

Plant quiz 2

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

1) Latin name (Genus, species), 2) Family name, 3) 2 characteristics that helped you place it in the correct family.

- 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.

Next discussion papers: Monday after spring break

Discussion Group 1,

1. Walker, D.A., J. C. Halfpenny, M. D. Walker, and C. Wessman. 1993. Long-term studies of snow-vegetation interactions. *Bioscience* 43:287–301.
2. Aitchison, C.W. 2001. The effect of snow cover on small mammals. P. 229-265 in Jones H.G. et al. *Snow Ecology*. Cambridge: Cambridge University Press.

Discussion Group 2,

1. Ehrlich, D., J.-A. Henden, R. A. Ims, L. O. Dronina, S. T. Killengren, N. Lecomte, I. G. Pokrovsky, G. Skogstad, A. A. Sokolov, V. A. Sokolov, and N. G. Yoccoz. 2011. The importance of willow thickets for ptarmigan and hares in shrub tundra: the more the better? *Oecologia* 168:141–151.
2. Tape, K. D., R. Lord, H.-P. Marshall, and R. W. Ruess. 2010. Snow-Mediated Ptarmigan Browsing and Shrub Expansion in Arctic Alaska. [dx.doi.org](https://doi.org/10.1890/1735-1891(2010)17[186::]2.0.CO;2) 17:186–193.

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.**
- 3. Sunday: Murphy Dome.**
 - 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 (will be posted on web page for field trip)

Required:

1-liter water bottle, fill with hot water and wrap in sweater

Sack lunch for both days

2 ski hats (in case one gets lost)

cap with visor for sun

sunglasses

bandana,

handkerchief

balaclava or face mask to prevent face frost bite

warm parka with hood

fleece jacket

light fleece or wool shirt (main shirt during the trip)

heavy polypro or wool pants or Carhart overalls (no jeans or cotton pants)

long underwear (preferably polypro, tops and bottoms)

2 pr fleece gloves or liners

over gloves or mittens

2 pair warm socks

Sorels or bunny boots or mukluks

Cup for warm drinks

backcountry skis w/metal edges, boots, poles, wax, gaiters OR snowshoes, poles, gaiters

Gaiters to keep snow out of boots (other options include plastic sacks over the socks and tucking pant legs in the boots snugly).

chapstick

day pack large enough to hold all clothing, lunch, etc.

field notebook,

pen, pencil

hand lens

pocket knife

small roll of toilet paper

sun protection

3-4 waterproof stuff sacks (to hold clothing and misc. gear in pack)

Optional: binoculars, camera, cell phone, GPS unit, matches, thermos for hot drinks, whistle (for emergency)

SNOW ECOLOGY

An Interdisciplinary Examination of Snow-Covered Ecosystems



Lesson 7a Snow Ecology

D.A. (Skip) Walker

Biol 488, Arctic Vegetation Ecology
University of Alaska Fairbanks

Overview of lecture 7

Focus on the ecology of snow

- **Lecture 7: An interdisciplinary examination of snow covered ecosystems**
 - Physical properties of snow (Pomeroy and Brun 2003)
 - Characterization of snow (UNESCO-IHP 2009)
 - Snow metamorphosis (Sommerfeld and Chapelle 1970)
 - Global snow cover classification (Sturm, Holmgren, Liston 1995)
 - Snow chemistry (Tranter & Jones 2001)
 - Snow ecosystems (Hoham 2001, Aitchison 2001)
- **Lecture 8: Snow biology**

THE INTERNATIONAL
CLASSIFICATION
FOR
**SEASONAL SNOW ON
THE GROUND**

IHP-VII



Characterization of snow

- ❖ Features of deposited snow
 - Grain shape and size
 - Snow density and hardness
 - Liquid water content
 - Layer thickness and total depth
 - Surface features
- ❖ Grain shape classification
- ❖ Observation guidelines

Fierz, C., R. L. Armstrong, Y. Durand, P. Etchevers, E. Green, D. M. McClung, K. Nishimura, P. K. Satyawali, and S. A. Sokratov. 2009. The International Classification for Seasonal Snow on the Ground. UNESCO-IHP, IHP-VII Technical Documents in Hydrology No. 83, IACS Contribution No. 1, Paris.

APPENDIX D. EXAMPLE OF A DATA SHEET FOR A SNOW COVER PROFILE

SNOW COVER PROFILE		Observer <i>Meister</i> Date <i>23 Feb 1989</i> Time <i>9:00:00</i>	Remarks <i>Wind loaded slope</i> Number <i>1</i>					
Location <i>Totalphorn</i>		Air Temperature <i>-5.0</i>						
H.A.S.L. <i>2500</i>	Co-ordinates <i>781500/190200</i>	Cloudiness <i>Cu, Ac lens 5/8</i>						
Aspect <i>N</i>	Slope <i>40</i>	Precipitation <i>None</i>						
HS <i>193cm</i> HSW <i>535mm</i> P <i>277 kg/m³</i> R <i>88 N</i>		Wind <i>SE 5m/s</i>						
T 20 18 16 14 12 10 8 6 4 2	R 1000 900 800 700 600 500 400 300 200 100	H	θ	F	E	R	HW p	Comments
[Grid with snow profile line]								
				/	1-1.5	X		
				φ	1.5	X	28	slide plane
				•	1-2		147	
				•	.5-1	/	39	
				∇	2-2	/	41	slide plane
				□	1-2		215	
							57	
							268	
				□	1-1.5	X	56	
							294	
				□			320	
							326	
				∧	1-3	/		

Snow description form



Also take photo of pit wall with tape for scale and markers showing layer boundaries.

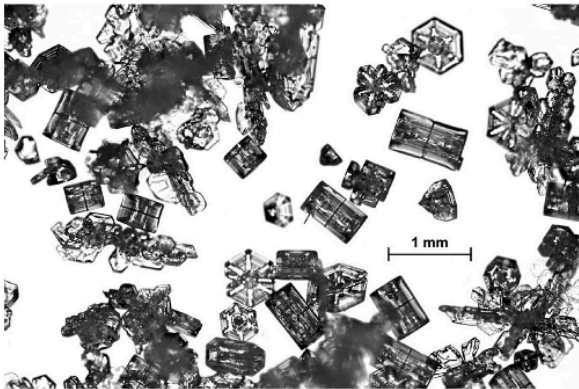
Mary Albert (CRREL) sampling snow in Antarctica. http://snow.usace.army.mil/heat_mass_transfer/

Grain shape classification

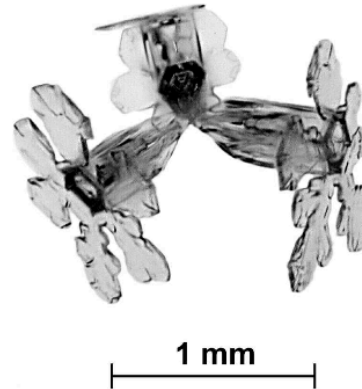
1. **Precipitation (PP)** (columns, needles, plates, stellar dendrites, irregular crystals, graupel, hail, ice pellets)
2. **Decomposing and fragmented precipitation particles (DF)** (partially decomposed, highly broken particles)
3. **Rounded grains (RG)** (small, large, mixed)
4. **Faceted crystals (FC)** (solid faceted, small faceted, mixed)
5. **Cup-shaped crystals and depth hoar (DH)** (cup crystals, columns of depth hoar, columnar crystals)
6. **Wet grains (WG)** (clustered rounded grains, rounded poly-crystals, slush)
7. **Feathery crystals (SH)** (surface hoar, cavity hoar)
8. **Ice forms (IF)** (Ice layer, ice column, basal ice, sun crust, rain crust)

Fierz, C., R. L. Armstrong, Y. Durand, P. Etchevers, E. Green, D. M. McClung, K. Nishimura, P. K. Satyawali, and S. A. Sokratov. 2009. The International Classification for Seasonal Snow on the Ground. UNESCO-IHP, IHP-VII Technical Documents in Hydrology No. 83, IACS Contribution No. 1, Paris.

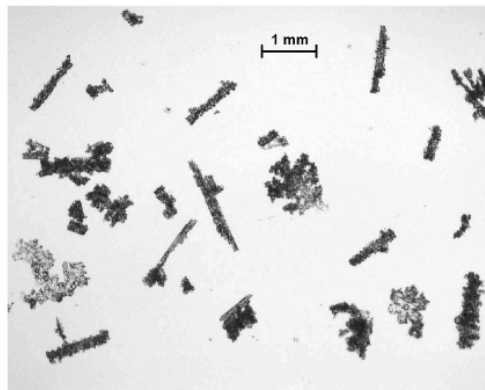
Precipitation particles (class PP cont)



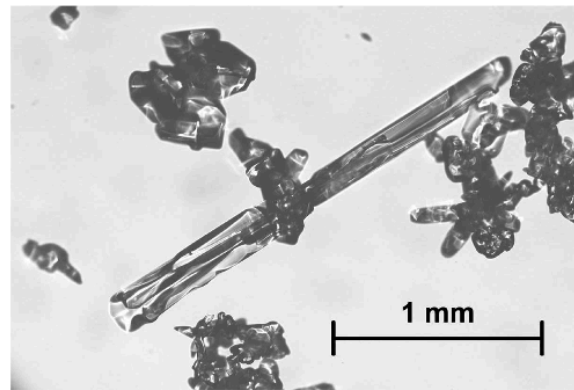
Columns PPco, □ (Elder) #01



Columns and plates PPco (PPpl), □ (⊙) (Span) #02



Rimed needles PPnd, ↔ (Fierz) #03

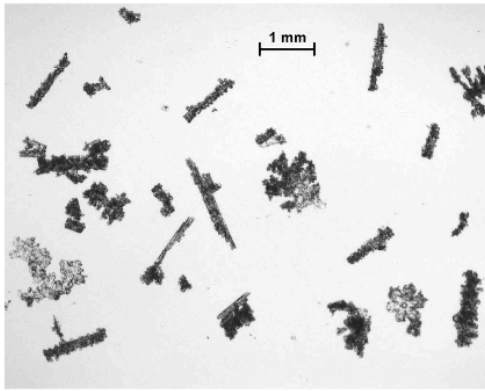


Needles PPnd, ↔ (Elder) #04

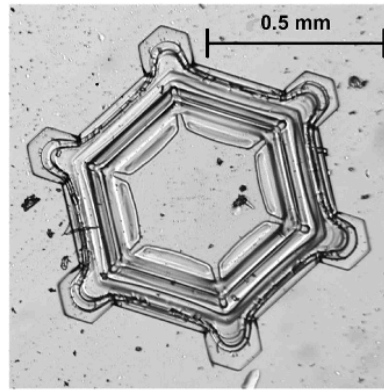
- ❖ **Columns (PPco):**
Growth from water vapour at -8°C and below -30°C
- ❖ **Needles (PPnd):**
Growth from water vapour at supersaturation at -3 to -5°C and below -60°C
- ❖ **Plates (PPpl):**
Growth from water vapour at 0 to -3°C and -8 to -70°C

Fierz, C., R. L. Armstrong, Y. Durand, P. Etchevers, E. Green, D. M. McClung, K. Nishimura, P. K. Satyawali, and S. A. Sokratov. 2009. The International Classification for Seasonal Snow on the Ground. UNESCO-IHP, IHP-VII Technical Documents in Hydrology No. 83, IACS Contribution No. 1, Paris.

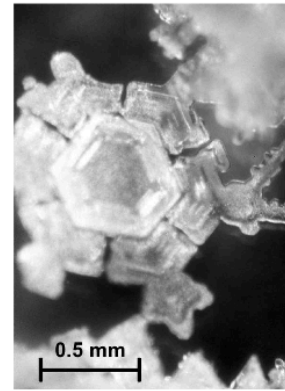
Precipitation particles (class PP cont')



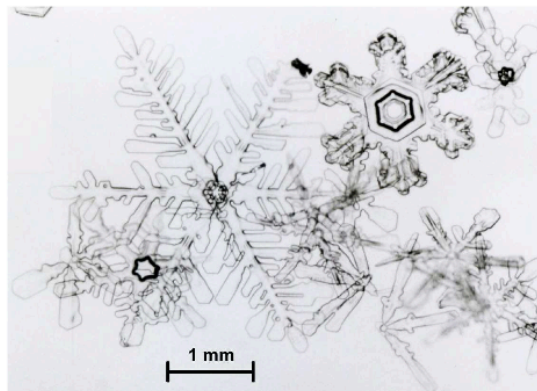
Plates PPpl, ○ (Elder) #05



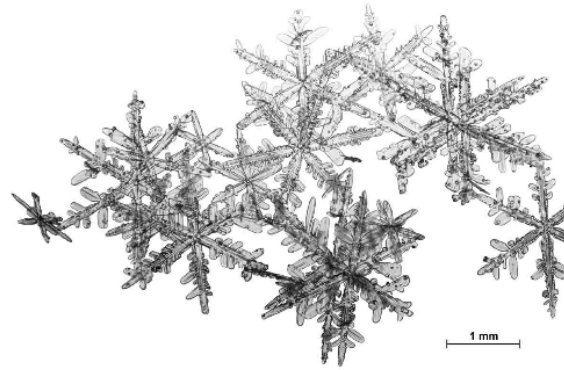
Plates PPpl, ○ (Greene) #06



Plates PPpl, ○ (AINEVA UniMilano) #07



Stellars dendrites, PPsd, * (JSSI) #08



Stellars dendrites, PPsd, * (Span) #09

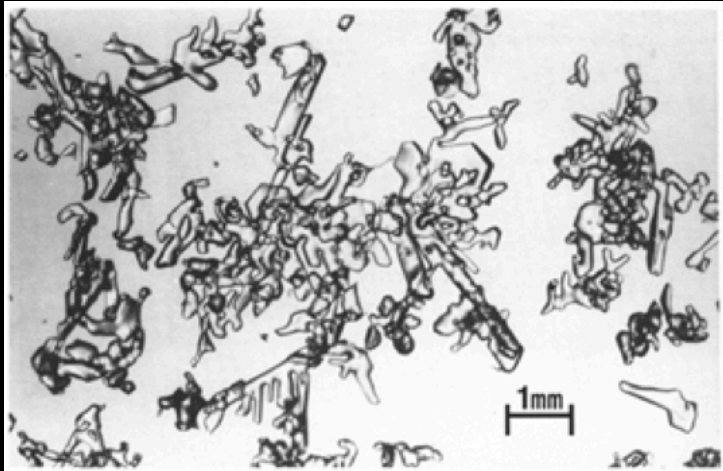
- ❖ Plates (PPpl)
- ❖ Stellars, dendrites(PPsd):
Growth from water vapour at supersaturation at 0 to -3°C and at -12 to -16°C

Fierz, C., R. L. Armstrong, Y. Durand, P. Etchevers, E. Green, D. M. McClung, K. Nishimura, P. K. Satyawali, and S. A. Sokratov. 2009. The International Classification for Seasonal Snow on the Ground. UNESCO-IHP, IHP-VII Technical Documents in Hydrology No. 83, IACS Contribution No. 1, Paris.

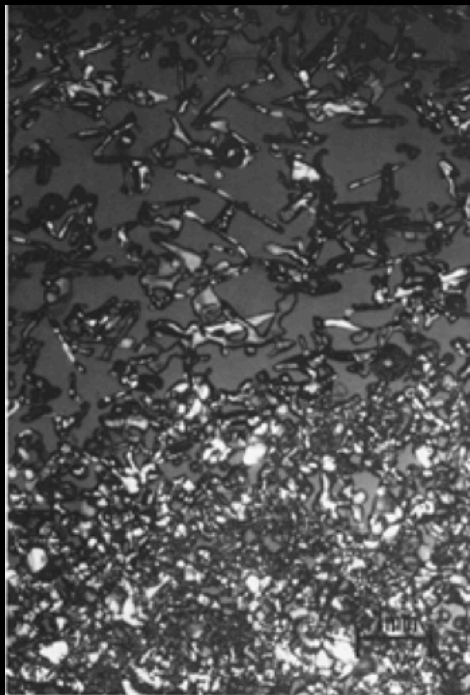
Decomposed precipitation snow particles (class DF)

Decomposition due to either increasing temperatures, decreasing thermal gradient (DFdc)

Or to fragmentation and packing by wind and sintering (DFbk)



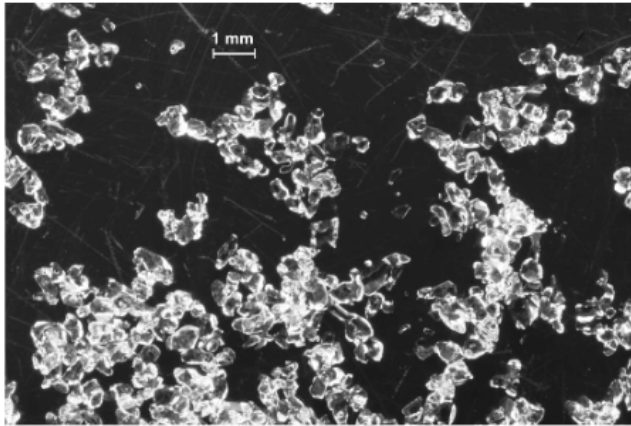
Class 2dc, partly decomposed precipitation particles. Photo by E. Akitaya.



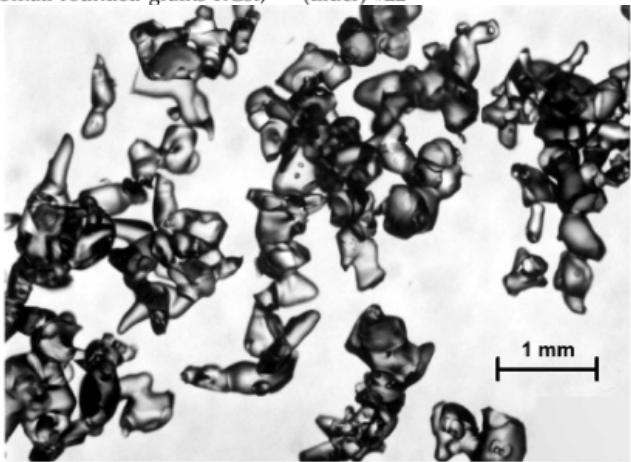
Class 2bk and 9wc, highly broken particles (on top) and wind crust (on bottom). Photo by E. Akitaya.

Fierz, C., R. L. Armstrong, Y. Durand, P. Etchevers, E. Green, D. M. McClung, K. Nishimura, P. K. Satyawali, and S. A. Sokratov. 2009. The International Classification for Seasonal Snow on the Ground. UNESCO-IHP, IHP-VII Technical Documents in Hydrology No. 83, IACS Contribution No. 1, Paris.

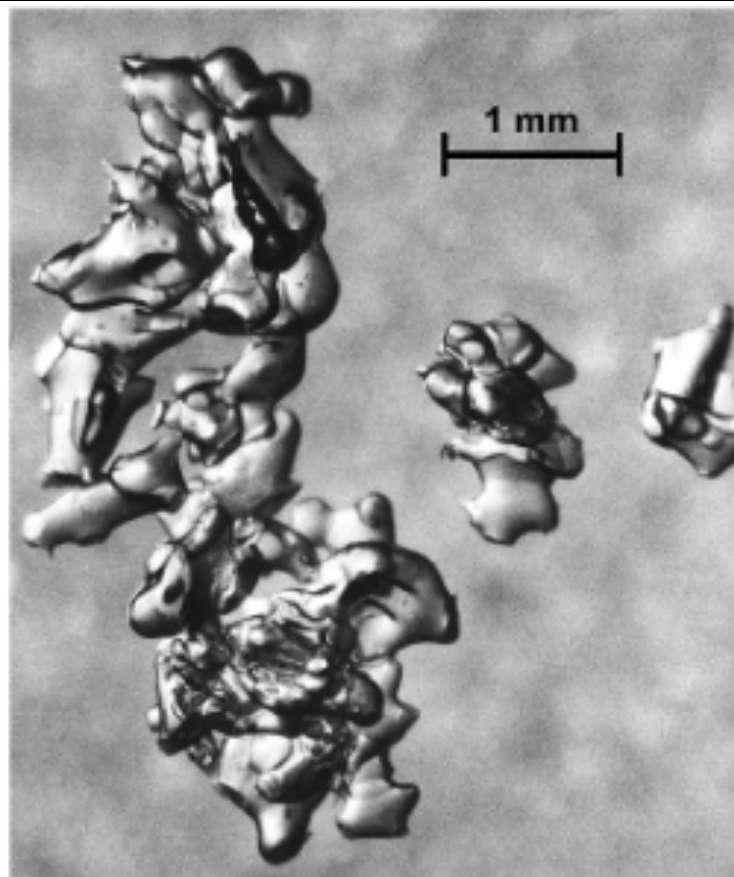
Rounded grains (class RG)



Small rounded grains RGsr, • (Elder) #22



Large rounded grains RGlr, • (JSSI) #23

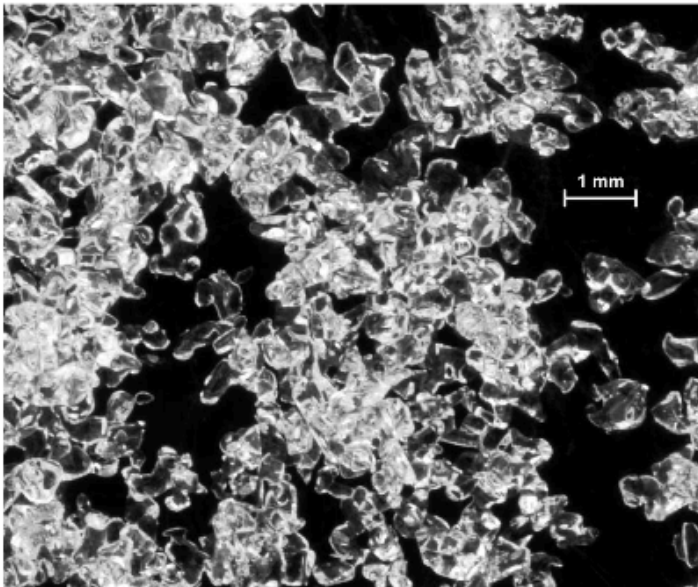


Wind packed RGwp, ■ (Sturm) #24

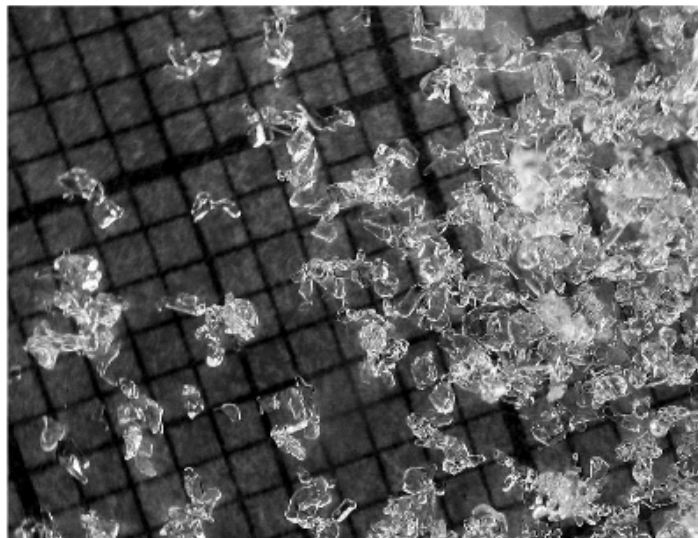
Small (RGsr): Result of low temperature metamorphosis, decrease in surface area, slow sintering.

Large (RGlr): Effect of grain to grain vapor diffusion and sintering.

Wind packed (RGwp): Packing and fragmentation with sintering.



Faceted rounded particles RGxf, (Elder) #25



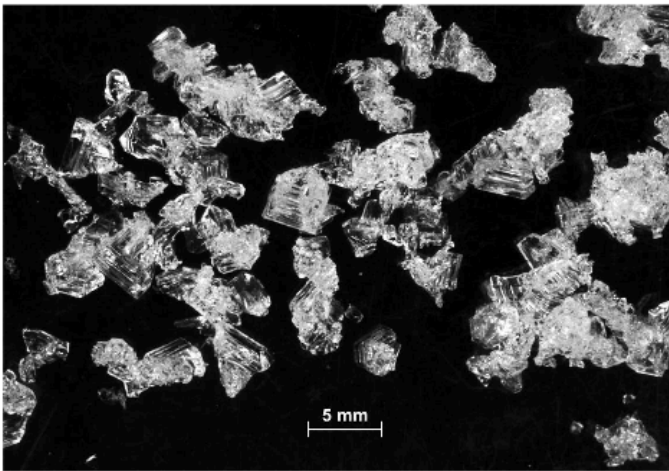
Faceted particles (class FC)

Grain to grain vapor diffusion driven by high temperature gradient.

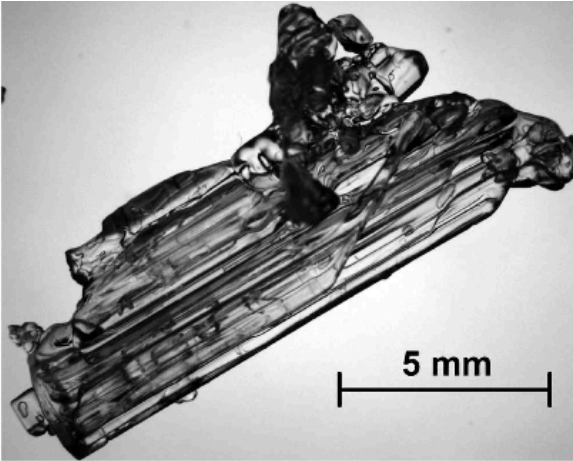
Faceted rounded particles (FCxr): Transitional form to faceted.

Solid faceted particles (FCso): Solid kinetic growth form with sharp edges, glassy smooth faces.

Fierz, C., R. L. Armstrong, Y. Durand, P. Etchevers, E. Green, D. M. McClung, K. Nishimura, P. K. Satyawali, and S. A. Sokratov. 2009. The International Classification for Seasonal Snow on the Ground. UNESCO-IHP, IHP-VII Technical Documents in Hydrology No. 83, IACS Contribution No. 1, Paris.



Hollow cups DHcp, \wedge (Greene) #33

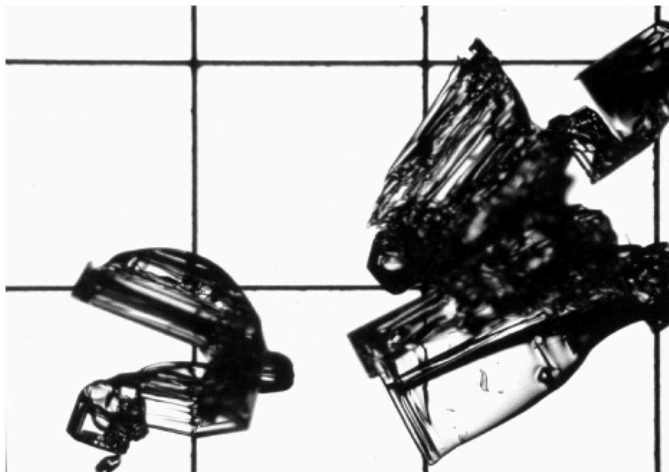


Large striated crystals DHla, \wedge (Fierz) #40

Depth Hoar (class DH)

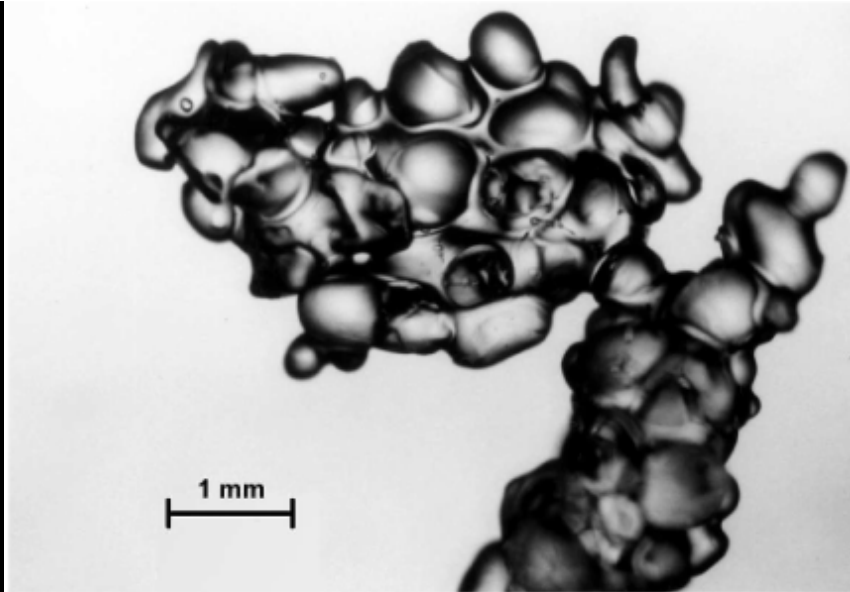
Grain to grain vapor diffusion driven by large temperature gradient.

Hollow cups (DHcp): Large temperature gradient
Large striated crystals (Dhla): Long time with large temperature gradient required.

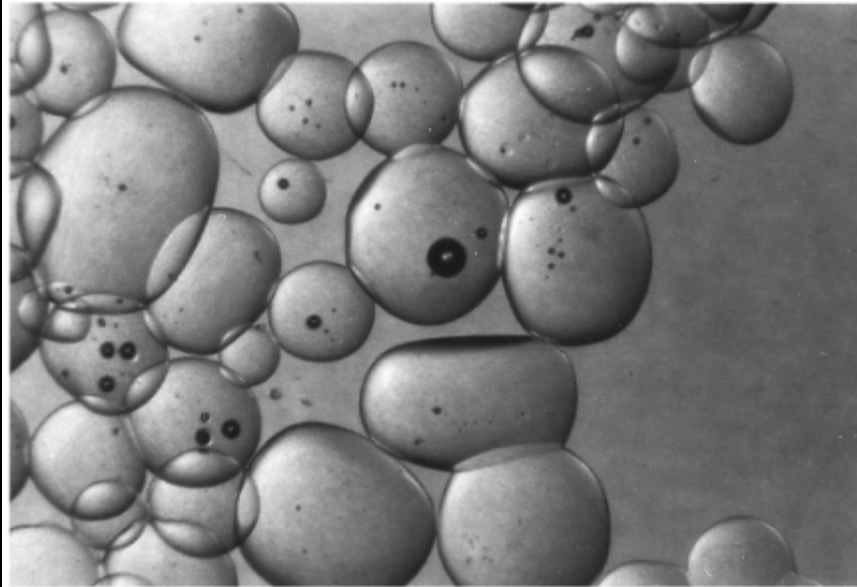


Hollow cups DHcp (DHpr), \wedge (\square), 2 mm grid (Fierz) #35

Fierz, C., R. L. Armstrong, Y. Durand, P. Etchevers, E. Green, D. M. McClung, K. Nishimura, P. K. Satyawali, and S. A. Sokratov. 2009. The International Classification for Seasonal Snow on the Ground. UNESCO-IHP, IHP-VII Technical Documents in Hydrology No. 83, IACS Contribution No. 1, Paris.



Clustered rounded grains MFcl. ☼ (ISSI) #49



Slush MFsl, ☼, grain size E 0.5-1 mm (Colbeck) #52

Melt forms (class MF)

Wet snow with liquid water content.

Clustered rounded grains (MFcl):

Wet snow with low liquid water content. Meltwater can drain, usually near the surface.

Slush (MFsl): Wet snow with high liquid water content. Meltwater is blocked, sometimes with very high solar radiation, temperature or rain.

Snow metamorphosis

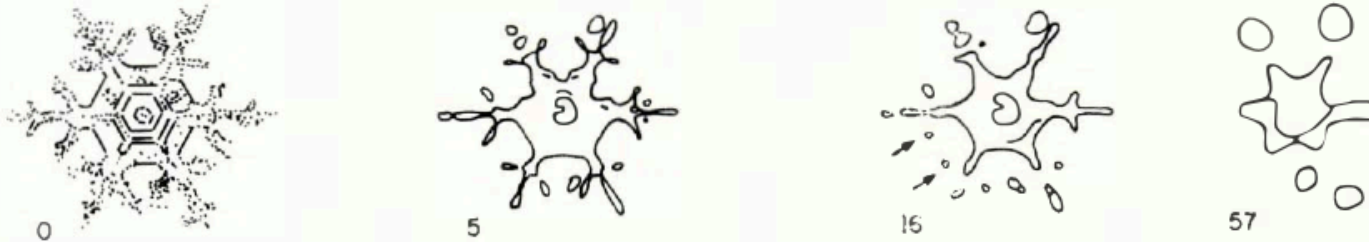


Fig. 2. The progress of equi-temperature metamorphism (the numbers are days). The temperature varied between -2.5°C and -11.5°C . Drawn from photographs in Bader and others (1939).

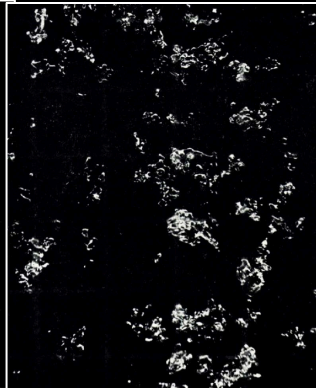
Sommerfeld, R. A. and E. LaChapelle. 1970. The classification of snow metamorphism. *Journal of Glaciology* 9:3-17.

Equi-temperature vs. temperature-gradient snow metamorphosis

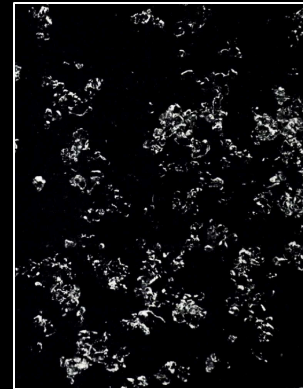
Beginning equi-temperature, decreasing grain size metamorphosis



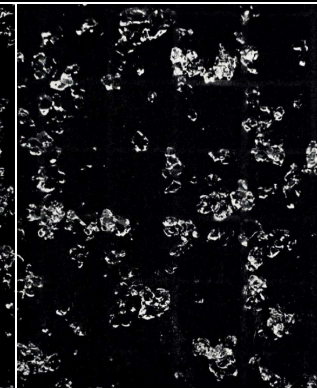
Late equi-temperature, decreasing grain size metamorphosis



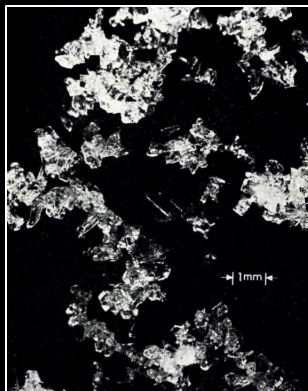
Beginning equi-temperature, increasing grain size metamorphosis



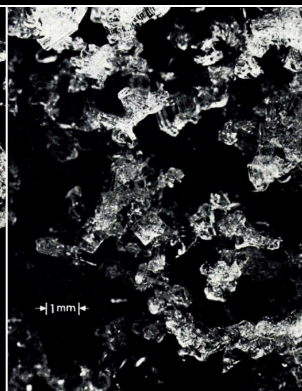
Advanced equi-temperature, increasing grain size metamorphosis



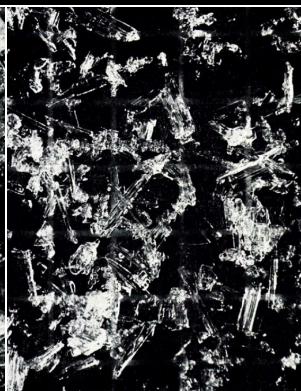
Beginning, early, temperature-gradient metamorphosis



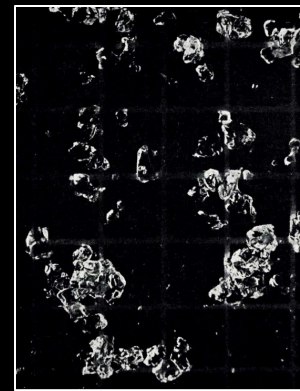
Partial, early, temperature-gradient metamorphosis



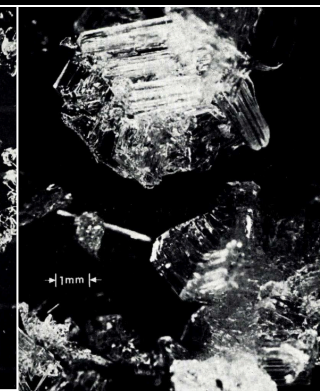
Advanced, early, temperature-gradient metamorphosis



Beginning, late, temperature-gradient metamorphosis



Advanced, late, temperature-gradient metamorphosis



Sommerfeld, R. A. and E. LaChapelle. 1970. The classification of snow metamorphosis. Journal of Glaciology 9:3-17.

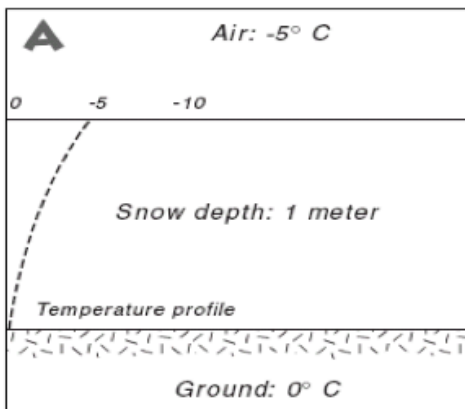
Low-temperature-gradient vs. High-temperature-gradient snow metamorphosis

Low-temperature-gradient metamorphosis: Temperature gradient $< 5^{\circ}\text{C m}^{-1}$, produces small rounded grains (class 3), efficient settling rate, good cohesion due to growth of ice bonds between grains (**sintering**). Typical of in regions with heavy snowfalls or strong redistribution by wind.

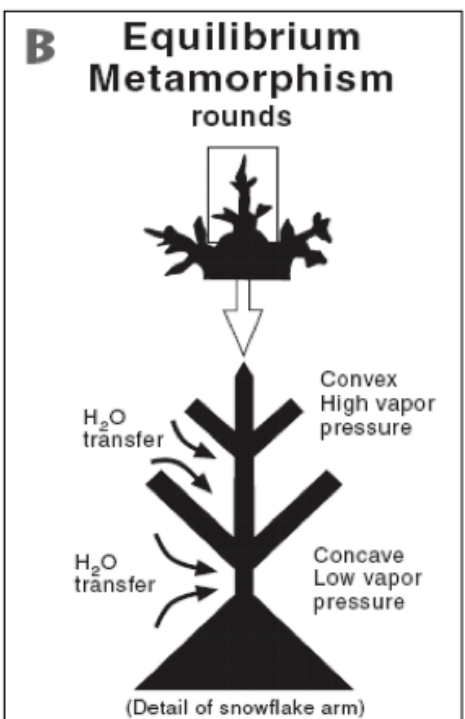
Medium-temperature-gradient metamorphosis: Temperature gradient $5\text{-}15^{\circ}\text{C m}^{-1}$, produces faceted crystals (class 4). Crystal growth is slow because gradient effects are partially balanced by redistribution of moisture due to crystal curvature effects (class 3).

High-temperature-gradient metamorphosis: Temperature gradient $> 15^{\circ}\text{C m}^{-1}$, produces depth hoar crystals (class 5). Large plate-like crystals grow quickly. Characterized by very slow settling rate, weak cohesion. Typical in cold and dry climate regions.

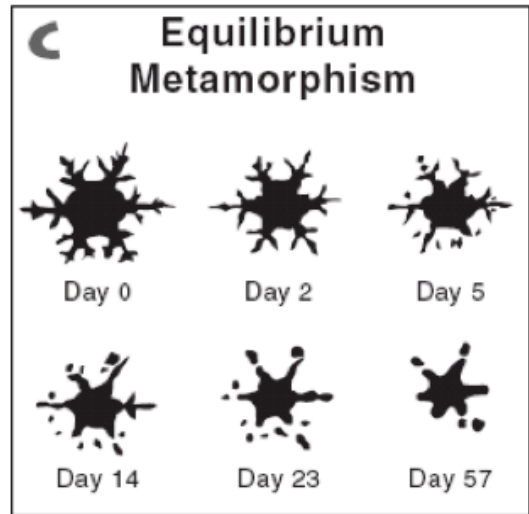
Pomeroy, J. W. and E. Brun. 2001. Physical properties of snow. Pages 45-126 in H. G. Jones, J. W. Pomeroy, D. A. Walker, and R. W. Hoham, editors. Snow Ecology: An Interdisciplinary Examination of Snow-covered Ecosystems. Cambridge University Press, Cambridge.



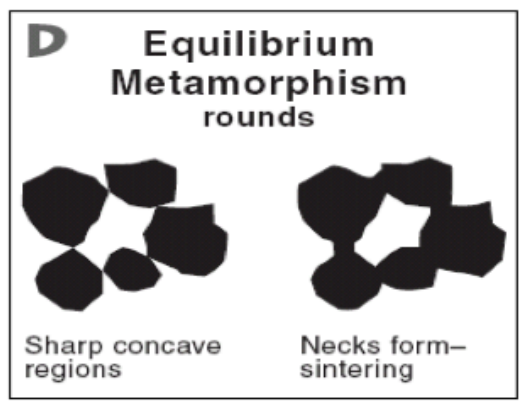
A small temperature gradient promotes equilibrium metamorphism



Original crystals lose their sharp points



Rounds develop from equilibrium metamorphism

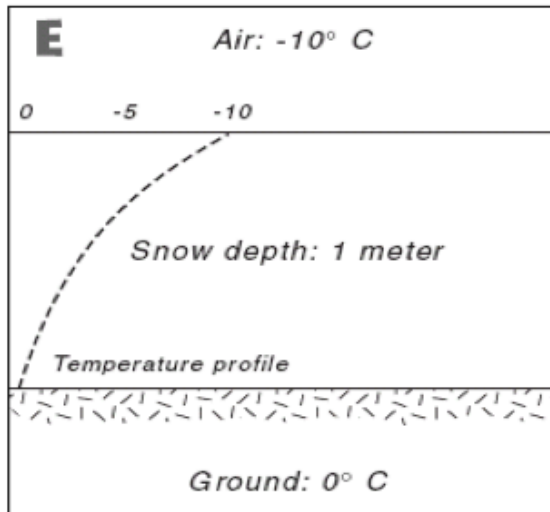


Strong bonds form between grains

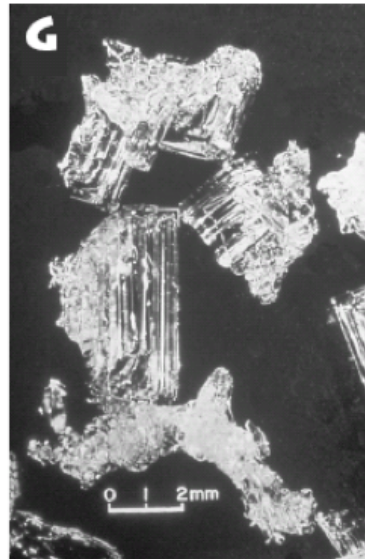
Equilibrium (= low-temperature-gradient) snow metamorphosis

<http://www.geotech.org/survey/geotech/Snow%20Metamorphosis.pdf>

Kinetic (= high-temperature-gradient) snow metamorphism

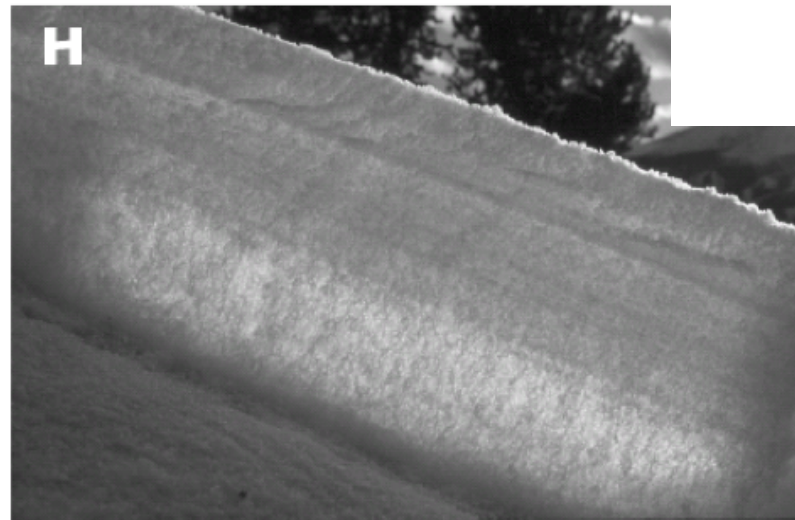
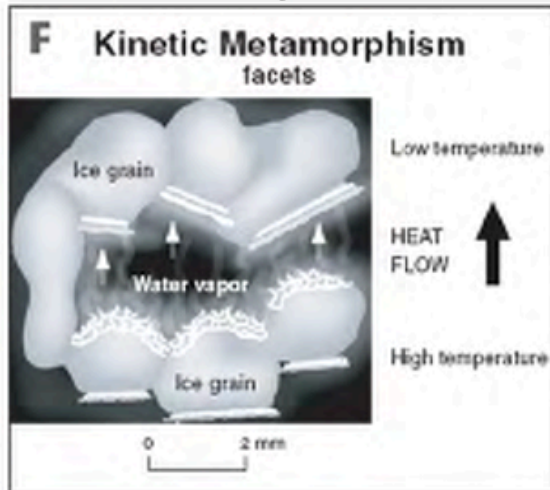


A large temperature gradient promotes kinetic metamorphism



Depth hoar grains with weak bonds

Squares developing from kinetic metamorphism



A snow profile that is back lit. The lighter layer near the bottom is a weak layer of faceted grains (depth hoar).

Snow metamorphosis animation

http://www.slf.ch/ueber/organisation/schnee_permafrost/projekte/schneemetamorphose/index_EN

WSL, Institute for Snow and Avalanche Research, Davos, Switzerland,
SLF

Sommerfeld, R. A. and E. LaChapelle. 1970. The classification of snow metamorphism. *Journal of Glaciology* 9:3-17.

Snow Cover Classification

1262

JOURNAL OF CLIMATE

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STURM ET AL.

1261

A Seasonal Snow Cover Classification System for Local to Global Applications

MATTHEW STURM AND JON HOLMGREN

U.S. Army Cold Regions Research and Engineering Laboratory, Ft. Wainwright, Alaska

GLEN E. LISTON

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(Manuscript received 1 September 1994, in final form 7 December 1994)

ABSTRACT

A new classification system for seasonal snow covers is proposed. It has six classes (*tundra, taiga, alpine, maritime, prairie, and ephemeral*), each class defined by a unique ensemble of textural and stratigraphic characteristics including the sequence of snow layers, their thickness, density, and the crystal morphology and grain characteristics within each layer. The classes can also be derived using a binary system of three climate variables: wind, precipitation, and air temperature. Using this classification system, the Northern Hemisphere distribution of the snow cover classes is mapped on a 0.5° lat \times 0.5° long grid. These maps are compared to maps prepared from snow cover data collected in the former Soviet Union and Alaska. For these areas where both climatologically based and texturally based snow cover maps are available, there is 62% and 90% agreement, respectively. Five of the six snow classes are found in Alaska. From 1989 through 1992, hourly measurements, consisting of 40 thermal and physical parameters, including snow depth, the temperature distribution in the snow, and basal heat flow, were made on four of these classes. In addition, snow stratigraphy and texture were measured every six weeks. Factor analysis indicates that the snow classes can be readily discriminated using four or more winter average thermal or physical parameters. Further, analysis of hourly time series indicates that 84% of the time, spot measurements of the parameters are sufficient to correctly differentiate the snow cover class. Using the new snow classification system, 1) classes can readily be distinguished using observations of simple thermal parameters, 2) physical and thermal attributes of the snow can be inferred, and 3) classes can be mapped from climate data for use in regional and global climate modeling.

Sturm, M., J. Holmgren, and G. E. Liston. 1995. A seasonal snow cover classification system for local to global applications. *Journal of Climate* 8:1261-1283.

Snow Cover Classification

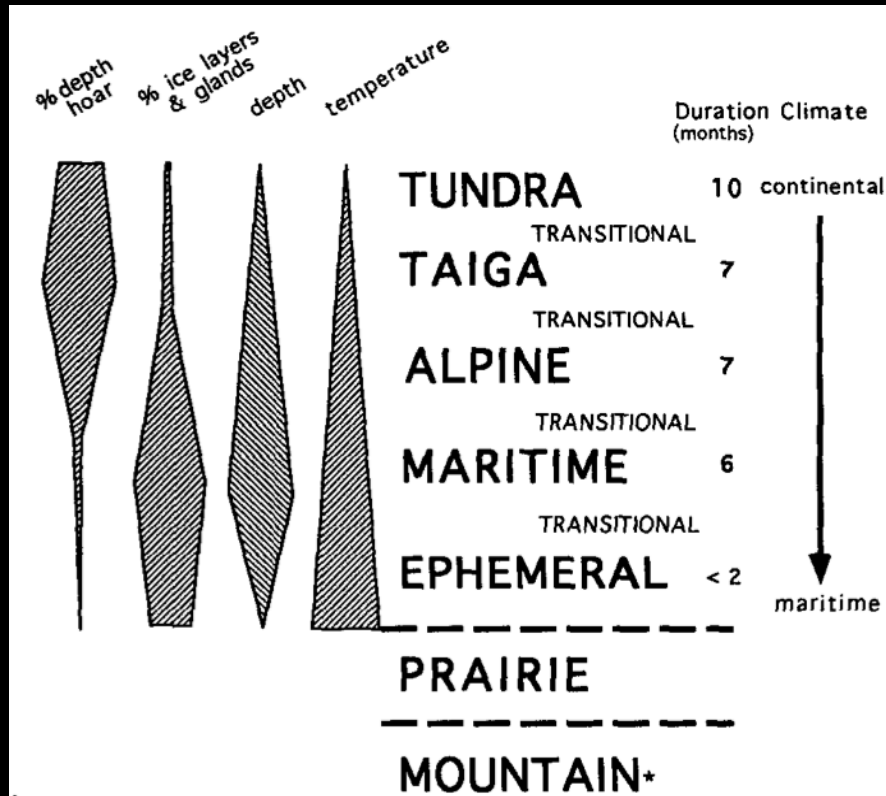


FIG. 1. Seasonal snow cover classes in the new system. Note that mountain (*) snow is a special designation for regions where the snow cover is highly variable.

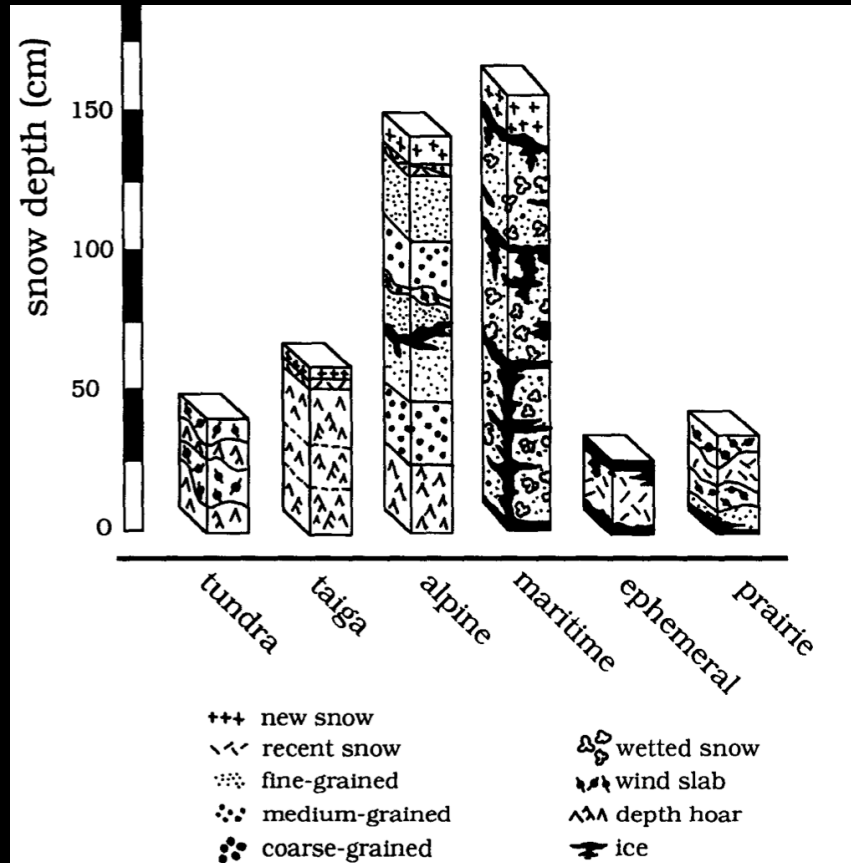


FIG. 2. The basic stratigraphic and textural attributes of each class of snow cover as they would appear in middle to late winter. Symbols follow Colbeck et al. 1992.

Sturm, M., J. Holmgren, and G. E. Liston. 1995. A seasonal snow cover classification system for local to global applications. *Journal of Climate* 8:1261-1283.

Snow Cover Classification

TABLE 2. Snow class descriptions.

Snow cover class	Description	Depth range (cm)	Bulk density (g cm ⁻³)	Number of layers
tundra	A thin, cold, wind-blown snow. Max. depth approx. 75 cm. Usually found above or north of tree line. Consists of a basal layer of depth hoar overlain by multiple wind slabs. Surface sastrugi common. Melt features rare.	10–75	0.38	0–6
taiga	A thin to moderately deep low-density cold snow cover. Max. depth: 120 cm. Found in cold climates in forests where wind, initial snow density, and average winter air temperatures are all low. By late winter consists of 50% to 80% depth hoar covered by low-density new snow.	30–120	0.26	>15
Alpine	An intermediate to cold deep snow cover. Max. depth approx. 250 cm. Often alternate thick and thin layers, some wind affected. Basal depth hoar common, as well as occasional wind crusts. Most new snowfalls are low density. Melt features occur but are generally insignificant.	75–250	no data	>15
maritime	A warm deep snow cover. Max depth can be in excess of 300 cm. Melt features (ice layers, percolation columns) very common. Coarse-grained snow due to wetting ubiquitous. Basal melting common.	75–500	0.35	>15
ephemeral	A thin, extremely warm snow cover. Ranges from 0 to 50 cm. Shortly after it is deposited, it begins melting, with basal melting common. Melt features common. Often consists of a single snowfall, which melts away, then a new snow cover reforms at the next snowfall.	0–50	no data	1–3
prairie	A thin (except in drifts) moderately cold snow cover with substantial wind drifting. Max. depth approx. 1 m. Wind slabs and drifts common.	0–50	no data	<5
^a mountain	A highly variable snow cover, depending on solar radiation effects and local wind patterns. Usually deeper than associated type of snow cover from the adjacent low-lands.		no data	variable

^a Special class.

Sturm, M., J. Holmgren, and G. E. Liston. 1995. A seasonal snow cover classification system for local to global applications. *Journal of Climate* 8:1261-1283.

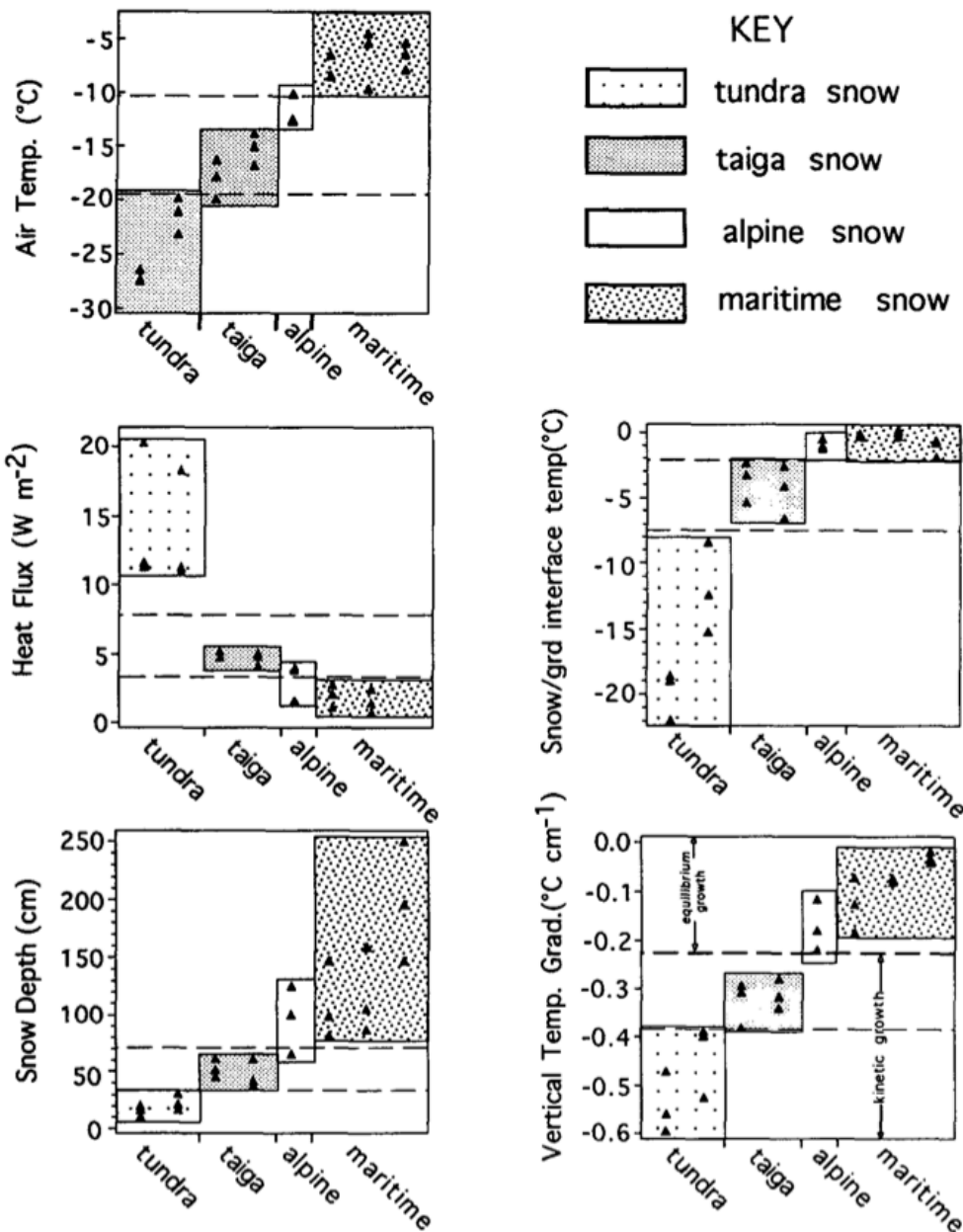
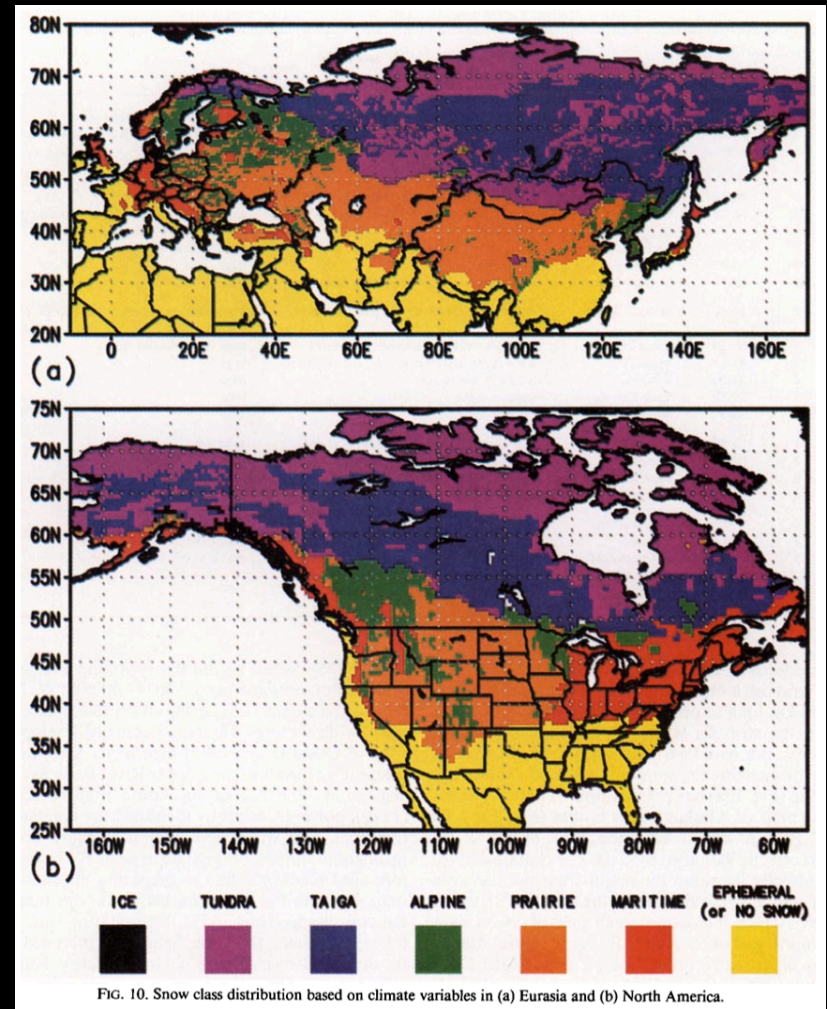


FIG. 5. Five representative single-value discrimination plots. The snow class is indicated along the abscissa, and the value of the parameter along the ordinate. The boundaries are set equidistant between the data points. Note that one boundary for vertical temperature gradients corresponds to the critical gradient necessary for depth hoar growth according to Akitaya (1974), Marbouty (1980), and Colbeck (1983).

Snow Cover Classification

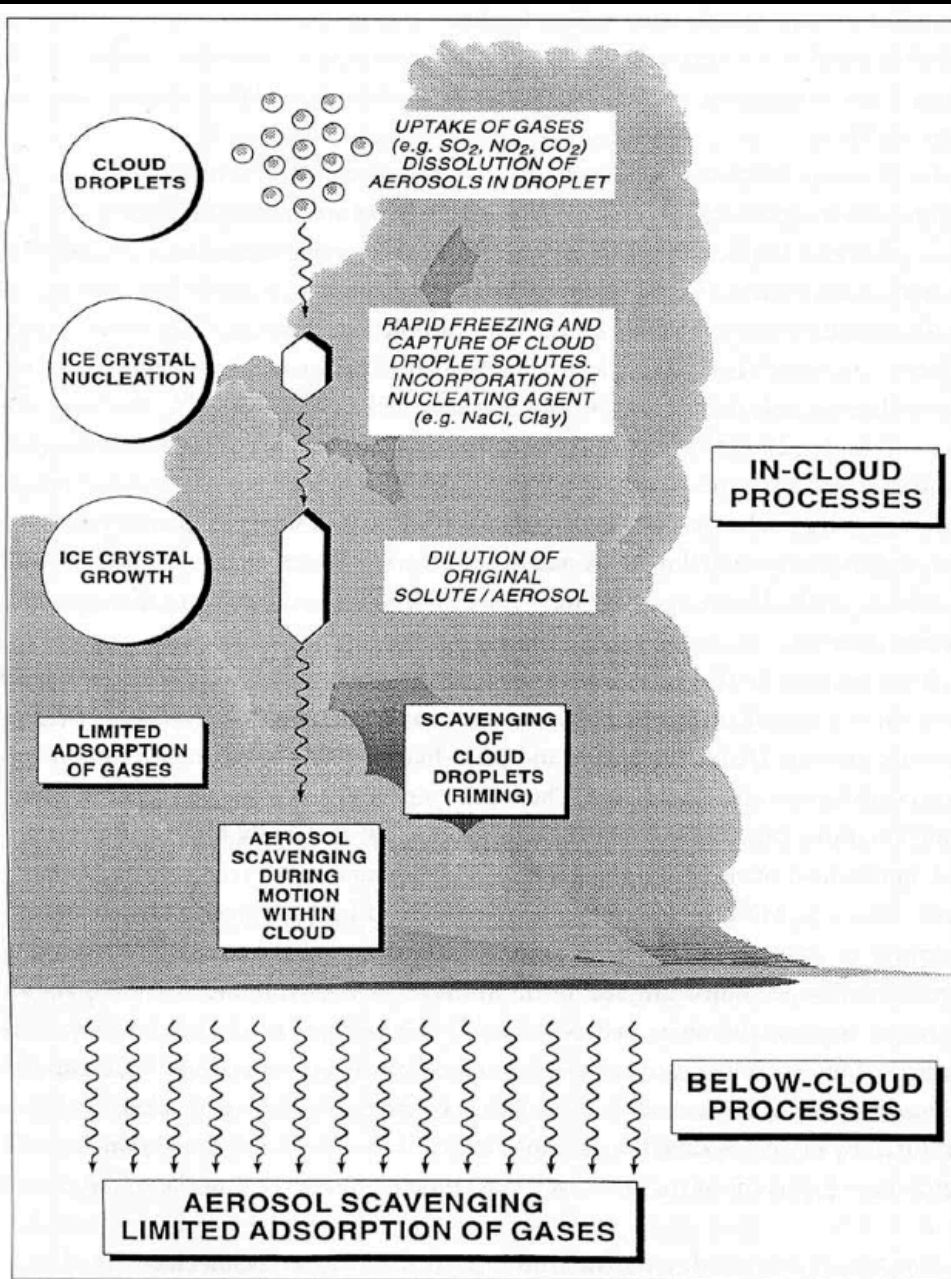


Sturm, M., J. Holmgren, and G. E. Liston. 1995. A seasonal snow cover classification system for local to global applications. *Journal of Climate* 8:1261-1283.

Snow chemistry

Processes affecting snow chemistry during growth and fall:

- In-cloud processes
 - Cloud droplet formation (uptake of gases)
 - Ice crystal nucleation (incorporation of nucleating agents)
 - Ice-crystal growth (dilution)
 - Scavenging of cloud droplet during motion within cloud.
- Below cloud processes
 - Aerosol scavenging of gases



Tranter, M. and G. Jones. 2001. The Chemistry of Snow: Processes and Nutrient Cycling. Pages 127-167 in H. G. Jones, J. Pomeroy, D. A. Walker, and R. Hoham, editors. Snow Ecology. Cambridge University Press, Cambridge.

Snow chemistry

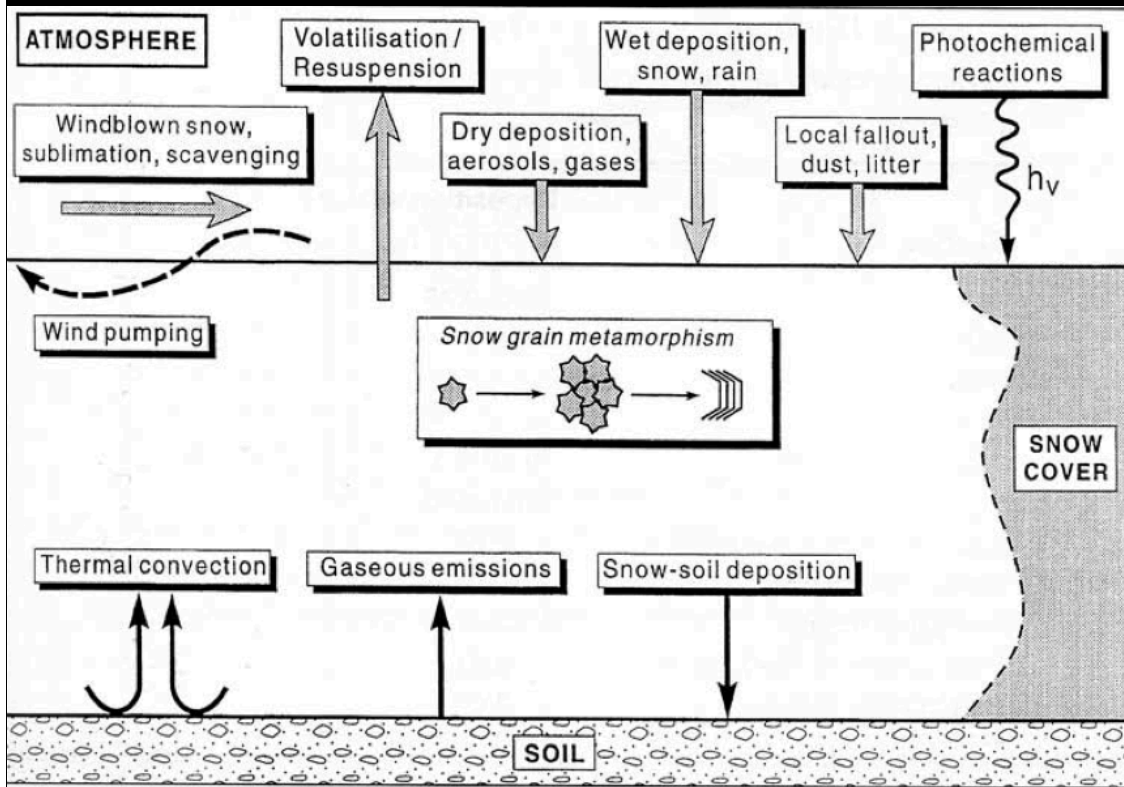
Chemical composition of snowfall at selected sites:

Location	pH	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	NH ₄ ⁺	NO ₃ ⁻	SO ₄ ²⁻	Cl ⁻	Source
European Alps	4.4–5.3	18–49	3–15	3–27	1–6	17–60	12–46	28–68	8–32	Puxbaum, Kovar, and Kalina (1991)
Central Asian Mountains	*	19–70	*	1–44	*	*	2.9–60	2.2–51	1–32	Lyons, Wake, and Mayewski (1991)
Turkey Lakes Watershed, SE Canada	4.57	34	0.9	10	0.2	7.5	19	17	3.7	Semkin and Jeffries (1988)
Mid-Wales	3.9–4.5	4–14	4–11	13–30	1–5	*	11–64	16–78	21–69	Reynolds (1983)
Sapporo, Japan	4.4–6.4	13–63	18–67	59–190	2.3–6.4	*	*	70–99	63–310	Suzuki (1987)
Cairngorms, Scotland	4.4	2.5	11	52	2.1	9.8	20	26	91	Davies et al. (1992)
Svalbard	5.4–6.7	0–46	0–200	4–2000	0–96	*	0–7	0–240	0–2400	Hodgkins, Tranter, and Dowdeswell (1997)
South Pole	5.4	*	0.16	0.63	0.03	0.16	1.4	1.5	1.3	Legrand and Delmas (1984)

*Missing values. Single values refer to volume-weighted mean concentrations. All units (except pH) are $\mu\text{Eq/L}$.

Tranter, M. and G. Jones. 2001. The Chemistry of Snow: Processes and Nutrient Cycling. Pages 127-167 in H. G. Jones, J. Pomeroy, D. A. Walker, and R. Hoham, editors. Snow Ecology. Cambridge University Press, Cambridge.

Snow chemistry



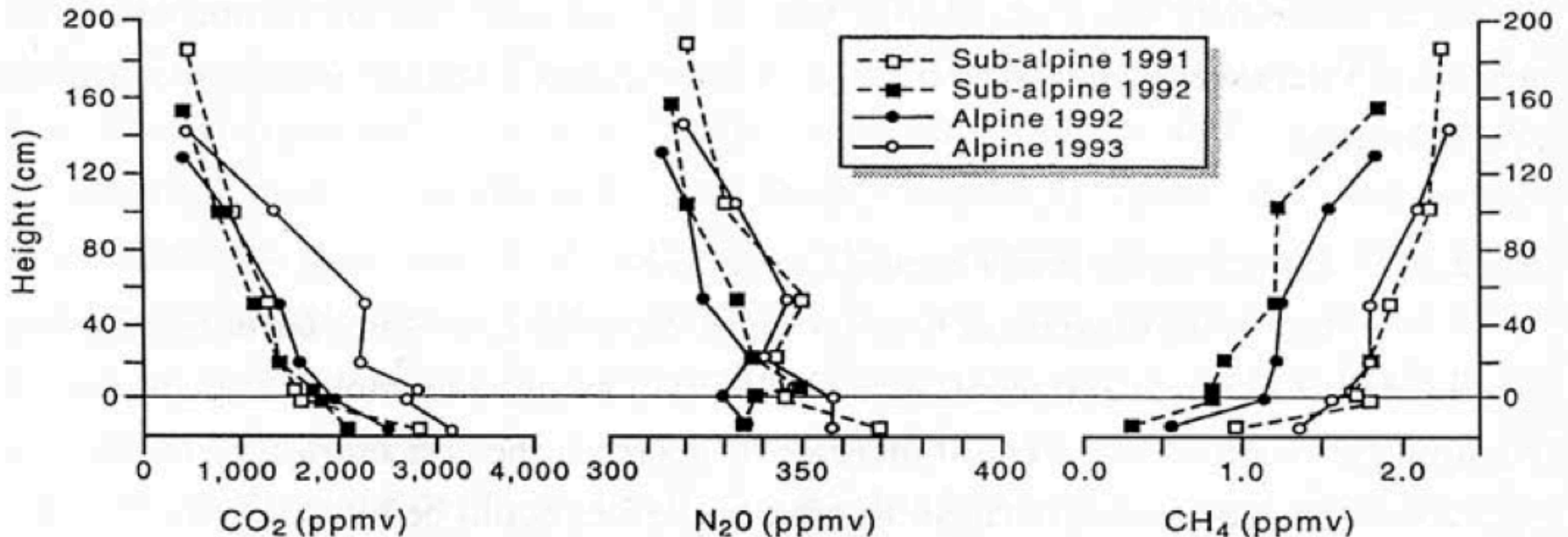
Processes affecting dry snow chemistry during **accumulation season**:

- **Above-snow processes:**
 - Windblown snow scavenging
 - Dry deposition.
 - Wet deposition
 - Local litter, dust
 - Photochemical reactions
- **Within snow processes:**
 - Dry snow metamorphism
- **Below-snow processes:**
 - Gaseous emissions
 - Snow- soil deposition
 - Microbial activity (if soil is warm enough)

Tranter, M. and G. Jones. 2001. The Chemistry of Snow: Processes and Nutrient Cycling. Pages 127-167 in H. G. Jones, J. Pomeroy, D. A. Walker, and R. Hoham, editors. Snow Ecology. Cambridge University Press, Cambridge.

Snow chemistry: Exchange with soil surface

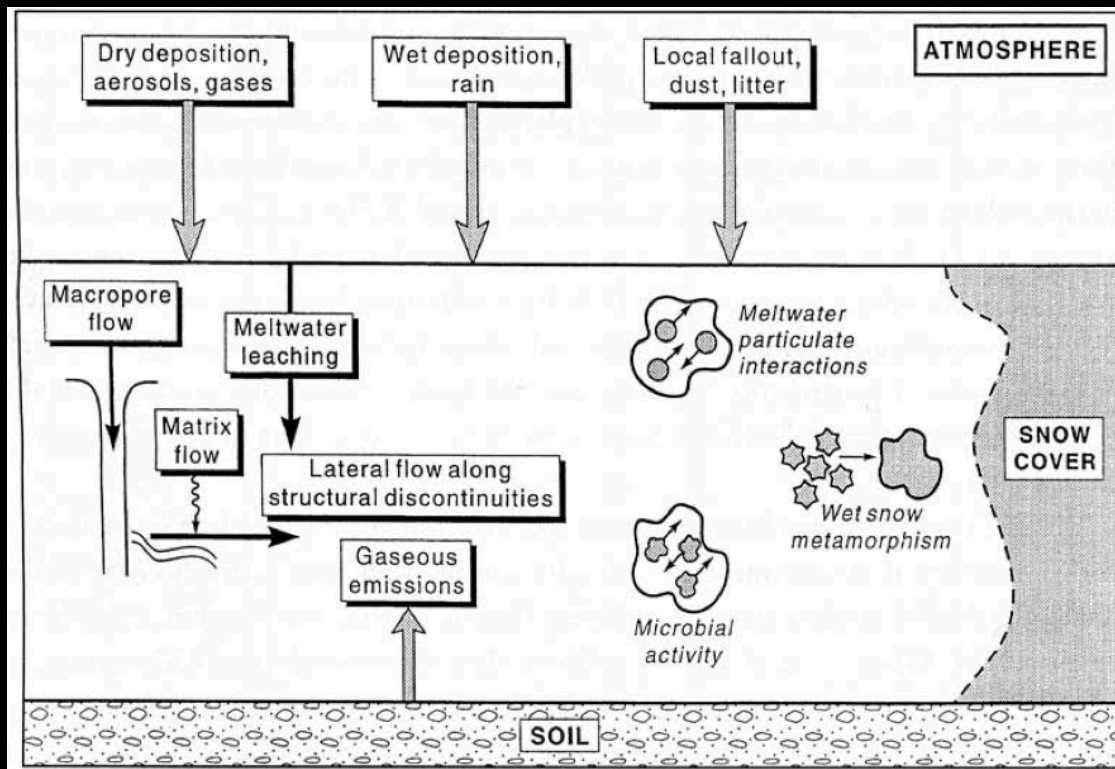
Gas concentrations within snow pack:



- Mainly a result of microbial decomposition beneath the snowpack.
- Ceases at about -8°C.

Tranter, M. and G. Jones. 2001. The Chemistry of Snow: Processes and Nutrient Cycling. Pages 127-167 in H. G. Jones, J. Pomeroy, D. A. Walker, and R. Hoham, editors. Snow Ecology. Cambridge University Press, Cambridge.

Snow chemistry



Processes affecting snow chemistry during thaw:

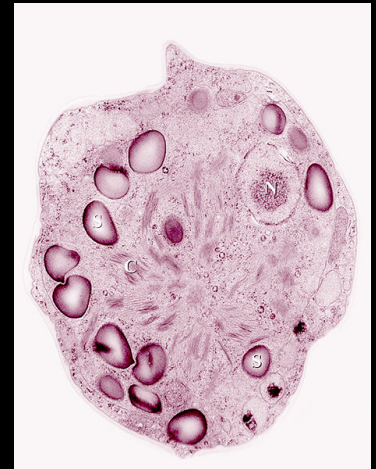
- **Above-snow processes:**
 - Windblown snow scavenging
 - Dry deposition.
 - Wet deposition
 - Local litter, dust
- **Within snow processes:**
 - Wet snow metamorphism
 - Micro-pore flow
 - Melt-water leaching
 - Melt-particulate interactions
 - Microbial activity
- **Below-snow processes:**
 - Gaseous emissions
 - Microbial activity

Tranter, M. and G. Jones. 2001. The Chemistry of Snow: Processes and Nutrient Cycling. Pages 127-167 in H. G. Jones, J. Pomeroy, D. A. Walker, and R. Hoham, editors. Snow Ecology. Cambridge University Press, Cambridge.

Next lecture: Snow as a habitat and snow-vegetation interactions



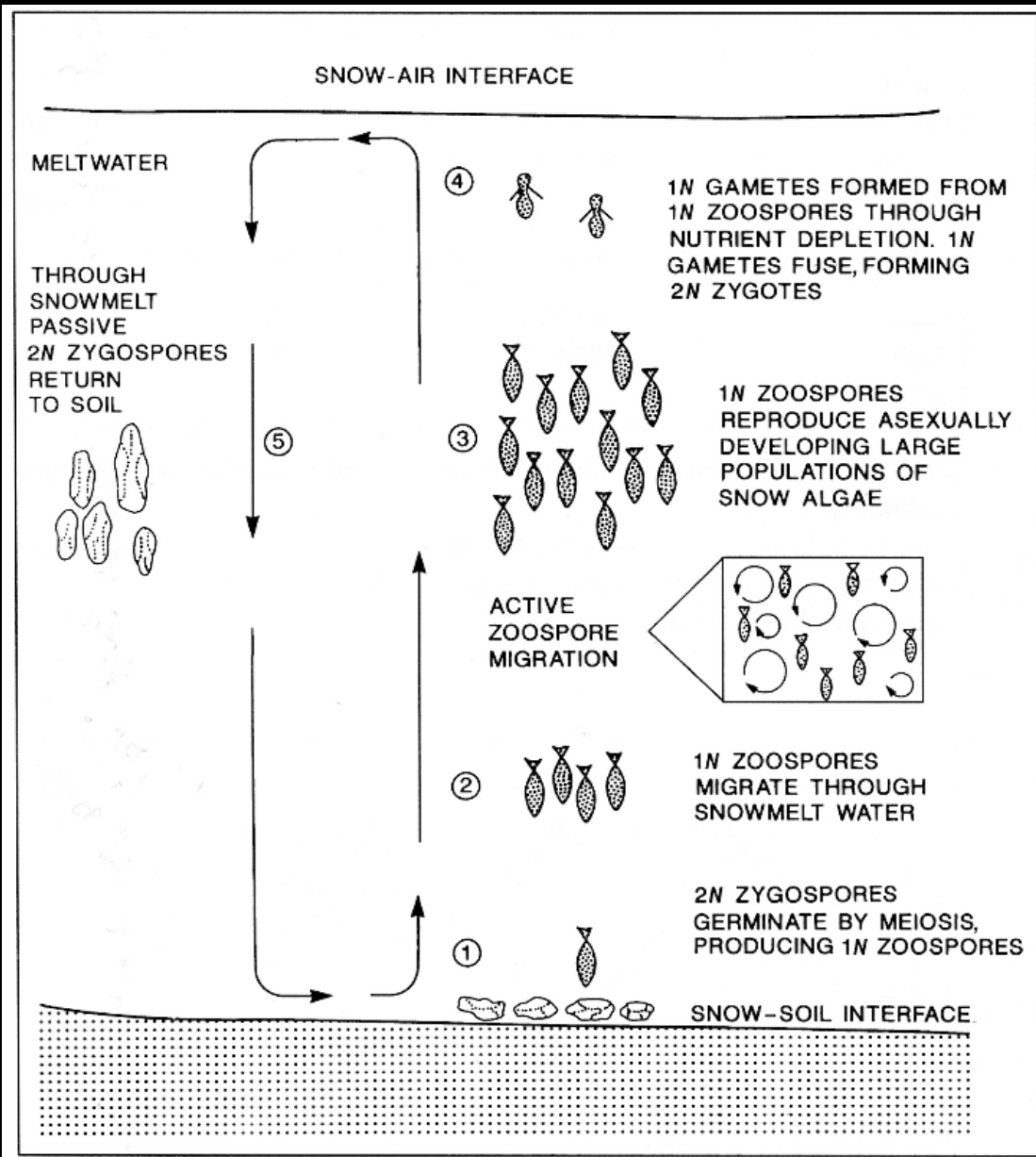
Watermelon snow



Green alga:
Chlamydomonas nivalis.
Source: [http://
emu.arsusda.gov/
typesof/pages/green
%20algal.html](http://emu.arsusda.gov/typesof/pages/green%20algal.html)

Photo: Watermelon snow in Sierra mountains, Green snow alga: *Chlamydomonas nivalis*
Will Beback, http://en.wikipedia.org/wiki/File:Watermelon_snow_streaks_3.jpg

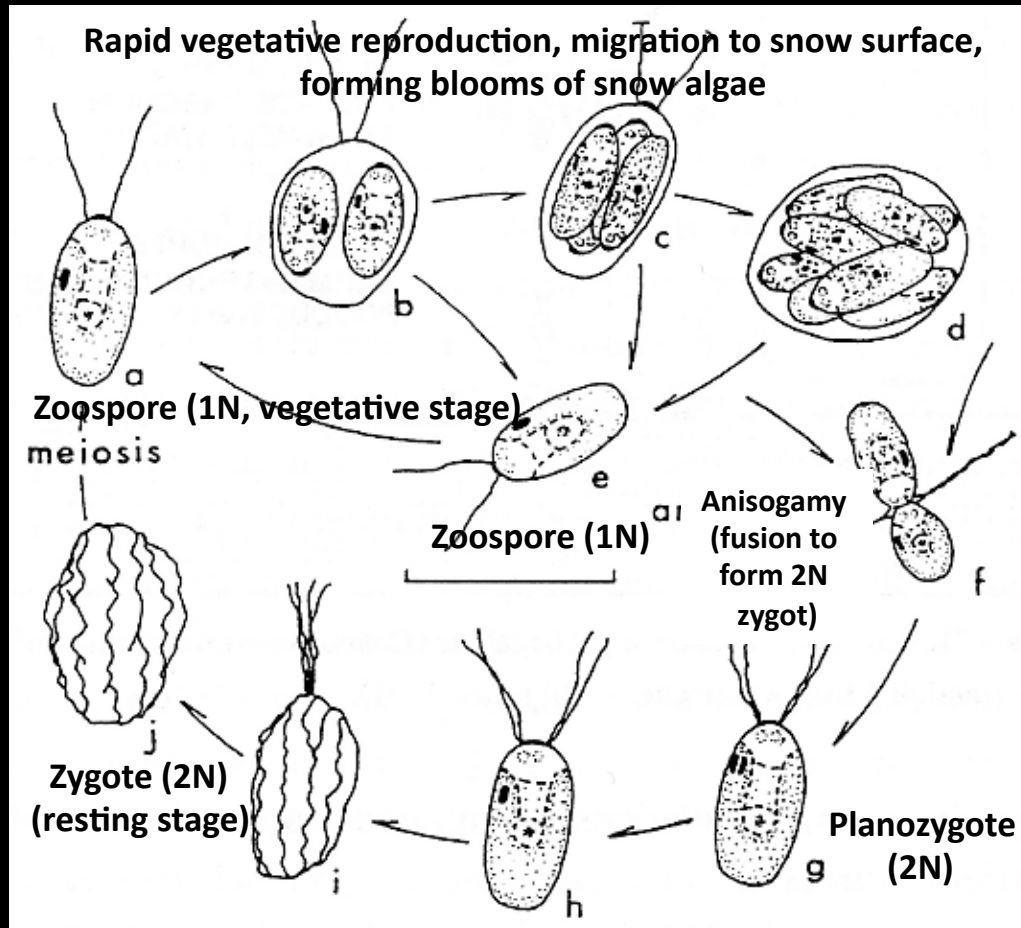
Life cycle of algal flagellate, *Chloromonas*



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.

Hoham, R. W. and B. Duval. 2001. Microbial ecology of snow and freshwater ice with emphasis on snow algae. Pages 168-228 in H. G. Jones, J. W. Pomeroy, D. A. Walker, and R. W. Hoham, editors. Snow Ecology. Cambridge University Press, Cambridge.

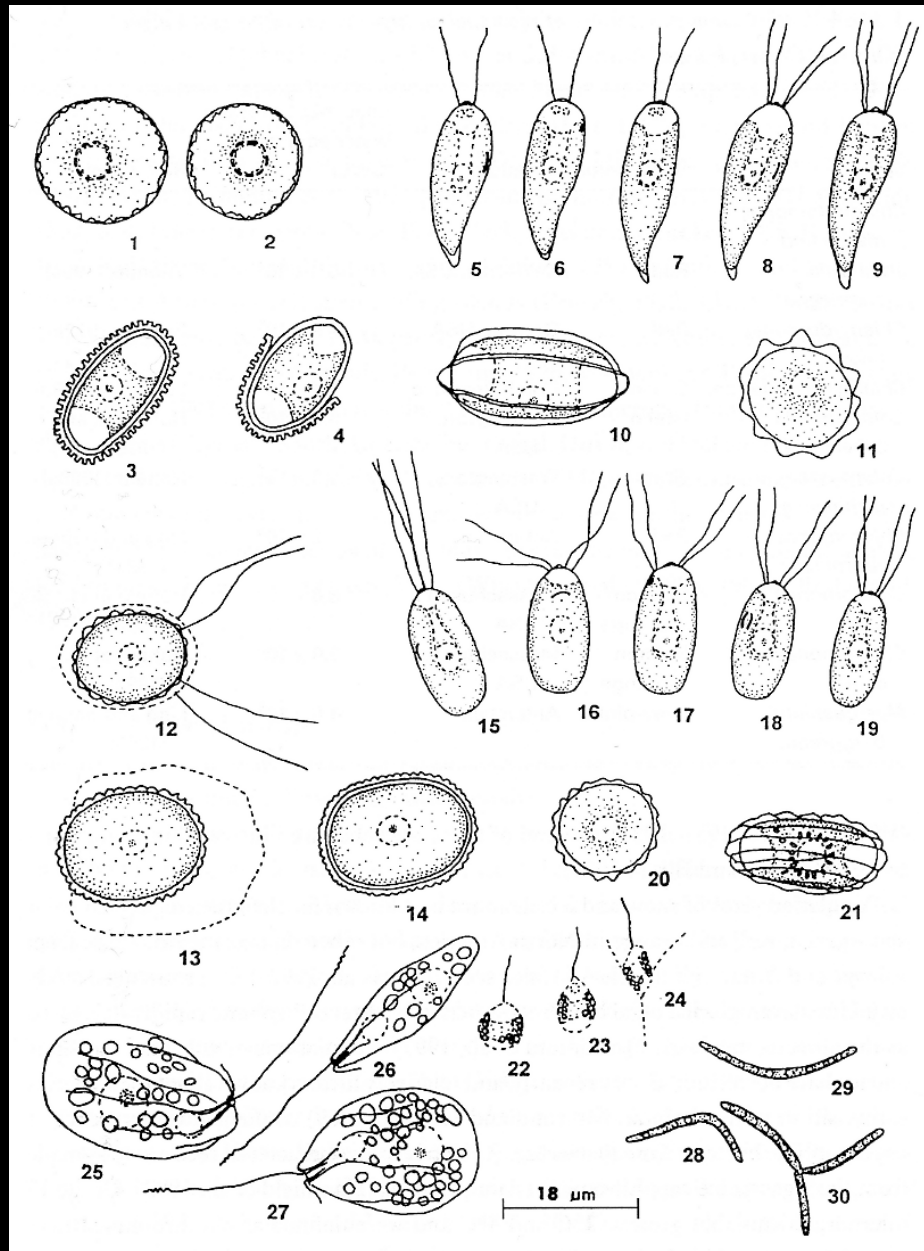
Life cycle of algal flagellate, *Chloromonas polyptera*



- a. bi-flagellated 1N zoospores.
- b-e. 1N Zoospores “swim” upward to snow surface within liquid water surrounding snow crystals of isothermal snow. Zoospores reproduce asexually developing large populations of snow algae. Zoospores create visible blooms of snow algae on the snow surface.
- f. With nutrient depletion, 1N gametes from 1N zoospores fuse (anisogamy) to form 2N resting zygotes.
- g-j. Zygotes return to soil passively through meltwater percolation melting and settling of the snow.

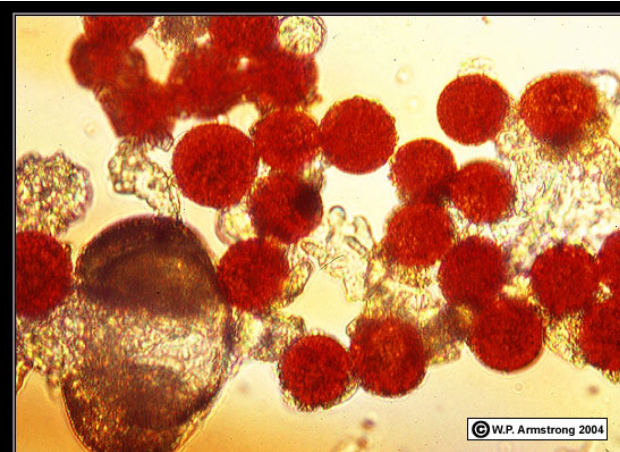
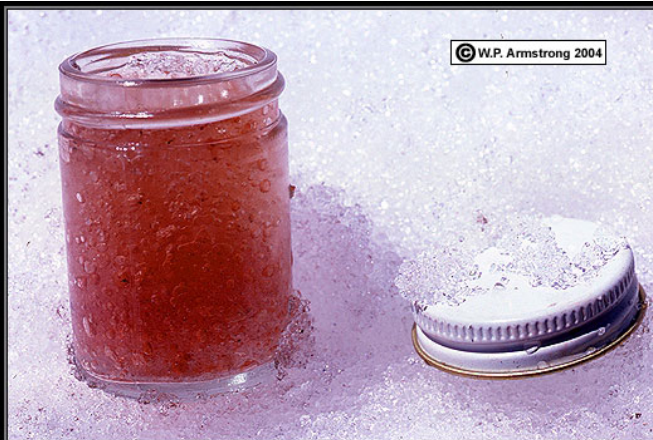
Hoham, R. W. and B. Duval. 2001. Microbial ecology of snow and freshwater ice with emphasis on snow algae. Pages 168-228 in H. G. Jones, J. W. Pomeroy, D. A. Walker, and R. W. Hoham, editors. Snow Ecology. Cambridge University Press, Cambridge.

Other cryophilic organisms found in snow



- 1-2 Green alga (*Chlamdomonas nivalis*) resting spores
- 3-4 Green alga (*Chloromonas brevispina*) zygospores.
- 5-9 Green alga (*Chlamdomonas nivalis*) vegetative cells.
- 10-11 Green alga (*Chlamdomonas nivalis*) zygospores.
- 12-21 Other green algae forms.
- 22-24 Golden alga (*Chromolina chionophila*)
- 25-27 Euglena (*Notosolenus* sp.)
- 28-30 Fungus (*Selenotila nivalis*)

Hoham, R. W. and B. Duval. 2001. Microbial ecology of snow and freshwater ice with emphasis on snow algae. Pages 168-228 in H. G. Jones, J. W. Pomeroy, D. A. Walker, and R. W. Hoham, editors. Snow Ecology. Cambridge University Press, Cambridge.



Red snow in the Sierras

Upper right Microscopic view (400 X) of the bright red resting cells (aplanospores) of *Chlamydomonas nivalis*. The larger winged structure (lower left) is a pollen grain from the timberline whitebark pine (*Pinus albicaulis*). The smaller, transparent-green cells (center) with a lipid droplet at each end are *Chloromonas*, another species of snow alga. The red coloration is due to carotenoid pigments that protect the cells from intense solar radiation. (From Wayne's World, Noteworthy plant for 1998. <http://waynesword.palomar.edu/plaug98.htm>).

<http://waynesword.palomar.edu/index.htm>

Yellow snow (where the doggies didn't go!)



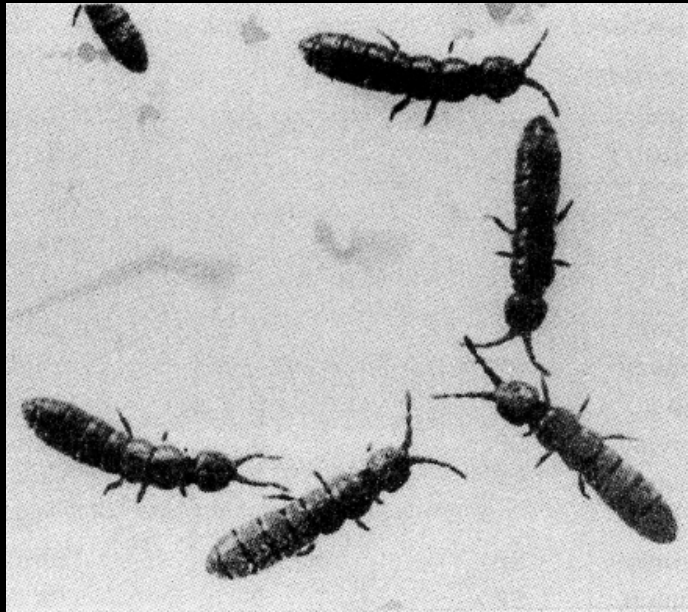
Photo: Brian Duval

- Non red forms thrive in shaded areas, e.g. spruce and fir forests.

Some consequences of snow algae:

1. Bacterial colonies develop around the algae.
2. These are fed on by rotifers and other higher-level predators.
3. More complex animals, such as *Mesenchytraeus* ice worms, and Collembola, snow fleas, also graze on algae.
4. Tardigrades, or water bears, prey on a variety of organisms.
5. Fungi decompose the organic material.

Snow fleas (Collembola)



Collembola (*Isotoma* sp.)

Aitchison, C. A. 2001. The effect of snow cover on small animals. Pages 229-265 in H. G. Jones, R. W. Hoham, J. W. Pomeroy, and D. A. Walker, editors. *Snow Ecology*. Cambridge University Press, Cambridge.

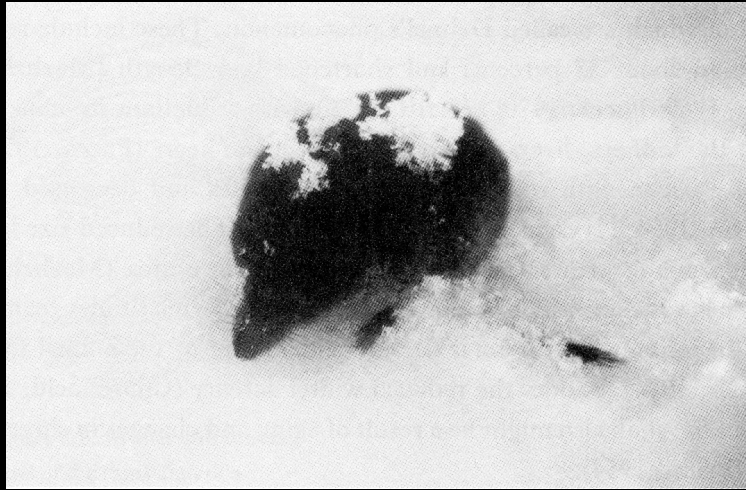
Table 5.3. *Collembolans associated with snow cover in different countries, location in the snow cover, and temperature range of activity.*

Species	Country	Location*	Temperature (°C)	Reference
<i>Dicyrtomina rufescens</i>	Japan	SP	eats at -1	Uchida and Fujita (1968)
<i>Hypogastrura socialis</i>	USA	SP	eats at 0	MacNamara (1924)
<i>Hypogastrura socialis</i>	Finland	SP	0	BK & BK (1980)†
<i>Hypogastrura socialis</i>	Norway	SP	migrates at 0	Hågvar (1995)
<i>Hypogastrura</i> spp.	Nepal	SP	0	Mani (1962)
<i>Hypogastrura</i> spp.	Norway	SP	0	Østbye (1966)
<i>Hypogastrura</i> spp.	Finland	SP	0	Levander (1913), Koponen (1983)
<i>Hypogastrura</i> spp.	Germany	SP	0	Strübing (1958)
<i>Entomobrya nivalis</i>	Finland	SP	0	BK & BK (1980)†
<i>Entomobrya</i> spp.	USA	SB	0	Holmquist (1926)
<i>Tomocerus flavescens</i>	USA	SB	0	Holmquist (1926)
<i>Tomocerus flavescens</i>	Finland	SP	0	BK & BK (1980)†
<i>Tomocerus flavescens</i>	Canada	SB	eats at -2	Aitchison (1983)
<i>Tomocerus</i> spp.	USA	SP	eats at 0	Knight (1976)
<i>Lepidocyrtus cyaneus</i>	Canada	SB	eats at -2	Aitchison (1983)
<i>Lepidocyrtus lignorum</i>	Finland	SP	0	BK & BK (1980)†
<i>Orchesella bifasciata</i>	Finland	SP	0	BK & BK (1980)
<i>Orchesella ainslei</i>	Canada	SB	eats at -2	Aitchison (1983)
<i>Isotoma alpa</i>	USA	SB	>-4	Schmidt and Lockwood (1992)
<i>Isotoma gelida</i>	USA	SB	>-4	Schmidt and Lockwood (1992)
<i>Isotoma hiemalis</i>	Finland	SP	0	BK & BK (1980)†
<i>Isotoma hiemalis</i>	Switzerland	SP	>-3	Zettel (1984)
<i>Isotoma olivacea</i>	Poland	SP	+5 to -5	Wolska (1957)
<i>Isotoma saltans</i>	Poland	SP	0 to -4	Wolska (1957), Wojtusiak (1951)
<i>Isotoma saltans</i>	Germany	SP	+5 to -5	Strübing (1958)
<i>Isotoma viridis</i>	Sweden	SP	>-8	Agrell (1941)
<i>Isotoma viridis</i>	Canada	SB	eats at -2	Aitchison (1983)
<i>Isotoma viridis</i>	USA	SB	>-4	Schmidt and Lockwood (1992)

*SB – subnivean; SP – supranivean.

†BK & BK, Brummer-Korvenkontio and Brummer-Korvenkontio.

Winter food of shrew (*Sorex minutus*)

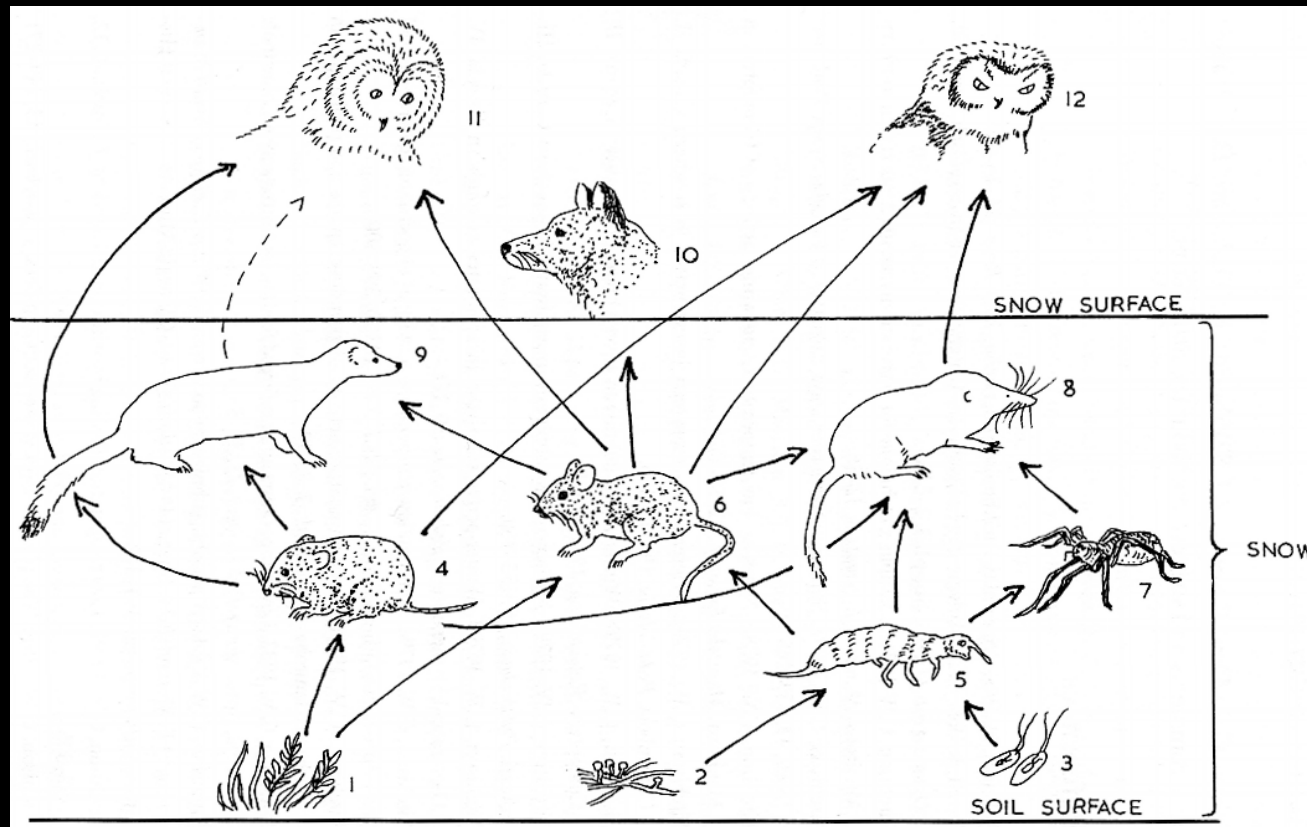


Aitchison, C. A. 2001. The effect of snow cover on small animals. Pages 229-265 in H. G. Jones, R. W. Hoham, J. W. Pomeroy, and D. A. Walker, editors. *Snow Ecology*. Cambridge University Press, Cambridge.

Table 5.5. *Percentage frequency of occurrence of winter food items in the guts of S. minutus (after Grainger and Fairley, 1978; Yudin, 1962).*

Food item	Ireland (<i>n</i> = 87)	Siberia (<i>n</i> = 35)
Lumbricids	0	5.6
Molluscs	0	19.6
Isopods	69	0
Araneae	21	47.6
Acari	42	5.6
Opilionids	30	0
Collembola	0	11.2
Hemiptera	37	17.0
Carabidae	0	42.0
Staphylinidae	0	19.6
Chrysomelidae	0	14.0
Coleopteran adults	90	58.8
Coleopteran larvae	37	0
Hymenoptera	0	16.8
Diptera	49	16.8
Vegetation	53	0

Snow as a habitat: Snow ecosystems



1. Subnivian plants.
2. Fungi
3. Snow algae
4. Red backed vole (*Clethrionomys gapperi*)
5. Collembola (*Isotoma* sp.)
6. Deer mouse ()
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*)

Aitchison, C. A. 2001. The effect of snow cover on small animals. Pages 229-265 in H. G. Jones, R. W. Hoham, J. W. Pomeroy, and D. A. Walker, editors. Snow Ecology. Cambridge University Press, Cambridge.

Take home points

1. Go over methods of describing snow pits in the UNESCO manual (slides 8-32). We will describe three snow pits during the field trip.
2. Understand the processes of low-temperature-gradient (equilibrium) and high-temperature-gradient (kinetic) snow metamorphosis (slides 33-39).
3. Be able to recognize the physical properties of tundra, taiga, prairie, alpine, and maritime snow (slides 40-43).
4. 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).

Next papers: Week after spring break

Discussion Group 1,

1. Walker, D.A., J. C. Halfpenny, M. D. Walker, and C. Wessman. 1993. Long-term studies of snow-vegetation interactions. *Bioscience* 43:287–301.
2. Aitchison, C.W. 2001. The effect of snow cover on small mammals. P. 229-265 in Jones H.G. et al. *Snow Ecology*. Cambridge: Cambridge University Press.

Discussion Group 2,

1. Ehrlich, D., J.-A. Henden, R. A. Ims, L. O. Dronina, S. T. Killengren, N. Lecomte, I. G. Pokrovsky, G. Skogstad, A. A. Sokolov, V. A. Sokolov, and N. G. Yoccoz. 2011. The importance of willow thickets for ptarmigan and hares in shrub tundra: the more the better? *Oecologia* 168:141–151.
2. Tape, K. D., R. Lord, H.-P. Marshall, and R. W. Ruess. 2010. Snow-Mediated Ptarmigan Browsing and Shrub Expansion in Arctic Alaska. [dx.doi.org 17:186–193](https://doi.org/10.1890/1735-1375-17.1.186).