Introduction

The Canadian technical approach to skiing is a result of the evolution of the sport. Even if equipment has changed since the first skiers hit the slopes, the laws of physics have not.

Many of the forms of balance and movements of contemporary skiing can be traced back to McCullough of the 1950s, Killy in the 1960s, and Stenmark through the 1970s into the 1980s. Tomba and Maier led the way to the new millennium, with Raich and others continuing to define efficient ski technique. They all showed the world the best way to ski with the equipment of the day, and all of them balanced according to physics and biomechanics.

The sport of skiing can be defined by science, but the best development tools are practical and effective. In both competitive and recreational skiing, instructors and coaches have developed systematic approaches to analyzing and developing skiers.

The building blocks of the Canadian Approach stem from the combined efforts of thousands of people in two organizations (CSIA and CSCF) who have worked with these ideas through ski schools or coaching.

The concepts presented here result from people sharing ideas on skiing, and looking for better ways to teach or coach.
Chapter 3

**Physics and Skiing**
- Forces in skiing
- Balance while sliding and turning
- Moving on an arc

**Biomechanics and Skiing:**
- Stability
- Maximum force
- Velocity
- Impulse
- Direction
- Angular motion
- Angular momentum

*Skier:* Thomas Grandi  
*Photo:* Courtesy of the Canadian Alpine Ski Team
Physics and Skiing

In many sports, speed and forward motion are a result of internal muscular effort. In alpine skiing, gravity provides the pull, and the skier uses movement and muscular effort to influence speed and direction.

Defining Efficiency

With gravity as the primary motive force, speed in skiing has much to do with reducing braking. Carefully timed muscular effort can also contribute to speed, if the skier “pushes” in a way that complements gravity.

From a technical perspective, there are two criteria for skiing success:

- The ability to choose and maintain a trajectory. For racers, the line is imposed by the race course. Recreational skiers choose it according to terrain and the desired outcome.

- Efficiency: For racers this means speed. For recreational skiers it means creating a direction change with the least amount of physical effort and resistance.

For skiers of any level, maintaining momentum and conserving muscular effort while controlling direction change, produces balanced, relaxed and controlled skiing. The skier can generate and/or maintain speed wherever possible, and can control speed when necessary or desirable.

Francois Bourque, World Cup GS, Are (Sweden), 2006, Photomontage by Ron LeMaster
Movement and Motion - 25 Years as a Technical Perspective

The concept of Movement and Motion was introduced by the CSIA at Interski in 1983. It provides a perspective on the sport of skiing, and still successfully explains observed movement patterns at all skill levels and situations.

Movement and Motion defines balance in skiing as the relationship between the centre of mass (COM) and the base of support (BOS). Movements are what the skier does to influence the line of motion, or the path of the COM. As the mass moves down the slope, it seeks the path of least resistance, or the most direct line. To change direction, the skier places the skis, or BOS, at an angle to the trajectory of the COM and edges them. Skiing on an arc is a series of deflections, with the BOS supporting and deflecting the COM on every point of that arc.

With the goal of following a chosen trajectory at a chosen speed with the least possible resistance and muscular effort, the skier must move constantly to maintain balance and control direction change.

Technique vs. Methodology

It is valuable to make a distinction between the technical analysis of skiing and the practical approaches to developing skiers.

According to the principles of physics and biomechanics, technique is the theoretical or scientific analysis of balance and movement patterns of a skier.

Methodologies are the practical tools and approaches to skier development.

A good technical understanding does not necessarily imply an effective working method. However, an effective working method will be based on a good technical understanding, and it will be simple and effective.
Forces in Skiing

On a slope, gravity is divided into two components. One portion acts perpendicular to the slope and is opposed by an equal and opposite reaction force. The other portion of gravity acts parallel to the slope and pulls the skier forward down the hill.

Opposing these forces is the friction between the skis and the snow, and the friction of air against the skier.

Turning involves other forces. As defined in Newton’s first law, the natural tendency of a mass is to move in a straight line. To deflect the mass, the skis are placed across the line of travel and the skier provides a resistance (centripetal force). Deflecting the mass from a straight line creates an inertial pull towards the outside of the turn (inertial force).

Combined Forces

Above the fall line, turning forces and gravity pull in different directions, and after the fall line they combine. The various combinations of gravity and turning forces is what the skier is balancing against and determines the degree of lean, or inclination, at any point in a turn.
**Balance While Sliding and Turning**

Balance is defined in terms of the relationship between the centre of mass and the base of support. The COM is supported by the BOS at whatever angle is appropriate to resist outside forces.

**The Centre of Mass**

All bodies have a centre of mass. The COM represents the balance point of a three-dimensional object. Gravity and all other forces act on the COM.

The COM is usually inside an object but not always. In a doughnut for example, the COM is in the hole. It may actually be outside an irregularly shaped object.

The COM is not a fixed point, and moves as an object changes shape. In skiing, any body movements displace the COM. Due to the weight of equipment the COM is lower in a skier than a non-skier.

In efficient skiing, movements are controlled to maintain a smooth trajectory for the COM both within the body and down the slope. Good balance implies a smooth trajectory of the COM and unnecessary movements disrupt this.
**The Base of Support**
For a body to balance, the forces acting through the COM must also act through the BOS. This means the BOS supports the COM.

The BOS is the area between all points that support the body. A wider stance broadens the BOS, and increases stability. A pole plant also momentarily increases the BOS.

Balancing over a smaller BOS is also possible, although the forces required to push the skier over are less. A smaller BOS gives a smaller margin for error.

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**Maintaining Balance**
A skier balances with continual series of adjustments in anticipation and reaction to the forces encountered.

To stay in balance, the skier must be able to adjust either the COM or BOS quickly. Because the lower body has less mass than the upper body, quick adjustments are often made with the feet (BOS).

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**Overcoming Resistance**
Heavy snow, skidding, edging or bumps can continually or momentarily increase ski/snow friction, or resistance. To stay in balance, the skier compensates by moving the BOS forward relative to the COM so that forces continue to act through the middle of the ski.
Moving on an Arc

When moving, the COM has momentum. At any point on an arc, the COM wants to fly off in a straight line called a tangent (line of momentum).

The angle between the line of momentum (tangent of the arc) and where the skis are pointing is called a steering angle. A larger steering angle means the skis are turned more across the direction of travel and implies more skidding. A smaller steering angle means the skis are turned less across the line of momentum and implies a cleaner track. How much the skis are turned across the line of travel depends on the desired trajectory, and whether the skier wishes to decrease, maintain, or increase speed.

Ski sidecut provides a built-in steering angle between the centre axis of the ski and the flare of the tip. This steering angle decreases the length of the ski, hence the tips provide more turning potential than underfoot or the tail of the ski. This provides the self-steering effect of today’s skis.