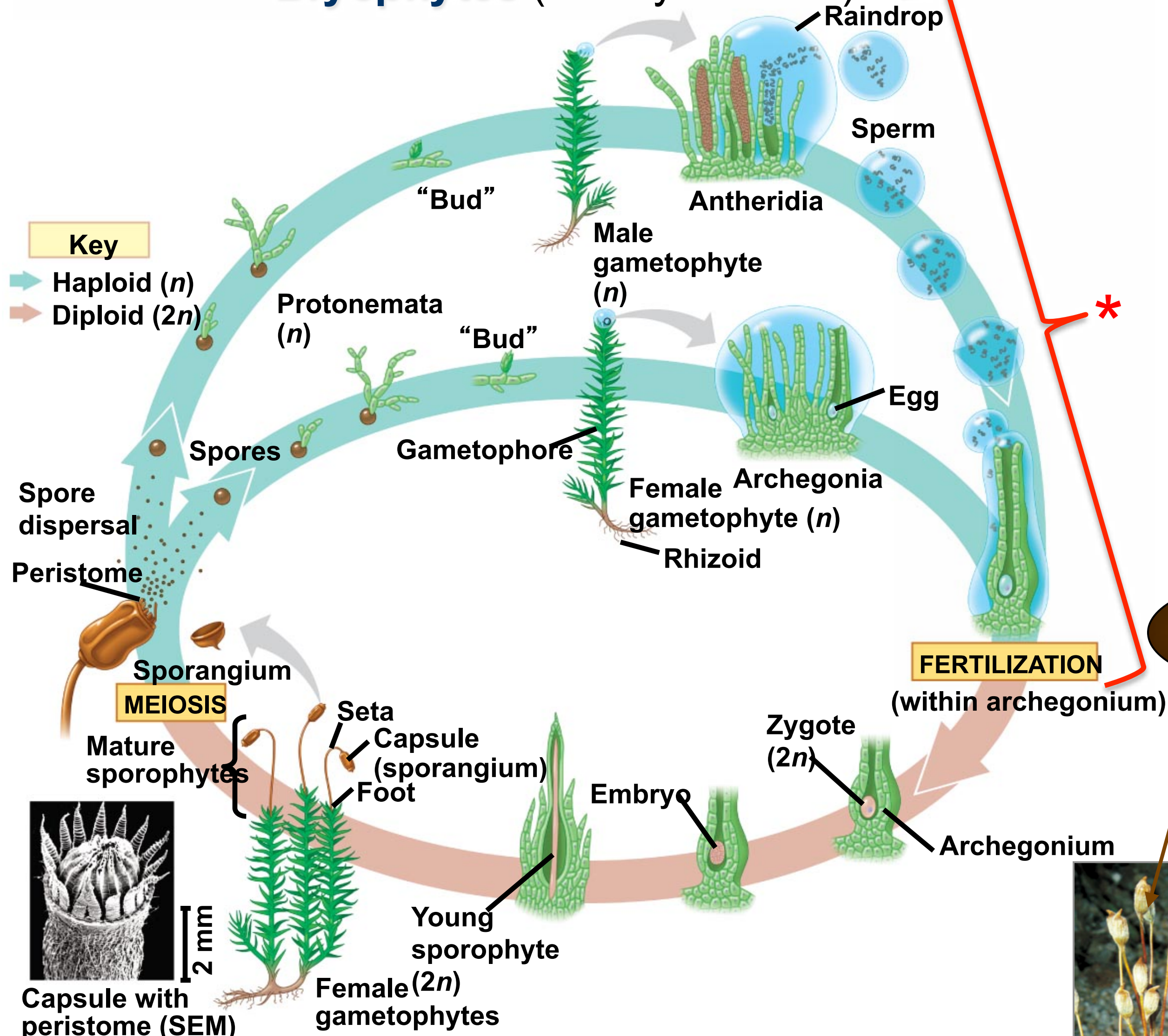
Thus, the only diploid phase in the life cycles of the ancestors of land plants

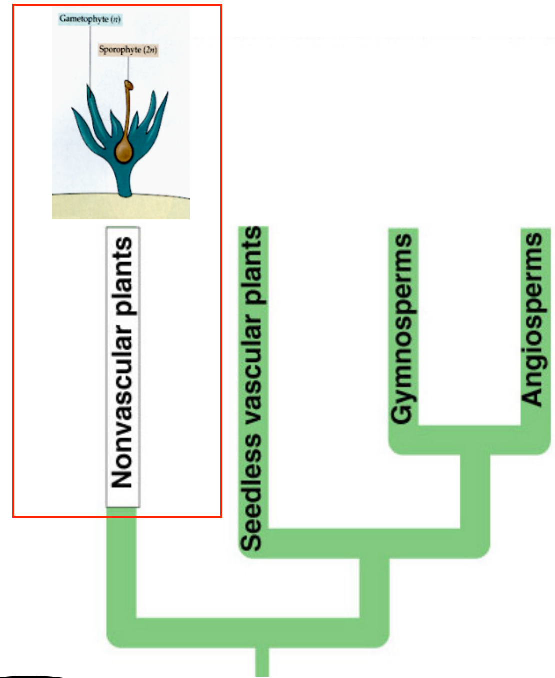
The multicellular sporophyte as we know it (such as a leafy fern, pine tree, water lily, and buttercup) is a developmental innovation of land plants.

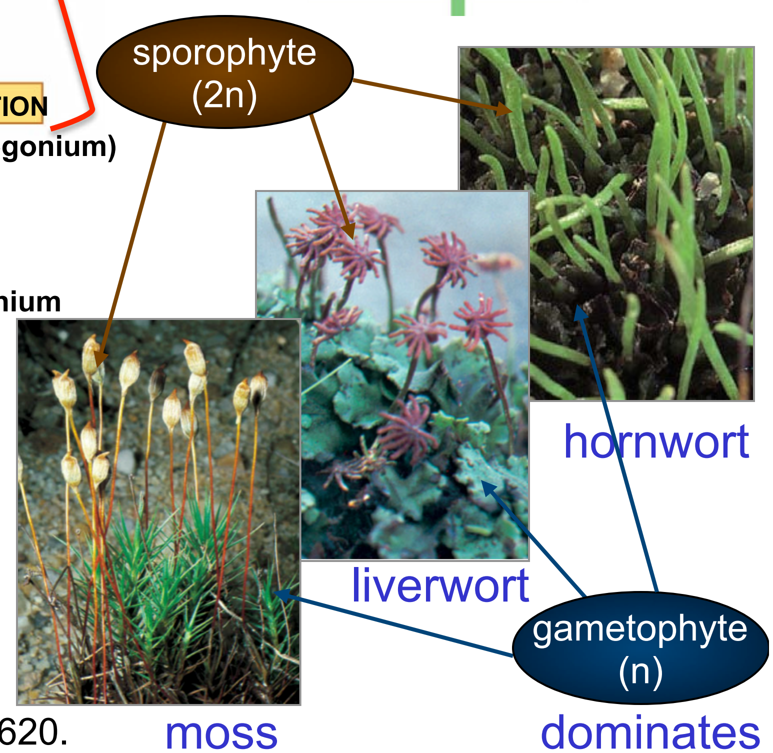
{*note: multicellular diploid gamete forming body in animals – such as yourself*!}

The KNOX2 gene plays a critical role in the development of a multicellular diploid sporophyte in land plants. {*by suppressing it*}

nonvascular **Bryophytes** (mostly mosses)







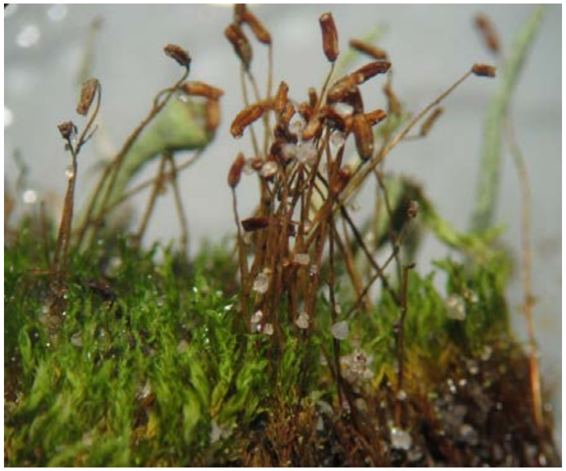
sphagnum - future peat;
Defrosting the Carbon Freezer of the North
E. Stokstad *Science* 2004:1618-1620.

NATURE | LETTER

Sex-specific volatile compounds influence microarthropod-mediated fertilization of moss

Rosenstiel et al. *Nature* (2012) doi:10.1038/nature11330

http://en.wikipedia.org/wiki/File:Ceratodon_purpureus.jpegz



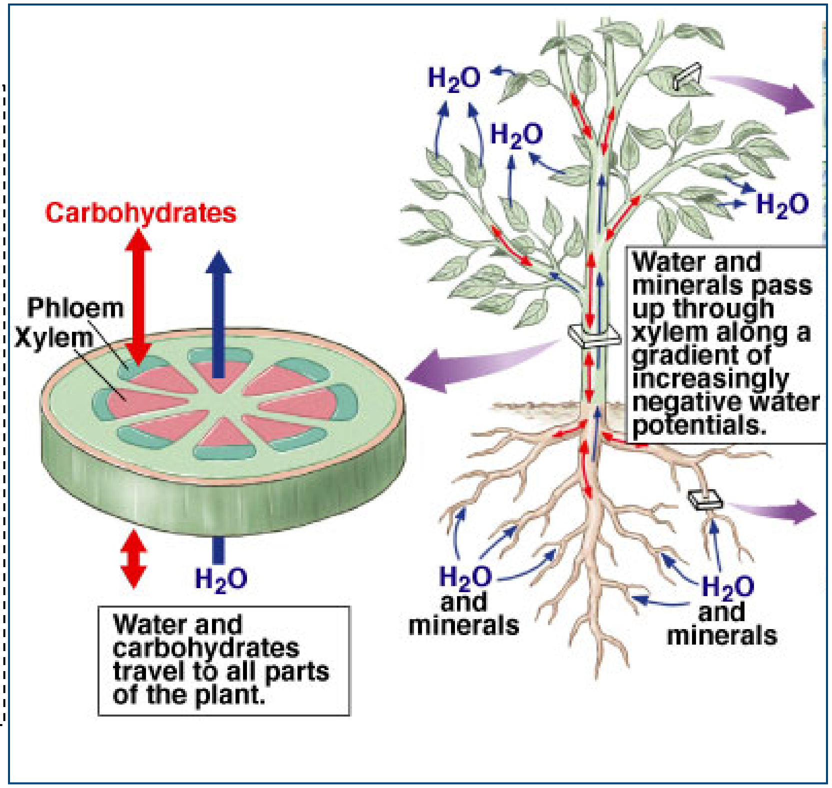
Sexual reproduction in non-vascular plants

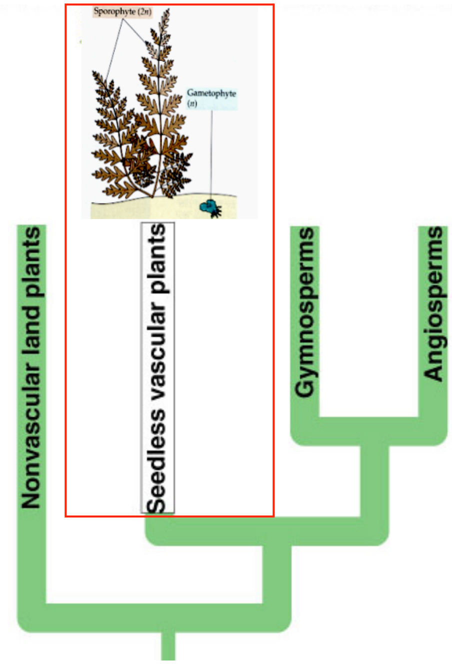
Here we show that tissues of the cosmopolitan moss Ceratodon purpureus emit complex volatile scents, similar in chemical diversity to those described in pollination mutualisms between flowering plants and insects, that the chemical composition of C. purpureus volatiles are sex-specific, and that moss-dwelling microarthropods {*springtails* & *mites*} are differentially attracted to these sex-specific moss volatile cues.

Furthermore, using experimental microcosms, we show that **microarthropods significantly increase moss fertilization rates,** even in the presence of water spray, highlighting the important role of microarthropod dispersal in contributing to moss mating success.

Taken together, our results indicate the presence of **a scent-based 'plant–pollinator-like' relationship that has evolved between two of Earth's most ancient terrestrial lineages, mosses and microarthropods.**

Roots, shoots & vascular tubes (plumbing)
appeared in **sporophytes** of fossil Cooksonia
~420mybp (ch 35 & 36)





There is no transmembrane water pump in nature,
but cells do pump solutes & create osmotic gradients;
water follows (up) osmotic gradient → pressure (ch 36.1)

http://www.nature.com/news/2004/040419/full/040419-5.html

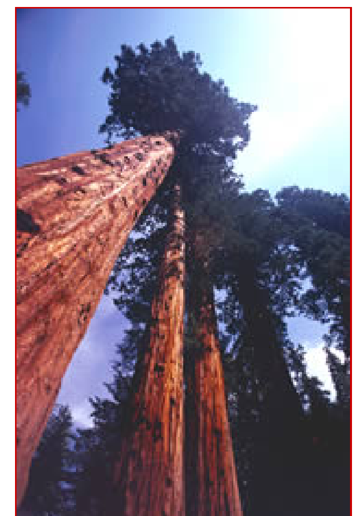
news@nature.com
The best in science journalism

Michael Hopkin

Height limit predicted for tallest trees.

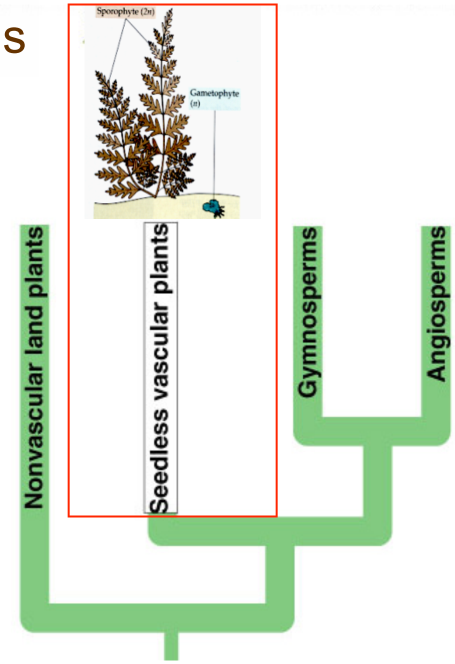
How tall can a tree grow? … researchers … have placed the theoretical height limit at 130 metres: the height of a 35-storey skyscraper. …

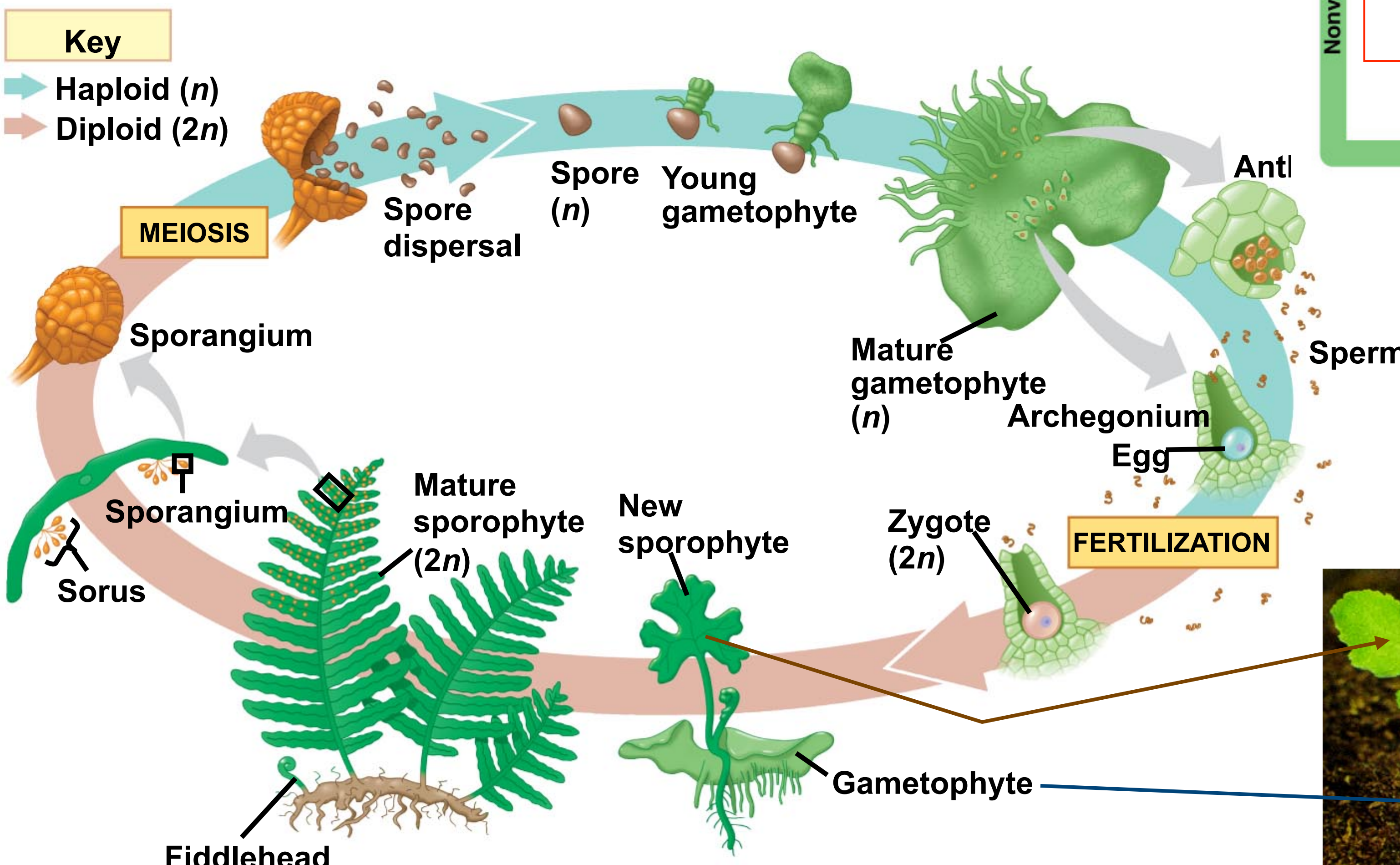
Koch et al. 2004. *Nature*, **428,** 851-854.

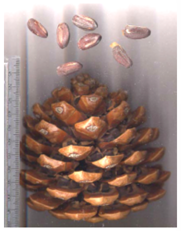


The tallest redwood is 112.7m, a few meters off the maximum 130m.
© *Brand X*

vascular Ferns, horsetails & club mosses: roots & shoots; no seeds

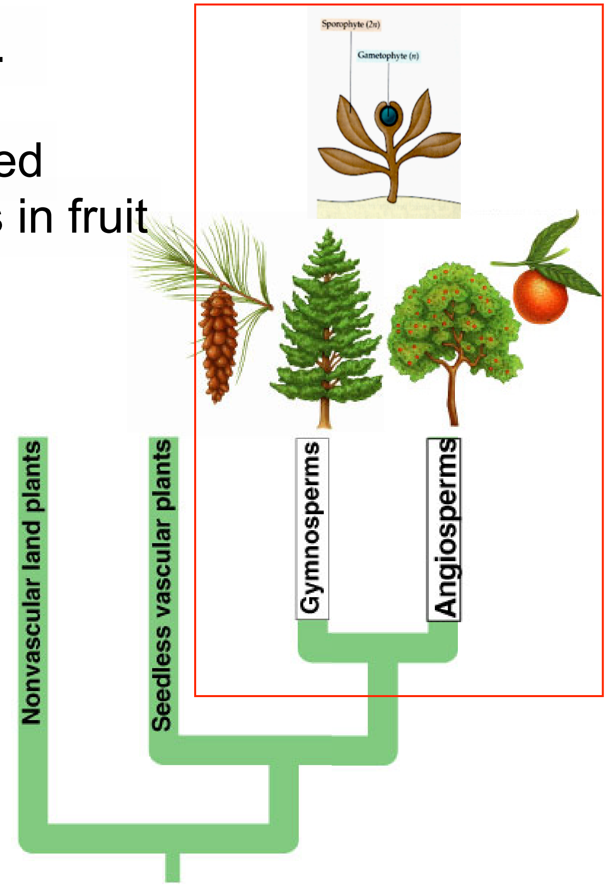






Seed plants are vascular plants that produce seeds.
The two clades of seed plants are

- **gymnosperms**: non-flowering, ‘naked ovules’; seed
- **angiosperms**: flowers w/ ovules in carpels; seeds in fruit

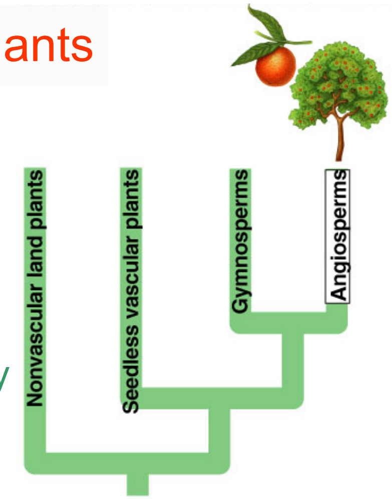


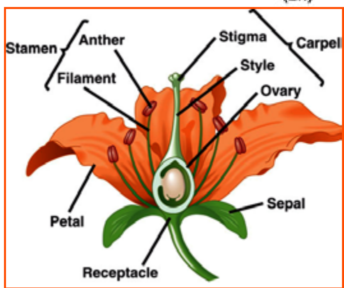
Three important reproductive adaptations:

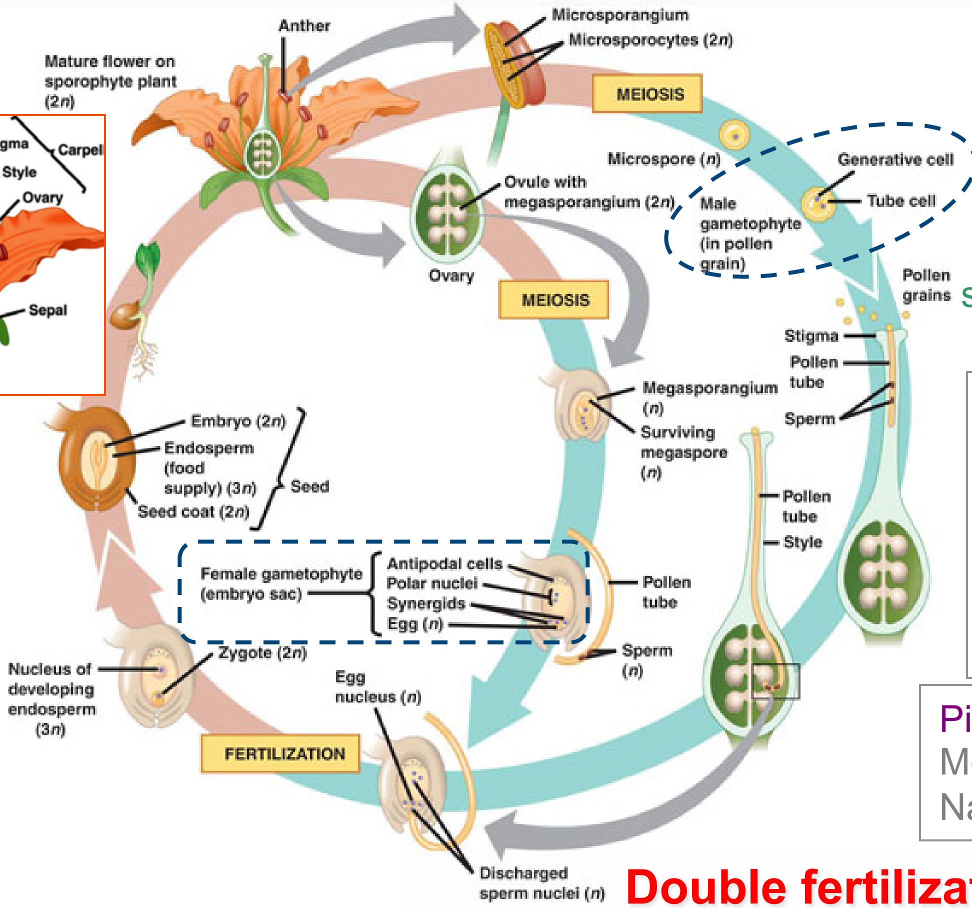
Raven et al. **Table 29.1** The Seven Phyla of Extant Vascular Plants

Phylum	Examples		Key Characteristics	Approximate Number of Living Species
SEED PLANTS Anthophyta	Flowering plants (angiosperms)		Heterosporous. Sperm not motile; conducted to egg by a pollen tube. Seeds enclosed within a fruit. Leaves greatly varied in size and form. Herbs, vines, shrubs, trees. About 14,000 genera.	250,000
Coniferophyta	Conifers (including pines, spruces, firs, yews, redwoods, and others)		Heterosporous seed plants. Sperm not motile; conducted to egg by a pollen tube. Leaves mostly needlelike or scalelike. Trees, shrubs. About 50 genera.	601
Cycadophyta	Cycads		Heterosporous. Sperm flagellated and motile but confined within a pollen tube that grows to the vicinity of the egg. Palmlike plants with pinnate leaves. Secondary growth slow compared to that of the conifers. 10 genera.	206
Gnetophyta	Gnetophytes		Heterosporous. Sperm not motile; conducted to egg by a pollen tube. The only gymnosperms with vessels. Trees, shrubs, vines. Three very diverse genera (*Ephedra*, *Gnetum*, *Welwitschia*).	65
+ Ginkophyta	Ginko tree		male trees OK, female fleshy seeds (not fruit) a mess!	1

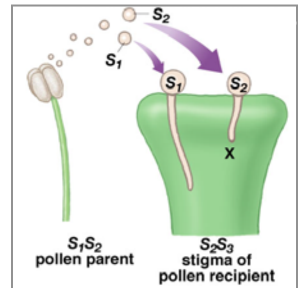
Vascular Flowering Seed Plants – Angiosperms ~90% of all land plants







self-incompatibility
pg 775

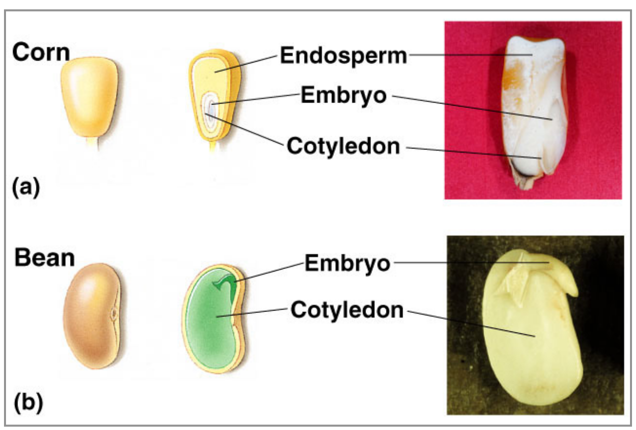


(a) Gametophytic self-incompatibility

Pillow talk in plants
McClure, B. 2004.
Nature 429: 249-250

Double fertilization: (ch 38.2)

1. of 1n egg: diploid **2n zygote**
2. of 2x1n double haploid cell: triploid **3n endosperm**

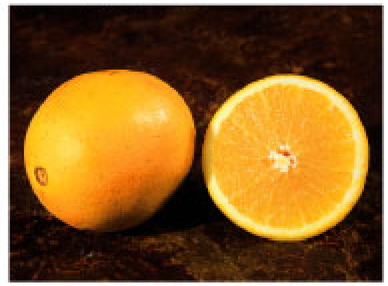


Beans have converted 3n endosperm into 2n embryo.

Fruits are mature ovaries that contain seeds (ch 38.2)

Drupes
Single seed enclosed in a hard pit; peaches, plums, cherries.

True berries
More than one seed and a thin skin; blueberries, tomatoes, grapes, peppers.

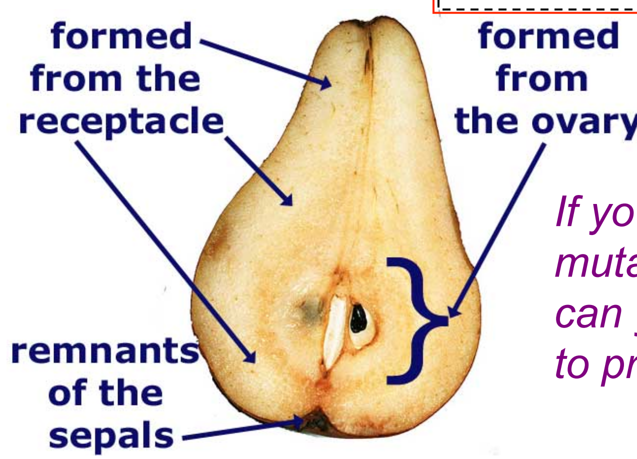


Hesperidia
More than one seed and a leathery skin; oranges, lemons, limes.

Aggregate fruits
Derived from many ovaries of a single flower; strawberries, blackberries.

Multiple fruits
Develop from a cluster of flowers; mulberries, pineapples.

Note: For mamma plants, carbohydrate is cheap but nitrogen is dear.



If you find a tastee new mutant variety of apple, can you plant the seeds to propagate the variety?

Pomes - include: apples, pears & quinces.
The core is the ovary (maternal)
with seeds (partly maternal, partly recombinant),
and the rest (the tastee part)

Address http://www.bbc.co.uk/worldservice/sci_tech/highlights/010730_chillies.shtml

BBC WORLD SERVICE

The Capsaicin Receptor

A Pepper's Pathway to Pain

Plant Manipulation

Many plants have ripe, fleshy, coloured fruit in order to attract animals that will eat them and then disperse their seeds in droppings.
However, the chilli plant has developed another way of ensuring its seeds are spread far and wide.

What raises the roof of your mouth when you eat a chilli is a substance called **capsaicin**.
This stimulates the areas of the skin and tongue that normally sense intense heat and pain, falsely telling the brain that the area affected is burning.

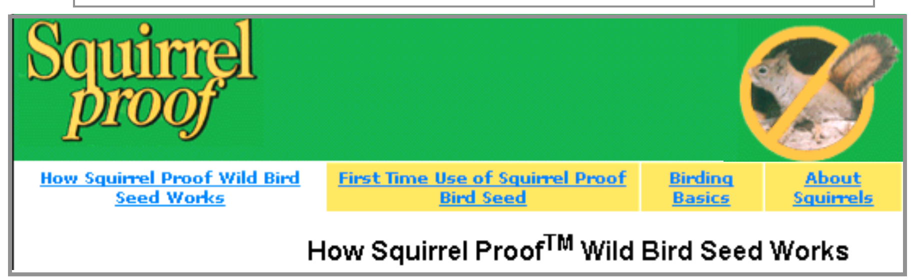
New research … has discovered that this characteristic peppery taste repels certain animals *{mammals}* – which are no good at dispersing the seeds.

{ Seed dispersal –
Directed deterrence by capsaicin in chillies.
Tewksbury & Nabhan 2001 Nature 412:403-404 }

Digestion And Dispersal

… scientists observed … animals living around a group of wild-growing chillies in Arizona. … desert mice and rats avoided spicy chillies, but birds fed almost exclusively on the plants.
… when birds ate the chillies, many seeds germinated, but there was no germination after mice had eaten the chilli seeds.
… seeds pass through a birds' digestive systems very quickly and come out unharmed,
whereas in mice, rats and other mammals, the seeds don't make it out in one piece …
The researchers suggest that chilli plants have evolved to produce capsaicin as a repellent for animals *{mammals}* … whilst still allowing birds to eat their seeds.

Molecular basis for species-specific sensitivity to "hot" chili peppers.
Jordt & Julius 2002. CELL 108:421-430.
{the vanilloid receptor subtype 1 (VR1)}

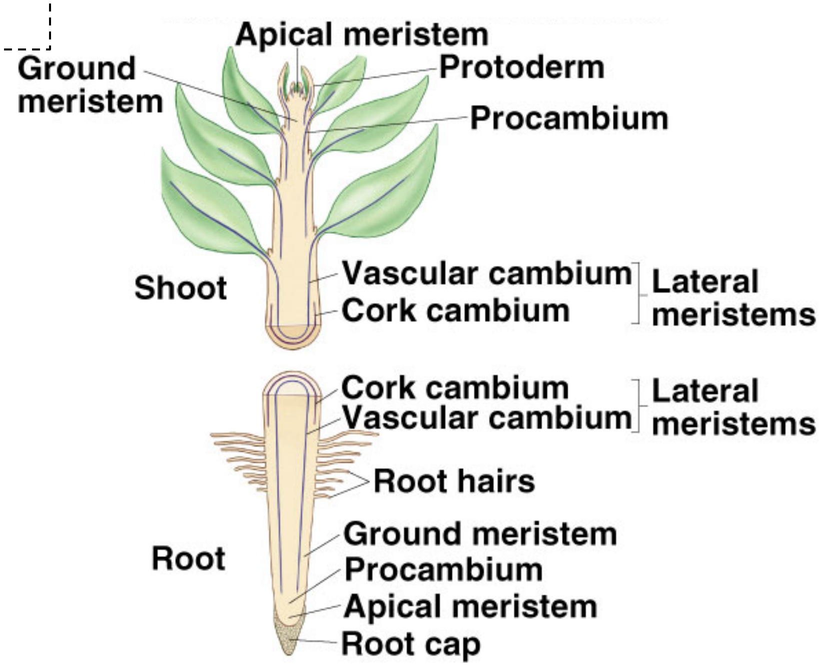


Meristems (ch 35.2, Fig 35.10) act like stem cells,
when they divide, one cell remains meristematic,
other cell differentiates – important for growth and elongation

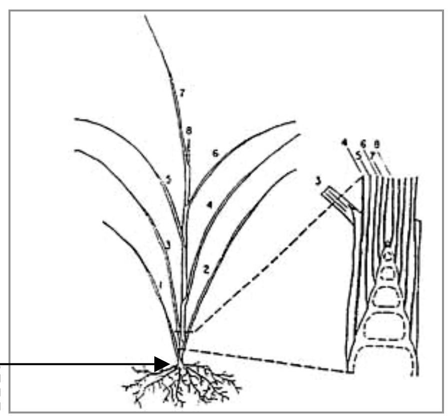
In terrestrial habitats, the resources

(b)

This growth in length is sustained
by the activity of **apical meristems**
localized regions of cell division at the tips of
shoots and roots



Grasses
have apical meristem



Grasses are modern, specialized (derived) flowering plants

Most **grasses are pollinated**

All the world's cereal crops are grasses.

Top agricultural products, by individual crops (million metric tons) 2004 data	
Sugar Cane	1,324
Maize	721
Wheat	627
Rice	605
Potatoes	328
Sugar Beet	249
Soybean	204
Oil Palm Fruit	162
Barley	154
Tomato	120
Source: Food and Agriculture Organization (FAO)[30]	

Grass plants and grazing mammals
appeared in the fossil record
at the same time
in the lower Miocene Epoch about
20 million years ago. *{recent!}*
and have evolved together.

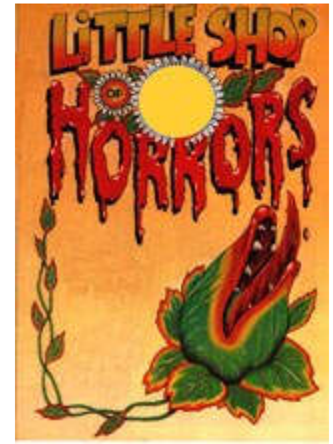

(c) TNC

Another economically significant use of grasses is **lawns** …
grasses are well adapted for use in lawns,
because their basal meristems (growing points)


Prairie Meadows Burning
by George Catlin

Plants are sensitive creatures!

In touch: plant responses to mechanical stimuli.
Braam J 2005 NEW PHYTOLOGIST 165:373-389



Perception and response to mechanical stimuli
are likely essential at the cellular and organismal levels.
Elaborate and impressive touch responses of plants
capture the imagination as such behaviors are unexpected
in otherwise often quiescent creatures.
Touch responses can turn plants
into aggressors against animals,
trapping and devouring them,
and enable flowers to be active
in ensuring crosspollination
and shoots to climb to sunlit heights.
Signaling molecules and hormones ...
have been implicated in touch responses.

Remarkably, **touch-induced gene expression is widespread**;
more than 2.5% of Arabidopsis genes
are rapidly up-regulated in touch-stimulated plants.
Many of these genes encode
calcium-binding, cell wall modifying,
defense, transcription factor and kinase proteins. ...

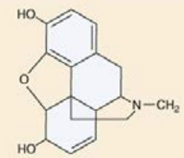
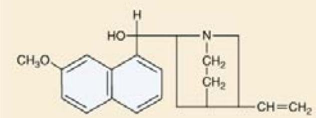
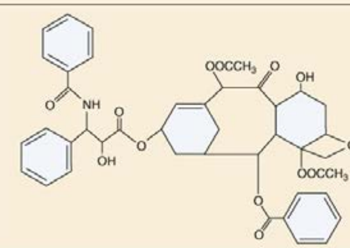
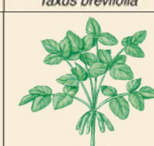
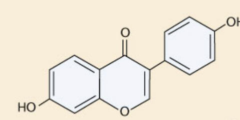
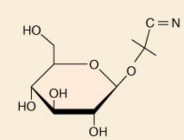
Altering gene expression by touch in Arabidopsis .
The shorter plant on the left was touched twice a day.
{hiding from grazers?}
The unmolested plant (right) grew much taller.

Ch 39: Plants have evolved a variety of **defensive mechanisms** to reduce damage from attack by viruses, bacteria, fungi, animals and other plants.

A deer browse-line on a row of cedars.

Plants have (or induce) **toxins** to poison herbivores,
ex: cyanogenic glycosides & alkaloids
also phytoestrogens (ex in soy)

Raven et al. Table 39.1 Secondary Metabolites

Compound	Source	Structure	Effect on humans
Morphine (alkaloid)	 Opium poppy *Papaver somniferum*		Narcotic pain killer
Quinine (alkaloid)	 Quinine bark *Cinchona officinalis*		Antimalarial drug
Taxol (terpenoid)	 Pacific Yew *Taxus brevifolia*		Anticancer drug
Genistein (phytoestrogen)	 Soybean *Glycine max*	 Genistein	Estrogen mimic
Manihotoxin (cyanogenic glycoside)	 Cassava *Manihot esculenta*		Metabolized to release lethal cyanide

Herbal & folk medicines exploit these, including for disease control:
ex: quinine & taxol

Ethnobotany/ethnopharmacology and mass bioprospecting:
Issues on intellectual property and benefit-sharing
Soejarto et al.2005
J. Ethnopharm 100:15-22

Spices – tickle tongue & kill pathogens!

BioNews.in LATEST BIOLOGY NEWS

Bitter Taste Identifies Poisons in Foods

Scientists at the Monell Chemical Senses Center report that bitter taste perception of vegetables is influenced by an interaction between **variants of taste genes** and **the naturally-occurring toxins in the vegetable**.

Scientists have long assumed that bitter taste evolved as a defense mechanism to detect potentially harmful toxins in plants.

Glucosinolates in some plants act as anti-thyroid compounds ... inhibit iodine uptake.

... 35 healthy adults were genotyped for **the hTAS2R38 bitter taste receptor gene**; the three **genotypes** were PAV/PAV (**sensitive** to bitter-tasting PTC),
AVI/AVI (insensitive), and
PAV/AVI (intermediate).

Subjects then rated bitterness of various vegetables; **some contained glucosinolates (broccoli, bok choy, kale, kohlrabi, & turnip)** while others did not (radicchio, endive, eggplant and spinach).

Subjects with the sensitive PAV/PAV form of the receptor rated glucosinolate-containing vegetables as 60% more bitter than did subjects with the insensitive (AVI/AVI) form.

"The sense of taste enables us to detect bitter toxins within foods, and genetically-based differences in our bitter taste receptors affect how we each perceive foods containing particular toxins."

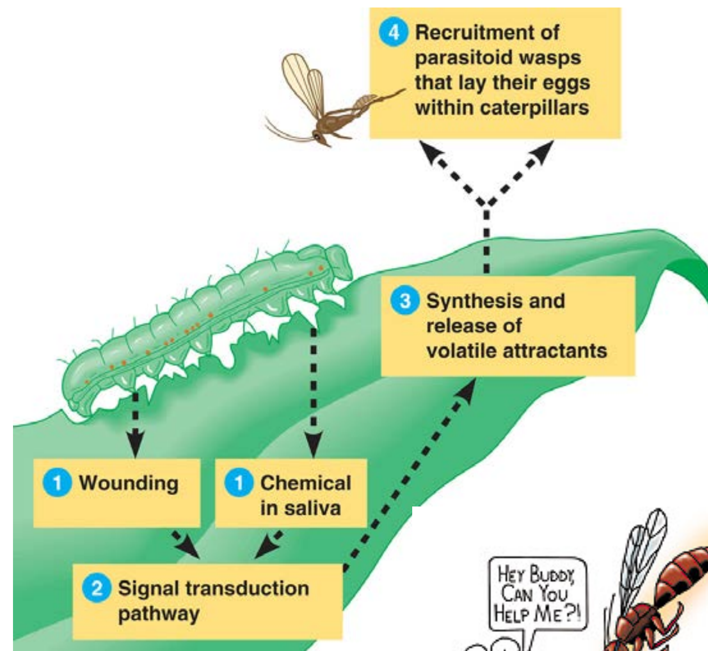
Induced defenses: (sec 39.5) Plants allocate more to defense after attack.

see: http://dogbert.gi.alaska.edu/ScienceForum/ASF7/762.html

… and warn their neighbors!
("Talking Trees")

Sometimes they call for help! (Fig 39.29)

Herbivore-infested plants selectively attract parasitoids.
De Moraes et al. 1998. NATURE 393:570-573.



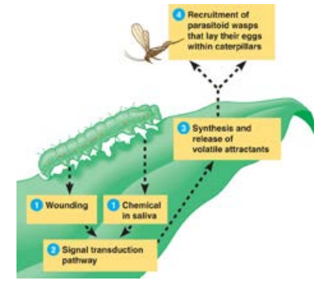
... but "predators" might be eavesdropping!

News of the Week: **Parasitic Weed Uses Chemical Cues to Find Host Plant**
Elizabeth Pennisi *Science* 2006 313, p. 1867
Dodder may be the bloodhound of the plant world.
A plant that parasitizes other plants,
it sniffs out its victim ...

Volatile Chemical Cues Guide Host Location and Host Selection by Parasitic Plants
JB Runyon et al. 2006.
Science **313**, 1964.

DEPARTMENT OF BIOCHEMISTRY
University of California, Riverside

Nancy E. Beckage
Professor of Entomology & Cell Biology and Neuroscience



Biochemical Host-Parasite Relationships
Insect Endocrinology

We use the **tobacco hornworm**, *Manduca sexta*, and its interactions with the **wasp parasite** *Cotesia congregata* as a model system ...

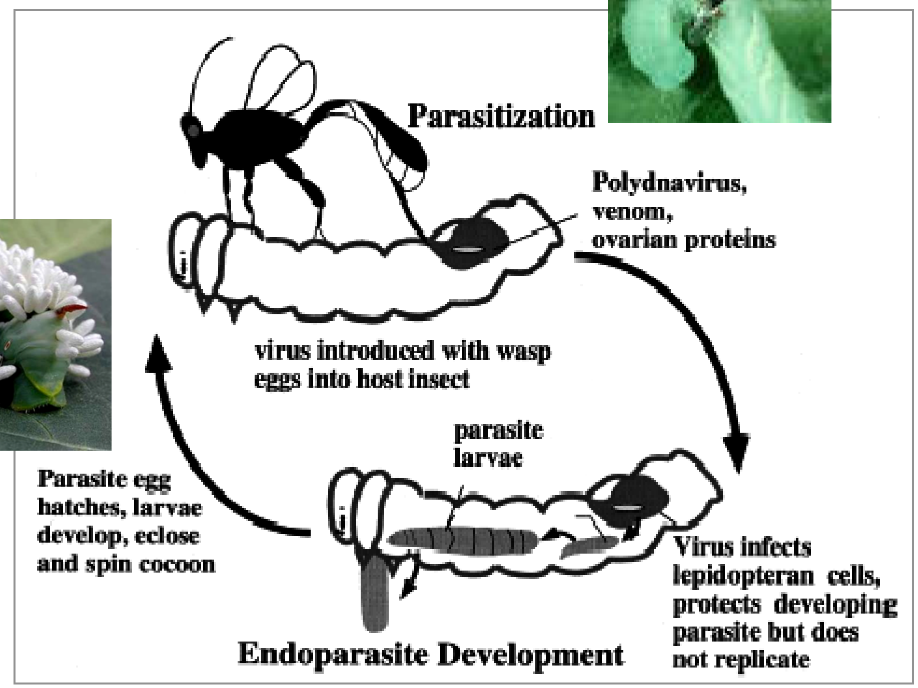
This parasite injects a large, multi-segmented DNA virus, a polydnavirus, into the host during parasitization.

Viral sequences are integrated in the genomic DNA of the parasite and the **PDV is a symbiont of the wasp**.

Following oviposition, the virions enter host cells and become transcriptionally active.

... **cause host immunosuppression**, which allows the parasites to develop ...

Parasitoids and polydnaviruses.
Beckage, N.E. Bioscience
48: 305-310 (1998).



USDA ARS United States Department Of Agriculture Agricultural Research Service

Research Project Title:

PARASITOID POLYDNAVIRUSES:
... POTENTIAL FOR USE IN BIOLOGICAL CONTROL