Chapter 3

Anatomy and Biomechanics:

Fundamentals Applied to Skiing

Federico Sollini

"*They call it coaching but it is teaching. You do not just tell them…you show them the reasons.*"

Vince Lombardi

Learning Objectives – At the end of this chapter you will be able to:

- Have a general understanding of the body anatomy and its implications in skiing.
- Understand how body alignment can affect ski technique.
- Understand how skiing is a sport of physics.
- Understand how physics and anatomy dictate how ski technique is established.

List of Topics:

- Human Anatomy.
- Muscles and Joints.
- The Foot/Ankle.
- The Knee.
- The Pelvis and Hips.
- Misalignments: Pelvis and Legs.
- Physics in skiing.
- Applications in skiing.

Introduction – The reason behind this chapter

This section of the manual wants to provide a general knowledge on how the human body is made, how it moves and how this affects skiing at all ability levels.

Holding a basic knowledge of how the body works is essential to understanding how we can affect our performance, by training accordingly, as well as how the limits in our top performances can come from our own body rather than external factors.

Aware that this subject can be difficult to digest, we will try to point out cause and effect at each stage of the presentation. The aim is to provide information that can be applied to everyday life on skis.

As snowsport professionals **this knowledge is useful on two main fronts**:
- **on a personal basis**: To excel in the demonstrations performed while teaching or free skiing.
- **on a working basis**: To better guide a learner during the lesson.

Often the limits in performance, whether we are a high level skier or a beginner, are dictated by physical limitations rather than technical abilities.

This section on anatomy and biomechanics will also redirect the reader to the physical preparation section, as the two subjects are directly correlated, and one cannot be put into useful practice without the other. As well, we will try to make connections between the anatomy parts and their implications in skiing, linking an otherwise 'abstract' subject to more tangible scenarios.

Part 1

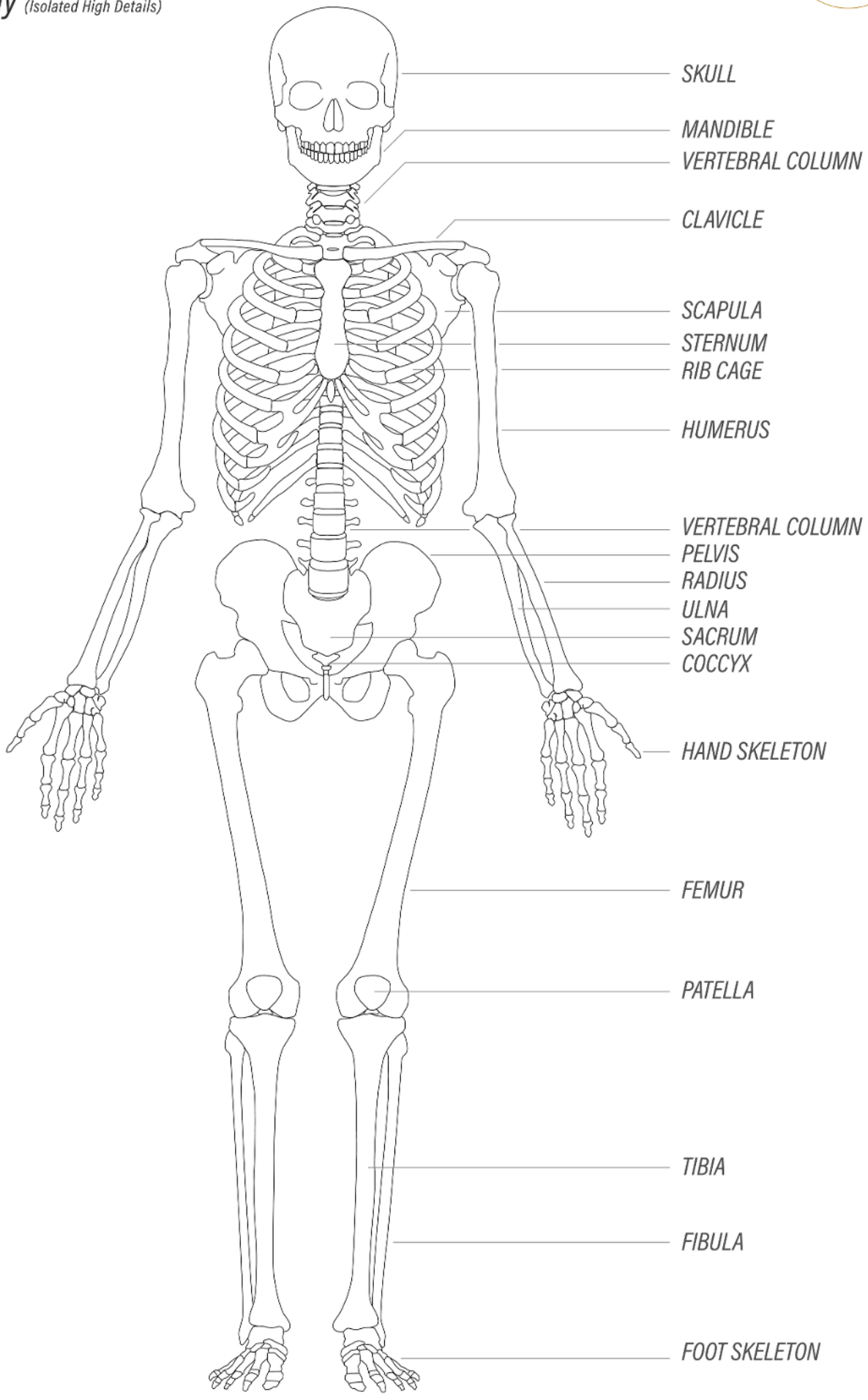
Human Anatomy

Anatomy is the science that studies how the organism is structured and what it is made of.
For the purpose of this manual we will leave behind the vital organs and concentrate on the body parts directly responsible for our stance and movements: **the musculo-skeletal system**.
This system consists of the **muscles, tendons, ligaments, joint and bones.**

Bones	the most rigid part of the structure, they constitute the skeleton system.
Joints	section of the body where the bones come together.
Ligaments	connect one bone to another bone.
Tendons	connect the muscles to the skeleton.
Muscles	tissue structure with the ability to contract, allowing the bones to move.
Nerves	channels through which the voluntary and involuntary contraction signals are sent through.

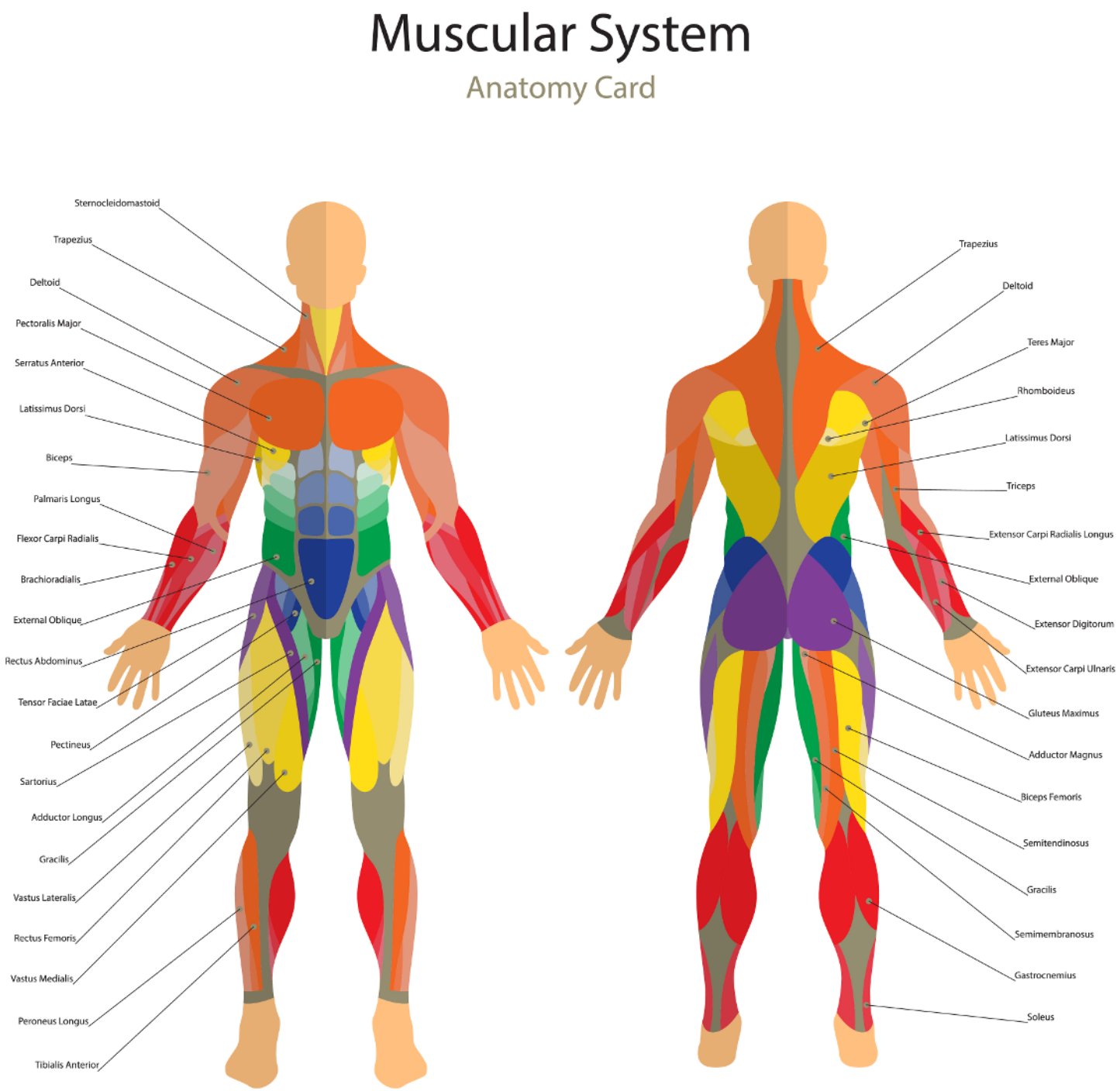
THE HUMAN SKELETON

Anatomy Study *(Isolated High Details)*

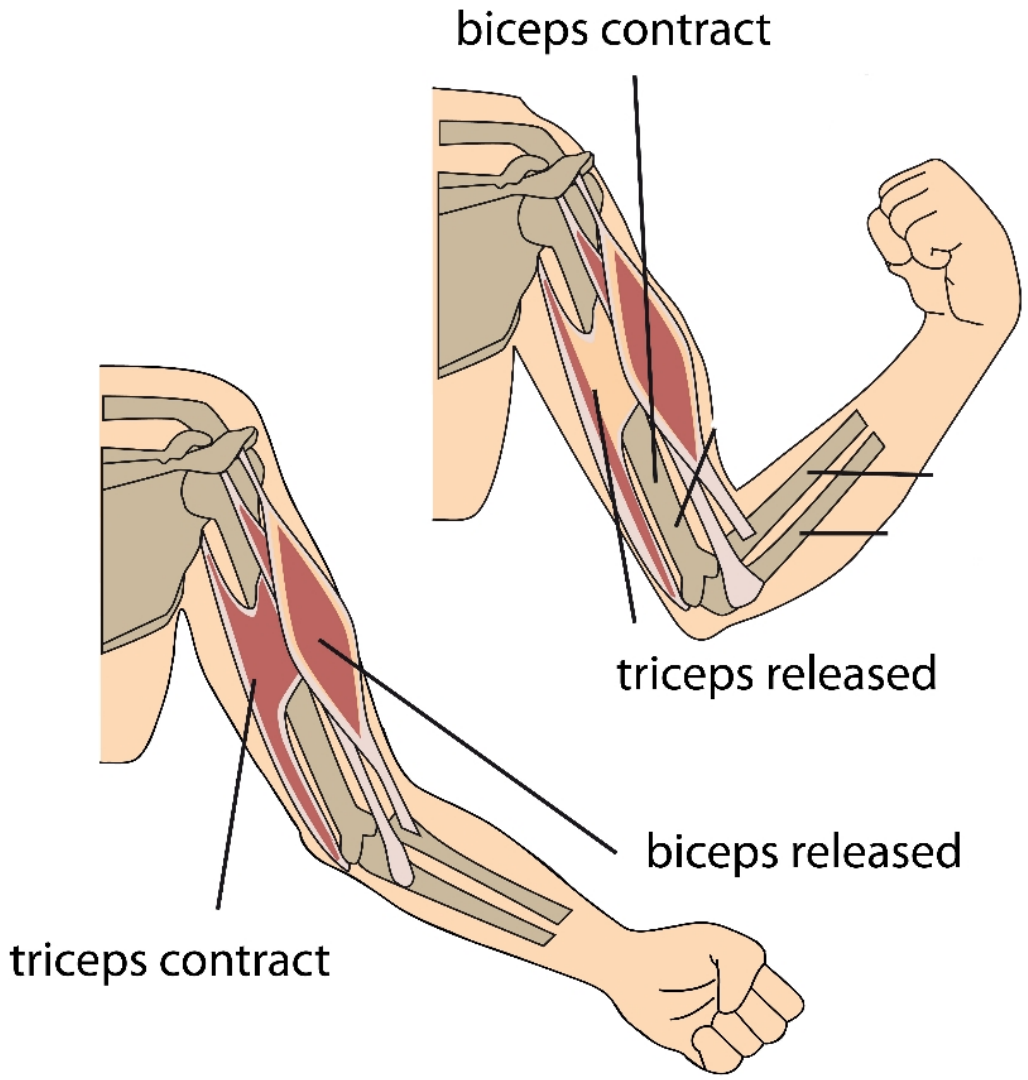


Muscles

Through our nervous system we can only control the contraction of the muscles, all other parts move as a consequence. This is important to keep in mind when we refer to any movement as we are referring to a contraction relationship between alternated muscles, as **each muscle can only pull and not push**. To straighten our right leg while sitting down, we consciously tell the quadriceps to contract, but we are also telling (less consciously) the hamstring to relax and stretch, to allow the bones around the knee joint to move.



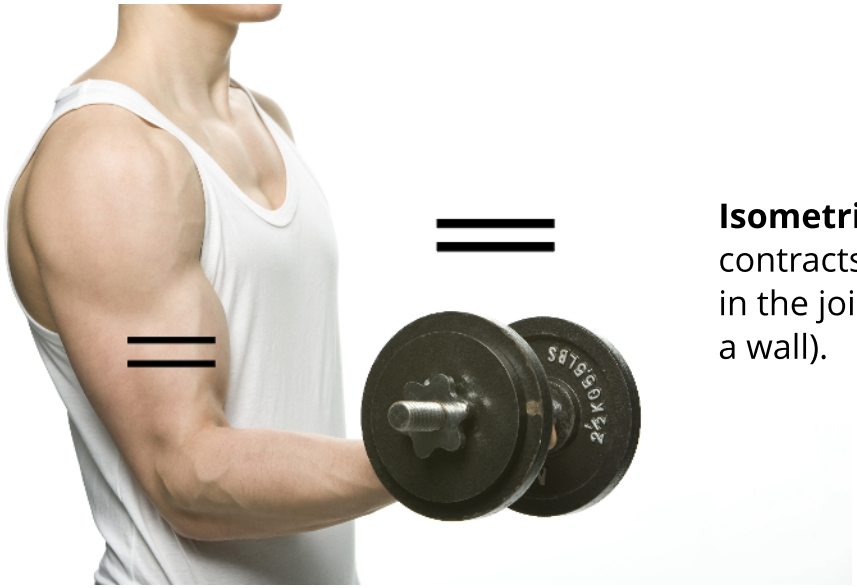
This is an important factor to remember, as **performance is dictated not just by the 'strength' in contracting but also by the ability of extending the opposite muscle** (Range of Motion (ROM) + Flexibility).
Each single muscle will have an opposite one, called **antagonistic muscle**. Keeping the correct ratio between them is of fundamental importance in reaching higher performance.



Muscular Contraction Types

Concentric contraction: When a muscle shortens its length, producing a movement in the joint.

Eccentric contraction: When a muscle extends its length, producing a movement in the joint.



Isometric contraction: When a muscle contracts without producing a movement in the joint (the effect of pushing against a wall).

Where do they fit in skiing?

Isometric contractions are used to hold a certain position, so at each given moment our body is performing an isometric contraction, sometimes so gentle that we don't even realize it (your current head position while reading). Stress and psychological tension can also provoke strong isometric contraction, any scared skier will contract more than a non-scared one, for example.

In order to hold a **static basic position** on skis we rely on isometric contractions.

Taking the legs as an example, starting from a static basic position **when standing up we perform a concentric contraction** of the quads. **When lowering down, we perform an eccentric contraction** of the quads.

Muscles are stronger in an eccentric contraction. This is one of the reasons it's easier, muscle wise, to end up in the back seat (eccentric movement) rather than coming up from it (concentric movement).

Correct training (on and off the slopes) should increase general body awareness. By either guiding the guest or through self discovery, every instructor should learn to feel the body moving and the muscles contracting. If we are aware of our body standing or moving we have greater chances of understanding how to create the correct technical gesture.

Joints

There are 6 types of joints in the body, which allow the bones to move in a certain direction. Each joint has a form of liquid (synovial) or padding (cartilage) to keep a minimal distance between the bone heads. Protecting this padding is essential to guarantee a long life of skiing, or any other movements.

Ball and Socket Joint	allows the most movement of the joint (shoulder, hip).
Hinge Joint	allows bones to move back and forth (ankle, knee, elbow).
Sliding Joint	allows small movements of the bone (vertebrae, carpals, tarsal).
Condyloid Joint	allow movements on two axis (wrist).
Pivot Joint	allows rotational movement (forearm).
Fixed Joint	does not allow any movement (skull).

Foot

In each foot alone we find 26 bones and 100+ muscles, joints, ligaments and tendons. Each movement of the foot and the toes is a result of many mobile parts collaborating with each other.

Balance starts from here and it's essential to keep this body part in health.	This also goes through a **correct placement inside the ski boots**, that needs to be adapted to the skier and should not be too constrictive.

Ankle & Foot

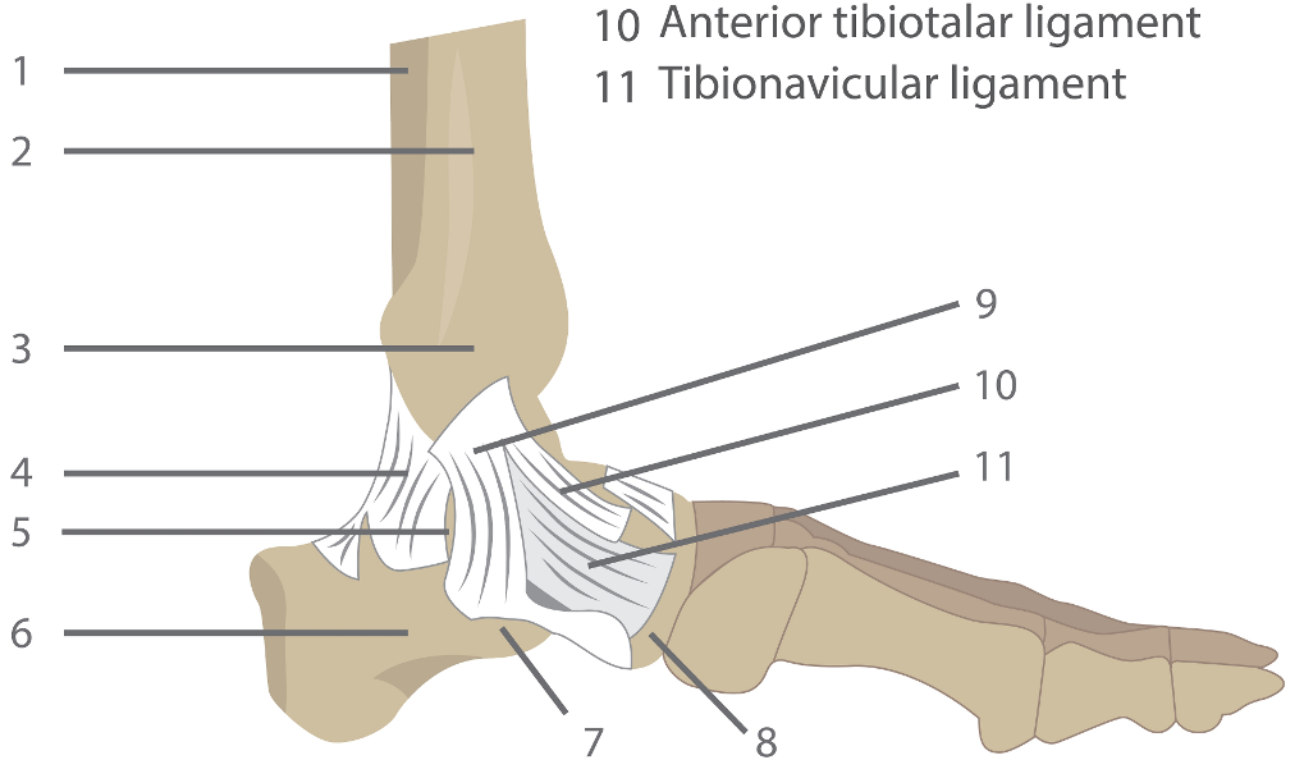
Dorsi-Plantar Flexion

The hinge joint of the ankle allows us to move the **foot upwards (dorsiflexion)** or **downwards (plantarflexion)**. Again, this movement is dictated by muscles above and below the foot as well as muscle around the shin.
- the average range of movement is between 8 and 20 degrees.
- the average forward upper cuff angle in ski boots is between 12 and 17 degrees.

Being able to find the '**neutral stance**' in ski boots is a fundamental element of ski performance. However, ski boots are still limiting the overall ROM of the joint, so specific training is advised to maintain healthy ankle mobility.

ANKLE anatomy

1 Filbula
2 Tibia
3 Medial malleolus
4 Posterios tibiotal ligament
5 Talus bone
6 Calcaneus
7 Sustentaculum tall of calcaneus
8 Navicular bone
9 Tiblocalcaneal ligament
10 Anterior tibiotalar ligament
11 Tibionavicular ligament



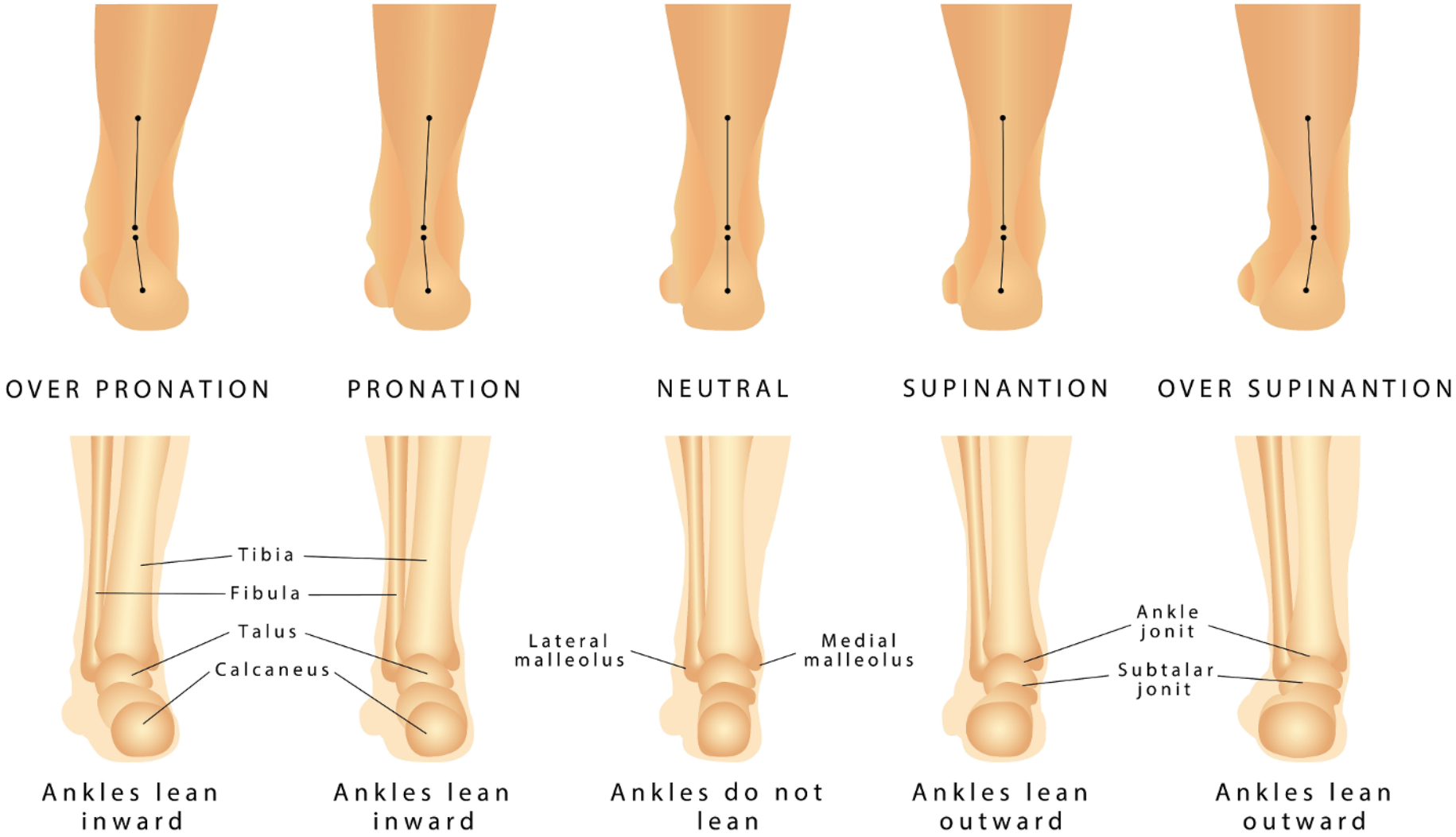
In skiing the fore-aft and tilt (edging) movements are initiated and controlled from these joints upwards

Pronation – Supination

The combination of another joint (subtalar) allows us to move the foot in two other directions:

Pronation: Turns the foot inwards, sending the big toe lower than the little toe.

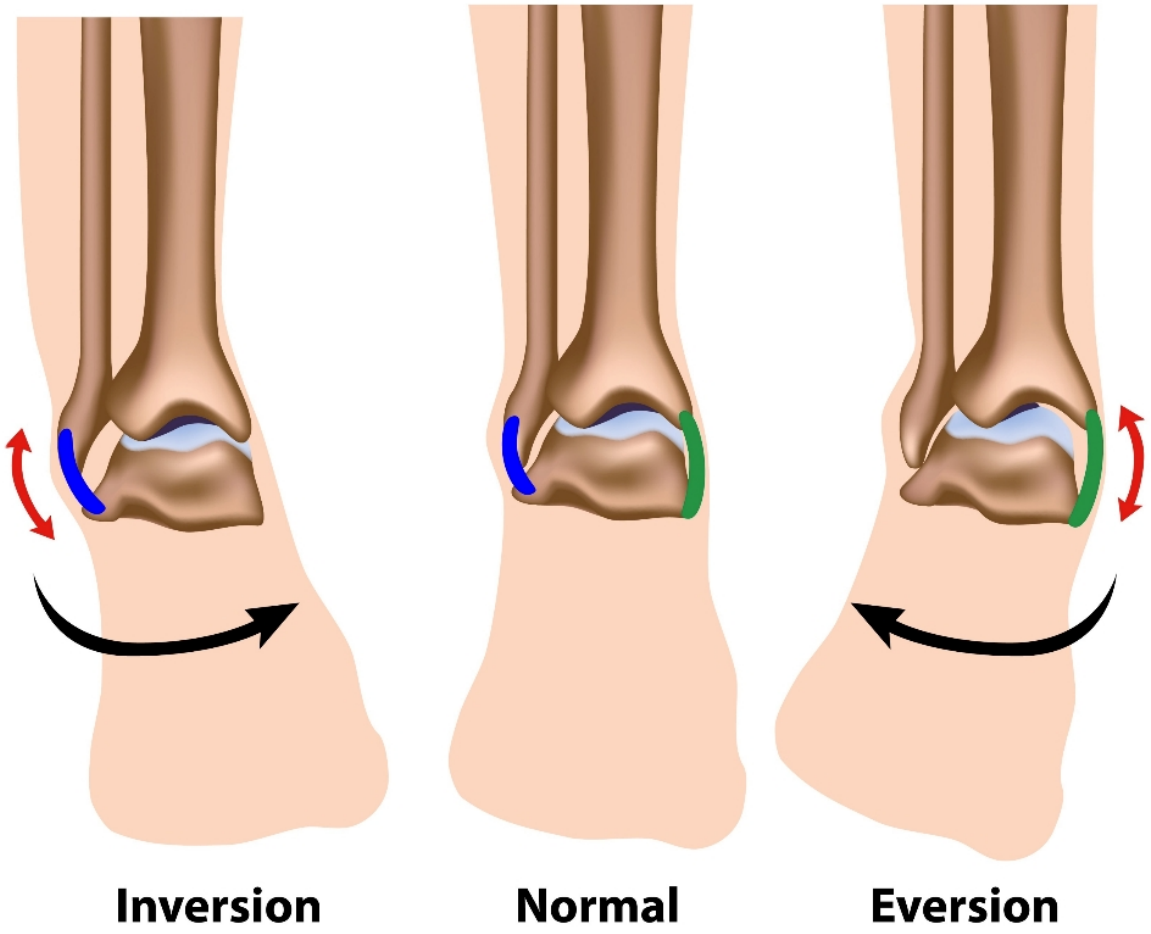
Supination: Turns the foot outwards, sending the big toe higher than the little toe.



Combining these with a rotational movement we also have:

Eversion: Foot goes outwards combined with a lateral rotation.

Inversion: Foot goes inwards, combined with a medial rotation.



These movements are required to find better contact and control edge-snow. As well as, of course, **overall balance in response to all other movements**.

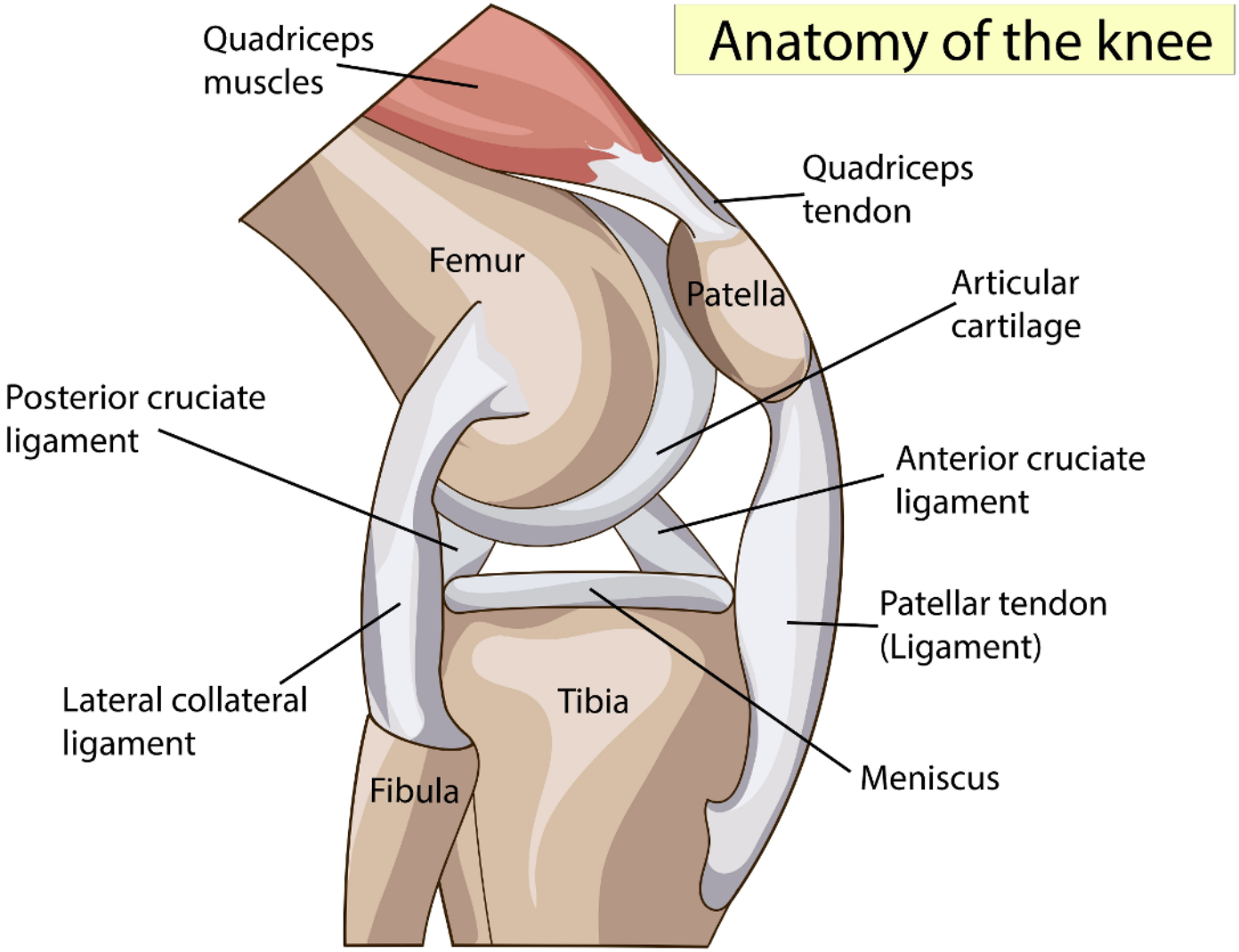
Ski boots, again, are constrictive in this ROM, so it's important to have the correct fit and correct underfoot support. In relation to this it's also important to point out that the foot works on a **tripod**:

It is over this tripod that we find balance. It is essential for every skier to be aware of these points of contact with the ground and work towards better balance from here upwards.

In terms of ski boots choice and foot support it really is up to the individual and to his/her general posture and foot set up to decide which support is more appropriate.

Knee joint

The knee is also a hinge joint, which **allows flexion and extension movements**. There is a very minimal amount of rotational and lateral movement, which is often confused with the rotation of the femur inside the hip ("point the knee in the direction of travel/inside the turn" is actually done by the femur not the knee).



In skiing the **fore-aft movement is started at the foot-ankle** and then supported by the rest of the body muscles and joints, also through the knees. Because of the flexion and extension ROM the knee and its muscles allow the upper mass of the skier to shift forward or backwards in the sagittal plane.	It is important to notice that, as well as correct technique, the knees **ligaments can be protected by tendons and muscles** of the legs. These, however, need to be maintained in the correct strength ratio, as all muscles need to balance each other off to work together in synergy (correct ratio between quads and hamstrings, for example).

Pelvis and hip joints

The hip is the **meeting point between the upper body and the legs**, playing a crucial role in the balance, health and the successful performance of the full body.
For this reason, it is important to have the correct ROM in all directions (flexion, extension, adduction, abduction, medial and lateral rotation) of the femur head inside the pelvis.

In skiing the rotational movements of the lower legs are initiated by the feet but are actually carried out, in the wider ROM, **by the rotation of the femur inside the hip**. So, it's the full length of the leg that rotates, and not just the foot or just the knee on their own.	The pelvis, sometimes confused with the hips, is the bone onto which the femur locates itself. Pelvis and femur-head find each other in the hip joint. The upper part of the pelvis is connected to the spinal column, via the sacroiliac joint. **This means that any imbalance of the spine can affect the legs and vice a versa, leg issues can affect the spine.** The spinal column has 33/34 vertebrae, connected together by discs that allow a great amount of movement. It presents three main curves, needed to absorb impact and carry the weight of the rest of the body.

Part 2

Misalignments and implications in skiing

Pelvis

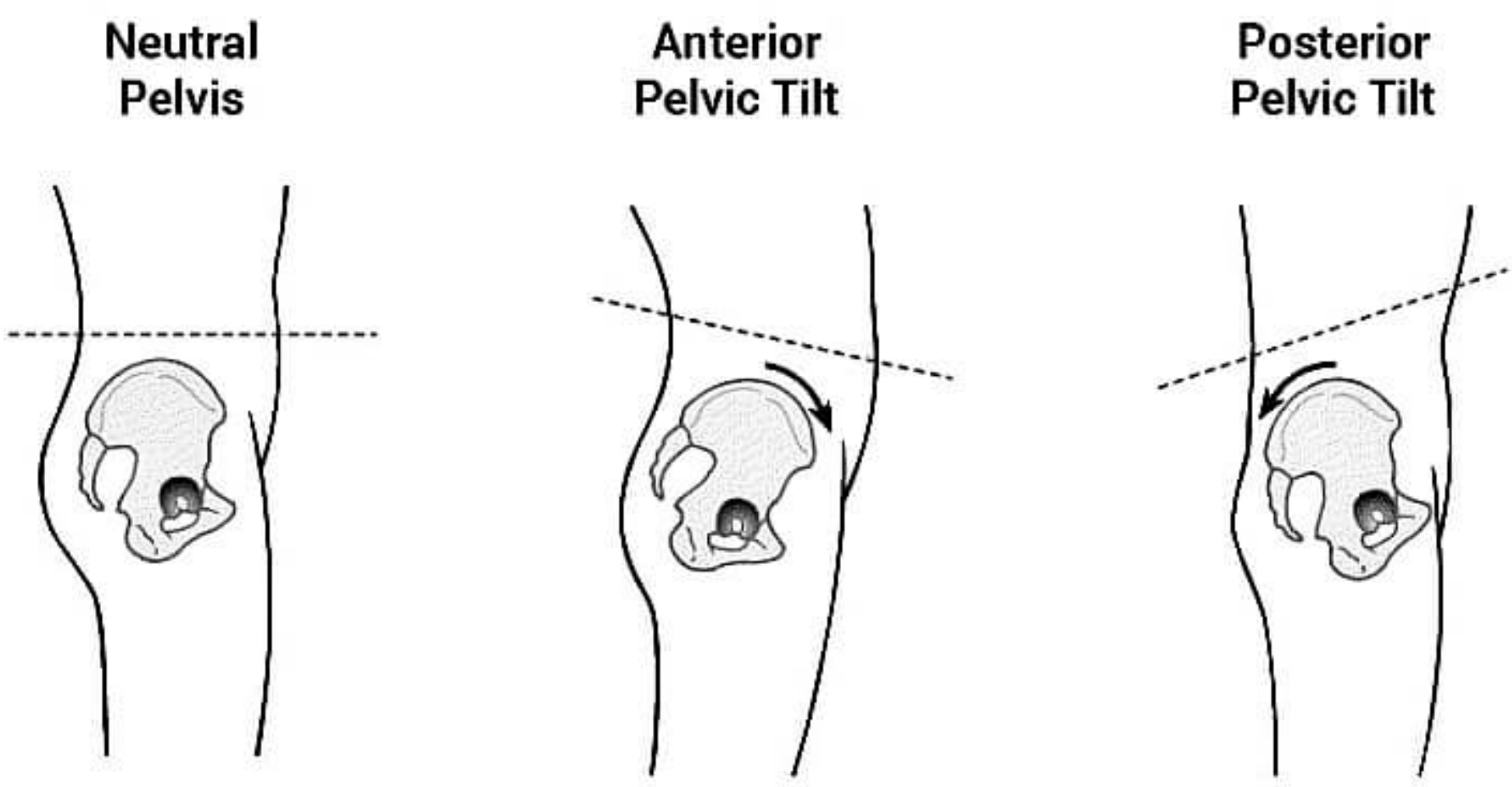
Any misalignment in the pelvis or the spinal column has direct and evident consequences in skiing. These need to be taken into consideration when teaching and training as they can be the most limiting factors in the technical progression.

Anterior pelvic tilt:

Showing a **downwards tilt in the pelvis**. This stance is often considered to be the 'athletic' stance. An over done anterior tilt though is the first cause of lower back pain, as **the spine is forced in an excessive curve at the lumbar area**.
When this tilt becomes normal posture rather than a position, it will be a limiting factor on some terrain (moguls for example) as it limits the femur/hip ROM and can possibly cause injury.

Posterior Pelvic tilt:

Showing an **upwards tilt of the pelvis**. When present in a high degree it limits the 'athletic' stance, as it forces the upper body in a vertical position. By forcing the **lumbar region of the spine to straighten excessively** it is often the cause of sciatic nerve inflammation and pain. A posterior pelvic tilt can usefully be used in moguls, as it allows easier (comparatively) ROM of the femur/hip but also exposes the spine to injury.


Neutral
Pelvis
Anterior
Pelvic Tilt
Posterior
Pelvic Tilt

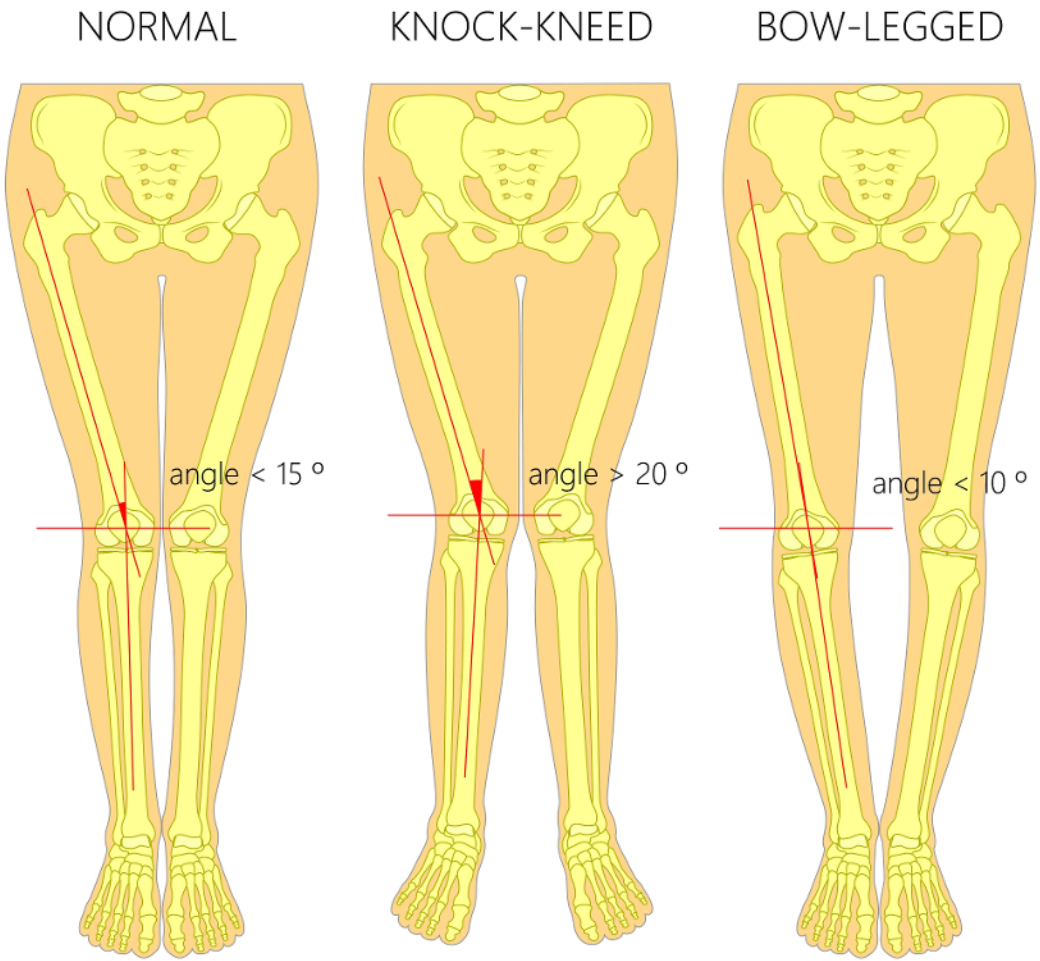
Legs alignment

Bow-legs (genu varum)

Knees are set apart from each other, creating an oval shape with the legs.

Knocked legs (genu valgus)

Knees tend to fall towards each other, creating an X shape with the legs.



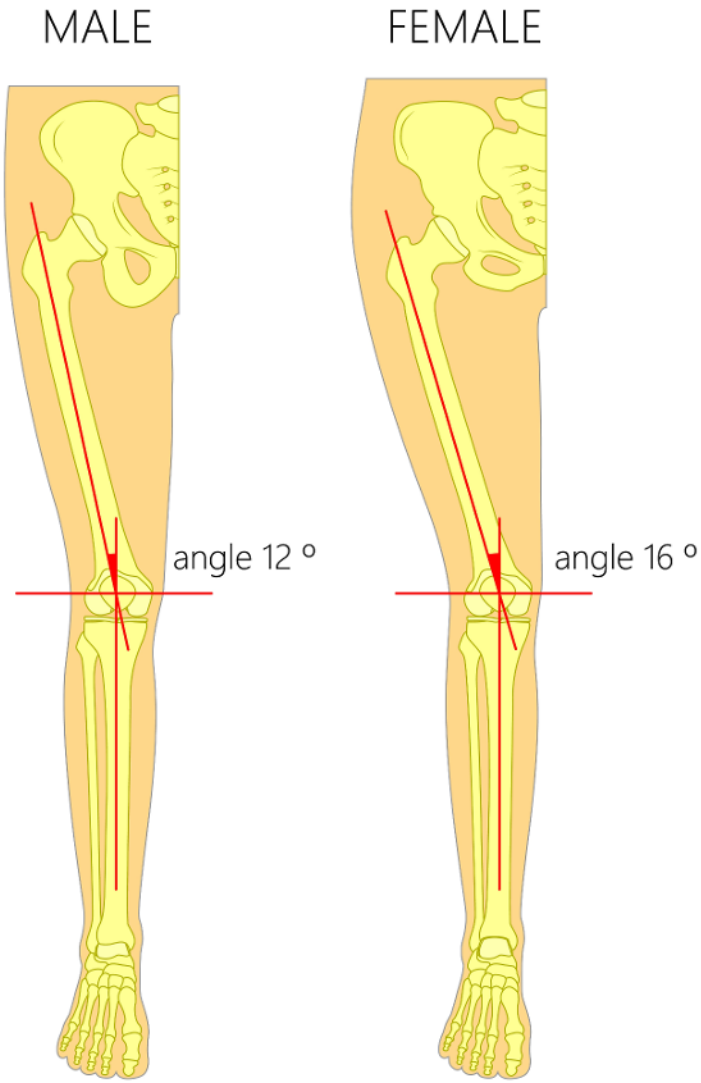
Q-Angle

Is the angle between the imaginary mid line from the thigh to the patella and the real mid line of the femur. This angle is often greater in women as they carry, in proportion, a wider pelvis than men.

Leg alignment can be helped while skiing, through the correct modification of ski boots. However, it's important to understand that ski boots are not an orthotic device and should not be used in the hope of changing the body alignment. By giving better support to the leg, customised ski boots can help the individual only in the purpose of skiing better and more comfortably.

Correct physical training and physiotherapy can greatly help the correct alignment of the legs as well as preventing the deterioration of a current misalignment.

While it is not the job of the ski instructor to correct all the above possible cases, **holding a general understanding of these postural situations can be of great help in finding the real cause of discomfort or technical limitation in the student's skiing progression**.



Part 3
Physics in skiing

Skiing is having fun with physics on snow. Physics we 'feel' even though we don't see and yet they are the reason why we enjoy the sport. We will have a look at what are the main forces and laws of physics we deal with every day on snow and how the body works in relation to them.

Forces can be:

Internal	created by the person through movement.
External	forces that act upon the skier, who will need to manage and proactively move in order to use them for their own benefit.

Gravity

We slide down the hill because earth's gravity pulls us downwards. Given all other variants fixed, the steeper the slope the more gravity can pull us down and have a pull-effect on the body.

Snow/Wind Resistance

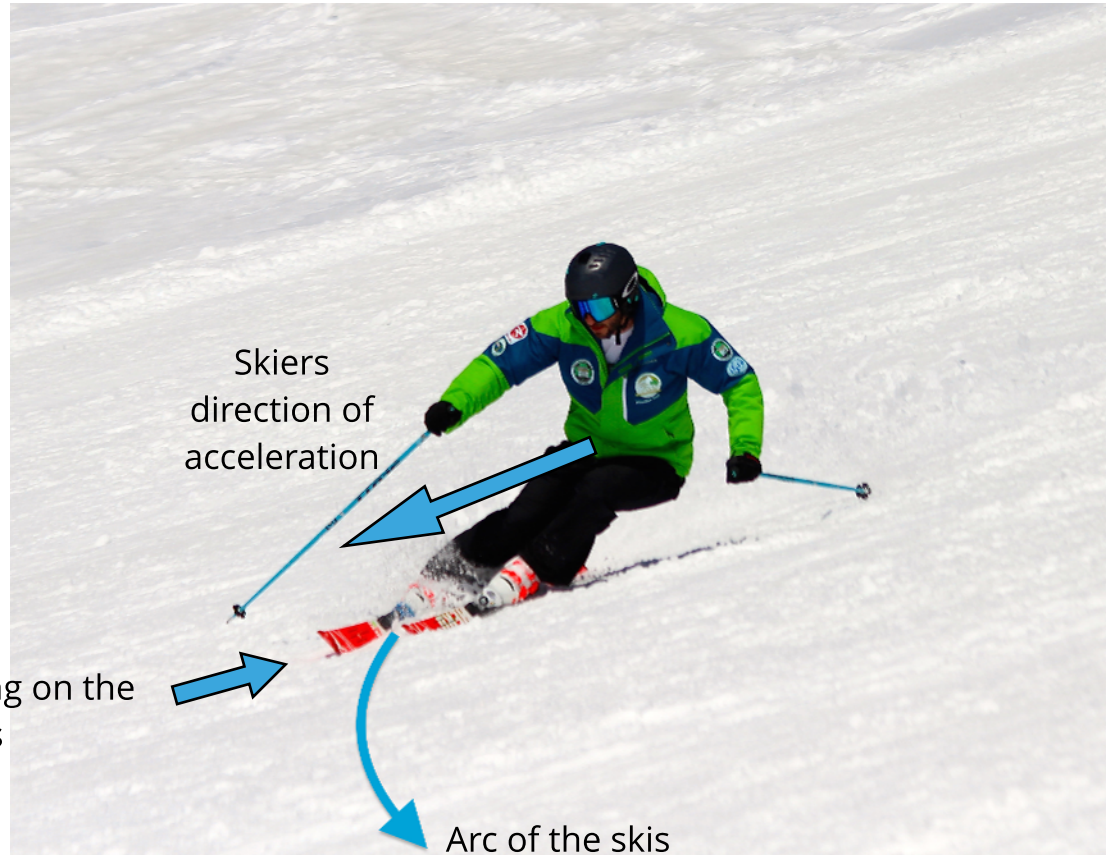
Snow is the surface we stand on and can vary in resistance, depending on its composition.
Wind is also a factor as the skier will be impacted upon by the direction of the wind as well as the air resistance while moving forward.

Newton's Laws

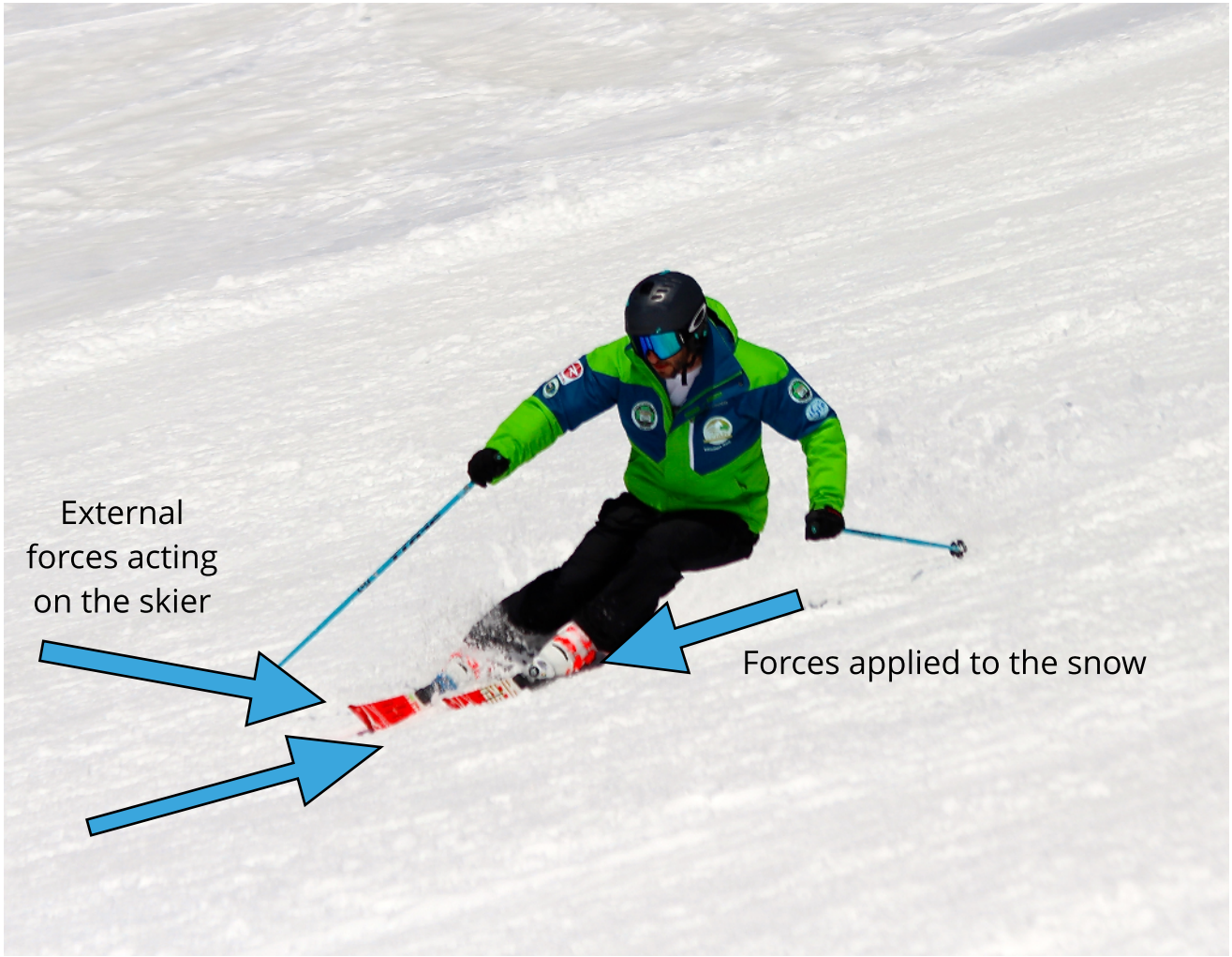
Sir Isaac Newton identified three laws of physics that rule our world. With these laws **the skier 'plays' with physics.** Understanding the laws and their application with skiing explains how skiing works.

First Law: Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it. **Without this, a skier (or any mass) would not move**. Further, a skier in a straight run would not stop or turn if the snow didn't create the needed external force (friction).

Second Law: F = ma it's the relationship between mass, force and acceleration. The acceleration is proportional to the total force on the object. **This law gives us direction and speed: we lose acceleration and gain direction depending on friction.** A skier tilts the skis onto the left edges, the snow pushes against that edge and the direction of that force causes the skier to veer in the same direction.



Third Law: Every reaction as an equal and opposite reaction. When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body. **In a curved motion, because the snow pushes back the skier with an equal amount and in opposite direction we can make turns** (and need muscle tension to do so, in order to counteract the generated forces).



Centripetal Force

Is a **force that makes a body follow a curved path**. It's direction is always **perpendicular** to the motion of the body and towards the fixed point of the instantaneous centre of curvature of the path.

When edging into the snow we gain a **reaction of the snow pushing the ski back**.
In a circle (steered or carved) the force acting on the skis is directed towards the centre of the turn, as it's always perpendicular to the motion of the skier.

The tighter the arc or the faster the skier, the more centripetal force is generated.

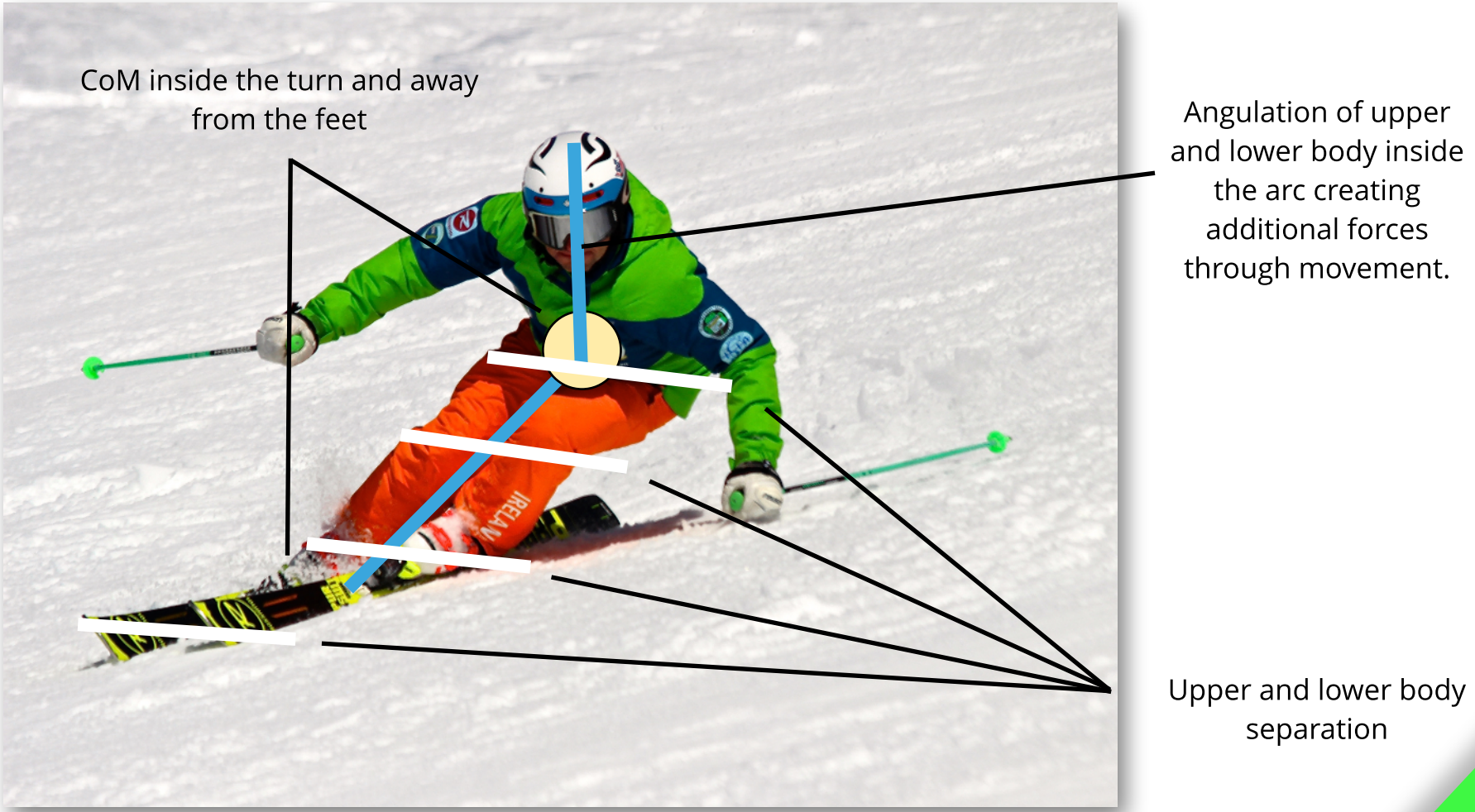
The **centrifugal force** is the feeling of being pulled towards the outside of the turn, which **is equal and opposite to the centripetal force.**

These **forces** and their combinations act on the skier and **dictate why certain technical movements are needed in skiing.**

Applications in skiing

A skier is composed by a **point of contact** with the snow (feet or skis) and it's **centre of mass (CoM)**, identifiable with a main point where the mass of a body is focused.

Because the centripetal force is present in every turn (and so the centrifugal one) **the skier needs to adapt and move to resist these forces and use them towards his/her purposes.** In order to do so he/she needs to **move the center of mass inside the turn while turning**. This implies the body of the skier will need to be inside the turn and away from the feet (point of contact).



Depending on how much centripetal force is applied, the distance between the center of mass and point of contact (body vs. feet) will change. The greater the centripetal force (increased by speed and/or tight radius) the greater the need to effectively balance away from the feet (high speed carving vs. basic parallel). The greater the forces, the greater the skier needs to work his/her body to resist these tensions.
Correct technique will help by minimising unnecessary movement, translating into higher levels of performance creating greater forces to deal with. The better a skier becomes, the more correct physical preparation can make the difference in efficiently using the laws of physics.

Notions like **angulation and inclination** were created to help the skier to understand where the body (centre of mass) is positioned above the skis (point of contact). Blending these two movements finds the ideal position to contrast yet using the forces that act upon us is one of the great challenges of skiing.
The point of contact with the snow can also vary, as we can **tilt the skis** to edge more or less. **Also by changing the way our point of contact interacts with the snow we can modulate the forces that act upon us**.
The more powerful the forces, the more precise the movements need to be. Because balance is the first goal and the feet are the closest to the point of contact, it is from there that the skier will need to gain **efficiency in his/her technical movement** (**fore-aft, edging**).
Because the majority of the mass is by definition in skiing, further away from the point of contact with the snow, the aim of the body movements is **to relocate the body mass** (from the legs up) to a convenient place (ahead of the next turn) for the skier to be able to manage the forces over and over again (**fore-aft, cross-over, cross-under, upper body separation, upper body rotational separation**).

Summary - key points from this chapter

- This chapter covered three main parts: Human Anatomy (part 1), Misalignments and implications in skiing (part 2) and Physics in skiing (part 3).
- Holding a basic knowledge of how the body works is essential to understanding how we can affect our performance.
- As snowsport professionals this knowledge is useful both on a personal basis and on a working basis.
- Any misalignment in the pelvis or the spinal column has direct and evident consequences in skiing.
- Skiing is having fun with physics on snow.

References and Suggested Reading

Tecnico di Educazione Posturale - L. Franzon & R. Mastromauro

Pattern Abilities Training - C. Dolzan & V. Fabozzi

IASI Coaching Theory Module Presentations - F. Sollini

Swiss SnowSport – Manuale di Sci Alpino

Ultimate Skiing – Ron LeMaster

Australian Professional Snowsport Instructors Inc. (APSI) – Alpine Teaching Manual

New Zealand Snowsports Instructors Alliance (NZSIA) – Ski Instructors Manual