Nov. 13, 2017

Competition-Coaching Introduction L2T

Step 2:

Equipment selection and ski preparation

Reference Material
for On Snow Workshop

Nov. 13, 2017

PARTNERS IN COACH EDUCATION

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This section on equipment selection and ski preparation complements the information provided in section 3 of your Introduction to Community Coaching Reference Material and section 7 of your Community Coaching Reference Material. CCC has created a waxing video going over the proper technique to apply waxes and prepare base available in the Athlete Matrix on CCC's website.

2.1 Equipment Selection for L2T Athletes

During the L2T stage of development, a child should have two sets of equipment – one for skating technique and one for classic. Dual-purpose skis are not recommended.

2.1.1 Skis

- Classic skis should reach just below the skier's wrist when the arm is raised above the shoulder, and the camber should be suitable for classic skiing. A basic test can be performed to find out if the camber is suitable. With the skis on a flat floor or table top, when the skier is standing on one ski, the ski base should fully contact the floor or table surface beneath the foot. When the skier is standing on both skis at the same time (i.e. weight equally distributed), it should be possible to slide a piece of paper between the ski and surface in the area beneath the foot (i.e. the wax pocket). If the paper slides in this way, the camber is appropriate. Note: The camber of the ski is much more important than the length. Some ski companies don't use height as criteria for ski selection because the more important factors to consider are weight and technique.

- Skating skis should be 3-10 cm above the head of the skier. Before purchasing new equipment, skiers/parents should confirm - by consulting a coach or by checking the F.I.S. Rules and Regulations (on the F.I.S. website) - the current competition rules pertaining to the height of skis.

- Skating skis require a camber that is suitable for skating (i.e. the camber needs to be sufficiently stiff). Skating skis for children often have too soft a camber. When the skier is standing on one ski on a flat surface, it should be easy to pull a piece of paper out from under the foot with a gentle tug.

- If skis are not of the correct length and/or camber, skiers will have difficulty mastering the technique benchmarks that have been established for this stage of development.

2.1.2 Poles

- As a starting point, classic poles should reach to the top of the under arm of the skier when the poles are standing on the floor - to the point where the poles are uncomfortable. Poles used for skating should be the same height as the chin. These are good reference points and skiers can adjust from there.

- There is no advantage to using poles that are too long. Conversely, poles that are too long can hinder technique and cause unnecessary fatigue.

- If poles are too long or too short, the skier will have difficulty mastering the technical skills necessary to become competent in the sport.

- ❑ Poles must have adjustable straps. The strap should be adjusted so that the pole can fit firmly against the hand at the point where the forefinger and thumb are joined.

- ❑ When straps are properly adjusted, the pole grip should reach above the point where the hand grips it.

- ❑ When the pole is released in the follow-through motion, the skier should still have control of it.

- ❑ Skiers should use sport specific (i.e. cross-country ski) gloves or mitts.

2.1.3 Boots/Bindings

- ❑ Boots should be comfortable. A constrictive ski boot doesn't allow for proper circulation. On the other hand, boots that are too large can lead to blisters and provide less control on the hills.

- ❑ It is recommended that skiers use classic boots for classic technique and skating boots for skating technique. However, a good quality, pursuit-style combination boot is also an option.

- ❑ Skating boots must provide firm ankle support.

- ❑ In addition to the annual club ski swap, a boot exchange program within your club can help reduce the cost of purchasing boots during the rapid growth years.

- ❑ Good quality boots are worth the investment.

Coaching Tip: Parents are unlikely to have the information they need to ensure their children have appropriate ski equipment for developing good technique. In addition, parents probably won't know how to prepare their children's skis (1) for a practice session, or (2) to take with them to a competition (i.e. cleaned and ready for the coaches to work with).

As a result, it is important to hold parent meetings each year before the ski season begins in order to explain what is needed.

2.2 Base Preparation

For practical demonstrations of base preparation and waxing videos please see CCC's waxing demo video

Terms Used to Describe the Construction of Skis

- ❑ **Base.** This refers to the material used in the manufacture of the base of the ski. There are variations in bases; some are harder, softer, more porous and less porous. It is preferable to have a P-Tex base, rather than a cheaper substitute that doesn't hold wax as well.

- **Metal Scraping**. Metal scraping describes the removal of base material (i.e. P-Tex) with a hand-held sharp metal scraper. At one time this was done to new skis in order to create a smooth and flat surface. However, most skis being marketed today do not require this preparation; they are ready to wax right off the rack. Metal scraping is now used primarily in the repair of skis that have been damaged or, in some cases, to recondition the ski base. Because metal scraping has potential to damage the ski base if done incorrectly, it is a task that should only be performed by an experienced skier or coach.
- **Structuring.** This describes the process used to alter the surface texture/finish to allow theski to glide better on the snow surface.
- **Grinding.** Grinding is a process that uses a machine to renew the base of a ski by removing a thin layer of base material. It has two purposes: to make the base flat; and to press or cut a particular structure into it.
- **Rilling.** Rilling tools press or cut parallel groves into the base of a ski to create structure to improve ski base performance (generally by helping to reduce suction).
- **Tractor.** A "tractor" is a hand structuring tool that creates a pattern similar to a grinding machine. Unlike some of the rillers and grinding machines, tractor-type structuring tools will press the structure into the base, making it possible to remove it easily with hot glide waxing techniques.

Structure

Structure is an important aspect of the preparation of a cross-country ski for racing. When we speak of structure, we are referring to specific patterns placed on the ski base to enhance its glide properties. The structure on a ski base is as important as the wax, and like wax, it must be done properly in order to be effective.

When base structuring takes place, patterns are pressed or cut into the base of the ski. The purpose of these patterns is to help break up the suction that occurs between the ski base and the snow. In dry, cold conditions it will decrease the surface contact area and thus reduce friction between the ski and the snow. In warmer, wetter snow it helps remove excess water from the base.

Structure may account for as much as 20% of the performance of a ski.

Structuring can be done either with a grinding machine or manually; however the structure from grinding is more precise.

Grinding

Cross-country skis are ground on grinding machines that are designed specifically for that purpose. Some points to note:

- An infinite number of patterns that can be created.
- Grinding patterns can be reproduced.
- The finish on a properly ground ski is very clean – no burning, hairs, etc.
- A ground ski may be faster than factory-prepared skis. However, many racing skis are now being produced with very good factory grinds.

Hand Structure

If a grinding machine is not available, a ski can be tuned by hand. Hand tuning does not offer as many possibilities as grinding, but it can prepare a very good ski. The following tools are required:

- ❑ A sturdy jig.
- ❑ Tools for sharpening scrapers.
- ❑ A sanding pad.
- ❑ Rilling tools.
- ❑ Steel scrapers.
- ❑ FIbertex.
- ❑ A tractor.
- ❑ Brushes.

The first step is to get the work area set up. Ensure that your scrapers are sharp, your brushes are clean, there is good lighting, etc.

- ❑ Place the ski in your jig; clean off all the old wax.
- ❑ Make a couple of passes with a steel scraper; hold the ski up to the light to inspect it.
- ❑ Proceed to flatten the base. Check the ski frequently; hold it up to a light and look for shadows on the base. When the base is flat you will have uniform light along the length of it.
- ❑ Usually you can flatten the ski with a scraper, but sometimes it is necessary to use a sanding block/paper.
- ❑ Once the ski is flat, take a sharp scraper and make one or two continuous passes along the entire ski base.
- ❑ Wipe the ski with fibertex.
- ❑ You are now ready to consider structures.
- ❑ With hand structure, there is a progression of options you can choose. These range from a very smooth ski (e.g. a basic metal scraped ski) through to a coarse ski (as much as 3mm rills). The structure you decide to use should be based on testing and/or experience.
- ❑ A useful tool for hand structure is a “tractor”. This tool gives a pattern to grinding. If more structure is needed, you can make more passes. A tractor can be used with rilling tools.

Tips

- ❑ Practise on old skis first!
- ❑ If the ski track is soft, cold and dry, a metal scraped ski will work well.
- ❑ Begin by using two to three different structures and getting to know them and their application well.
- ❑ Keep track of which structures have worked well in different conditions.

2.3 Wax Room Safety

The following guidelines for wax room safety are intended to improve the health and safety in our sport and limit the exposure of wax technicians, support staff,]coaches and athletes to the hazards associated with ski preparation. Wax rooms are considered active work zones whenever irons are in use. Limit exposure to unprotected athletes/support staff by organizing bib pick-up, warm-up and race ski exchanges outside of wax room.

2.3.1 Hazards

Fluoro waxes: The main route of exposure is inhalation when heat is applied with the wax iron heat gun or torch.

Particles in the air: Exposure through applying wax, scraping and brushing. Small particles can penetrate deep into the respiratory system and cause acute inflammation.

Wax removers: Many products contain numerous occupational carcinogens.

a) Recommended means to control the hazards

Waxroom environment:

- ✓ Separate, detached wax room facility with adequate ventilation is required.
- ✓ Wax room safety signs/reminders posted
- ✓ Be prepared for optional grip wax application outdoors (portable bench, shelter)

Fluoro waxes:

- ✓ Use a modern waxing iron with controls for temperature setting. The temperature setting is crucial to the proper melting temperature of the wax.
- ✓ Avoid higher temperatures than necessary. A temperature 20oC above the manufacturers recommended melting point will double the amount of inhalable particles
- ✓ At temperatures higher than 200oC, fluoro components will start to degrade and form toxic gases

Particles in the air:

- ✓ Use mask when applying any fluoro waxes.
- ✓ Always! Use mask when applying powders. The mask reduces the particle concentration up to 30 times.
- ✓ Use safety glasses when brushing, particularly roto brushing.
- ✓ Maintain a clean wax area by regularly sweeping wax shavings and disposing of them in garbage bags.

Wax removers:

- ✓ Use citrus-based solvents with minor petroleum distillate properties. Not only do they smell better, they are less volatile.

b) Mitigating Risks in the Wax Room

- ✓ Personal Protective Equipment (PPE) includes a respirator/mask, apron, gloves, eye protection
- ✓ Respirator: ensure it fits properly and doesn't leak. Maintain the respirator according to the manufacturer's instructions and adhere to the expiry date of the respirator eg 3M T4277 Protective Mask or for the professional waxer the Scott Autoflow T317590 or the 3M powerflow.
- ✓ Ensure that every wax technician is outfitted with and wears the appropriate PPE.

2.4 Ski Preparation and Competitions

2.4.1 Tool Box

As you gain experience as a coach, your needs will change and your tool box will grow accordingly. In most situations, the club should assume responsibility for the specialized tools and tools and waxes needed for competitions.

Possible Ancillary Equipment for Your Club Tool Box

Metal scraper, thin, sharp	Plastic scrapers
Groove scraper	File(s)
Carborundum stone and/or diamond file	Putty knife
Paint brush	Can for wax removal
Groove plane	Iron
Tractor	Rilling tools – iron
Heat gun	Natural cork
Brushes – many	Synthetic Cork(s)
Straight edge	Nails
Rope	Gas mask
Dust filter	Power drill
Power brush	

Waxing Journal**:** Coaches are encouraged to keep a journal of their waxing experiences from the time they begin coaching. To do this effectively you will require waterproof forms that include a place to record the date, location, technique, air temperature and snow temperature of each waxing situation experienced.

2.4.2 Setting Up Shop

Setting up a work area is an important aspect of providing waxing support at a competition and one that often requires some improvising on the part of the waxing support team. In order to do fast, efficient and effective work, the support team needs a work area that lends itself to this.

Following are some key considerations to keep in mind:

- ❑ Lighting: When you are working on a ski you need to be able to inspect your work on a regular basis. Moreover, the final inspection of the ski is crucial. To do this the lighting must be good enough for you to see the base of the ski and make a proper assessment. Often you will find that you require portable lights, because the existing lights will not be adequate.

- ❑ Power Source: Irons, heat guns, power drills, extra lights and similar equipment can require more power than a single circuit can supply. When you are setting up your work area, try to spread the load over two or more circuits. In addition, make sure you have access to the main breaker or fuse box, both on the days leading up to and the day of the competition.

- ❑ Benches: Your work benches should be solid and secured to the building. In a temporary situation this can be done with duct tape, nails and bracing, etc. The ski forms that you use should be stiff, and the vices on the forms should be strong enough to hold the skis securely (adjustable forms are preferable). The ski should “fit” the form.

- ❑ Equipment Storage: All unnecessary equipment should be stored out of the way. Those working in the ski preparation area shouldn’t have to climb over anything in order to move around. At the same time, the work area should be set up so that everyone can access the supplies they need without disrupting the others in the room.

- ❑ Ski Storage:
  - ✓ All too often, skis are piled in a corner or placed against a wall, only to come crashing down when something bumps against them. This is not going to go over well with your support team, who by then may have spent hours working on the skis to get the bases up to racing condition. One way to avoid this is to use portable racks that can be secured to the wall. They offer an easy way to keep the skis out of the way, safe and organized.
  - ✓ It is advisable to have a system of racking so that, when you are preparing a large number of skis, you don’t miss anything. It can be stressful for everyone involved if one of the support team takes down a pair of race skis 15 minutes prior to start time and discovers they haven’t even been glide-waxed yet.

- ❑ Ventilation: The fumes created when applying glide wax to skis are harmful – all fumes, not just those from fluorocarbon powders. If at all possible, arrange to have the work area well- ventilated. See guidelines in pervious section.

- ❑ Temperature Control: The work area should be warm when you are glide-waxing the skis. This is an ideal environment for the ski to absorb wax, although it will be hot for the support team that is working there.

- ❑ Layout: It is important to lay out the work area so that members of the support team can work effectively without interfering with each other.
  - ✓ Position the ski racks so that those who need to can reach them from their work benches.
  - ✓ Secure the power cords so that they do not become people traps.
  - ✓ Have enough tools for each work station so that, with the exception of a few special tools, they don’t need to be passed around.
  - ✓ If power brushes are being used, position that station so that the dust from them doesn’t fall on finished skis.
  - ✓ Have shelves to keep the wax supplies off the benches.
  - ✓ Set up the area so that it is possible to keep it clean.

2.5 Snow and Weather Terminology

The following section outlines the standard snow and weather terminology used for cross- country ski competitions.

Type of Snow	Description
New snow	Snow which retains much of its original crystalline form and has been packed, but not tilled.
Fine-grained snow	Old snow which has been packed and tilled, but has not been subject to overworking or thawing and freezing.
Coarse-grained snow	Old snow which has been extensively worked and has been subject to cycles of thawing and freezing.
Man-made snow	Snow containing a significant percentage of recently man-made snow. This snow will change over time to resemble fine or coarse-grained snow.

Snow Conditions

- ❑ Packed.
- ❑ Loose grained.
- ❑ Re-frozen.
- ❑ Icy.
- ❑ Dirty.

Water Content

- ❑ Dry - cannot form a snowball easily.
- ❑ Moist – can form a snowball easily.
- ❑ Wet - can squeeze water out of snowball.
- ❑ Slush – can obtain water out of a snowball without squeezing.

Trail Density (for competitive skiing)

- ❑ Low
  - ✓ Racing basket leaves significant impression.
  - ✓ Sides of track break away easily.
- ❑ Medium
  - ✓ Skating technique leaves significant impression.

  - ✓ Screwdriver penetrates easily.
- ❑ High
  - ✓ Skating technique leaves shallow marks.
  - ✓ Screwdriver has to be forced into snow.
- ❑ Frozen
  - ✓ Icy – cannot penetrate with screwdriver.

Standard Meteorologicial Terms

Precipitation	Cloud Cover	Wind
Light snow	Clear	Calm
Moderate snow	Partly cloudy	Light
Heavy snow	Cloudy	Moderate
Very light rain	Overcast	Strong
Light rain		
Moderate rain		
Heavy rain		
Freezing rain		

Precipitation, wind and humidity can be quantified using the units provided in the chart below.

Units	
Snow depth	cm
Rain	mm
Humidity	%
Wind Speed	Km/h

2.6 Snow Physics

To better understand the various snow conditions that skiers need to prepare for, it is worthwhile taking a look at snow physics from a groomer's perspective.

a) Snow Physics for Groomers

Knowledge of how snow reacts to changes in temperature and temperature gradients will allow you to better understand what happens when you groom trails in different conditions. It will help you to:

- ❏ pack the snow to achieve suitable density for a variety of different users;
- ❏ provide the same track conditions for all skiers in a competitive event; and
- ❏ extend your skiing season by working the snow the right amount.

b) The Three States of Water

If you want to fully understand the changes that take place when you groom and pack ski trails, read the following section which explains the basic physical concepts governing the three states of water: gas, liquid and solid (vapour, water and ice).

1- Water Vapour. Think of water vapour as individual molecules of water dashing around the atmosphere in a state of rapid but random motion. Each molecule consists of one blob of Oxygen with two "eyes" of Hydrogen attached.

✓ Dew Point**:** Imagine a large number of molecules of water vapour floating along quite happily in their own cubic centimetre or so of air space. As they are propelled by the prevailing winds landward over the ocean, more molecules freed by evaporation rise up to join them. Eventually they reach land and are swept upwards over high ground. As they rise, the air expands and the molecules slow down, their kinetic energy reduced. The more the air expands, the cooler the molecules become and the closer together they huddle, until at a certain temperature known as the Dew Point they condense into water droplets. When this occurs, the air is said to be "saturated". It contains as many free molecules as it possibly can at that particular temperature. The lower the temperature, the fewer molecules the air can hold before condensation takes place.

2- Water. Water is formed of molecules sliding over each other but held together at the same time in a loose liquid form by the attraction of one molecule to another. Because water molecules form strong bonds, a very large amount of energy is required to convert water to vapour. In fact, the evaporation of water requires approximately 540 calories to change one gram of water to vapour without a change of temperature. This is known as the Latent Heat of Vaporization. Conversely, condensation releases the equivalent amount of heat to the atmosphere.

✓ Super-Cooled Water**:** If water vapour molecules encounter a temperature below freezing before they condense, the clouds that form will be composed of minute droplets which remain in the liquid state below the freezing point. The purer the water, the more the droplets can be cooled. But there is a lower temperature limit;

at -40□C water droplets freeze instantly.

- ✓ Vapour Pressure**:** Some molecules attain enough speed to break away from the surface of water. The higher the temperature, the more active the molecules and the greater the evaporation. Many of the molecules that break free remain in the form of an atmosphere of free-moving molecules hovering over the surface of the water. A concentration of these molecules is called "vapour pressure". As the temperature falls, the vapour pressure becomes lower.

3- Ice. Ice is a state of matter where the molecules are firmly joined and their movement is restricted to vibrations. However, just as in the case of water molecules, the molecules are able to break away from the surface of the ice and form an atmosphere of vapour.

- ✓ Vapour Pressure over Water and Ice: For a given temperature below freezing, the vapour pressure over water is greater than the vapour pressure over ice. This is because the molecules are able to escape more readily from the water than from the ice. This concept and the concept of supersaturation are most important in the formation of ice crystals, both in the atmosphere and on the ground.

- ✓ Condensation: Condensation happens when a large number of molecules join together to form a water droplet. If there is no foreign surface on which to condense, the molecules can only come together by accidental collisions which may require a high degree of supersaturation, especially in the case of slower moving molecules at lower temperatures. If a sufficient number of molecules get together, then the droplet will continue to grow rather than evaporate away. In the atmosphere, this is achieved by the presence of foreign particles such as dust and salts called "condensation nuclei", which provide a surface on which water molecules can begin to condense.

- ✓ Supersaturation: Consider a glass of iced water. If the humidity is high enough, it will soon become coated on the outside with condensed water droplets. Like the molecules around the cold glass, high flying molecules in the atmosphere need some surface on which they can begin to condense. In the absence of such a surface, in the very clean air conditions at higher altitudes, it is possible for many more molecules to crowd together before condensation occurs. This higher moisture content is called supersaturation.

- ✓ Sublimation: Sublimation is the ability of water molecules to change from ice to vapour and back again without passing through the water stage. A warm dry wind blowing over an ice surface will carry off water molecules, and because the vapour pressure over the ice is momentarily lower more molecules will be encouraged to break away from the surface thus hastening evaporation.

- ✓ Saturation with Respect to Ice: If the atmosphere over a particle of ice contains the same concentration of water vapour as that given off by the ice, it is said to be "saturated with respect to ice". If the vapour concentration in the air is higher than the vapour pressure over the ice, it is said to be "supersaturated with respect to ice". Some molecules condense onto the ice surface.

c) Heat Gain and Loss in the Snow Layer

- **Temperature Gradient.** The temperature gradient is the difference in temperature between two snow layers or between a snow layer and the ground, expressed in terms of degrees Celsius per metre of depth. For example, consider one metre of snow lying on a ground surface the temperature of which is 0□C. If the air temperature drops to -20□C, there is a difference of 20□C in one metre of snow depth or 20□C/m. Because the temperature gradient influences the movement of water molecules within the snowpack, it has a significant effect on changes in snow structure within the snowpack.

The physical processes that cause changes at and beneath the surface of the snow are driven by temperature gradient or the lack thereof and by transfer of heat to the snowpack.

For the purpose of grooming, the interfaces that most concern us are:

- ✓ The ground and the snow surface.
- ✓ The air just above the snow surface and the snow surface.
- ✓ The snow surface and the snow 1-2 cm below the snow surface.

- **Factors that affect the above interfaces are:**

- ✓ Incoming Ultra-Violet Radiation (i.e. Sunlight): This will heat up the snow and cause melting within the top few centimetres of the snowpack. The amount of warming depends upon the albedo (reflectivity) of the snow, the amount of impurities (dirt) mixed with the snow and the granular structure of the surface layers. Machine groomed snow is not highly reflective and therefore a large percentage of the incoming solar radiation is absorbed, which may create a significant temperature gradient within the top 2-3 cm or may allow melting of the surface layers.

- ✓ Outgoing Infra-Red Radiation: This cools the snow surface. In clear conditions, in midwinter, outgoing infra-red radiation may cool the snow surface at the same time as incoming radiation warms the snow beneath the surface, creating or enhancing a significant temperature gradient. During a clear, cold night, a crystalline deposit of surface hoar may form on the snow surface.

- ✓ Rain: Rain transfers heat directly to the snow. It may remain as liquid water in the snowpack.

- ✓ Wind: A warm moist wind results in heat being transferred to the snowpack. A dry wind, while causing the snow to evaporate at a high rate, transfers little heat into the snowpack.

d) Metamorphism

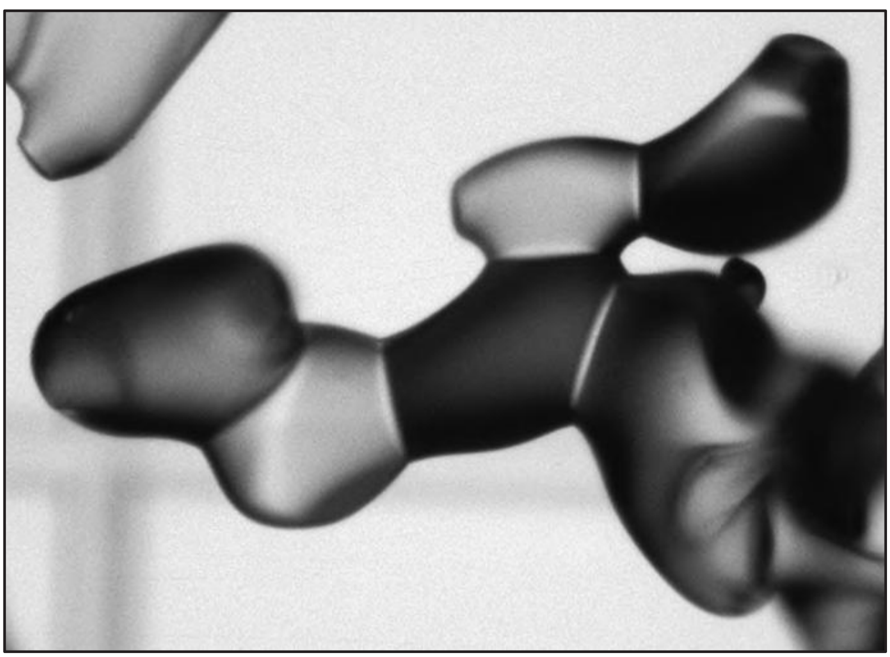
- **The Process of Rounding.** Snow begins to change as soon as it reaches the ground (or at higher temperatures, in the air before it reaches the ground). The rate at which it changes depends upon the temperature. Close to 0□C, the change is rapid. Below about -20□C, there is little discernable change from day to day.

When outside temperatures are moderate or when the snowpack is deep, the temperature gradients within the snowpack will be small. Snow will then change by a process known as "rounding". The natural process of minimizing surface area breaks down the intricate

crystalline snow structure of the ice crystals into smaller, more rounded ice grains. At the same time, because of the reduction in volume of the snow particles, the snowpack consolidates and settles. When snow is first deposited, it is light and fluffy, the crystal branches interlocking to form a cohesive mass. The snow during this period is stable and will remain plastered on steep slopes and rock bands. After a period of time, water molecules are transferred by vapour movement from the extremities to the body of the crystal. The destruction of the interlocking branches results in a critical period during which the snow becomes unstable. Eventually, the ice grains lose all sign of their previous crystalline structure and become more and more rounded. The larger ice grains grow at the expense of the smaller particles, resulting in a uniformity of size within each snow layer.

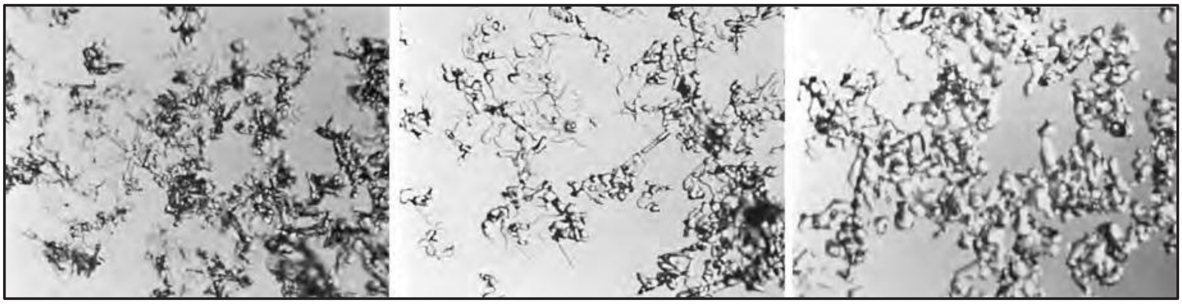
- **How Snow Gains Strength and Density**. You've probably noticed that soft, new snow, when packed, will harden overnight. Necks form between the ice grains forced into contact with each other. The process where snow gains strength by the joining of ice grains is called "sintering".

Figure 2.1: Sintering



In the case of the ski trail, the snow crystals or ice grains are forced close together by the mechanical compaction of your grooming equipment. Because vapour pressure is higher over a convex surface than over a concave surface, water molecules move from the air above the convexities to the air above the concavities. More molecules sublime from the ice surface to replace those lost above the convexities. At the same time, the air above the concavities becomes supersaturated and molecules are deposited on the surface. On re- warming, the necks between the ice grains will be reduced, weakening or destroying the bond between grains.

Figure 2.2



Newly fallen snow (left image), starts to loose its crystalline form as rounding of the ice crystals takes place (centre image). The ice crystals take on a rounded form (right image) becoming ice grains. Sintering occurs and the snow pack settles and strengthens.

- **Importance of Density.** If your trails are to stand up to their intended use, you should pay attention to the density of the groomed snowpack. The following table of densities gives typical snow densities and indicates suitable densities for various levels of use. Kilograms/ cubic metre (Kg/m3) is the usual measure of density.

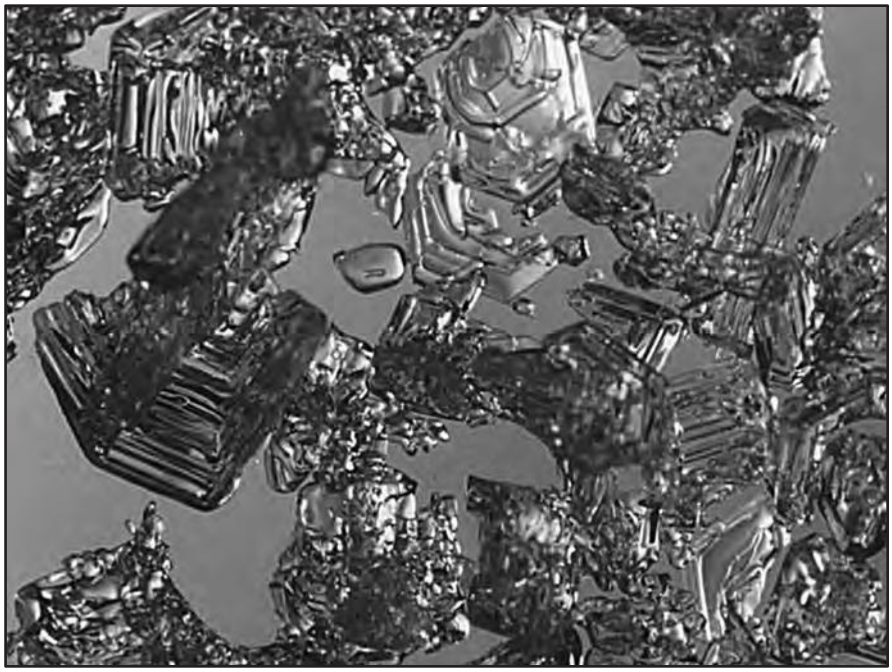
✓ New snow	150 - 200 Kg/m3
✓ Wind-packed snow	250 - 300 Kg/m3
✓ Packed with snowmobile alone	300 - 350 Kg/m3
✓ Support required for racing basket	> 350 Kg/m3
✓ Recreational trails - moderate use	450 Kg/m3
✓ Racing trails	500 Kg/m3 or >
✓ World Cup and higher events	540 - 560 Kg/m3
✓ Dog sled races	560 Kg/m3 or >

- **Recrystallization Due to Cold.** Crystal growth is the result of a relatively large temperature difference between two layers within the snowpack. For instance, the loose, sugar-snow, found in shallow, early-season snowpacks in some snow climates is the result of large temperature differences between the ground surface and the snow surface. In other cases, layers of loose snow grains may be found in the upper layers of buried crusts formed by a high temperature gradient between the warmer crust and the colder snow above.

  Depth hoar forms when vapour, due to a large temperature gradient, recrystallizes on the bottom of ice grains.

  Growth occurs because of an upward movement of water molecules within the pore spaces in the snowpack. The rounded ice grains formed at more moderate temperatures begin to take on a more angular form as water molecules move from the top of a grain and are deposited on the bottom of the grain above. This process is called recrystallization.

Figure 2.3: Depth Hoar



Recrystallization due to large temperature gradients is prevalent in colder climates early in the winter, when the snowpack is both shallow and unconsolidated. Extreme growth occurs when temperatures are very cold, below -20□C.

In denser snow, where smaller pore spaces allow little space for the growth of individual crystals, large temperature gradients result in faceted grains. In very dense snow, with small pore spaces, faceting may not occur.

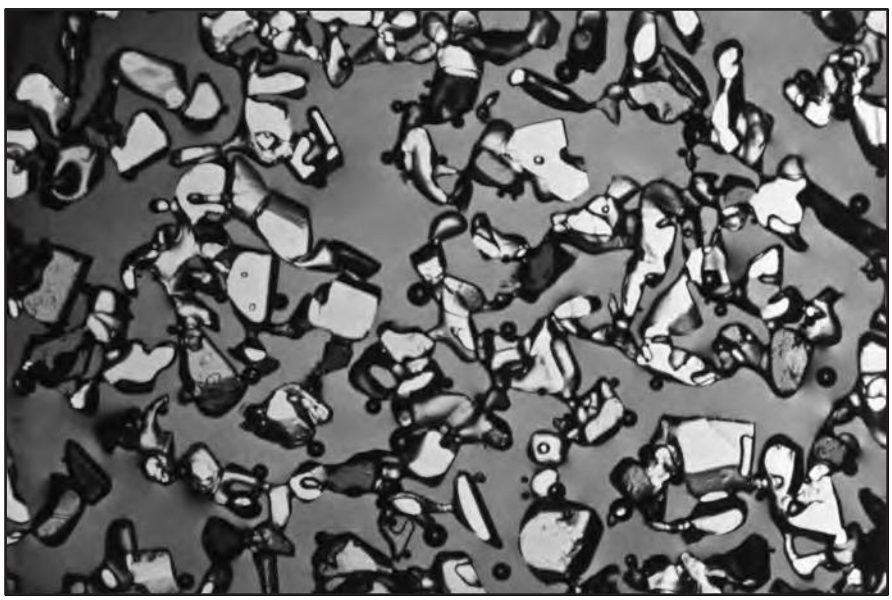
Grain shape classification recognizes several stages of the recrystallization process. The two main ones are faceted grains and cup-shaped crystals (depth hoar). For practical purposes we will limit the discussion here to faceted crystals. You should not encounter depth hoar in your trail system unless you have neglected your grooming.

- **Faceted Grains**. The formation of faceted grains marks the beginning of crystal growth, which is characterized by the development of angular grains with flat crystal faces or facets, just like the faces on a cut diamond. As long as there is sufficient temperature difference between individual grains in the snowpack, crystal growth due to the temperature gradient will successfully compete with the tendency for rounding. If the size of the initial ice grains is large enough and the pore spaces big enough, the process of crystal growth will continue and large cup crystals with well-developed stepped surfaces will form. These large crystals are called depth hoar.

In cold weather, some faceting occurs in the lower layers of almost all shallow snowpacks. How much the process will weaken the snowpack depends upon the temperature, the temperature gradient and the density of the snow. As temperature gradients moderate as a result of further snowfall or warmer temperatures, the process of rounding will prevail and the snowpack will be strengthened due to sintering. However, if cold conditions continue, and the snow is not too dense, depth hoar will form, substantially weakening the base of the snowpack.

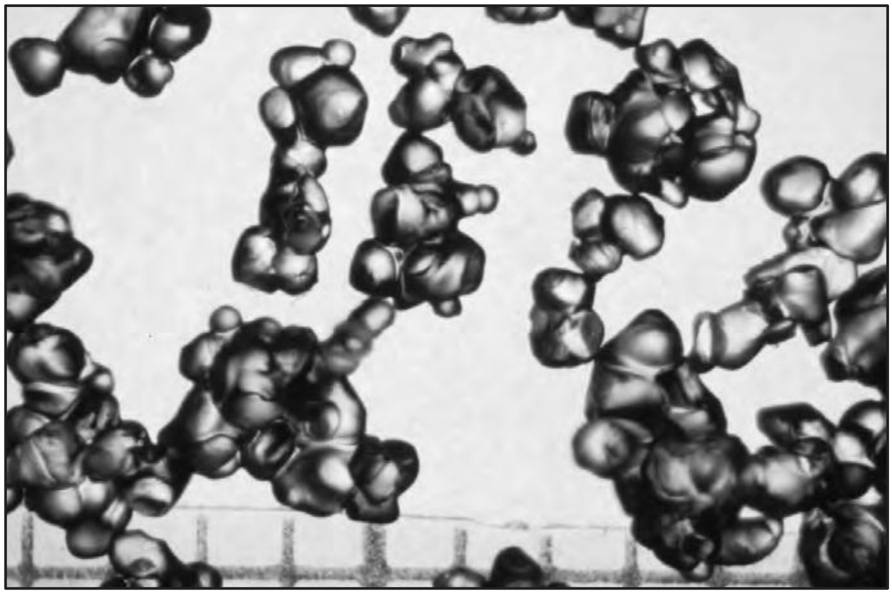
- **Hoarfrost**. Hoarfrost is a bright, sparkling crystalline growth of crystals which can be found on, above or in some cases below the snow surface. It is formed in much the same way as snow crystals, and could be considered the snow equivalent of dew. What happens is that daytime radiation allows the air above the snow surface to hold a substantial amount of water vapour. On a cold clear night when the snow surface is cooled by loss of heat to the atmosphere, the air becomes supersaturated with respect to the ice, and water vapour condenses on the snowpack to form a crisp, crystalline coating that will slow down a skier's skis. In cold northern climates, this sandpaper-like frosting can form in a matter of hours, and will persist in cold, clear conditions unless skied off. In competitive skiing, this is one of the primary purposes of forerunners.

Figure 2.4: Faceted Grains



- **The Melt-Freeze Process**. When the sun is sufficiently strong to melt the top layers of the snowpack during the day, and when night-time temperatures fall below 0C, cycles of freezing and thawing will occur. In this process, called "melt-freeze metamorphism", smaller grains will melt before larger ones, and so during the course of a number of melt-freeze cycles larger grains will grow at the expense of smaller ones. The meltwater wetting the surface of these larger grains eventually re-freezes and firmly cements the grains together. MF-grains have a tendency to freeze together in clusters, leaving large pore spaces unless some packing is done.

Figure 2.5: Clusters of Melt-Freeze Grains



e) Types of Snow

1- Falling or Newly Fallen Snow

- ✓ In Cold Conditions (-1°C and Lower): Low density snow, highly crystalline, possibly interlocking crystals, matting, building up on trees, etc. This type of snow will be hard to pack if you allow it to get too deep. Such snow packs well in 4-6" layers at temperatures close to 0□C. It is more difficult to pack as the temperature decreases.

- ✓ In Warmer Conditions (0°C and Above): Wet heavy snow, with little remaining crystalline form. If accompanied by wind, this type of snow is plastered on trees, signs, buildings, etc. It packs easily into a hard, dense layer at temperatures close to freezing. It may turn to slush at higher temperatures.

2- Partially Settled Snow (Fresh Powder). This type of snow has begun the rounding process and, if left alone, will settle and strengthen naturally over a period of time as pore spaces are reduced and sintering takes place. Mechanical disturbance such as blading, tilling or packing will reduce the air spaces by pushing the ice grains closer together, allowing better sintering. The snow, now "machine-groomed powder, becomes both denser and stronger.

3- Settled Snow. Grain size becomes smaller and more uniform. Pore space decreases, sintering increases and density increases. The ability of the snow to recrystallize due to large temperature gradients, and hence loosen-up, is reduced due to smaller pore spaces. In continental snow climates (Alberta and the Rockies, Saskatchewan, Manitoba, Yukon, NWT), a well-packed trail system will not have recrystallization problems. Pack early and well.

4- Dry Granular Snow. There are three possibilities:

- ✓ Faceted Surface Grains. This is unlikely at low elevations (i.e. most cross-country ski areas).

- ✓ Faceted Grains (In Bottom of Snowpack). This is common in continental snow climates, but will not be a problem if trails are well packed.

- ✓ Re-Frozen Melt-Freeze Grains. These are enlarged grains produced by several cycles of melting and freezing. This may be a loose surface layer, but more likely will be frozen clusters that will break up as temperature rises and skier traffic increases. When partial melting has occurred (free water content <8%), it is known as "corn snow". Excessive grooming will tend to loosen and enlarge these grains.

5- Corn Snow. This snow consists of frozen, loose melt-freeze grains. See "Re-Frozen Melt- Freeze Grains" above.

f) Surface layers of refrozen melt-freeze grains can be reconstituted in two ways:

1- Mix with fresh snow; either new snowfall or old dry snow from layers beneath the granular layer.

2- Using a gyro-groomer to mill the snow. This reduces the size of the particles, allowing densification and sintering to take place.

If melt-freeze cycles continue, the snow will eventually become sloppier when unfrozen and icier after freezing and renovation will be needed. There is little you can do at this stage to alter the physical characteristics of the snow grains. Tilling will help to dry out the snow by exposing more surface area to evaporation. Wind will speed up this process.

REFERENCES

Akitaya, E. (Figure 2.4), *Faceted Grains*, The Institute of Low Temperature Science, Sapporo.

Perla, R. (Figures 2.1 and 2.5), *Sintering, Clusters of Melt-freeze Grains*.

La Chapelle (Figure 2.2), USDA Avalanche Handbook (1976).

Daffern, T. *Snow and Weather Terminology for Cross-Country Ski Competitions*.

Masson, A. Shop Set Up.

Daffern, T. (2000) *Avalanche Safety for Skiers, Climbers & Snowboarders*, Rocky Mountain Books.

Avalanche.org (Figure 2.3).