The Botany of Fall Color

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Powhatan WMA,
road along Lower Lake
Sassafras albidum – sassafras
Dutch Gap, Chesterfield Co., VA
Sassafras albidum – sassafras
Powhatan Co., VA
*Acer saccharum* – sugar maple  
University of Richmond
Acer rubrum – red maple
University of Richmond
Basic physiology during active growth:

- **Shoot apical meristem**
- **Root apical meristem**
- **Water & minerals from root to shoot**
- **Leaf**
  - Sugars, from source to sink

Physiology of senescence (overview):

- **Environmental signal**
- **Developmental signal**
  - **Initiation phase:**
    - sink → roots only
    - photosynthesis decreases
  - **Degenerative phase:**
    - cell organelles & macromolecules degrade
    - abscission layer forms, xylem & phloem transport inhibited
  - **Terminal phase:**
    - cell death
    - abscission

Modified from diagram in:
Physiology of senescence (late summer & fall)

- Environmental signals:
  - photoperiod – less daylight
  - temperature decrease

- Internal signals (hormones):
  - auxin decreases
  - ethylene increases
  - abscissic acid increases

- active meristems → dormant buds
- new chlorophyll synthesis
  - slows,
  - eventually stops completely
- existing chlorophyll degrades
  - green color is lost
  - carotenoid pigments unmasked
- macromolecules degrade
  - AA’s simple sugars, etc., transported to roots for winter storage
- leaf abscission begins, impairs:
  - xylem – water transport to leaf
  - phloem – sugar transport from leaf
    - induces anthocyanin pigments

Aesculus parviflora
bottlebrush buckeye
Lewis Ginter Botanical Garden
Leaf Abscission

- abscission or separation layer
  - small, weak cells
  - under hormone induction
    middle lamella dissolves
- protective layer of cork cells
  - impermeable
  - becomes leaf scar

*Raven 26.34*

*Liquidambar styraciflua* – sweet gum
Acer x freemanii – Freeman maple
(Acer rubrum x Acer saccharinum)
University of Richmond

The pigments . . .
Chlorophyll & Carotenoid Pigments
- lipid-soluble molecules
- components of chloroplast thylakoid membranes

Photosynthetic pigments:
- Chlorophyll a
- Chlorophyll b
- Carotenes
- Xanthophylls

Whole plant (dandelion)
Chromatographic separation of photosynthetic pigments

Acetone or ethanol extract of green leaf pigments

“Spotting” pigment extract on chromatography paper

Chromatographic separation of pigments

Images from: http://www.hsu.edu/pictures.aspx?id=1653
Beta Carotene (pure hydrocarbon)

Xanthophyll (hydrocarbon + some O)

Carotenoid Pigments

Sassafras albidum
Sassafras
University of Richmond
Taxa with carotenoids dominant in fall color (brilliant yellows):

- **Acer** – maple
- **Alnus** - alder
- **Betula** - birch
- **Carya** – hickory
- **Fraxinus** – ash
- **Liriodendron** – tulip/yellow poplar
- **Platanus** - sycamore
- **Populus** – aspen/poplar
- **Prunus** – cherry
- **Sassafras** – sassafras

(List from Wikipedia)
Aesculus parviflora
bottlebrush buckeye
Lewis Ginter Botanical Garden
Carya sp. – hickory
University of Richmond
Cercis canadensis – redbud
University of Richmond
Liriodendron tulipifera – tulip poplar
University of Richmond
Morus alba – mulberry
Piedmont Virginiana Community College
Anthocyanin Pigments:
• water soluble pigments
  • contained in cell vacuoles
  • red to purple
  • color can be pH sensitive
• in some plants, always present
• in other plants, increases in Fall

*Tradescantia pallida* Chesterfield Co.

Anthocyanidin basic structure;
addition of sugar molecules converts it to anthocyanin
(image ex Wikipedia)

Single cell from stamen-hair of *Tradescantia*;
purple anthocyanins pigments contained in vacuole (which occupies most of the cell volume)
Some plants produce large amounts of anthocyanins in young foliage

• new growth, young leaves:
  • delicate, tender
  • fibers and sclereids immature

• protective functions of anthocyanins in young plant tissue:
  • “sun block” effect
  • color effect on herbivores, red leaves:
    • not recognized as food?
    • foil green insect camouflage from predators

*Photinia x fraseri* – red-tip
University of Richmond
Oxydendrum arboreum – sourwood

Taxa with anthocyanins dominant in fall color (reds & purples:

Acer – maple
Cornus – dogwood
Diospyros - persimmon
Liquidambar – sweet gum
Nyssa – tupelo, sour gum
Quercus – oak
Oxydendrum – sourwood
Prunus – cherry

(List from Wikipedia)
Acer rubrum – red maple
Powhatan Co., VA
Acer rubrum – red maple
U.S. National Arboretum
Cornus florida – flowering dogwood
University of Richmond
Hydrangea quercifolia ‘Sike’s Dwarf’
Lewis Ginter Botanical Garden
Nyssa sylvatica – black gum
U. S. National Arboretum
Quercus alba – white oak
University of Richmond
Rhus aromatica – fragrant sumac
Sweet Briar College
Oxydendrum arboreum – sourwood
Lewis Ginter Botanical Garden
Diospyros virginiana
persimmon
Powhatan Co., VA
Acer saccharum – sugar maple
University of Richmond

Combinations of Carotenoids & Anthocyanins
Acer rubrum – red maple
Powhatan Co., VA
Acer rubrum – red maple

East Tennessee State University
Prunus serrulata ‘Kwanzan’
University of Richmond
Cornus florida – flowering dogwood
University of Richmond
Toxicodendron radicans – poison ivy
University of Richmond
Dominance of anthocyanins vs carotenoids may depend on environmental conditions

*Sassafras albidum* – sassafras
Johnson City, TN

*Sassafras albidum* – sassafras
University of Richmond
Cercis canadensis ‘Forest Pansy’ – redbud (spring)
Van Dusen Bot. Gard., Vancouver, BC

Cercis canadensis – redbud (fall)
University of Richmond
Brown Colors

• from deposits of tannins in leaves
• like anthocyanins, also deposited in cell vacuoles

(Wikipedia states that brown colors in leaves come from the cell walls, but this is just plain incorrect!!!)

Fagus grandifolia – beech
Powhatan Co., VA
Fagus grandifolia – beech
University of Richmond
Magnolia virginiana – swamp bay
University of Richmond
*Taxodium distichum* – bald cypress
U. S. National Arboretum

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White fall "color"

• absence of pigments
• rare

*Eupnynmus americanus*
strawberry bush
University of Richmond
Eupnymus americanus

strawberry bush

University of Richmond
Fall color in shrubs

*Hydrangea quercifolia* ‘Sike’s Dwarf’
Lewis Ginter Botanical Garden
Itea virginica ‘Harry’s Garnet’
U. S. National Arboretum
Rhus aromatica – fragrant sumac
Lewis Ginter Botanical Garden
Rhus copallinum – winged sumac
Powhatan Co., VA
Rhus glabra – smooth sumac
U. S. National Arboretum
Viburnum acerifolium
maple-leaf viburnum
University of Richmond
Apocynum cannabinum
dogbane
Palmyra, VA

Fall color in herbs
Amsonia hubrechtii – bluestar
Lewis Ginter Botanical Garden
Very few monocots have notable fall color

. . . but some grasses do:

_Miscanthus floridulus_  
_Molina coerulea ssp. arundinacea ‘Sky Racer’_  
_Panicum virgatum ‘North Wind’_

All photos: U. S. National Arboretum
Season of Fall Color

Calendar:
- Oct 13 - Nov 3
- Oct 27 - Nov 10
- Nov 1 - Nov 15

Average Time of Peak Foliage Color

Fall Foliage
Typical Peak Color Periods

Virginia Department of Forestry
Fall color: a global perspective

- some degree of fall color occurs wherever deciduous trees are found

“best” areas:
- Eastern US & southern Canada
- Western Europe north of Alps (incl. Scandinavia)
- Caucasus region (near Black Sea)
- Russia
- Eastern Asia (NE China, Korea, Japan)
- South island of New Zealand

http://www.vectortemplates.com/raster-maps.php
Acer x freemanii – Freeman maple
(Acer rubrum x Acer saccharinum)
University of Richmond

Fall color:

Eastern N America vs Western Europe

800 tree species  51 tree species
70 oaks  3 oaks
N-S mountains  E-W mountains
Glacial refugia  no glacial refugia
Fall color in exotic plants as grown in the mid-Atlantic region

*Metasequoia glyptostroboides*

dawn redwood

U. S. National Arboretum
Lagerstroemia indica – crepe myrtle
University of Richmond
Euonymus alatus ‘Compactus’
Lewis Ginter Botanical Garden
Parrotia persica
Lewis Ginter Botanical Garden
Prunus serrulata ‘Kwanzan’
University of Richmond
Viburnum dilatatum – linden viburnum
Lewis Ginter Botanical Garden
Viburnum prunifolium – black haw
Lewis Ginter Botanical Garden

Fall color with fruits
Rhus copallinum – winged sumac
Norfolk Botanical Garden
Nyssa sylvatica – black gum
Chesterfield Co., VA
Cornus florida ‘Xanthocarpa’
Lewis Ginter Botanical Garden
Aronia arbutifolia ‘Brilliantissima’
Red Chokeberry
U. S. National Arboretum
Direction of Fall Color Progression

Distal To proximal

Proximal

Proximal To distal
Acer rubrum – red maple
Piedmont Virginia Community College
(distal first)
Acer rubrum – red maple
University of Richmond
(distal first)
Calycanthus floridus – carolina allspice
Powhatan Co., VA
(proximal first)
Cornus florida – flowering dogwood
University of Richmond
(proximal first)
Liquidambar styraciflua – sweet gum  
Powhatan Co., VA  
(proximal first)
Sassafras albidum – sassafras
University of Richmond
(proximal first)
Viburnum x burkwoodii ‘Mohawk’
Lewis Ginter Botanical Garden (proximal first)
Fagus grandifolia – beech
University of Richmond
fallen leaves
Hamamelis virginiana – witch hazel
U. S. National Arboretum
fallen leaves
Fagus grandifolia – beech
Little River Park, Hanover Co., VA

Marcescent Leaves
Fagus grandifolia – beech
Powhatan Co., VA
Cornus florida – flowering dogwood
Lewis Ginter Botanical Garden
+/− uniform leaf color
Cornus florida – flowering dogwood
University of Richmond
Diospyros virginiana – persimmon
Norfolk Botanical Garden
Carpinus caroliniana – ironwood
University of Richmond
Viburnum acerifolium
maple-leaf viburnum
University of Richmond
Sunfish Lake
Powhatan Wildlife Management Area