Plant quiz 4

12 examples plants from the teaching collection for you to identify with the following information:

1) Latin name (Genus, species), 2) Family name,

- Latin names are underlined (or italicized).
- Capitalize the genus name, no caps on the species name.
- Items like ssp., var. cf. are not italicized.
- Family names are not italicized.

Flash Cards

For remaining species, Edie will do these.
Next discussion papers: Monday after spring break

Discussion Group 1: one or the other


Discussion Group 2: Both

Next discussion papers: Monday after spring break

**Discussion Group 1:**
Frehill, Victoria A.
Friedrich, Kayla D.
Garrett, Emily
Gilbert, Breanne M.
Grimes, Amanda L.
Hendricks, Amy S.
Hogan, David A.
Jones, Samantha N.
Klingensmith, Sara M.
*(group leader)*

**Discussion Group 2:**
Liebermann, Robert J.
Luce, Jamie R.
McClendon, Stephanie A.
Nakanishi, Eri
Pavic, Karolina
Skinner, Kailey E.
Strehlow, Leigh E.
Suzuki, Aina
Swanberg, Sheila R.
Yancey, Laramie L.
*(group leader)*
Research Papers

Send me title and expanded outline by end of March 19.
Field trip, Mar 9 & 10

1. Saturday & Sunday, Mar 9 and 10. Meet in the parking lot west side of Arctic Health Building at 9 am both days.

2. Saturday: North Campus Lands, Smith Lake.
   a. Snow pit descriptions: Forest and lake.
   b. Winter vegetation.
   c. Animal winter activity and tracks.

   a. Snow pits in the alpine.
   b. Observations of wind pack, sastrugi, animal tracks, etc.
   c. Fun day in the alpine if the weather permits.

4. Need snow shoes or skis for both days. On Saturday walking may be possible because we will be near the walking trails on the NCL.

5. Bring a sack lunch both days. We will set up Coleman stoves for hot drinks at Smith Lake. Sunday will likely be a half day trip.
Field trip equipment list (now posted on the web in course schedule for Mar 9, 10)
Take home points from Lecture 8

1. Understand the life cycle associated with snow algae (slides 9-15).
2. Understand the components of the snow food chains, the role of snow algae, fungi, collembolla and other invertebrates, capable of surviving on and in the snow pack (slides 16-18).

3. Understand the processes of low-temperature-gradient (equilibrium) and high-temperature-gradient (kinetic) snow metamorphosis (slides 33-39).

4. Be able to recognize the physical properties of tundra, tiaga, prairie, alpine, and maritime snow (slides 40-43).

5. Be able to describe the major processes contributing to changes in snow chemistry in the atmosphere, in dry snow on the ground, and during the snow melt period (slides 44-48).
1. 2N Zygospores germinate by meiosis on soil surface producing bi-flagellated 1N zoospores.
2. 1N Zoospores “swim” upward to snow surface within liquid water surrounding snow crystals of isothermal snow.
3. Zoospores reproduce asexually developing large populations of snow algae.
4. Zoospores create visible blooms of snow algae on the snow surface. With nutrient depletion, 1N gametes from 1N zoospores fuse to form 2N resting zygotes.
5. Zygotes return to soil passively through meltwater percolation and settling of the snow.

Snow as a habitat: Snow ecosystem food chains

1. Subnivian plants.
2. Fungi
3. Snow algae
4. Red backed vole (*Clethrionomys gapperi*)
5. Collembola (*Isotoma* sp.)
6. Deer mouse (*Peromyscus maniculatus*)
7. Wolf spider (*Pardosa* sp.)
8. Masked shrew (*Sorex cinereus*)
9. Shorttail weasel (*Mustela erminea*)
10. Red fox (*Vulpes fulva*)
11. Great gray owl (*Strix nebulosa*)
12. Boreal owl (*Aegolium funereus*)

Snow has effects on vegetation at nearly all spatial and temporal scales of study, and is best approached with a hierarchic conceptual framework.

Alpine snow beds are different than arctic snow beds

- Different types of snow (Tundra vs. Alpine snow of Sturm et al. (1995))
- Alpine: Generally deeper snow, warmer, much deeper drifts, many remain unfrozen at base all winter. Stronger contrast and more variation in micro-environments and in snowbed plant communities and fellfield communities.
- Arctic: Soils remain frozen most of winter.
Comparison of snow studies at Niwot Ridge and Toolik Lake LTER sites

Both LTER sites utilized a multi-scale GIS approach to looking at snow-vegetation interactions.

Characteristics of snowbed environments along mesotopographic gradients

- Described world-wide from many mountain ranges.
- Most comprehensive studies:
- Mesotopographic framework of Billings (1973) (right) was used on Niwot and in Alaska.

Cryptobiotic crusts in snow flush sites in High Arctic

Typical Toposequence in Canadian Extreme High Arctic

Vegetation was mapped during the summer

Mapped according to plant associations of Komárková (1980) and May and Webber (1982) vegetation noda.

Grid points (+) are marked in the field at 50-m spacing.


GIS database of Niwot Saddle Grid

- Distribution of vegetation types within snow depth, slope and aspect classes.

Plant species responses to variations in snow cover, Niwot Ridge, CO

- Komárková recognized these as characteristic taxa for plant communities along the snow gradient.


Figure 6.2. Distribution (plus or minus standard error) of six common species along the snow gradient. *Paronychia pulvinata* and *Kobresia myosuroides* are diagnostic taxa for the Alliance *Kobresio-Caricion rupestris*, which includes associations that are typical of broad, well-drained, stable windswept ridges in the Front Range. *S. procumbens*, *T. parryi*, and *C. pyrenaica* are diagnostic species for syntaxa within the snowpatch *Salicetum herbaceae*. *Acomastylis rossii* occurs across a broad range of snow-depth classes and is most abundant in areas with moderate snow cover. From Walker et al. (1993).
Six characteristic plant species along Niwot snow gradient

**FELLFIELD**

*Paronychia pulvinata*
Photo D. A. Walker

**DRY MEADOW**

*Kobresia myosuroides*
Photo: D.A. Walker

**MOIST MEADOW 1**

*Acomastylis rossii*
Photo: ?

**MOIST MEADOW 2**

*Sibbaldia procumbens*
Photo D. A. Walker

**MOIST MEADOW 3**

*Trifolium parryii*
Photo: D.A. Walker

**DEEP SNOWBED**

*Carex pyrenaica*
Other plant species showing differential responses to variations in snow cover, Niwot Ridge, CO

- Komárková also recognized most of these as differential taxa for plant communities along the snow gradient.

Chionophytes: Adapted to high snow environments

*Chionophila jamesii*, Niwot Ridge, CO  
Photo: D.A. Walker

But what makes a chionophyte a chionophyte?
Growth strategies of snowbed plants

Some adaptations to poor nutrient conditions & short growing season:

- Evergreen leaves (e.g. Empetrum, Cassiope)
- Long-lived, slow-growing species. (However, note that many deep Arctic snowbeds are dominated by deciduous shrubs (e.g. Salix rotundifolia, S. herbacea), and at Niwot there are no evergreen shrubs in snowbeds.
- High above-ground to below-ground biomass ratios compared to other Arctic plant communities. (e.g. biomass ratio in Cassiope community on Ellesmere Island is 1:1 compared to 1:3.8-1:6.7 in wet sedge-moss meadows).
- However, many moderate snow-bed plants especially in the alpine have well-developed roots, rhizomes, and stem bases for storage of photosynthate.
- Abundant attached dead contributes to high aboveground:belowground ratios. Over 90% of aboveground standing biomass is non-photosynthetic tissues. Attached dead may improve thermal regime of plants.
- Animals complicate the nutrient picture (more on this later).

Photos: D.A. Walker

Cassiope tetragona
Growth strategies in snow bed plants

- **Foliosphere** (aboveground plant parts)
  - Function most influenced by light, air temperature, humidity, wind.
- **Rhizosphere** (belowground)
  - Most influenced by soil temperature, soil stability, and water, nutrient and oxygen availability.

- **Contrast between foliosphere and rhizosphere microclimates can be extreme**
  - especially in high alpine snow bed sites with intense solar radiation and high temperatures in the foliosphere vs. very cold rhizosphere environment caused by snow meltwaters.
- **Microenvironments within snowbeds are spatially very complex.**
  - Soil temperature, length of growing season, and exposure to winds are highly dependent on snow depth and timing of snow melt.
  - Soil moisture conditions highly dependent on topographic situation.

- Very hard to study this environment.
Short growing season: Phenology

- The study of the time of appearance of characteristic periodic events in the life cycles of organisms and how these events are influenced by factors, such as temperature, latitude, altitude, and snow. Example shows timing of phenology events for *Acomastylis rossii* after snow melt in each of the major plant noda on Niwot Ridge.
Growth strategies for fellfield plants

Much more information on tundra plants growing in extreme cold and windy environments:

Adaptations to windy cold-winter conditions:

- Cushion forms and tightly packed small leaves minimize effects of abrasion by wind-blown snow and mineral material (Billings and Mooney 1968).

High UV radiation (high UV):

- Anthocyanin (red) pigments (Caldwell 1968) decrease epidermal UV penetration. Common red tissues in many alpine plants.


Production

- Measurements of production in Niwot communities (Table, May, 1976; M.D. Walker 1994) and showed the least production in the deepest snowbed (less than the fellfield).
- However, heavy snowfall years (for example following El Niño years in the Colorado alpine) often correspond to years of high productivity in moderate and low snow areas (M.D. Walker et al. 1995).
- Greater leaf lengths and number of leaves related to higher soil moisture from snow melt during period of maximum growth.
- McGuire (1991) showed positive correlation between number of flowers and cumulative snowfall. Cold winter soil temperature in low-snow years appear to negatively affect production.
- In the alpine, soil moisture was overwhelmingly important to biomass production, and is most strongly linked to spring soil moisture.

<table>
<thead>
<tr>
<th>Plant community</th>
<th>Production (g m⁻² day⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fellfield</td>
<td>164 ± 12</td>
</tr>
<tr>
<td>Dry meadow</td>
<td>197 ± 18</td>
</tr>
<tr>
<td>Moist meadow</td>
<td>218 ± 23</td>
</tr>
<tr>
<td>Wet meadow</td>
<td>214 ± 21</td>
</tr>
<tr>
<td>Snowbed</td>
<td>113 ± 15</td>
</tr>
</tbody>
</table>
Conclusion: Very difficult to make generalities about the nature of chionophytes

- Highly variable nature of snowbed environments creates high diversity of adaptations to survive in these environments.

- Best approaches are detailed autecological studies of the physiology of the plants such as those of Katherine Bell’s (1979) heroic efforts to study *Kobresia myosuroides* year round in the alpine of Rocky Mountain National Park.

Subnivian temperature

Much biological activity occurs beneath the snow because of relatively warm conditions, especially in the lower alpine of temperate regions.

But other factors are also important:
- Shortened growing season
- Delayed warming in spring.
- Large year-to-year effects on soil moisture (depending on position in snow bed)

Subnivian Temperatures much colder in the Arctic

Figure 6.8. Soil temperature at 2-cm depth at two sites at Toolik Lake Alaska, August 1995–July 1996. (a) A windblown south-facing slope with minimal snow cover throughout the winter. Vegetation at this site is a dry Dryas octopetela–Selaginella sibirica community. (b) A deep north-facing snowdrift with over 500 cm of maximum snow accumulation. Vegetation at this site is a moist Cassiope tetragona–Carex microchaeta community.

Note: warmer soil temperatures on north-facing slope because of deeper snow.

Auerbach and Halfpenny (1991) found the same in the Tetons despite colder mean air temperatures.

Landscape-scale response to snow: heterogeneous alpine and arctic snow environments

Marked effect of topography and snow distribution on soil conditions and plant communities.

Photo: Niwot Ridge treeline area, D.A. Walker
Windblown sites: (Fellfields)

- Association: *Sileno – Paronychietum* Willard 1963
- Dry wind-exposed fellfields, >200 snow-free days.

Photos: D.A. Walker
Dry meadows, shallow snow

- Association: *Selaginello densae* – *Kobresietem myosuroidis* Cox 1933
- Subxeric to mesic turfs on gentle slopes, 150-200 snow-free days.

Photos: D.A. Walker
Moist meadows, early melting snow beds

Subxeric to mesic turfs on gentle slopes, often with strong gopher disturbance, 100-150 snow-free days.

- Upper left: Association: *Stellario laetae – caespitosae* Willard 1963 (mesic)
- Lower left: Association: *Acomastyletum rossii* Willard 1963 (mesic)
- Right: Association: *Deschampsio caespitosae – Trifolietum parryi* Komárková 1976 (subxeris to mesic)
Late-melting snowbeds

- At least 5 associations including Association *Caricetum pyrenaicae* in deep well drained snowbeds, snow free <75 days.

*Carex pyrenaica*
Photo: D.A. Walker

*Photos: D.A. Walker*
## Site characteristics along alpine snow gradient at Niwot Ridge, CO

### Table 6.1. Site characteristics of the Niwot Ridge alpine snow gradient.

<table>
<thead>
<tr>
<th>Site (code in Figures 6.3 and 6.4)</th>
<th>Microsite description</th>
<th>Snow-free days</th>
<th>Typical plant associations (Komárková, 1979)</th>
<th>Soils, US soil taxonomy (Burns, 1980)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fellfield, extremely windblown</td>
<td>Xeric, extremely wind-exposed ridges and west-facing slopes</td>
<td>&gt;200</td>
<td><em>Silico-Paronichietum,</em> <em>Potentillo-Carectem rupestris,</em> <em>Trifolicytum dasyphylli</em></td>
<td>Dystric Crychrept, Typic Cryumbrept</td>
</tr>
<tr>
<td>Dry meadow, windblown</td>
<td>Subxeric to mesic turfs on gentle wind-exposed west-facing slopes</td>
<td>150–200</td>
<td><em>Selaginello densae-Kobresietum myosuroidis</em></td>
<td>Dystric Crychrept, Typic Cryumbrept</td>
</tr>
<tr>
<td>Moist meadow, early-melting snowbank</td>
<td>Earlier melting snowpatches of the Front Range, subxeric to mesic snowpatches, leeward slopes and depressions</td>
<td>100–150</td>
<td><em>Acomastylidietum rossii,</em> <em>Deschampsioc caespitosae-Phruretum parry,</em> <em>Stellario laetae-Deschampsietum caespitosae</em></td>
<td>Typtic Cryumbrept, Pachic Cryumbrept, Dystric Crychrept</td>
</tr>
<tr>
<td>Late-melting snowbank</td>
<td>Later melting snowpatches of the Front Range, includes a wide variety of microhabitats from subxeric margins of late melting snow to subhygic, bryophyte-dominated, very late-melting snowpatches</td>
<td>50–100</td>
<td><em>Toninio-Sibbaldietum,</em> <em>Caricetum pyrenaicae,</em> <em>Juncetum drummondii,</em> <em>Phleo commutati-Caricetum nigrlicantis,</em> <em>Poa arcticae-Caricetum hydrianae,</em> <em>Polytrichastro alpini-Anthelietum juratzkanae</em></td>
<td>Dystric Crychrept</td>
</tr>
<tr>
<td>Wet meadow</td>
<td>Alpine fens, willow shrublands and springs; subhygic to hydric sites on mineral soils</td>
<td>&gt;100</td>
<td><em>Caricetum scopulorum,</em> <em>Rhodiolo integrifoliae-Salicetum planifolii,</em> <em>Clementsio-Calathetum leptosepalae</em></td>
<td>Pergelic Cryaquept, Humic Pergelic Cryaquept, Histic Pergelic Cryaquept, Pergelic Cryohemist, Pergelic Cryaquoll, Histic Pergelic Cryaquoll</td>
</tr>
<tr>
<td>Semipermanent snowbank</td>
<td>Snowbeds that occasionally melt, rocky unstable sites</td>
<td>0–50</td>
<td><em>Oxyric digynae-Poetum arcticae or no vegetation</em></td>
<td>Lithic Crychrept (headwall soil), Pergelic Cryoboralf over Pergelic Cryochrept (navigation hollow soil)</td>
</tr>
</tbody>
</table>

*Note: Summarized from Burns and Tonkins (1982) and Komárková (1979).*
Interactions between snow, soil temperatures, gophers, vegetation and ecosystem function on Niwot Ridge

• In winter gophers excavate tunnels in the snow and in the soil beneath the snow.
• They only are able to dig in unfrozen soils, so their distribution is limited to snow beds where the subnivian soil temperatures are near freezing.
• They stuff their snow tunnels with soil from their soil diggings and these long tubes then form the snake-like deposits (gopher castings) seen in spring on the soil surface after snow melts.

Photos: D.A. Walker
### Distribution of gophers by vegetation type along the snow gradient

<table>
<thead>
<tr>
<th>Plant community</th>
<th>Gophers per ha</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fellfield</strong> (Sileno-Paronychietum &amp; Trifolietum dasyphyllum)</td>
<td>3.6 ± 5.7</td>
</tr>
<tr>
<td><strong>Dry meadow</strong> (Selaginello-Kobresietum myosuroidis)</td>
<td>7.1 ± 13.5</td>
</tr>
<tr>
<td><strong>Moist meadow</strong> (Acomastylidetum rossii &amp; Stellario-Deschampsietum caespitosae)</td>
<td>18.2 ± 25.1</td>
</tr>
<tr>
<td><strong>Snowbank communities</strong> (Toninio-Sibbaldietum &amp; Caricetum pyrenaicae)</td>
<td>67.0 ± 72.9</td>
</tr>
</tbody>
</table>

Evolution of gopher mounds during the summer

• Strong winds winnow fine-grained silts and clays out of the mounds, leaving the courser particles.


Photos: D.A. Walker
Evolution of gopher mounds during the summer

• Jim Halfpenny studied gopher mounds for many years in the Martinelli snowbed on Niwot Ridge.
• Made detailed maps of mounds in relationship to vegetation and tracked through time.
• Susan Sharrod followed with a Ph.D. dissertation that looked at nutrient and plant community details (Sharrod and Seastedt 1989; Sharrod et al. 2005)

Photo: D.A. Walker. Maps courtesy of Jim Halfpenny
Soil biogeochemistry monitored at Martinelli Snowbed grid points using suction lysimeters

Major conclusions:

• Gopher are a keystone species in these ecosystems and are particularly important geomorphic agents, altering the physiochemical environment of the alpine tundra (Thorn 1982, Sharrod et al. 2005, Litaor et al. 1996).

• Mixing activities of gophers lower the concentration of SOM, C, N, total P, exchangeable Ca, and K in mounds compared to surface horizons (Litaor et al. 1996), but NO$_3^-$ and plant available P increased in the short term (Sharrod et al. 2005).

• Concentration of nitrate and ammonium in soil and interstitial water indicate that gophers greatly increased N cycling in well aerated soils (Litaor et al. 1996).

• Forbs recovered fastest from the disturbance, bestowing a competitive advantage to many flowers contributing strongly to species richness of the forb-rich communities found in most moist alpine meadows (Sharrod et al. 2005).
Treeline phenomena

- Krummholz
- Flagged trees
- Tree islands
- Ribbon forests

Niwot Ridge Treeline, Photo D.A. Walker

Ribbon forests

Parallel tree ribbons with snow glades between the ribbons occur in areas of deep winter snow and strong winds. Contributing causes include:

- natural topographic high points such as solifluction lobes for seedling establishment,
- shortened growing season,
- more pocket gophers,
- late seed germination or germination failure,
- breakage and bending of the few trees that do become established,
- higher frequency of parasitic snow molds (Buckner 1979).
Migration of tree islands

a. Open alpine fellfield with slight depression where fine grained loess and humus accumulate.

b. Seedlings establish in areas favorable for germination and growth, forming an incipient snow drift downwind of the seedling.

c. Tree island shaped by the wind with modified habitat within and downwind of the island.

d. Tree island controls the microsite, dieback on the windward side, and extension occurs on the leeward side through layering of the island.

Snow manipulation experiments

- Arctic site at Toolik Lake, AK
- Alpine site at Niwot Ridge, CO
Experimental alteration of snow cover and temperature

- 2-m high snow fences at Toolik Lake and Niwot Ridge.
- International Tundra Experiment (ITEX) open-topped chambers (OTCs, greenhouses) to increase temperature.

Niwot and Toolik snow fences

Toolik Dry Site Fence

Toolik Moist Site Fence

Both Toolik Fences in Winter

Niwot Fence and Drift in Spring

Photos: D.A. Walker
Snow drift depth zones

Vegetation Map of snow-fence area
Fence effect on subnivian soil temperatures

Figure 6. Soil surface temperatures beneath the Toolik Late dry-site fence and control plots, winter 1994–1995. Temperatures were recorded every 48 minutes using Hobo temperature logging devices (Onset Computer Corporation, Pocasset, MA). A very similar pattern was found at Niwot Ridge.

Comparison of effects of Niwot and Toolik fences on snow pH, mineral and organic-matter deposition and decomposition

- More input of loess and organic debris in snow pack at Toolik
- Higher snow pH at Toolik
- Fence had greater effect on decomposition rates at Niwot because of warmer soils.

Meltout dates at Toolik and Niwot

- Much later meltout dates in alpine, for both experimental and ambient plots.

Experimental effects of increased temperature and snow on plant phenology

- Phenological events recorded weekly.
- Earlier start and end to growing season at Toolik.
- Compressed phenology on snow treatment plots.
- Increased snow had much greater effect on phenology than temperature.
- Greater effects of both temperature and snow in the alpine.

Experimental effects of increased snow on vegetation NDVI at Niwot Ridge

- End of season NDVI (early Sept.) at four distances from the snow fence.
- Ambient areas are just outside fence area at same distances.
- Natureal gradient reflects drier conditions downwind from the fence area.
- Fence has significant effect at all distances.

Snow-shrub hypothesis

Experimental effects of increased snow on nitrogen mineralization and phenology

Effects of Simulated Climate Change on Plant Phenology and Nitrogen Mineralization in Alaskan Arctic Tundra

Andrew P. Borner*
Knut Kielland*‡ and
Marilyn D. Walker†

Abstract

This study was part of the Internazional Tundra Experiment (ITEX) and examined the effects of increased winter snow depth and decreased growing season length on the phenology of four arctic plant species (Betula nana, Salix pulchra, Eriophorum vaginatum, and Vaccinium vitis-idaea) and seasonal nitrogen availability in arctic snowbed communities. Increased snow depth had a large effect on the temporal pattern of first date snow-free in spring, bud break, and flowering, but did not affect the rate of plant development. By contrast, snow depth had a large qualitative effect on N mineralization in deep snow zones, causing a shift in the timing and amount of N mineralized compared to ambient snow zones. Nitrogen mineralization in deep snow zones occurred mainly overwinter, whereas N mineralization in ambient snow zones occurred mainly in spring. Concentrations of soil dissolved organic nitrogen (DON) were approximately 5 times greater than concentrations of inorganic nitrogen (DIN) and did not vary significantly over the season. Projected increases in the depth and duration of snow cover in arctic plant communities will likely have minor effects on the rate of plant phenological development, but potentially large effects on patterns of N cycling.

DOI: 10.1657/1523-0438(06-099)[BORNER]2.0.CO;2


• Focus of Literature Discussion group 2 on Thursday.
1. Snow affects ecosystems at a variety of scales and has different effects in temperate alpine areas compared to the Arctic (slides 10-14).
2. Landscape-level effects of snow can be seen in the pattern of plant species, plant communities, plant phenology, plant production, rhizosphere and foliosphere temperatures, and soil moisture along mesotopographic gradients, and these vary in alpine compared to arctic areas (slides 15-34).
3. Compared to windy sites, site factors within snow drift environments are quite complex and species responses and plant communities reflect this complexity (slides 15-29).
4. Subnivian animals complicate the effects of snow cover. For example, gopher distribution is controlled by snow in the Colorado alpine and has a major effect of biogeochemistry and plant communities of alpine environments (slides 35-40).
5. Treeline tree growth is altered by snow and wind (e.g., krummholz, migrating tree islands, ribbon forests) (slides 41-43).
6. Snow fence studies in Arctic and alpine areas are examining the possible effects of altered snow regimes due to climate change (slides 44-54).