The Organism in Its Environment

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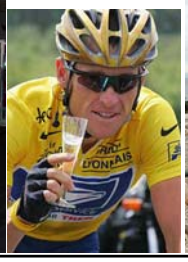
- I. The Meaning of Adaptation
- II. Tolerance
- III. Constraints and Trade-Offs
- IV. Autotrophs and Heterotrophs

I. The Meaning of Adaptation

- Adaptation: an inherited characteristic that enhances an organism's ability to survive and reproduce in a given environment

I. The Meaning of Adaptation

- Fitness?



I. The Meaning of Adaptation

- Fitness: an organisms ability to produce viable offspring (reproductive success)
  - Genetic contribution by an individual's descendants to future generations
  - Natural selection → those individuals most able to cope with the environmental situation succeed (survival of the fittest)

II. Tolerance

- Ability to function between some upper and lower limits in a range of environmental conditions
- Justus von Liebig → 1940's
- Chemistry and plant growth

II. Tolerance

- Ability to function between some upper and lower limits in a range of environmental conditions
- Justus von Liebig:
  - "…crops will diminish or increase in exact proportion to the diminution or increase of the mineral substance conveyed to it in manure"

II. Tolerance

- Ability to function between some upper and lower limits in a range of environmental conditions
- Justus von Liebig:
  - "…corn will grow depending on the quality of the poop…"

II. Tolerance

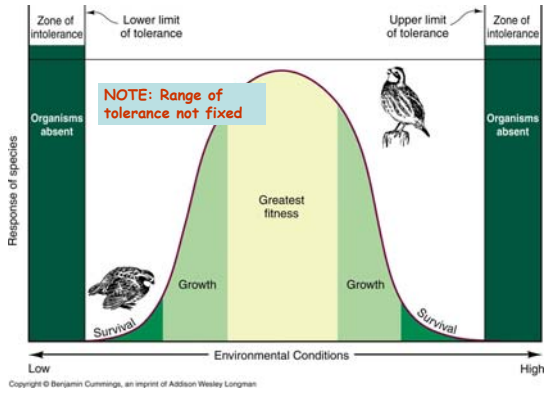
- Liebig's Law of the Minimum
  - Plant growth responds to the nutrient that is most limiting
  - Only applies under equilibrium conditions ("steady state")
  - Applies to other resources or factors of the environment (i.e., water, light, space)

II. Tolerance

- F. F. Blackman (1905):
- "…too much of a good thing can be just as bad"
- Law of the Limiting Factors
- Both emphasize environmental conditions @ steady-state
- What about time? How does it affect these conditions?

II. Tolerance

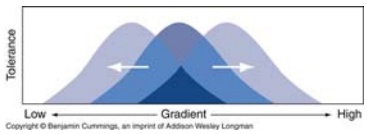
- V. E. Shelford (1913)
- The Law of Tolerance
- Organism's live within a range of too much and too little (limits of tolerance)
- Organism's ability to reproduce, grow, and survive within the environmental limitations



NOTE: Range of tolerance not fixed

Varies with season, climate, life stage, etc.

Acclimatization



Explains local and geographical distribution of species

Characteristics that enable an organism to do well in certain environments may limit the same organism in different environments

III. Constraints and Trade-Offs

- CHALLENGE:
  - External Conditions ≠ Internal Environment
- Homeostasis: maintenance of a relatively constant internal environment
  - Positive & negative responses
  - Physiological and behavioral
  - (i.e., seek shade to avoid ↑ Temp; increase layer of fur, feathers, fat when Temp ↓)

IV. Autotrophs & Heterotrophs

- Acquisition of C = FUNDAMENTAL!
- Autotrophs: use energy derived from solar radiation to fix CO_2 (carbon dioxide) into organic compounds
  - Primary producers
- Heterotrophs: obtain organic sources of carbon by consuming other organisms or their by-products
  - Consumers (secondary producers)

IV. Autotrophs & Heterotrophs

- Heterotrophs:
  - Consumers → feed on other organisms (dead or alive)
  - Decomposers → feed on dead organic matter or waste products

Plant Adaptations

Plant Adaptations

- Photosynthesis: the process by which energy from the sun is used as a driver of chemical reactions that result in the fixation of CO_2 into carbohydrates (simple sugars) and the release of O_2 as a by-product

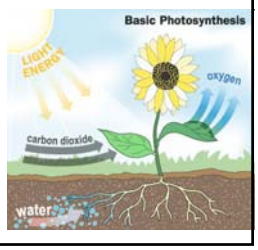
sugar

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Light and Dark Reactions

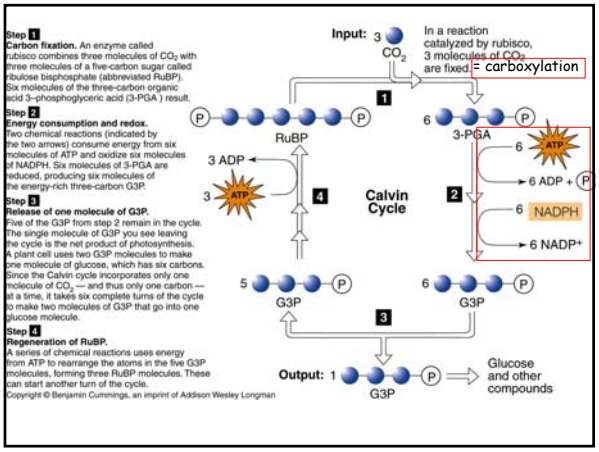
- The initial process (light reaction) → light energy is trapped in absorbing pigments (chlorophyll) within the chloroplast

→ Produces ATP (energy substance) & NADPH (strong reductant)



Light and Dark Reactions

- Dark Reactions
- The process by which CO_2 is incorporated into sugars (does not require sunlight)
- Requires:
  - ATP & NADPH
  - Rubisco (most abundant enzyme on the planet)
- Calvin Cycle (C_3 cycle) → C_3 plants



Light and Dark Reactions

- Calvin Cycle (C_3 cycle) → C_3 plants
- Drawback:
  - Photorespiration: Oxygenation of RuBP (by rubisco) and eventual release of CO_2
  - Competitive reaction to carboxylation process
  - Reduces efficiency of C_3 photosynthesis

Uptake of CO_2

- Atmospheric CO_2 enters the plant through on the surface of the leaf (stomata)
- Plants maintain a gradient between atmospheric CO_2 and CO_2 inside the leaf by opening and closing stomata (reducing the rate of CO_2 flow)

Transpiration

- Plants may also lose water through the stomata (transpiration)
- Major constraint in the uptake of CO_2 by terrestrial plants
  - Function of humidity (availability of water vapor outside)
  - Driven by vapor pressure deficit
- Plant replaces water loss through stomata with water taken up from roots
- NOTE: Aquatic plants lack stomata (CO_2 acquired via direct diffusion)

Dark Respiration

- Different from photorespiration
- Involves the oxidation of carbohydrates (i.e., glucose) to generate energy from ATP

$(CH_2O)_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$

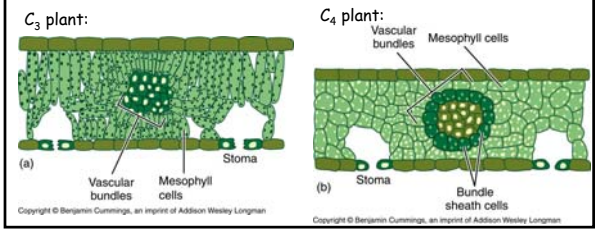
- Occurs exclusively in the mitochondria
- Not restricted to the dark (light as well)

Dark Respiration

- Two components:
  - Growth and synthesis (R_g)
    - Depends directly on photosynthesis
  - Maintenance (R_m)
    - Temperature sensitive
    - Proportional to dry weight of living tissue

Alternate Pathways

- C_4 photosynthesis (C_4 plants)
  - Produces a four carbon compound, malic or aspartic acid, as its first step

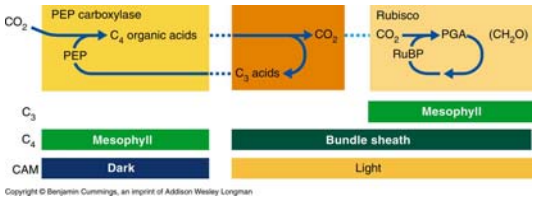


Alternate Pathways

- C_4 photosynthesis (C_4 plants) advantages:
  - Higher affinity for CO_2
  - No photorespiration
  - Higher rate of net photosynthesis
- C_4 plants:
  - Mostly grasses (tropical/subtropical)
  - Some shrubs
  - Dicot herbaceous plants (arid and saline)

Alternate Pathways

- Crasulacean Acid Metabolism (CAM)
  - Succulent, semidesert plants (15 families)
  - Resemble the C_4 pathway
    - CO_2 → four-carbon compound
    - CAM plants don't have bundle sheath cells
    - Open stomata in cooler temperatures (night)
    - Most fixation occurs @ night (C_4 pathway)
    - Close stomata during the day
    - Reduce water loss
    - During the day → fixation via C_3 pathway



Comparison of the basic features

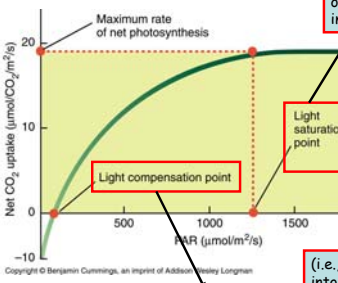
C_4 plants → carboxylation occurs in different cells

CAM plants → carboxylation takes place in same cells but at different times of day

Light

- Response of Net Photosynthesis to Variation in PAR
  - Photosynthetically active radiation (PAR)
    - Only a fraction of light energy available to autotrophs → PAR (range 400 – 740 nm)
  - Photon flux density → actual quantity (flux) of PAR (measured in *µmol/m²/sec*)
  - Light Response Curve: net exchange of CO_2 (net photosynthesis) with variation in PAR

Light Response Cu



When no further increase in photosynthesis occurs regardless of increase in PAR

(i.e., diffusion of CO_2 into leaf)

Not exhibited in many C_4 plants

When the rate of (the loss of CO_2 in r

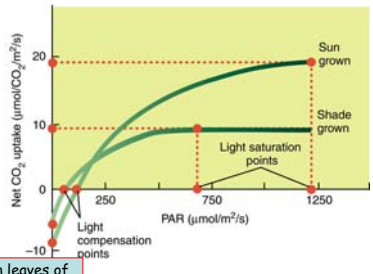
Light

- Response of Net Photosynthesis to Variation in PAR
  - In some plants, values of PAR above the light saturation point result in a decline in net photosynthesis (photoinhibition)
    - Can result in permanent damage if exposure is long-term

Light

- Plant Responses to Reduced PAR
  - Plants grown under reduced light levels display reduced rates of net photosynthesis (per leaf unit area)
  - Responses include changes in:
    - Biochemistry (less amount of necessary comps)
    - Physiology (reduced respiration rates)
    - Morphology (leaves usually larger and thinner)

Light Response Curve



Can occur on leaves of the same plant:

Top vs. bottom canopy

Light

- Plant Adaptations to Variation in the PAR Environment
  - Shade Intolerant Plants: species adapted to high light environments
  - Shade Tolerant Plants: species adapted to shade environments
- Direct impact on their ability to survive under no-light (shaded) conditions

Light

- Shade Tolerant vs. Shade Intolerant

• Can maintain high levels of photosynthesis @ increased light levels	• Can maintain high levels of photosynthesis @ reduced light levels
• Photosynthesis, growth, and survival dramatically reduced under shaded conditions	• reduced PAR required to maintain positive C balance
	• Photoinhibition potential @ high-light levels

Light

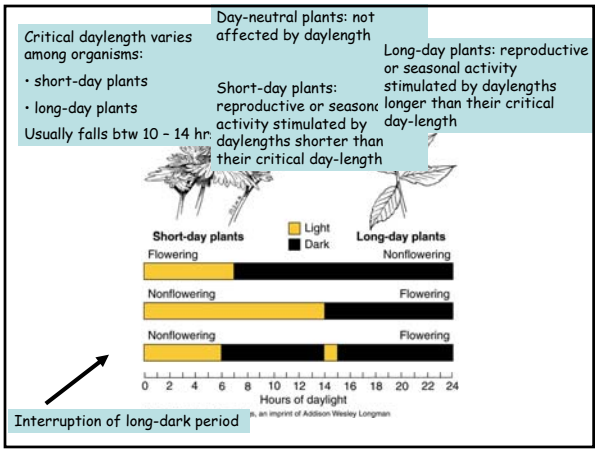
- Response to Ultraviolet Radiation
  - Increased levels of UV B radiation in recent year (due to depleted ozone layer)
  - UV B radiation can damage plant DNA and partially inhibit photosynthesis
    - Alter growth form of plants
    - Reduce overall yields

Light

- Response to Ultraviolet Radiation
  - As a defense to UV B increases, plants have evolved to increase reflectance levels within their outer layers
  - Tropical and alpine plants more effective than temperate species

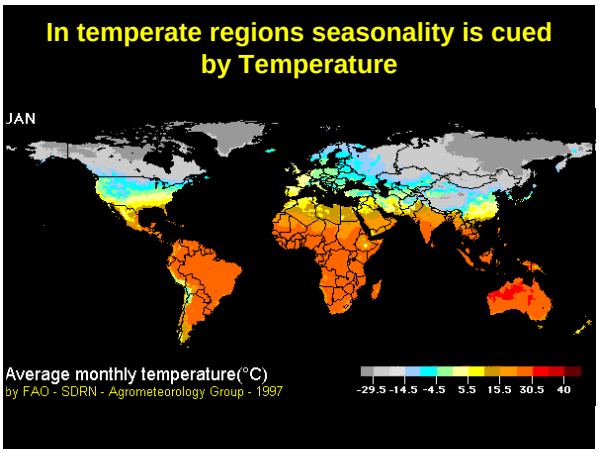
Periodicity and Plant Processes

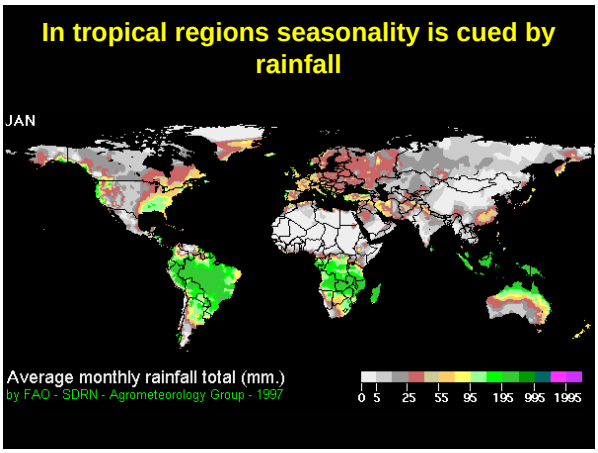
- Aside of being a major energy source, light also functions as a timing mechanism for plants
  - Keeps plant activity in tune with seasonal and daily changes in the environment
- Critical daylength: the period of daylight that triggers a long-day or a short-day response in organisms



Periodicity and Plant Processes

- Other plant responses to seasonality
  - Unfolding of leaves during Spring
  - Dropping of leaves during Fall
  - Blooming of flowers
  - Ripening of seeds
- The study of the causes of the timing of such events, the causes, and interrelations among each phase is called Phenology
  - Latitudinal differences (Tropical vs. Temperate)


In temperate regions seasonality is cued by Temperature
JAN
Average monthly temperature(°C)
by FAO - SDRN - Agrometeorology Group - 1997
-29.5 -14.5 -4.5 5.5 15.5 30.5 40


In tropical regions seasonality is cued by rainfall
JAN
Average monthly rainfall total (mm.)
by FAO - SDRN - Agrometeorology Group - 1997
0 5 25 55 95 195 995 1995