GROWTH AND DEVELOPMENT

VEGETATIVE GROWTH AND DEVELOPMENT

- Shoot and Root Systems

- Root functions
  - Anchor
  - Absorb
  - Conduct
  - Store

As the shoot system enlarges, the root system must also increase to meet demands of leaves/stems

MEASURING GROWTH

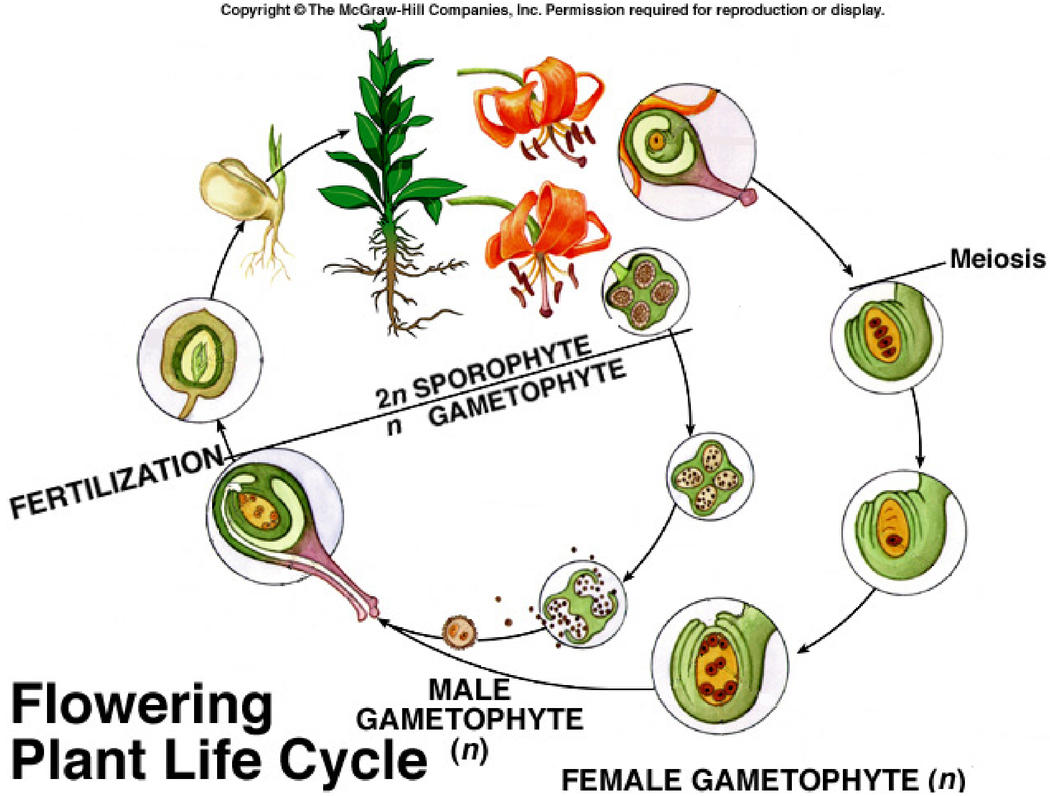
- Increase in fresh weight
- Increase in dry weight
- Volume
- Length
- Surface area

MEASURING GROWTH

- Classifying shoot growth
  - **Determinate** – flower buds initiate terminally; shoot elongation stops; e.g. snap beans
  - **Indeterminate** – flower buds born laterally; shoot terminals remain vegetative;

SHOOT GROWTH PATTERNS

- Annuals
  - Herbaceous (nonwoody) plants
  - Complete life cycle in ***one growing season***


Meiosis
2n SPOROPHYTE
n GAMETOPHYTE
FERTILIZATION
Flowering
Plant Life Cycle
MALE
GAMETOPHYTE
(n)
FEMALE GAMETOPHYTE (n)

SHOOT GROWTH PATTERNS

- Biennials
  - Herbaceous plants
  - Require ***two growing seasons*** to complete their life cycle (not necessarily two full years)
  - Stem growth limited during first growing season;

    see fig. 9-4; Note vegetative growth vs. flowering

    e.g. celery, beets, cabbage, Brussels sprouts

SHOOT GROWTH PATTERNS

- Perennials
  - Either herbaceous or woody
  - **Herbaceous** roots live indefinitely (shoots can)
    - Shoot growth resumes in spring from adventitious buds in crown
    - Many grown as annuals
  - **Woody** roots and shoots live indefinitely
    - Growth varies with annual environment and zone
    - Pronounced diurnal variation in shoot growth; night greater

ROOT GROWTH PATTERNS

- Variation in pattern with species and season
- Growth peaks in spring, late summer/early fall
  - Spring growth from previous year’s foods
  - Fall growth from summer’s accumulated foods
- Some species roots grow during winter

HOW PLANTS GROW

- Meristems
  - Dicots
    - Apical meristems – vegetative buds
      - shoot tips
      - axils of leaves
    - Cells divide/redivide by mitosis/cytokinesis
    - Cell division/elongation causes shoot growth
    - Similar meristematic cells at root tips

HOW PLANTS GROW

- Meristems (cont)
  - Secondary growth in woody perennials
    - Increase in diameter
      - due to meristematic regions
    - vascular cambium
      - xylem to inside, phloem to outside
    - cork cambium
      - external to vascular cambium
      - produces cork in the bark layer

GENETIC FACTORS AFFECTING GROWTH AND DEVELOPMENT

- DNA directs growth and differentiation
  - Enzymes catalyze biochemical reactions
- Structural genes
  - Genes involved in protein synthesis
- Operator genes
  - Regulate structural genes
- Regulatory genes
  - Regulate operator genes

GENETIC FACTORS AFFECTING GROWTH AND DEVELOPMENT

- What signals trigger these genes?

  - Believed to include:
    - Growth regulators
    - Inorganic ions
    - Coenzymes
    - Environmental factors; e.g. temperature, light

    - Therefore . . .
      - Genetics directs the final form and size of the plant as altered by the environment

ENVIRONMENTAL FACTORS INFLUENCING PLANT GROWTH

- Light
- Temperature
- Water
- Gases

Signal transduction pathways link signal reception to response

- All organisms received specific signals/respond to them in ways that enhance survival/reproductive success
- Plants have cellular receptors that detect changes in their environment (molecule affected by stimulus)
  - *For stimulus to elicit response, certain cells must have appropriate receptor*
  - *Stimulation of receptor initiates specific signal transduction pathway*

(a) Before exposure to light

Tall, spindly stem/nonexpanded leaves (morphological adaptations called etiolation enable shoots to penetrate soil, including short roots due to little need for water absorption from little water loss by shoots)

Expanded leaves hindrance as shoots push through soil/chlorophyll waste of energy (underground)

(b) After a week's exposure to natural daylight

Begins to resemble typical plant w/broad green leaves, short sturdy stems, long roots (transformation begins w/reception of light by specific pigment, phytochrome) by undergoing changes (de-etiolation) by reception of signal (light) which is transduced into responses (greening)

ENVIRONMENTAL FACTORS INFLUENCING PLANT GROWTH

- Light
  - Intensity
  - Quality
  - Duration

ENVIRONMENTAL FACTORS INFLUENCING PLANT GROWTH

- Light (cont)

  narrow band affects plant photoreaction processes

  PAR (Photosynthetically Active Radiation)

  400-700nm

  stomates regulated by red (660nm), blue (440nm)

  - **photomorphogenesis** – shape determined by light
    - controlled by pigment **phytochrome**
    - phytochrome absorbs red (660nm) and far-red (730nm) but not at same time

ENVIRONMENTAL FACTORS INFLUENCING PLANT GROWTH

- Light (cont)
  - importance of phytochrome in plant responses
    - plants detect ratio of red:far-red light
    - red light – full sun
      - yields sturdy, branched, compact, dark green plants
    - far-red light – crowded, shaded fields/greenhouses
      - plants tall, spindly, weak, few branches; leaves light green

ENVIRONMENTAL FACTORS INFLUENCING PLANT GROWTH

- Light (cont)
  - **Phototropism** – movement toward light
    - hormone auxin accumulates on shaded side
    - cell growth from auxin effect bends plant
    - blue light most active in process
    - pigment uncertain

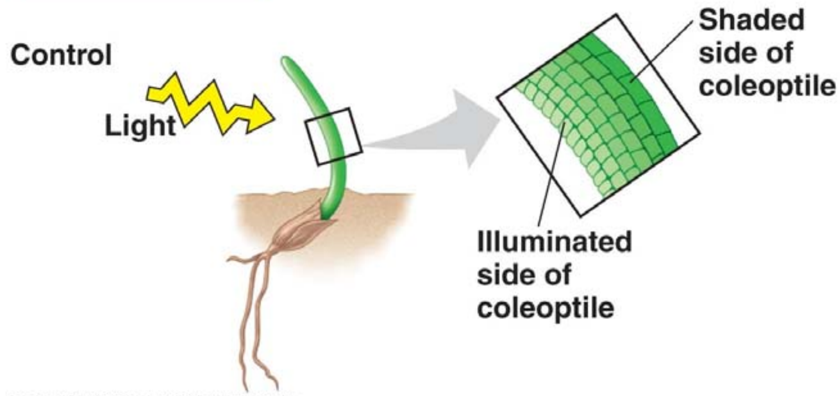
- ***Tropism****: any response resulting in curvature of organs toward or away from stimulus (often caused by hormones)*

  - Shoot of sprouting grass (enclosed in coleoptile) grows straight upward if seedling kept in dark/illuminated for all sides uniformly

  - *If illuminated form one side, grows toward light (results from differential growth of cells on opposite sides of coleoptile; cells on darker side elongate faster than those on brighter side)*

- <u>Postulated signal was transmitted from tip to elongating region</u>

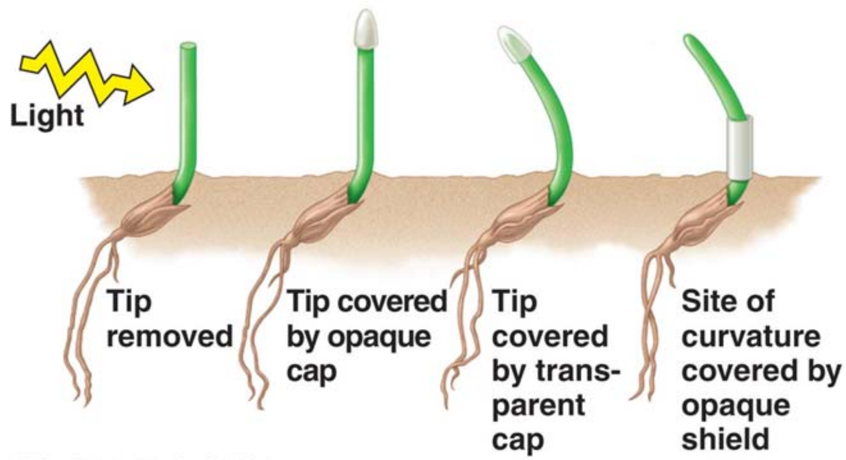
RESULTS



RESULTS

Darwin/Darwin: phototropic response only when tip is illuminated:

- **Only tip of coleoptile senses light**
- **Phototrophic bending occurred at distance from site of light perception (tip)**



ENVIRONMENTAL FACTORS INFLUENCING PLANT GROWTH

- Light (cont)
  - **Photoperiodism** – response to varying length of light and dark
    - shorter days (longer nights)
      - onset of dormancy
      - fall leaf color
      - flower initiation in strawberry, poinsettia, chrysanthemum
      - tubers/tuberous roots begin to form
    - longer days (shorter nights)
      - bulbs of onion begin to form
      - flower initiation in spinach, sugar beets, winter barley

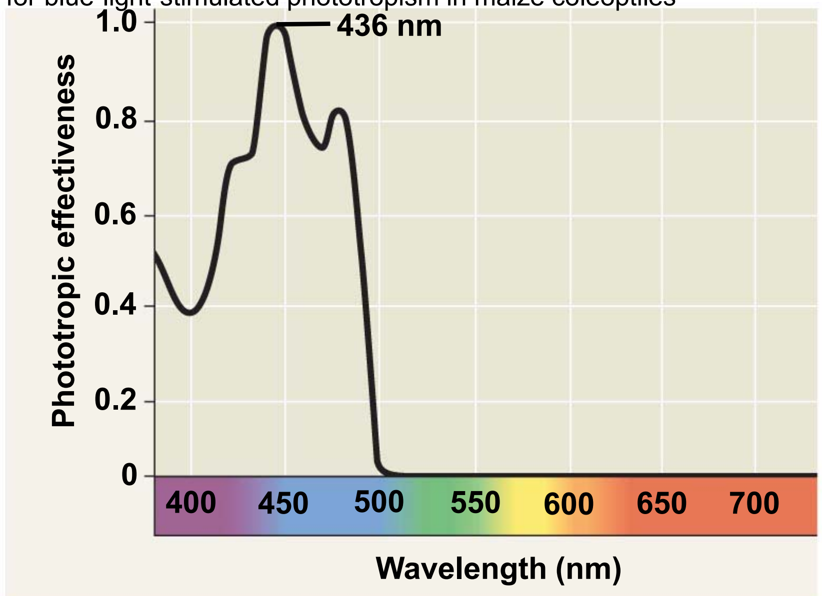
- Plants detect not only presence of light but also direction, intensity, and wavelength (color)

    - Two peaks (red/blue light) for photosynthesis

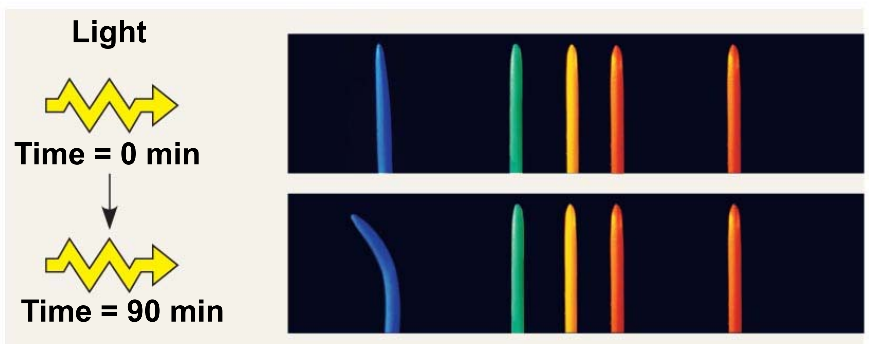
  - Action spectra are useful in studying any process that depends on light (phototropism)

  - Two major classes of light receptors: **blue-light photoreceptors** and **phytochromes**

Fig. 39-16 Action spectrum for blue-light-stimulated phototropism in maize coleoptiles



(a) Action spectrum for blue-light phototropism



(b) Coleoptile response to light colors

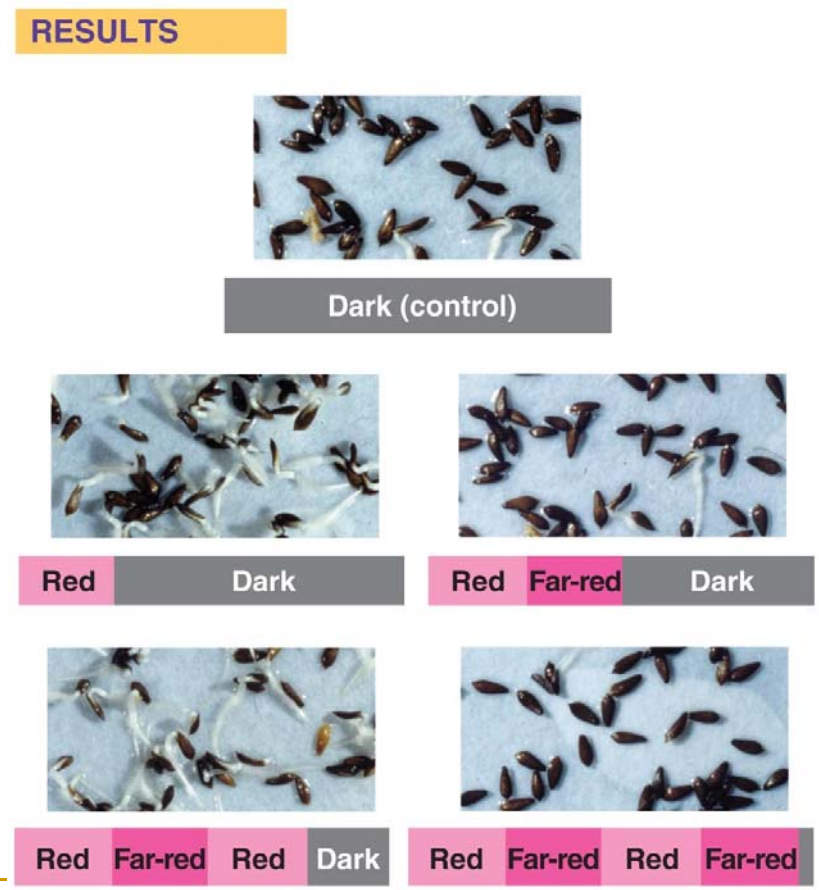
Phototropic bending toward light controlled by phototropin (photoreceptor sensitive to blue/violet light, particularly blue light

Blue-Light Photoreceptors
Phytochromes as Photoreceptors

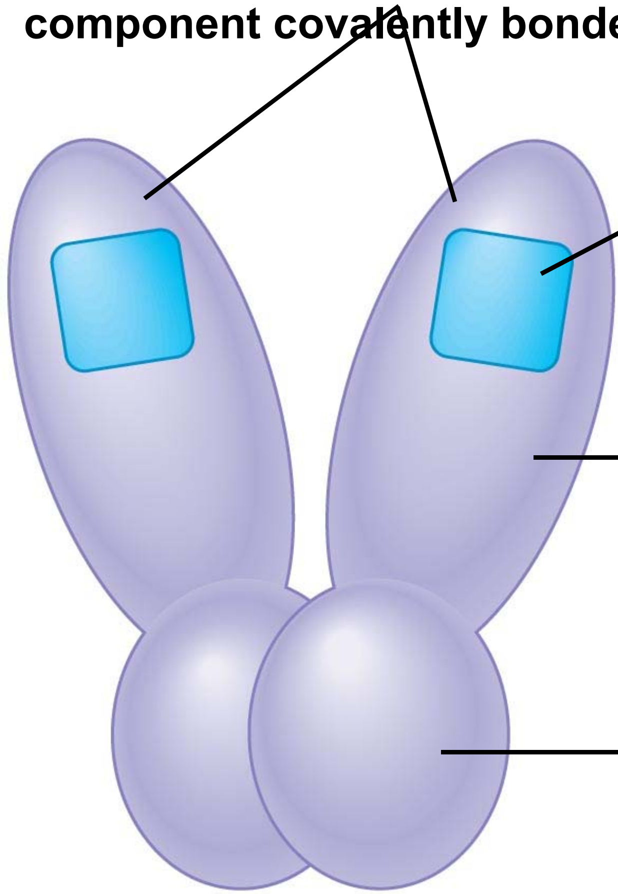
- Various blue-light photoreceptors control hypocotyl elongation, stomatal opening, and phototropism
- **Phytochromes** are pigments that regulate many of plant's responses to light throughout its life
  - These responses include seed germination and shade avoidance

Phytochromes and Seed Germination

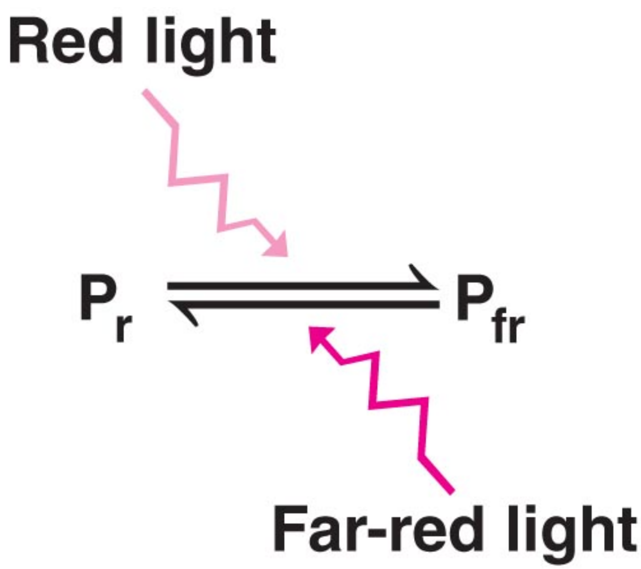
- Many seeds remain dormant until light conditions change
  - Red light increased germination, while far-red light inhibited germination
  - Final light exposure was determining factor
  - Effects of red/far-red light reversible

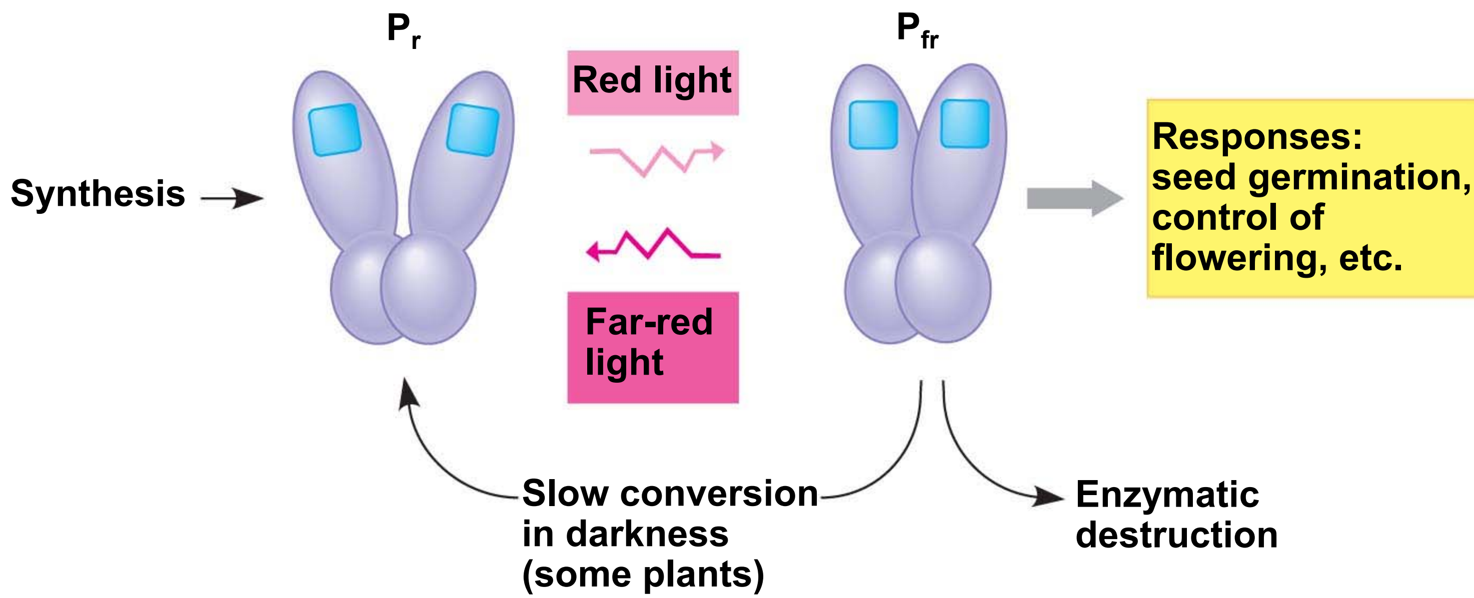


Photoreceptor responsible for opposing effects of red/far-red light are phytochromes



- Phytochromes exist in two photoreversible states
  - Depend on color of light provided
  - Converts P_r (inhibits germination) to P_{fr}, which triggers many developmental responses (germination)
  - Though light contains both red and far red light, conversion to P_{fr} faster than conversion to P_r so ratio of P_{fr} to P_r increases in light, triggering germination




P_r
P_fr
Red light
Far-red light
Synthesis
Responses: seed germination, control of flowering, etc.
Slow conversion in darkness (some plants)
Enzymatic destruction

Phytochromes and Shade Avoidance

- During day, $P_r \rightleftarrows P_{fr}$ interconversion reaches dynamic equilibrium, with ratio of two phytochrome forms indicating relative amounts of red/far-red light

- Allows plants to adapt to changes in light conditions

  - Shaded plants receive more far-red than red light
    - In **"shade avoidance" response**, phytochrome ratio shifts in favor of P_r when tree is shaded, inducing tree to allocate more resources to growing taller

  - Direct sunlight stimulates branching/inhibits vertical growth

Fig. 39-21 Photoperiodic control of flowering

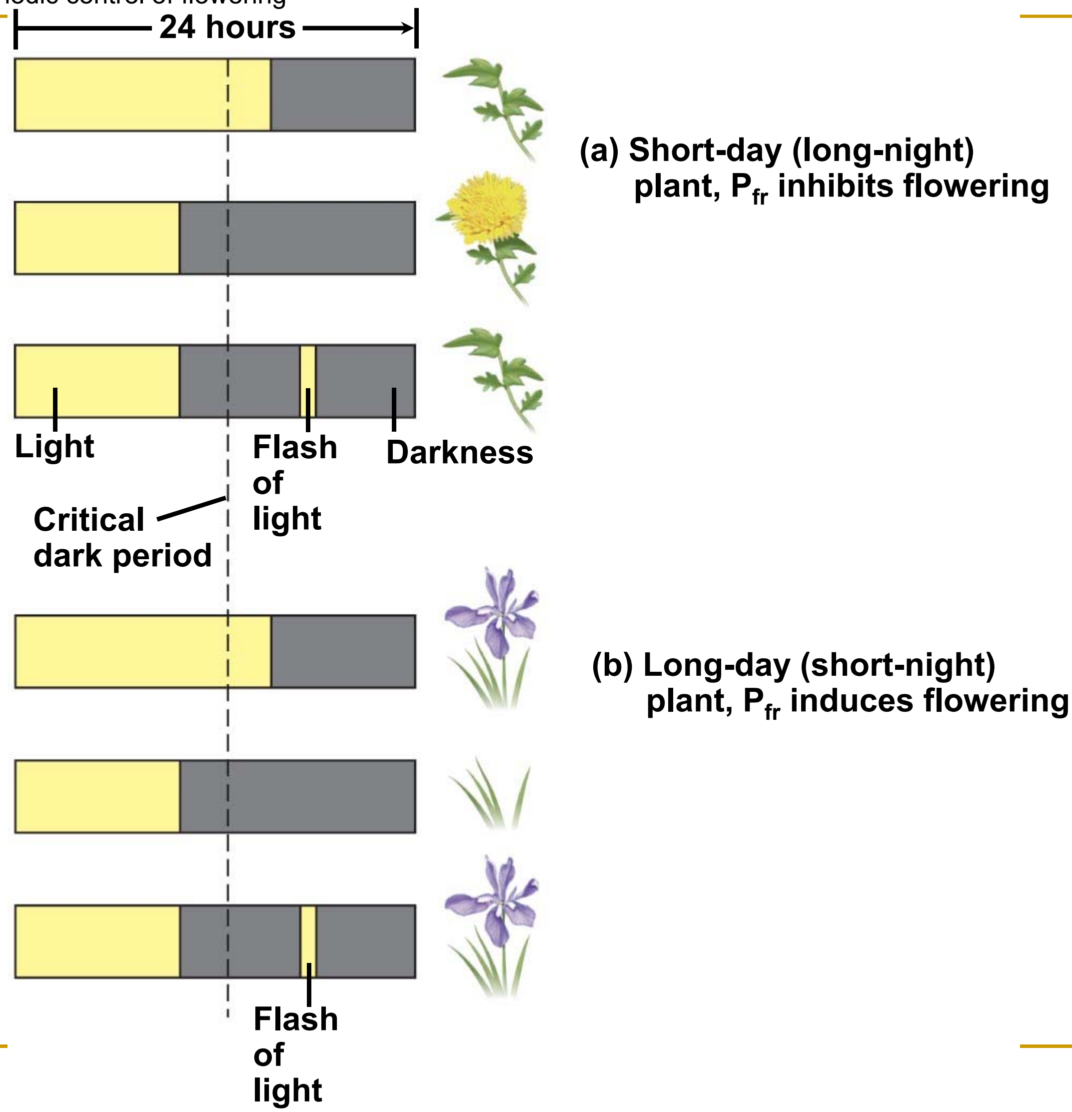
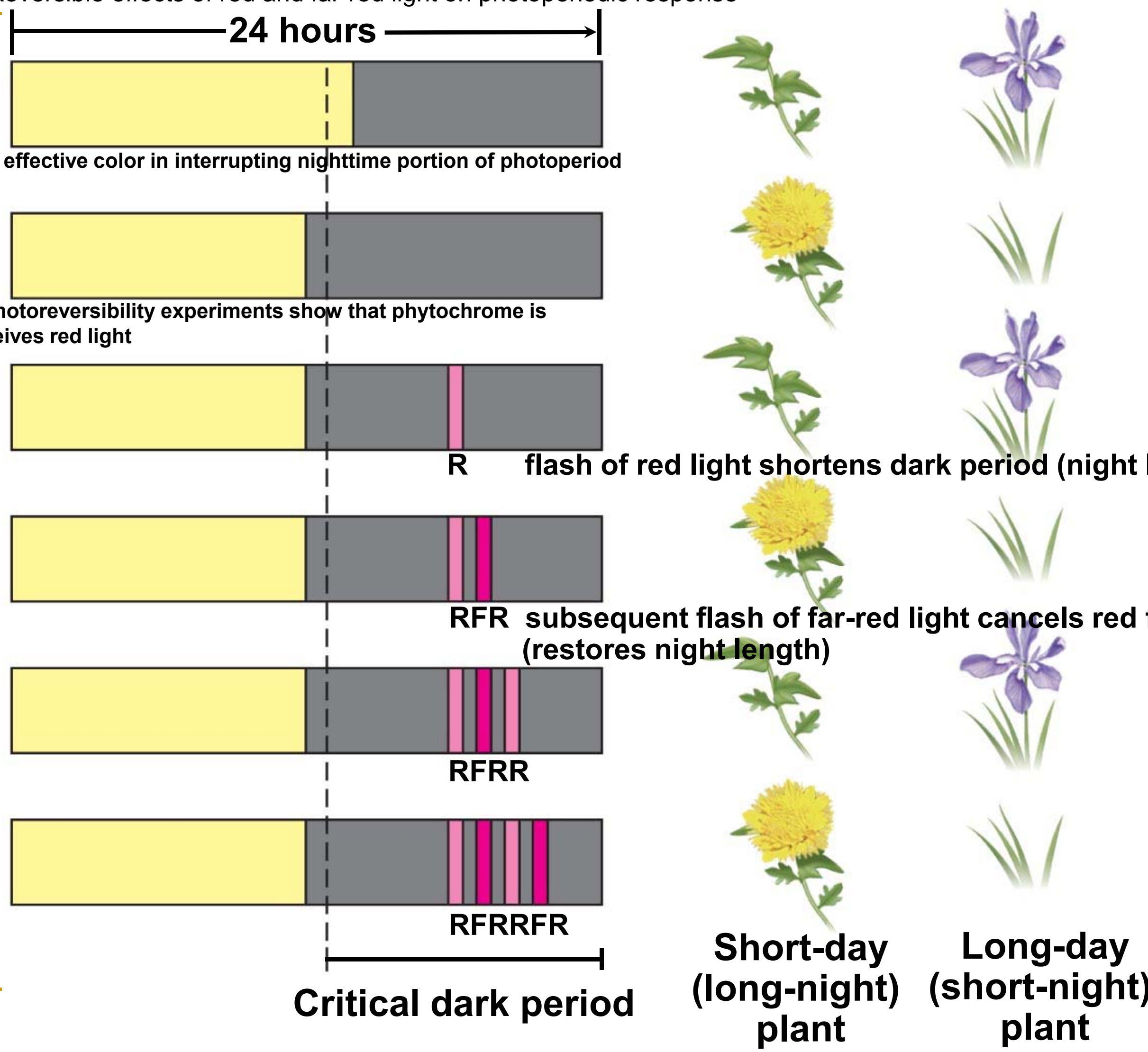


Fig. 39-22 Reversible effects of red and far-red light on photoperiodic response



Red light is most effective color in interrupting nighttime portion of photoperiod

Action spectra/photoreversibility experiments show that phytochrome is pigment that receives red light

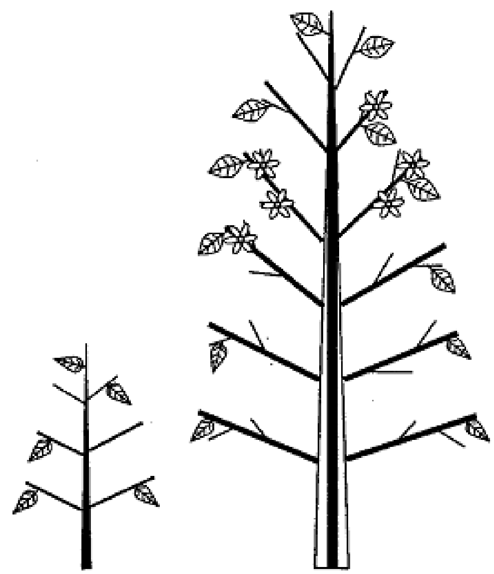
R flash of red light shortens dark period (night length)

RFR subsequent flash of far-red light cancels red flash's effect (restores night length)

http://bcs.whfreeman.com/thelifewire/content/chp39/3902002.html

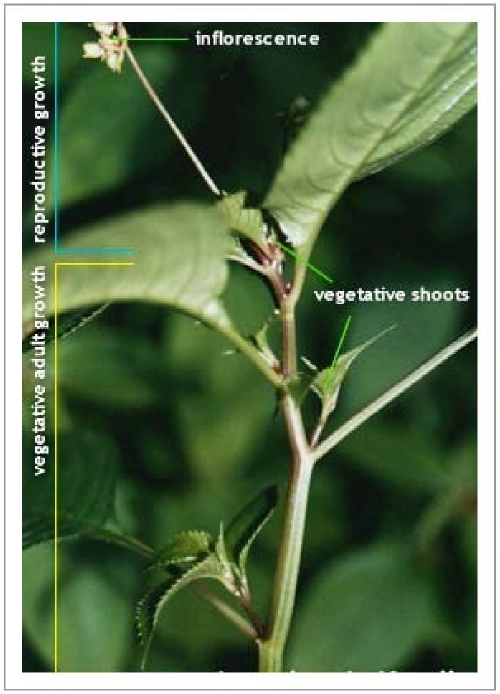
PHASE CHANGE: JUVENILITY, MATURATION, SENESCENCE

- Phasic development
  - embryonic growth
  - juvenility
  - transition stage
  - maturity
  - senescence
  - Death



- The shoot apical meristem (and therefore plants) undergo three distinct phases:
- Juvenile
- Adult vegetative
- Adult reproductive

Meristems in the juvenile phase have no ability to produce reproductive structures (cones or flowers) so are described as having no **competence**. Adult meristems are competent because they can now produce reproductive structures (ie. will respond to stimuli which trigger this), but the actual production of these will depend on environmental stimuli.



PHASE CHANGE: JUVENILITY, MATURATION, SENESCENCE

- Juvenility
  - terminated by flowering and fruiting
  - may be extensive in certain forest species
- Maturity
  - loss or reduction in ability of cuttings to form adventitious roots
- Physiologically related
  - lower part of plant may be oldest chronologically, yet be youngest physiologically (e.g. some woody plants)
  - top part of plant may be youngest in days, yet develop into the part that matures and bears flowers and fruit

AGING AND SENESCENCE

- Life spans among plants differ greatly
  - range from few months to thousands of years
    - e.g. bristlecone pine (over 4000 years old)
    - e.g. California redwoods (over 3000 years old)
  - clones should be able to exist indefinately
- Senescence
  - a physiological aging process in which tissues in an organism deteriorate and finally die
  - considered to be terminal, irreversible
  - can be postponed by removing flowers before seeds start to form

REPRODUCTIVE GROWTH AND DEVELOPMENT

- Phases
  - Flower induction and initiation
  - Flower differentiation and development
  - Pollination
  - Fertilization
  - Fruit set and seed formation
  - Growth and maturation of fruit and seed
  - Fruit senescence

REPRODUCTIVE GROWTH AND DEVELOPMENT

- Flower induction and initiation
  - What causes a plant to flower?
    - Daylength (photoperiod)
    - Low temperatures (vernalization)
    - Neither

REPRODUCTIVE GROWTH AND DEVELOPMENT

- Photoperiodism
  - Short-day plants (long-night; need darkness)
  - Long-day plants (need sufficient light)
  - Day-neutral plants (flowering unaffected by period)
- Change from vegetative to reproductive

REPRODUCTIVE GROWTH AND DEVELOPMENT

- Low temperature induction
- Vernalization
  - Any temperature treatment that induces or promotes flowering
  - First observed in winter wheat; many biennials
  - Temperature and exposure varies among species
  - Note difference/relationship to dormancy

REPRODUCTIVE GROWTH AND DEVELOPMENT

- Flower development
  - Stimulus from leaves to apical meristem changes vegetative to flowering
  - Some SDPs require only limited stimulus to induce flowering; e.g. cocklebur – one day (night)
  - Once changed the process is not reversible
  - Environmental conditions must be favorable for full flower development