Final Exam

Monday, Dec. 10, 2007
10:10 a.m. – 12:00 p.m.

~30% of the questions will come from material covered before the midterm.
~70% of the questions will come from the new material.

5 definitions @ 4 points each
all definitions will come from material covered after the midterm
10 short answer questions @ 10 points each
for 120 points total (34% of your grade)

Topics – Before Midterm (30%)

- Climate Change
- Tree Genetics & Regeneration Biology
- Tree Structure and Growth
  - Shoots and Stems
  - Roots
  - Leaves
- Bioclimatology
  - Radiation

Topics – After Midterm (70%)

- Bioclimatology
  - Temperature
  - Precipitation
  - Humidity
- Water Balance & Water Use
- Carbon
  - Photosynthesis, Respiration, Allocation
  - Net Primary Productivity (NPP)
- Stress Physiology & Dormancy Induction
- Decomposition & Nutrient Availability
  - Nitrogen cycle
  - Mineralization/immobilization
- Site Quality

Genetics

- **Influences on plant development**
  - Genotype
    - The exact genetic makeup of an individual
  - Environment
    - Climate, parent health, soil fertility, etc.
  - **Phenotype**
    - Influence of **BOTH** genotype and environment

Regeneration

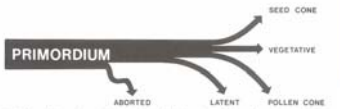
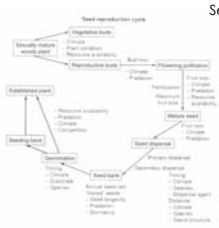


Figure 5.4. Alternative pathways of lateral bud primordial development. (After Allen and Owens, 1972. Reproduced by permission, Canadian Forest Service.)

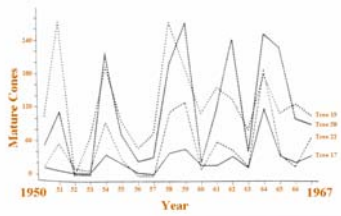
Primordium = group of cells representing the initial stages in the development of a plant organ

Regeneration

See also Table 5.1



Regeneration – Cone Crop Periodicity



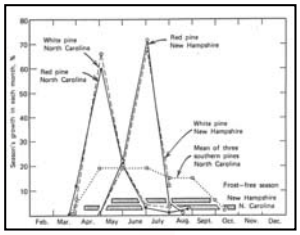
Anatomy

- Tree form – not on final
- Shoots – not on final
- Stems
  - Primary and secondary growth
- Roots
  - Primary and secondary growth
- Leaves
  - Primary growth

Anatomy – Environmental Conditions

- Temperate Forests
  - Environmental conditions
    - Daylength
    - Temperature
  - **In Montana**
    - **Drought**
    - **Cold**
    - **Daylength**
- Tropical Forests
  - Leaf senescence,
  - leaf/root imbalance

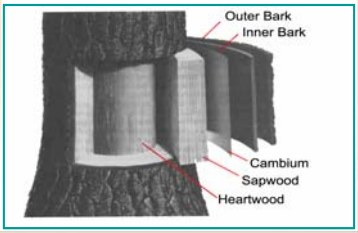
Anatomy – Tree Growth



Anatomy - Stems

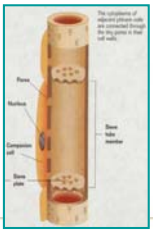
- The ability to form (and add) consecutive layers of structural tissues (secondary growth) to the primary stem distinguishes woody species from all other plants.
- Secondary growth
  - Strengthens the stem
  - Increases transport of food & water between shoots and roots

Anatomy - Stems



Anatomy – Stems

Phloem



Xylem

Anatomy – Stems

- Cavitation
- Earlywood to latewood transition
  - Growth rings

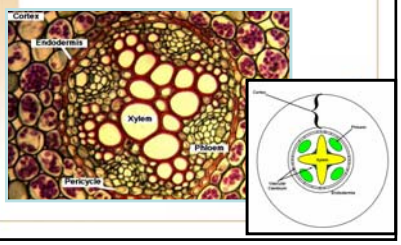
Anatomy – Roots

- Anchor the tree (whole root system)
- Store sugars (larger roots)
- Generation of vegetative shoots (e.g., aspen)
- Prevent soil erosion
- Absorption of water & minerals from soil (fine roots)

Anatomy - Roots

- Root Types
  - Tap root
  - Fibrous root
  - Adventitious root
- Root Distribution
  - Horizontal
  - Vertical

Anatomy – Roots - Morphology



Anatomy - Roots

- Suberized Coarse Roots (permanent)
  - Outer tissue is dead bark
  - Support (HOLD THE TREE UP!!!)
- Unsuberized Fine Roots
  - < 1 mm diameter, white
  - Live 1-3 months
  - Only 1-5% of root biomass, BUT 90% of root surface area
  - Nutrient & water uptake (DO THE WORK!!!)

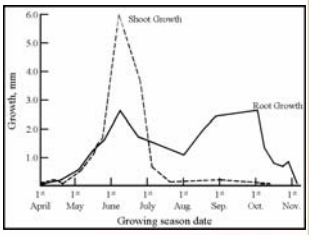
Anatomy - Roots

- Root cap
- Casparian Strip
  - Water travel into roots, and then into xylem
- Root growth and seasonal turnover
- Root hairs

Anatomy - Roots

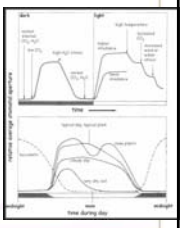
- Rhizosphere
- Mycorrhizae - **fungi**
- Root grafting
  - Benefits
  - Disadvantages
  - "The Living Stump"

Anatomy – Root:Shoot Growth

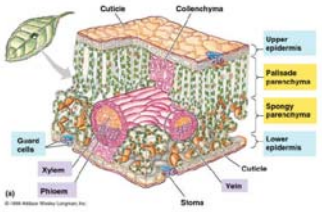


Anatomy - Leaves

- Why are leaves green?
  - Why do they change color?
- Stomatal dynamics
  - What are stomata?
  - What purpose do they serve?
  - What is osmotic potential?
  - How do stomata open/close? (e.g., guard cell dynamics
- Sun vs. shade leaves

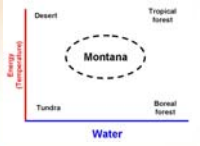


Anatomy - Leaves



Bioclimatology

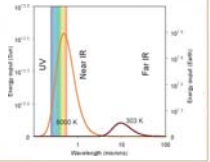
- Climate
- Weather
- Micro-climate



- Insolation
- Solar declination
- Seasons
- Daylength

Bioclimatology - Radiation

- Electro-magnetic spectrum
  - Shortwave radiation
  - Longwave radiation

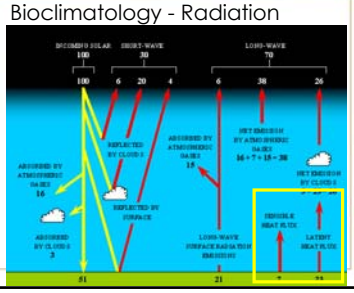


Bioclimatology - Radiation

- Radiation
- Conduction
- Convection

- Examples: wood stove, gecko

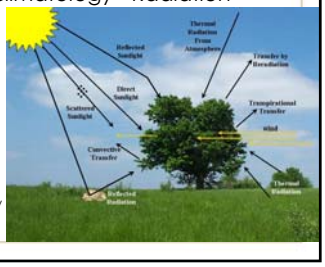
Bioclimatology - Radiation



Bioclimatology - Radiation

Net radiation for a tree
Rn
=
Incoming
–
outgoing

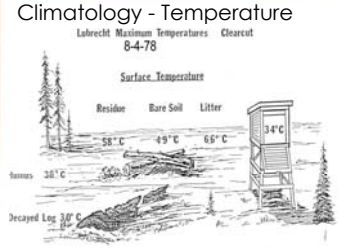
α is ***albedo***, which is the reflectivity of a surface



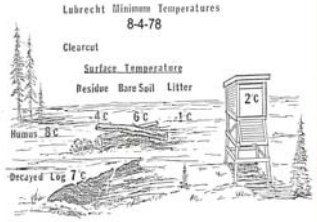
Bioclimatology - Radiation

- **Surface Energy Balance**
  - Rn – G = H + λE
- **Bowen Ratio**
  - β = H / λE

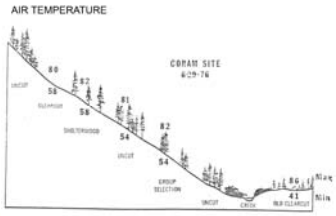
Climatology - Temperature



Climatology - Temperature



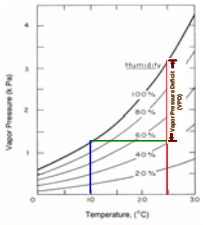
Climatology - Temperature



Climatology - Clouds

- Convective
- Orographic
- Frontal

Climatology – Vapor Pressure



Climatology - Temperature

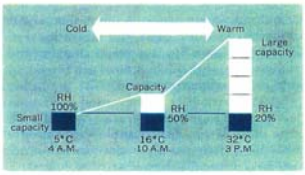


FIGURE 6.2 Relative humidity changes with temperature because capacity of warm air is greater than for cold air.

Climatology - Temperature

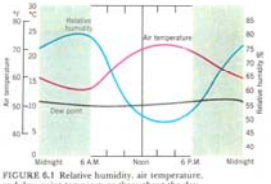


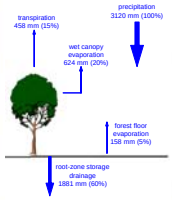
FIGURE 6.1 Relative humidity, air temperature, and dew-point temperature throughout the day at Washington, D.C. The curves show average values for the month of May. (Data from National Weather Service.)

Climatology - Temperature

- Effects of Precipitation on the Carbon Balance of Mount Jumbo

Water Balance & Water Use

- The Forest Water Balance



Water Balance & Water Use

- **Throughfall** is precipitation that reaches the surface directly through spaces in the canopy and by dripping from the canopy.
  - Contains nutrients leached from the leaf surfaces.

- **Stemflow** is water that reaches the ground surface by running down the trunk and stems.
  - More significant in smooth-barked trees.
  - Contains nutrients leached from leaf surfaces.

Water Balance & Water Use

Leaf Area Index (LAI)

LAI =

total leaf surface of a plant
ground area projection under plant

Water Balance & Water Use

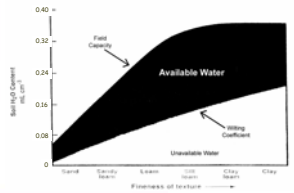
- **Water Potential**
  - For pure liquid water, $\Psi = 0$
  - For almost anything else, $\Psi < 0$

$$\Psi = \Psi_m + \Psi_p + \Psi_g + \Psi_o$$

- Ψm = matric potential; function of adhesion/cohesion
- Ψp = pressure potential; function of pressure applied to water (hydrostatic pressure)
- Ψg = gravitational potential; How much force is gravity using to pull the water down?
- Ψo = osmotic potential, caused by the presence of dissolved sugars and salts in water

Water Balance & Water Use

- Available water

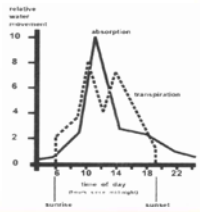


Water Balance & Water Use

- **Evaporation**
  - The gradual change of the state from a liquid to a gas, occurring at the liquid surface.
- **Transpiration**
  - The transfer of water from within leaves through stomata into the atmosphere.
- **Evapotranspiration**
  - Evapotranspiration is the **combination** of **evaporation** and **transpiration**, or the **total** water loss from a leaf or plant.

Water Balance & Water Use

- **Water Shortage Correction**
  - Relative difference between transpiration and absorption of water in a tree during a sunny day with adequate soil moisture.
  - Energy for nighttime water absorption (stomates closed) comes through tension in the water column within the xylem, which pulls water into the tree.



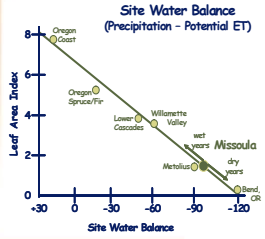
Water Balance & Water Use

- Water Use Efficiency
- **WUE =** Carbon gain (g) / Water lost (g)

Water Balance & Water Use

- **Ways That Water Deficits Reduce Plant Growth**
  - Stomatal Closure
  - Reduce cell expansion
  - Reduce phloem transport
  - Root/shoot partitioning increases
  - Leaves drop early
  - Decomposition decreases
  - Nitrogen availability decreases

Water Balance & Water Use



Water Balance & Water Use

- **Site Water Balance**
  - **Inputs**: Precipitation (snow, rain, sleet etc.)
  - **Outputs**: Evapotranspiration and runoff
  - **Storage**: Snow, soil

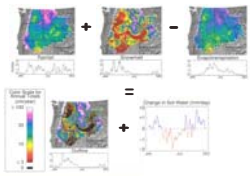
Precipitation + Snowmelt – ET

=

Outflow + Change in Soil Water Content

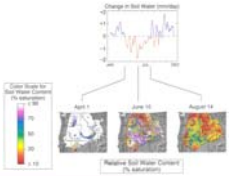
Water Balance & Water Use

- Simple Water Budget
  Rain + Snowmelt – ET = Outflow + Δ Soil Water



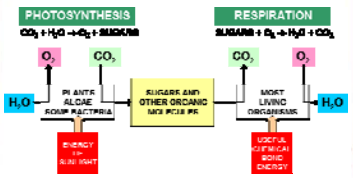
Water Balance & Water Use

- Simple Water Budget
  Δ Soil Water



Carbon – Photosynthesis, Respiration, Allocation

Carbon – Photosynthesis, Respiration, Allocation



Carbon – Photosynthesis, Respiration, Allocation

$CO_2 + H_2O + (e) \leftrightarrow CH_2O + ½\ O_2$

- ***Basic Components of Photosynthesis***
  - *PAR Interception*
    - *ATP*
  - *Biochemistry (Rubisco)*
    - *Ribulose bisphosphate (RuBP)*
  - *Absorption of CO_2*
    - *CO_2 diffuses at 0.625 * H_2O because of difference in molecular mass*

Carbon – Photosynthesis, Respiration, Allocation

CO_2 Compensation Point (Γ)

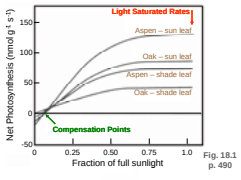
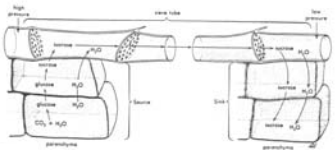


Fig. 18.1
p. 490

Carbon – Photosynthesis, Respiration, Allocation

Mass flow theory of phloem transport



Carbon – Photosynthesis, Respiration, Allocation

- 2 Types of Respiration
  - **Maintenance** Respiration ($R_{maintenance}$)
    - Maintain/replace **current** living tissue
    - Protein synthesis & replacement
    - Membrane repair
  - **Growth** Respiration (R_{growth})
    - Construct **new** leaves, **new** roots
    - Physical growth

Carbon – Photosynthesis, Respiration, Allocation

- **Environmental Controls on Respiration**
  - Substrate Availability (CH_2O)
  - O_2 Availability
  - Temperature
  - Water relations
  - Type & Age of Plant

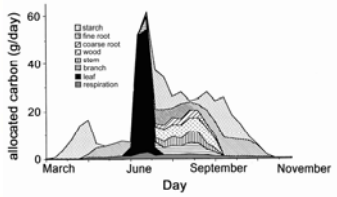
Carbon – Photosynthesis, Respiration, Allocation

- What Determines C Allocation?
  - Genetics
  - Age of tree
  - Time of Year (e.g., growing season)
  - Environmental Factors
    - light, water, nutrients

Carbon – Photosynthesis, Respiration, Allocation

- Potential Carbon Allocation
  - Respiration
  - Structure
  - Storage
  - Defense
  - Reproduction

Carbon – Photosynthesis, Respiration, Allocation



Carbon – Photosynthesis, Respiration, Allocation

- **Net Primary Production (NPP)**
  - **NPP** is the net amount of primary production after the costs of plant respiration are included.
  - In other words,
    NPP = GPP – Rautotrophic
    - Where Rautotrophic = Rgrowth + maintenance

Decomposition: How do trees get nutrients?

- Roots
  - growth and mycorrhizae
  - mass flow
  - diffusion
- Storage
- Internal cycling

Decomposition

- The process by which complex organic matter is structurally disintegrated into
  - CO_2
  - Water
  - Mineral components
- It constitutes the **major ecosystem process by which nutrients are recycled**

Decomposition is the Result of 3 Simultaneous Processes

- Leaching
- Weathering
- Biological activity

Litter Quality & Decomposition

- Type of chemical bonds and amount of energy released by decay (carbon quality)
- Size and 3-D complexity of molecule
- Nutrient concentration (nutrient quality)

Decomposition

- Glucose, simple sugars
- Cellulose*
- Tannins & Lignins

Humus

- Humus is a complex & amorphous form of organic matter in ecosystems.
- It is high in nitrogen and large polyphenolic molecules, but low in cellulose.
- It can take thousands of years to decompose.

	Larch	Fir
		
Growth N **Demand**:		
Stem	2	2
Needles	100 (100% turnover)	20 (20%)
	102	**22**
N **Supply** from:		
Retranslocation	50	10
Decomposition	***51***	***11***
Atmosphere	1	1
ANNUAL N Req.	**102**	**22**

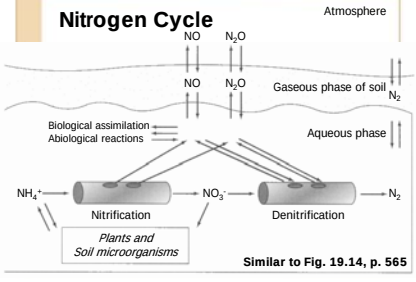
Nitrogen Cycle

Simple Organic N → NH_4^+ → NO_3^-

Mineralization →

← *Immobilization*

Nitrogen Cycle



Similar to Fig. 19.14, p. 565

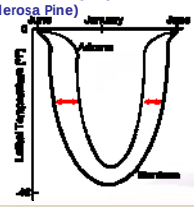
Cold Hardiness

- **Growth** = f (Means)
- **Survival** = f (Extremes)

Categories of Cold Hardiness	Lethal Temperature
Tropical	+10°C
Sub Tropical	0°C
Temperate	- 40°C
Boreal	↓

Cold Hardiness

Cold Dormancy Dynamics
(Ponderosa Pine)



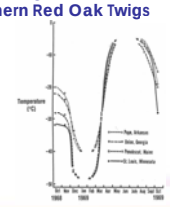
Cold Hardiness

Low Temperature Injuries Arise from

- Chilling
  - Mainly vegetative/reproductive tissue of tropical, subtropical & some temperate plants
  - 0°C < Tair < 15°C
  - Clear night followed by bright days
    - Chilling & light injuries interact
- Freezing
  - Ice formation in plant tissues (rapid freezing)
  - Dehydration of tissue from extra-cellular freezing (slow freezing)

Cold Hardiness & Dormancy

Hardening and Dehardening of Northern Red Oak Twigs



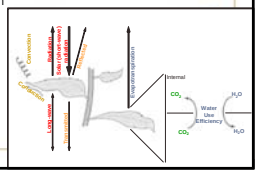
Credit: Flint, 1972

Heat Stress

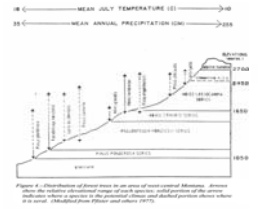
- **Overheating** often occurs
  on **calm** days
  to those **plants**
  close to the **ground**,
  on **open slopes**, or
  in depressions facing
  the **sun**.

Heat Stress

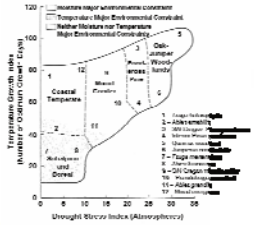
- Dissipation of Solar Energy
  - Re-radiation – 50%
  - Transpiration****
  - Convection



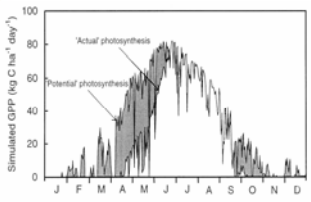
Site Quality



Site Quality



Site Quality



Site Quality