Plant Adaptations to the Environment

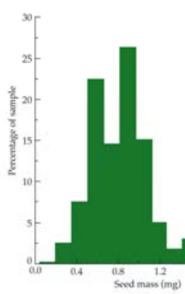
Part 1: Morphology and Life History Traits

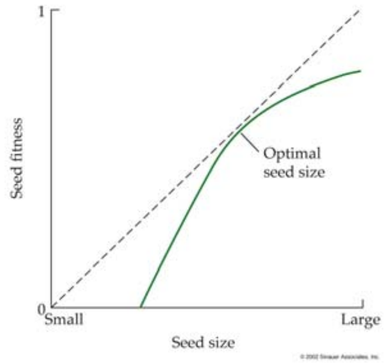
Reading Assignment: Chapter 8, GSF

Definition of environment: The aggregate of all the continuously varying external conditions, biotic and abiotic, that affect the distribution, development, and survival of an organism.

Many adaptations are associated with "trade-offs" that may limit the degree of adaptation

- Use a cost-benefit analogy to explain seed size.





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Morphological adaptations

Adaptations to life on land

- Photosynthesis developed in oceans; land plants had to cope with desiccation.
  – Cuticle: waxy covering over epidermal cells
  – Vascular tissues: xylem and phloem
  – Pollination by wind in dry conditions
  – Seeds with seed coat and endosperm

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Morphological adaptations

Growth forms

- Wide variety of growth forms and architectures have evolved to adapt to different light, moisture, temperature conditions
- The meristem is undifferentiated tissue that produces new growth; in the embryo of a seed, or in terminal buds, lateral buds, the cambium and elsewhere in perennial plants

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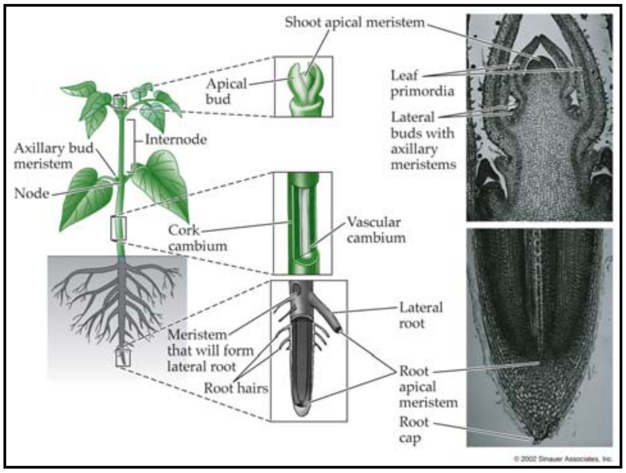

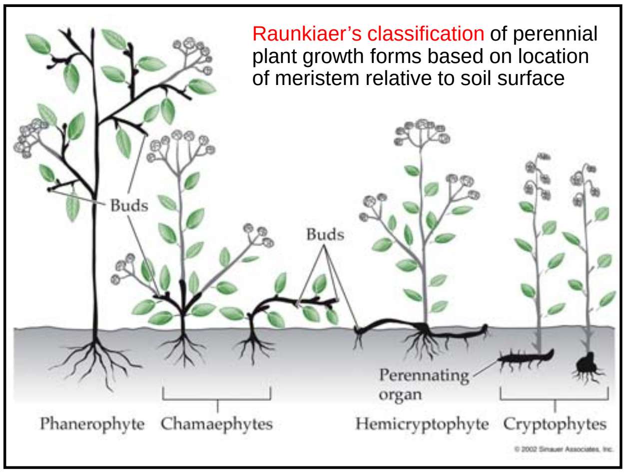

Raunkier's Growth Forms

- Therophyte – survives as a seed; deserts
- Phanerophyte – tall shrubs and trees with buds >25 cm above surface; forests
- Chamaephyte – small shrubs with buds <25 cm above surface; tundra
- Hemicryptophyte – herbaceous plants with buds at soil surface; grasslands
- Cryptophyte (aka geophyte) – plants with bulbs buried in soil; grasslands

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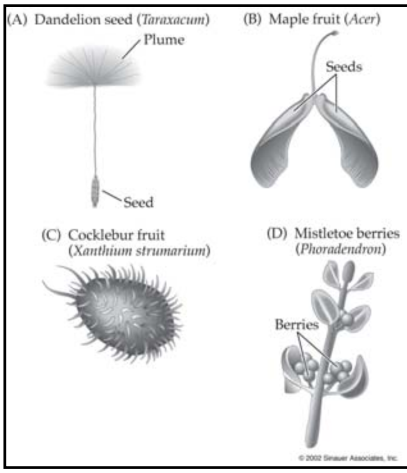
Morphological Adaptations

Leaf Morphology

Size: Smaller in arid environments, larger and thinner in forest environments. Why?

Pubescence on leaf surfaces is found in hot/dry, and cold environments. Why?



Dispersal is fundamental for species survival

Adaptations for seed dispersal

Many adaptations exist to ensure cross-fertilization (pollination)

Life History Traits

- Life history refers to differences in longevity and phenology
- Life history patterns offer different strategies for survival and maintenance of the gene pool
- Plant economics refers to how limited resources are allocated to various plant functions (consider trade-offs!)
  - Growth (new biomass; above and belowground)
  - Reproduction (flowering, seed production)
  - Maintenance (defense, survival of individuals)

Longevity

- ANNUALS
  - Adaptive where probability of an adult surviving an unfavorable season is low
  - Germination may be triggered by rain, light, smoke, heat, cold
- BIENNIALS
  - Live for 2 or more years before flowering and then dying (semelparous)
- PERENNIALS
  - Monocarpic—reproduce once, then die (semelparous)
  - Polycarpic—reproduce repeatedly (iteroparous)
  - Mast years, to reduce seed predation

Phenology

- EPHEMERAL PLANTS
  - Avoid periods during the year with environmental stresses
  - Take advantage of short, favorable periods with fast growth
- DECIDUOUS PLANTS
  - Avoid stressful periods by shedding leaves
  - Leaf growth and photosynthetic rates are high
  - Considered more "expensive" than evergreen leaves in terms of nutrient use
  - High nutrient cycling is required to support deciduous leaves

Phenology

- EVERGREEN PLANTS
  - Tolerate stressful periods with leaves that can withstand cold or drought
  - Leaves may live <1 to >20 years
  - Leaf growth and photosynthetic rates are low but can occur over wider range of conditions
  - Evergreen leaves cost about the same amount of energy as deciduous leaves, because lignin, fiber, wax are expensive to make
  - Adapted to tolerate lower nutrient status and slower cycling

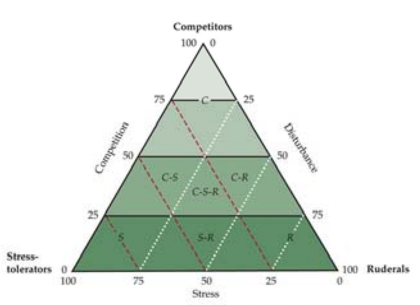
MacArthur & Wilson's r vs. K selection

- Opportunistic vs. climax species
- r-selected traits (favored at low pop'n density)
  - Fast growth and reproduction
  - Poor competitors
- K-selected traits (favored at high density)
  - Slow growth, delayed reproduction
  - Density dependent populations
- Most species fall in between these extremes
- This approach suggests that natural selection works on populations rather than individuals

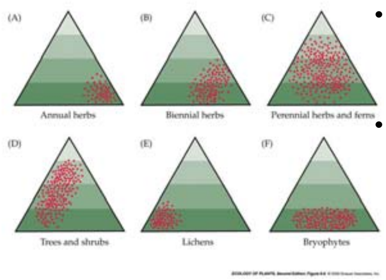
Grime's Triangular Model

- Extension of the r- and K-selection theory to include long-term competitive ability, termed C-selection
- Ruderals are r-selected
- Stress-tolerators are K-selected
- Competitors ("climax" species) are C-selected

How is this ternary diagram intepreted?



This approach is useful when comparing large groups of species



- Some argue that these approaches oversimplify nature
- A single species may have traits that are adapted to different pressures (ex: sagebrush)

Insight into trade-offs resulting from natural selection on certain traits

TABLE 8.1 Some characteristics of competitive, stress-tolerant, and ruderal plants, as described in Grime's triangular model

	Competitive	Stress-tolerant	Ruderal
Growth forms	Perennial herbs, shrubs, or trees	Lichens, perennial herbs, shrubs, and trees	Annuals
Seed production	Small	Small	Large
Maximum potential growth rate	Rapid	Slow	Rapid
Leaf litter	Abundant, often persistent	Little, often persistent	Little, not persistent
Leaf longevity	Short	Long	Short
Flowering phenology	Flowering near time of maximum productivity	No pattern	Flowering at end of favorable period
Vegetative phenology	Leaf production coincides with maximum productivity	Evergreens; various patterns	Brief period of leaf production at time of maximum productivity
Life span	Long	Long	Short

Source: Grime 1977.

Resource ratio hypothesis (Tilman)

- Focuses on the ratio between light and a soil resource, typically nitrogen
  - As light becomes less limiting, soil resources become more limiting
- Uses root/shoot ratios, which are easy to measure (another aspect of allocation)
  - R/S changes in relation to soil resource supply or years between disturbances
  - Recognizes some plasticity in proportion of energy allocated to leaves, stems, roots
  - Plasticity is limited genetically
- Two key elements driving community dynamics:
  - interspecific competition
  - long-term patterns of supply of limiting resources

Allocation to reproduction

- How much energy or carbon is spent on producing seeds, relative to growth or maintenance?
- Difficult to test!
  - When (phenologically) is best to measure proportion of energy spent on seeds?
- Demographic models based on survival or fecundity rates may predict population growth better than estimates from allocation

Bet hedging in variable environments

- Risk is spread across years
- Useful concept intuitively
- Difficult to model mathematically
- Examples?