Mountain Sustainability Course Notes (Grade 7-12) (1)

Resources:

Hand sanitizer
Mars Bar (5 minutes in freezer)
Thumball
MS 7-12 Field guides
RH Worksheets – 1 per group
Sling psychrometer
Anemometer
Soil thermometer
Compasses
Pencils
Laminates

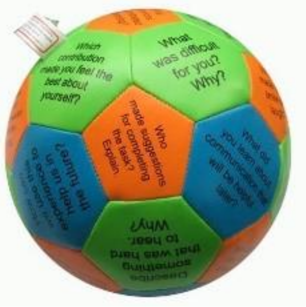
Please see corresponding Mountain Sustainability course Field Guide (Grades 7-12)

Notes to teachers and education guides: This is a circular program. We start by asking students what being on the mountain means to them. Their answer will be something along the lines of *"When I come to a mountain, I feel free/I can breathe/I'm out of the classroom/it reminds me of hiking with my family/I feel peaceful/I want to ski/I'm afraid of bears…"*

At the end of the program, students have 15 minutes to reflect individually to embed some of the learned material on an emotional and visceral level by writing a poem, sketching a landscape or anything they feel inspired to record in answer to the question: "What do mountains mean to you?" For those who want to share what they've done, they can post a photo of their work on social media with #mountainsmatter.

The 3 Things-to-Do at the end of the program are intended to empower this age group to build good habits of involvement in citizen-science, observation and record-keeping.

Activity 1

	**Thumballs:** Make a circle. Toss the ball to a student who has to answer the (random icebreaker-type) question where their thumb is on the ball. Then ask them "What does being out today on a mountain feel like to you?" e.g. freedom, fresh air, quiet, out of the classroom, being close to nature, enjoying the views…

Definitions of a mountain

There are many definitions of what should be called a mountain. One is that a mountain is a mountain if it rises more than 300 metres above the surrounding area. Another is that a mountain is a mountain if the people living near it consider it to be a mountain!

How to measure a mountain

There are also many views on how to measure a mountain. Mount Everest is generally considered to be the highest mountain in the world and it is still growing. It is 8,840 metres, that is, if you measure it from sea-level to its highest peak. But if you measure mountains from their actual base, where they protrude from the earth's crust at land or sea, Mauna Kea, the volcano in Hawaii is the highest, at almost 10,000 metres!.When you measure Mauna Kea from sea level, however, it is only about 4,000 metres.

What if we measured mountains from the earth's core to a mountain's peak? Then Chimborazo in Ecuador would be the highest mountain in the world. But because we measure freestanding mountains, from where sea meets land, Mount Everest is the highest.

How tall can mountains grow? They can't get much bigger than 9,000 metres because gravity has the effect of pulling the mountain back towards the earth, and the base of the mountain has to support that pressure. If there is water around the base of the mountain, like the volcano, Mauna Kea, that will help support the weight. If it's a freestanding mountain, and there isn't sufficient support, the base of the mountain will start to liquify.

It is possible to find much higher mountains in places with less gravity, like on Mars, where Olympus Mons is 25,000 metres high.

Mountain Creation: Long Story Short

If we want to understand how mountains are formed and raised, we need first to know something about the Earth's structure, and how it continues to evolve. (This is a seriously condensed version!)

We understand our planet's structure to comprise a solid-iron Inner Core at the centre, with a liquid-iron Outer Core circulating around it, and a Mantle of hot, 'plastic' rocky material moving very sluggishly around that.

The outer shell of the Earth – the crust – is the relatively thin layer of solid rock which forms the ocean floor, islands and continents. Oceanic crust is thinner – about 5 km to 10 km thick – than continental crust, which is mostly 30 km to 50 km, sometimes (around high mountain ranges) as much as 80 km, thick. When we look at average crustal thickness in comparison with the Earth's total diameter, it is thinner than a hen's eggshell in relation to the egg!

We can think of different areas of oceanic and continental crust as being a bit like pieces in a giant jigsaw puzzle, covering the entire planet. These pieces are called 'plates'. We know that new oceanic crust is formed by volcanic eruptions – almost always under the ocean – along the edges of pairs of oceanic plates, where those parts of the mantle which are less dense, and melt at relatively low temperatures and pressures, ooze out through cracks between the plates.

In other regions, where an oceanic plate and a continental plate are pushed against each other along their edges, one of these has to give. The thinner, denser oceanic plate is pushed underneath the edge of the (thicker, more buoyant) continental plate, back down towards the mantle. This is known as 'subduction'.

Not far offshore from the west coast of British Columbia, there are examples of both a constructive spreading ridge and a destructive subduction zone. While new ocean crust continues to be generated to the west of Vancouver Island, by remnants of what was once the Pacific mid-oceanic ridge (Juan de Fuca Ridge), the oceanic plate to the east of this margin (Juan de Fuca plate) is being subducted beneath continental North America (marked by the Cascadia Trench).

Magma, lava and volcanoes: igneous mountain-building processes

As the oceanic plate descends beneath the continental margin, it encounters higher temperatures and pressures, and begins to melt. Some parts of the rock forming the oceanic crust melt earlier, at shallower depths: being less dense and more fluid, these partial melts – we can think of them as 'bubbles' of magma – tend to move up through the edge of the continental crust, exploiting any lines of weakness in the structure. Some of these pathways are themselves likely to have been formed by stresses driven by the plate-to-plate collision and subduction. As the magma moves, it may also melt surrounding rock, which is added to the mix.

The combination of horizontal pressure along the plate-margins at the surface ,(folding and faulting), together with some vertical pressure from magma forcing upward from the regions of melting oceanic crust (doming,) are important mechanisms by which mountains begin to be raised.

If the magma finds its way to the surface, it will erupt as a volcano. Once a route has been forced from deep in the crust all the way to the surface, it tends to be exploited repeatedly by successive pulses of magma. Many of the mountains along BC's coast were formed in this way: through long periods of time, repeat eruptions of molten rock (now, when it appears on the Earth's surface, called lava) add more and more material to each vent.

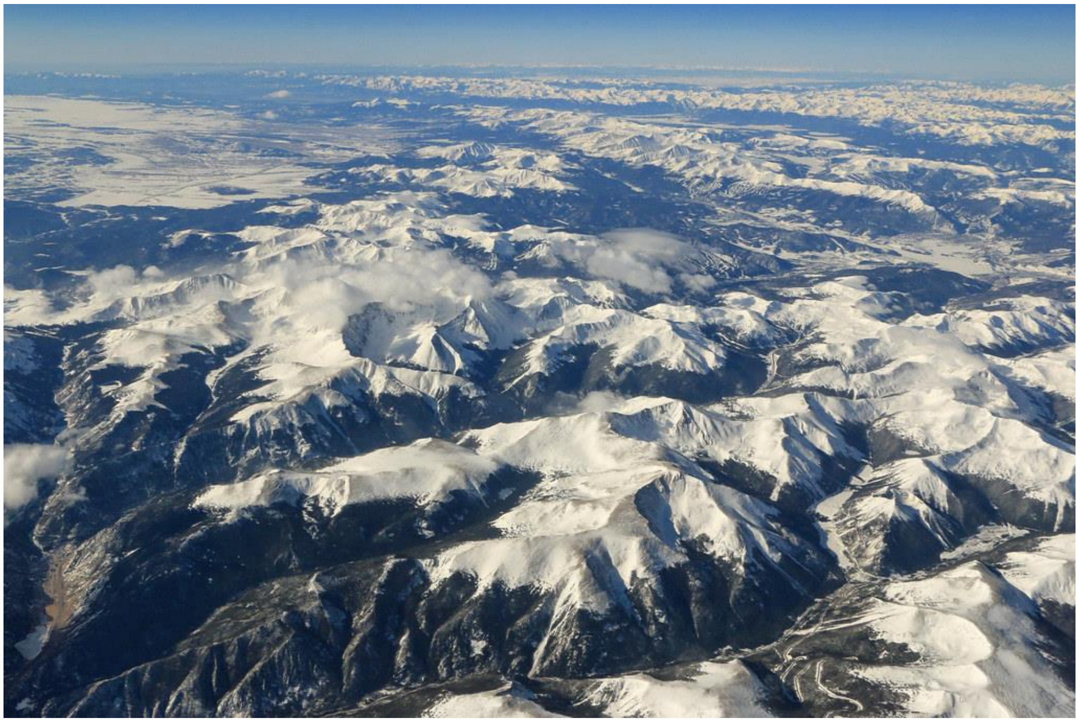
Building mountains by folding and faulting

Did you ever do that demonstration in elementary school, where you take a towel, fold it lengthwise, and then slowly slide the two ends towards each other to cause folds in the towel? As two plates are pushed against each another, compression forces the rock to change shape. This is known as deformation.

More rarely, two units of continental crust might be pushed against one another. In this case, there's no backing-down: it's a full-on collision, and the forces generated are immense. Through time, great chunks of land – known as terranes – formed new additions to BC and the western side of Canada, carried on the subduction-driven conveyor of the Pacific oceanic plate. With each new collision, new mountains were pushed up on the surface. This is also the origin of the Himalayas, formed by the northward collision of the Indian sub-continent (which it really is, in geological terms!) with south-central Asia.

"Himalayas - Aerial view" by Dr. Partha Sarathi Sahana is licensed under CC BY 2.0.

Ductile or plastic deformation results in 'folding'. Depending on the nature and scale of the stress applied, this may affect anything from an individual unit of rock to entire mountains.



"Rocky Mountains" by U.S. Geological Survey is licensed under CC BY 2.0.

If you fly over the Rocky Mountains on a clear day, you will see something like the image above – each ridge is a unit of rock which was folded by compressional stress, before ultimately failing (faulting), and being pushed sideways and upwards over the unit below it. The largest mountain ranges around the world – the Himalayan ranges, Rockies, Andes, European Alps, and much older ranges, of which only the exposed roots are now visible – have all been formed primarily by this process.

Mountain Destruction: Long Story Short

When large masses of rock are accumulated at or pushed to high elevations, they are immediately exposed to a wide range of destructive forces, which will – over tens to hundreds of millions of years – work to transform mountains, first into hills, and eventually to lowlands.

Arguably the most important influence is the range of meteorological (weather) conditions: mountains are exposed to stronger winds, higher precipitation, and wide ranges of temperature. Another important factor is gravity: raising something up gives it 'potential energy': if it is (or bits of it are) freed from whatever was previously keeping it in place, gravity will tend to move it to lower levels.

These processes work at a range of scales, from the microscopic to the truly enormous.

The two main stages involve firstly the disaggregation or destruction of the rock itself, and then the transport of the resultant particles.

Weathering

Rocks are 'picked apart' by a combination of processes known as 'weathering'. In general, weathering transforms solid rock into smaller pieces, called regolith, down through smaller and smaller particles: it may even dissolve a rock completely, so that it becomes part of a liquid. Weathering may take the following forms:

- **physical weathering:** mechanical stresses imposed on and within rock-units;
  - freeze-thaw cycles of water / ice cause cracking, deepening and widening cracks in rock by expansion and contraction: water finds its way into crevices, and – when it freezes – expands, forcing the crack wider, and flexing it again when it melts
  - extreme temperatures may also drive expansion (hot) / contraction (cold)
  - hydraulic fracturing – the varied impacts and forces of flowing water
  - abrasion – disaggregation by direct impact from particles (from boulders to fine sand) carried by wind or water (arguably a form of erosion, rather than weathering)
- **chemical weathering:** reactions between the rock's constituent minerals and external agents;
  - when minerals in rocks are unstable in the chemical conditions to which they are exposed (temperature, pressure, moisture, acidity, etc), they may react and break down
  - this is particularly true for volcanic rocks, in which the mineral crystals cooled rapidly, without time to take chemical forms more suited to stability at surface conditions
  - as the more vulnerable minerals break down through reaction with atmospheric gases and water-borne chemicals, they leave the less vulnerable (more stable) particles behind, leaving them more vulnerable to disaggregation from the parent rock
  - some rocks are made largely of minerals which dissolve in water: for example, limestone is composed very largely of calcium carbonate
  - accelerated by moisture and warmer temperatures
- **biological weathering: the activities of living organisms:**
  - burrowing
  - root action
  - bio-chemical weathering (eg by lichens)
- we can also think of the direct effects of human activities – mining is a good example
  Once regolith particles – bits of the original rock – have been detached or

disaggregated from their parent rock, they are liable to be moved. In mountain settings, this happens mainly under the influence of gravity, ice, and water (and just possibly wind).

Transportation of regolith by gravity

Relatively small particles and volumes of regolith may accumulate close to their source – perhaps just falling a short way down-slope under gravity – or may be transported great distances by water (including ice) and/or wind, undergoing further transformation as it travels. These accumulations are known as talus or skree. Similar processes on different types of rock may lead to the accumulation of gravels, sand or finer particles.

Most of the time, these talus or scree slopes find a natural configuration of internal organization and slope which permits them to be quite stable: they may even support the growth of vegetation, the roots of which help to anchor the loose, unconsolidated material. In general, a vegetated – particularly a forested – slope will be more stable than one without vegetation: this is partly because the roots bind the material together more cohesively, and partly because the vegetation canopy reduces and spreads-out the direct effects of rainfall and surface flows.

However, sometimes this balance or equilibrium is disrupted, and the slope may slide or flow. Most often this is through the reduction of friction by adding water from ***heavy rainfall or rapid snowmelt***. It is also possible that these events may be provoked by shaking (during an earthquake), or even by animals (including humans!) walking across the slope and dislodging important 'anchors'. It follows from the point above that removing the vegetation – again, particularly trees – from a slope will increase its vulnerability to erosion and 'mass-wasting'.

The regolith transported downhill or downstream by these processes will contribute to the formation of new (sedimentary) rocks on the floodplains of rivers and in the ocean.

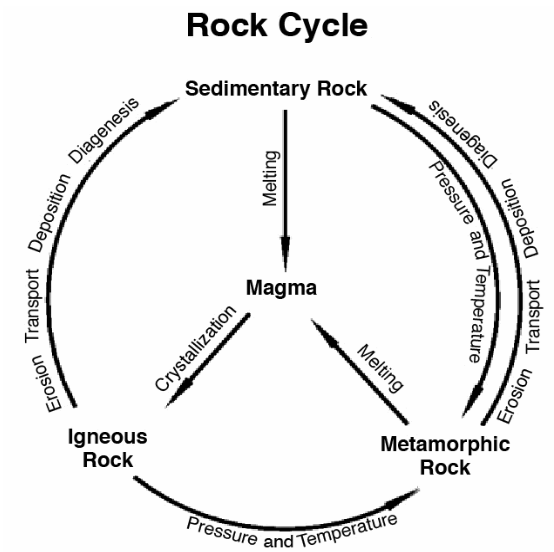
Glaciers represent immensely powerful agents of erosion and transportation. Formed initially as patches of snow which do not melt through successive summers, they begin to flow downhill under their own weight. As they do so, a complex range of processes works to weaken, disaggregate and move enormous volumes of rock along their paths. We'll talk about glaciers more in a minute.

In summary, we have the transformation of bedrock to regolith by:

Physical – mechanical stress on rock
Chemical – chemical reaction between minerals in the rock
Biological – physical and chemical but by plants and animals. Eg lichen secretes acids that break down the rock.

Having generated regolith from the bedrock, what happens next? Where does it go?

Do you remember learning the rock cycle in Grade 4?



https://commons.wikimedia.org/wiki/File:Rock_cycle.gif

You have the mass wasting, the redistribution of regolith under gravity. EROSION = redistribution of regolith by FLOWING MEDIA, namely:

- Water (fluvial erosion)
- Ice (glacial erosion)
- Wind (aeolian erosion)

The particles on Highline Trail, for example, are redistributed to the bottom of the trail.

Regolith on Highline Trail, Sea to Sky Gondola, Squamish, British Columbia.
Photo by Martha Warren

The regolith from the summit is redistributed to the bottom of Átl'ka7tsem/Howe Sound.

What we have is this constant movement in our mountains, where some mountains are rising, some are becoming small, weathering and eroding. Some mountains in the Himalayas are still rising at 1 cm a year due to crustal uplift.

We've talked about weathering, now let's look for moment at weather, as in climate.

As already mentioned above, mountains are exposed to stronger winds, higher precipitation, and wide ranges of temperature. Alongside weather, there is the issue of climate.

The energy that runs the Earth's weather comes from the sun. Weather is a product of solar energy and water vapour (which is a condensable gas) in our atmosphere. Like carbon dioxide, water vapour is a greenhouse gas. Greenhouse gases partially trap the energy radiated from the Earth's surface that is warmed by sunlight.

Scientists are seeing that mountain regions of the world are warming faster than the global average.

Why do we care about weather on the mountains?

Water vapour in the air is significant in terms of climate change and changes to mountains from climate change. Humidity is a big part of global warming. The big is question is how mountains create weather, and how mountains are changed by weather.

How do our mountains create weather? Mountains, topographically, are rainmakers. So for us here, air moves eastward off the Pacific Ocean, hits the mountains, begins to rise; cools as it moves up and over the mountain, resulting in clouds and rain, and as it continues east, we have these "rainshadows," these dry areas. So the west side of the mountains are wetter than the east; kind of a windward/leeward difference. The proper name is the orographic effect.

You see this all over the world. The same phenomenon happens with the Tibetan Plateau, where it's very dry, being on the leeward or rainshadowed-side of the Himalayas and the Kunlun Mountains and the Quilian Mountains in China.

As in circumpolar regions, mountains are experiencing faster rates of climate-change, introducing major implications for humankind and the ecosystems on which we depend. This is due to mountains extending above the surface boundary layer into the free atmosphere and are more directly exposed to major incoming weather systems. Extreme climate change is happening at above 3000 metres, with 90% of data coming from Utah, Colorado and Tibet. Areas already in crisis are the Andes and the Hindu Kush Himalaya.

So with climate change you see increasing mountain exposure to hazards such as storms, landslides, avalanches. But it's not just increased air temperature that's the issue. Rather, it's the increased humidity coming from warm air holding more water vapour and warming seas and land releasing more water into the atmosphere through evaporation.

Again, why do we care about weather? Because mountains, and vegetation, and animals will have to adapt in response. Where a mountain was once, say, cold and dry, but is now warmer and more humid, how will the vegetation change? How will natural hazards be different? How will animals and humans adapt? How will our water availability from glaciers and snowpacks change? These are the big questions of mountain sustainability.

Activity 2: Measuring the weather

What you will need: Outdoor thermometer, anemometer, soil thermometer, compass, sling psychrometer, Relative Humidity Chart.

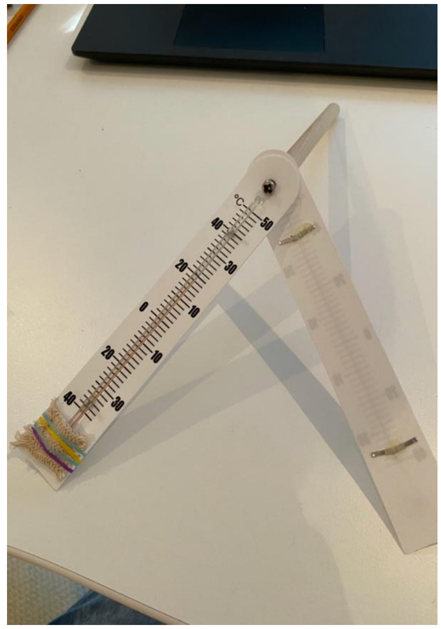
How to measure wind direction? – observation of vegetation, flagging, wet finger, compass.

How to measure wind speed and temp? - anemometer and thermometer.

How to measure soil temperature? - soil thermometer. Measure 5 cm below ground. Measure the surface temperature. Then measure the air temperature 2 metres above. Soil temp is important because warmer temperatures accelerate chemical weathering on mountains and determine what vegetation will grow. If our mountains grow warmer with climate change, what changes in plants will we see? What changes will happen for microorganisms so small we can't even see them with the naked eye?

How to measure relative humidity (RH)? – sling psychrometer. Dip sock at end of wet-bulb thermometer in water. Whirl sling psychrometer in air until you get a wet-bulb thermometer reading (approximately 5 minutes.) The spinning causes moisture in the sock to evaporate and has a cooling effect on the bulb. The difference between the wet and dry bulb temperatures help you find Relative Humidity. e.g. If the dry bulb measures 25C and the wet bulb measures 18C, then you have a wet bulb difference of 7C. Find the dry bulb measurement on the left of the chart and read across to the right, you have a Relative Humidity of roughly 50%. This cooling process, the evaporation of the water on the wet bulb thermometer, tells us how much water vapour is in the air today. As a result of the spinning, the sock at the end of the wet bulb thermometer undergoes a rapid cooling effect at a faster rate. Saturated water vapour would be 100% RH; No water vapour at all in the air would be 0% RH. Evaporation is faster when humidity is low, and as RH increases, the evaporation rate decreases.

Relative Humidity																	
	Difference between wet and dry bulb temp																
Dry bulb temp		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	0	81	64	46	29	13											
	2	84	68	52	37	22	7										
	4	85	71	57	43	29	16										
	6	86	73	60	48	35	24	11									
	8	87	75	63	51	40	29	19	8								
	10	88	77	66	55	44	34	24	15	6							
	12	89	78	68	58	48	39	29	21	12							
	14	90	79	70	60	51	42	34	26	18	10						
	16	90	81	71	63	54	46	38	30	23	15	8					
	18	91	82	73	65	57	49	41	34	27	20	14	7				
	20	91	83	74	66	59	51	44	37	31	24	18	12	6			
	22	92	83	76	68	61	54	47	40	34	28	22	17	11	5		
	24	92	84	77	69	62	56	49	43	37	31	26	20	15	10	5	
	26	92	85	78	71	64	58	51	46	40	34	29	24	19	14	10	5



Glaciers, Snow & Water

Glaciers form when layers of snow pile up over time. The weight of the snow squeezes it into a layered sheet of ice, and it begins to move slowly, pulled by gravity, scraping over everything in its path. It will sculpt the mountain and carve deep valleys. The Átl'ka7tsem/*Howe Sound* was carved by glaciers. It will leave scratches on the mountain. It will carry rocks of all sizes with it.

Glaciers erode, wear away, parts of the mountain as they slide down, dragging rocks along with them. Glaciers form when layers of snow pile up over time. The weight of the snow squeezes it into a layered sheet of ice, and it will begin to move slow, due to gravity, scraping over everything in its path. It will sculpt the mountain and carve deep valleys. It will scrape up the mountain. It will carry rocks of all sizes with it.

As large volumes of ice, they act as 'cold sinks', lowering the range of temperatures in the air around them: this in turn means that freeze / thaw weathering is more likely through longer periods of the (otherwise) warmer months. Where ice freezes onto rock, the latter – potentially of very large sizes – may be 'plucked' from their origins and moved by the ice, potentially for long distances. The rocks within the ice scrape and 'bulldoze' the surface as the glacier moves, further abrading and eroding the landscape (and the regolith itself, which tends to take on a rounded shape). This excavating action carves deep U-shaped valleys with steep sides – down which yet more regolith is able more easily to fall, under gravity. Also under and in front of the ice, meltwater streams flow, doing the same kind of work as those generated by rainfall and snowmelt, as described above.

Where more snow melts from a glacier each year than it receives, its end or 'snout' will retreat uphill. As it does so, large volumes of regolith previously deposited from the ice may remain perched along the sides of its valley, often precariously (particularly when the retreat is rapid). These accumulations are unlikely to be stable, and may suddenly give way and move rapidly down-slope – particularly with the addition of water and/or seismic shaking

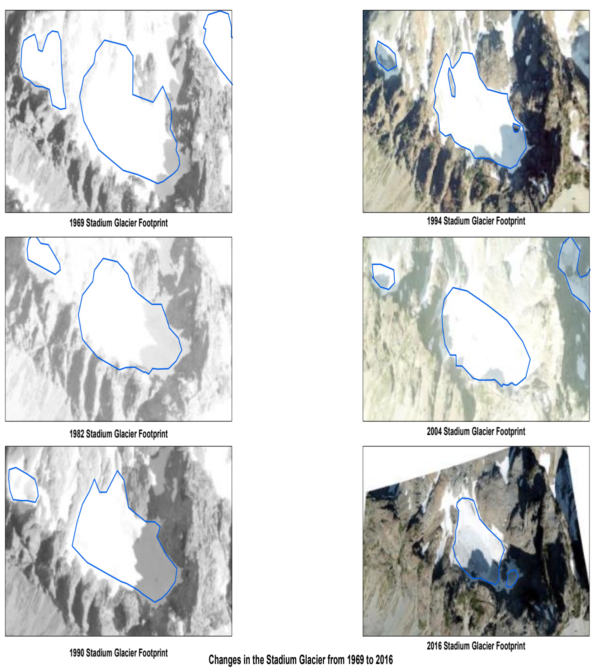
Glaciers can move from a few cm a day to a few hundred metres a day. The underside of the glacier moves more slowly than its top. With global warming, however, glaciers sometimes look like they're moving backwards. Because as they melt, the terminus, or end of a glacier is higher rather than lower on the mountain as you might expect from gravity. This is called glacial retreat.

Skypilot, Copilot and the Ledge, in Squamish, British Columbia, have retreating glaciers. Stadium Glacier sits in a cirque, a bowl-shaped indentation, next to Skypilot, at 1,740 metres.

Skypilot, Copilot and the Ledge, Squamish, British Columbia.
Photo by Martha Warren

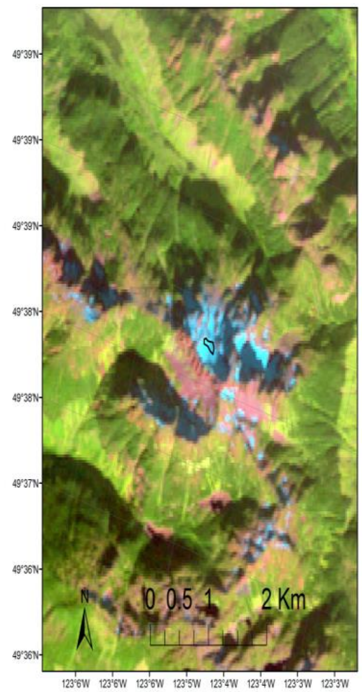
The photos below on the left show the size of Stadium Glacier from 1969 to 2016. What's it doing? (Getting smaller!) In the picture on the right, the blue in the Landsat image is from September 1984. The tiny black polygon you see is the glacier outline as at September 2021.

The glacier has lost a lot of ice. Instead of annual melt where the snow on top of the ice melts away, but the ice remains, we have a glacier that is retreating and will disappear.



Changes in the Stadium Glacier from 1969 to 2016

Figure by Robert Plummer



Stadium Glacier September 28, 1984 (blue) and September 2, 2021 (black polygon)

Figure by Scott Williamson

In the mountains, the majority of snow falls in the winter and melts in the summer. What snow that doesn't melt remains and has more snow added the next winter. The snow that remains is consolidated into firn - which is granular snow that looks a little like sugar but has not yet been compressed into ice.

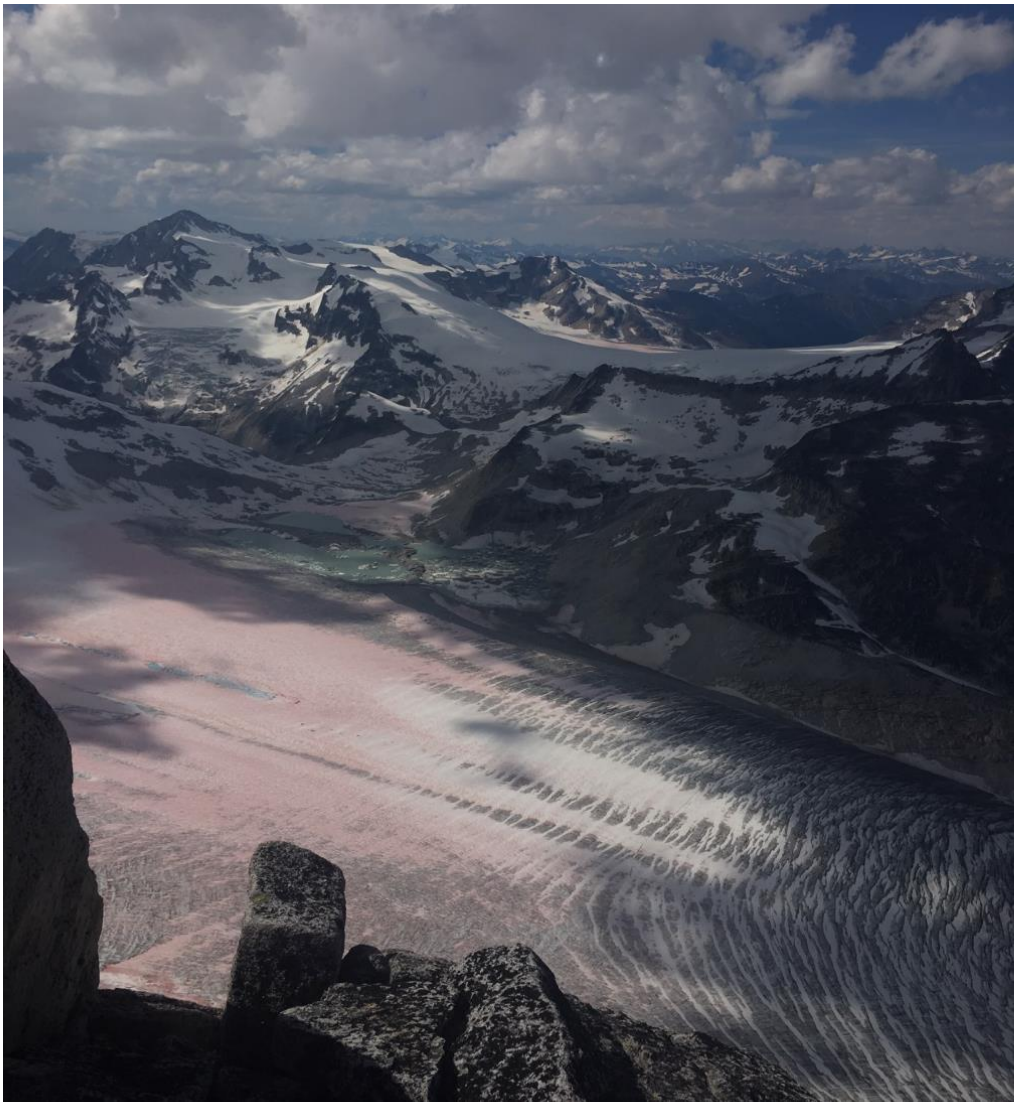
Axel-Heiberg Island Qikiqtaaluk Region, Nunavut.
Photo by Dr. Laura Thompson, Queen's University.

Glaciers are basically snow and firn that are transformed into ice by gravity. Gravity also makes glaciers flow downhill by deforming ice and by sliding on wet deformable sediment at a glacier's bed. So a glacier flows downhill like an escalator and transport rocks that fall on them at the end of the glacier as a terminal moraine. If not enough snow accumulates year after year to turn snow into ice then a seasonal snow patch occurs.

The top part of a glacier is the accumulation zone; the bottom part is the ablation zone. At the end of summer, the ablation zone is ice at the surface because the snow cover has melted. In the accumulation zone snow remains because at the higher elevation air temperature is not warm enough to melt the snow.

Sun, snow and ice interact to make a glacier. *Have you noticed that snow is bright, and ice is dull when viewed with your eyes?* The amount of sunlight a glacier absorbs or reflects is called albedo. Snow in the accumulation zone absorbs ¼ of the sunlight falling on it and reflects the rest. Ice in the ablation zone absorbs ¾ of the sunlight falling on it.

Snow in isolated patches or on glaciers can have algae grow on it. The algae are sometimes called watermelon snow because it is red, and some people think it smells like watermelon. The snow algae live in the meltwater between snow grains, is photosynthetic and makes the snow absorb more sunlight which promotes snow melt.



Vowell Glacier, Bugaboo Provincial Park, British Columbia.
Photo by Scott Williamson

Flowing glacier ice can form crevasses when the ice is stretched (strained). A crevasse will form when the glacier turns around a bend or rapidly loses elevation, such as flowing over a rock ridge. Fun fact - you can approximate how glacier crevasses form using a chocolate bar with a soft centre.

Activity 3: How is a chewy chocolate bar like a glacier?

You will need:

1 volunteer to handle the chocolate bar

1 Mars Bar or other chewy chocolate bar that's been in the freezer for 5 minutes

A Mars Bar is long and linear, u-shaped on bottom with steep sides, like a glacier.

It's flat on the bottom and steep on the sides, like a glacier.

Please gently bend your MB. You'll see it develops cracks like the crevasses of a glacier. The top layer of a glacier is brittle. It's a rigid zone.

Please pull apart your MB. The caramel undergoes "plastic flow", like the inside top layers of a glacier. This is the plastic zone of a glacier.

The nougat layer underneath is formed like firn, glacial ice and snow, compressed, less bendy. It's the intermediate stage between accumulated snow from snowfall and ice.

It leads to the basal sliding zone, and the deepest layer of compressed ice in a glacier.

If this were a Snickers bar, the peanuts could be the rocks carried along on the glacier, the erratics.

Tip your glacier so that it's on a slope. Which is the accumulation zone? Which is the ablation zone? Where is the snout?

Lastly, please bite into the end of your Mars Bar; this is glacier retreat!

What this demonstrates is that different glacial materials flow at different rates under different conditions, and how pressure from the top layers pushes down and compresses the lower layers into glacial ice. Gravity further pulls the glacier downhill.

You can see often see striations, scrapes left on rock by a glacier as it moves. And talus or skree, loose rock from erosion.

The water that comes from glaciers and snow melt is very important to us. 60-80% of our fresh water comes from glaciers. It's what we drink. It's what we use for hydroelectric power. It's used for farming. So there is concern that our glaciers are retreating.

Retreating glaciers also contribute to slope instability on our mountains and increased natural hazards like landslides of rock, regolith, and glacial lake outbursts.

Glaciers and snow patches are both important for contributing melt water to streams and rivers in the summer. They are also important in keeping streams and rivers water temperature lower than if they were fed only by rain. Many species of animals, including fish and amphibians, are very sensitive to water temperature.

Biodiversity

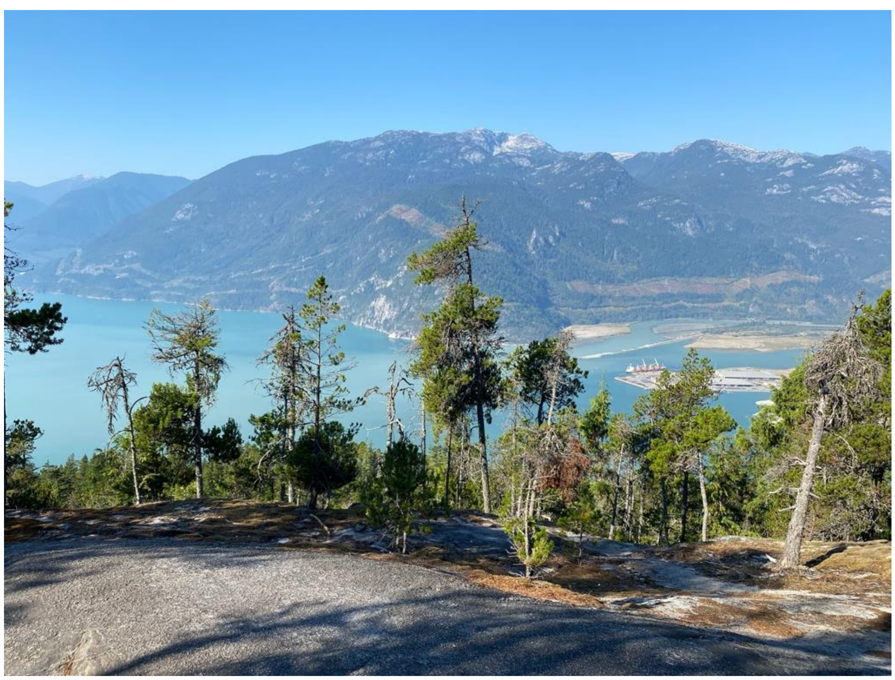
Which plant and animal species will adapt as our mountains change?

Charles Darwin studied Galapagos Finches and discovered that when bad weather affected plant growth and there were fewer seeds to eat, the finches had to eat larger seeds not normally a part of their diet to survive. Only the ones with large enough beaks to eat the larger seeds survived. The survivors had offspring with large beaks, and this inherited trait was passed on in reproduction. The species thereby evolved to have larger beaks than before, and this adaptation to their environment is natural selection.

What are the differences in the physical appearance of the environment at the Sea to Sky Gondola summit at 885 metres? How does the summit of our mountain, in the subalpine, look different to the coastal rainforest at base below? (Smaller trees, less underbrush, less plant diversity.)

The subalpine forest is a transition zone from dense forest below to alpine tundra above treeline. Subalpine areas can be buffeted by hurricane force winds, scoured by ice crystals, and weighted down by heavy snow—life can be a challenge for mountain trees. As a transition zone from dense forest below to alpine tundra above treeline, the treeline is not really a line, but rather a zone where trees gradually get smaller and more stunted until conditions are too challenging for tree growth. At the upper edges, centuries old trees may sprawl along the ground bowing before the wind. The plants that grow in these soils must be very hardy.

- Shape of trees you'll notice:
    - ***Krummholz*** = stunted or deformed vegetation in the subalpine
    - ***Flagging*** = where you have growth on only one side of a tree due to winds
    - And what are they growing out of? Rock!



Subalpine tree growth.
Squamish, British Columbia
Photo by Martha Warren

How have animals adapted to live in the subalpine? Here are some examples:

The Red Breasted Sapsucker get their name from how they eat! They drill rows of holes into tree trunks and then returning to those holes later to feed on the running sap and the insects attracted to it. Hummingbirds also use the Sapsucker feeding holes. The Rufous Hummingbird will follow the Sapsucker around during the day, feeding at the wells of sap that the Sapsucker keeps flowing.

Cougars will use the thick underbrush of the forest for shelter and to stalk their prey. Squamish is located in prime cougar habitat. Cougars are active throughout the year and are elusive animals that prefer to avoid contact with humans. Cougars prefer habitats with dense underbrush and rocky areas for stalking but can also live in open areas.

You will mostly likely see chipmunks on our hike. They live in trees and gather food on the ground in areas with underbrush, rocks, and logs, where they can hide from predators like hawks, foxes, coyotes, weasels, and snakes. They have striped bodies for camouflage. They have claws and are able climbers. They feed on insects, nuts, berries, seeds, fruit, and grain which they stuff into their cheek pouches and carry to their burrow or nest to store. Chipmunks hibernate, but instead of eating a lot and fattening up before they sleep, they keep a store of nuts and seeds to eat throughout the winter. They reduce their respiration and heart rate when food is scarce and reduce their overall body temperature. Chipmunks have 2-8 live young, once or twice per year. (Why might that be?) It is because they are food for so many other animals.

The black bear's greatest adaptation to living on the mountain is its ability to eat many different things. From fruits and nuts, grasses, twigs, and honey, to grubs, insects, fish, and small mammals. Its molars are great for grinding up foods and its large canine teeth for ripping apart fish. Bears can smell food up to 20 miles away. Their sense of smell also helps them locate other bears and detect and avoid danger. Bears have huge, strong legs to move or bend large objects like rocks or tree trunks to get to food. They have large, padded feet and strong, curved claws to climb trees easily to get to fruit. Their long and sticky tongue can reach insects in trees. They can even separate and spit out unwanted nuts or berries without using their paws.

What do you think will happen if our mountains get warmer? Some species will move higher up due to climate change.

Mountain goats are affected by warmer winters. If trees start growing higher up the mountainside, then there will be less of the lichens, ferns, grasses, herbs, and shrubs that goats currently eat. They will also have to go higher up the mountain in the summer to stay cool.

Yaks in Nepal can't live at the elevation they used to because it's too warm now for them. So they are moving further up the mountains to reach a cooler environment, forcing them into a smaller area where it's harder to find food and water.

Vernal pools/ephemeral wetlands – these are shallow ponds of water in the winter and spring, and dry out to be mud and soil in the summer and fall. So they only contain water for part of the year. What can live in these? Frogs. Salamanders. When mountain climates change, if there are longer droughts, these species can't live there.

For caribou in the Rocky Mountains' Jasper Park, it is difficult to dig through the deeper snowpack further up the mountain to find food. Instead, they stand on snow to eat lichen from trees. But if a snowpack is reduced or gone completely, the caribou are unable to reach arboreal lichens. Caribou use high-elevation snow-patches for respite from summer heat and insects.

Measuring biodiversity is important so we can see how species are adapting to global climate change. Watching the Himalayan yak, for example, may tell us a lot about how cattle and other animals will be impacted by climate change.

Remember that man-made disturbances such as recreational hiking can have an adverse effect on plant biodiversity. We've seen the destruction of lichen and vegetation on sides of trails at Sea to Sky Gondola. There used to be *lipstick cladonia* - a kind of lichen, fungi and algae together, with small leaves and red caps. It's still present elsewhere on the mountain but has disappeared from the sides of the trail because visitors from the mountain keep walking on it.

Activity 4: Field Guide Group Discussion

Whole group exercise using Field Guide Discussion Points. Read each point aloud and discuss.
If there is time, complete the Salal and Mountain Goat case studies.

Activity 5: Hike

Watch for…

Erratics
Felsic/mafic dykes
Pluck marks
Abrasions
Biological weathering: lichen, tree roots, us walking on it…
Skypilot/Copilot jagged tops, rust coloured horizontal stripes are chemical weathering
Stadium Glacier retreat

Krummholz
Flagging
Regolith
Duff
Skree
Volcano - Mount Garibaldi
Átl'ka7tsem/Howe Sound fjord
Lichen
Old Man's Beard
Salal
Vernal pools/ephemeral wetlands
Colour of water – rock flour in glacial runoff
Olsen Falls
Woodpecker holes

Mountains and People

Mountains have always been a source of inspiration for spirituality, traditions, and the arts.

Take **Mount Olympus**. It's one of the highest peaks in Europe, and to the ancient Greeks, it was the home of the Greek Gods who lived on Mytikas Peak.

Haleakela volcano in Hawaii was considered to be *wao akua*, or "the realms of the gods" by the Polynesians, and many religious ceremonies are still held on the rim of the summit and in the crater to this day.

What about art inspired by mountains? I think of the Group of Seven – Lawren Harris' Mount Robson, and Norval Morrisseau's Riding the Great Thunderbird to the Mountain World.

When you think of mountains and literature, what do you think of? I think of **Thomas Mann's The Magic Mountain** and **Li Bai's** poetry: *"We sit together, the mountain and me, until only the mountain remains."*

And what about mountains as inspiration for music? From **Modest Mossorgsky's Night on Bald Mountain** to **John Denver's Rocky Mountain High**. I also think of music outdoors on mountains: the Vancouver Symphony Orchestra playing outdoors at Whistler and the Squamish Constellation Festival.

What else are mountains to us? They are borders, geopolitical divides. The border between British Columbia and Alberta is in the Rocky Mountains; the boundary between France and Spain is along the Pyrenees Mountains; the boundary between Italy and France is the Alps. Historically, countries chose mountains as borders because they could defend themselves from attacks by their neighbours. And in severely rugged mountain areas, we still see that today. In the Himalayas between India and China, and in the Andes between Chile and Argentina.

But we also see efforts of international cooperation on some mountain borders. For example, near Testa Grigia peak, the Theodol glacier's retreat has moved a hotel on the Swiss-Italian border requiring 100 metres of border to be redrawn.

Efforts in cross-border cooperation and collaboration such as those seen with the Hindu Kush Himalayan Monitoring and Assessment Programme, which includes India, Pakistan, China, Nepal, Afghanistan, Bangladesh, Bhutan, and Myanmar, is another example of transboundary cooperation. What do they cooperate on? One initiative is mapping human-wildlife conflict hotspots in the Eastern Himalaya. They know they want to enhance wildlife habitats and corridors, and like us in Canada, they have bears (Himalayan Black Bears,) and antelope (Tibetan antelope,) deer (musk deer,) gaur (Indian bison,) but also the Asian elephant, royal Bengal tiger, snow leopard, and red panda.

Another example of transboundary collaboration is the Kangchenjunga Landscape Initiative. The Southern side of Mount Kangchenjunga is shared by three countries, Bhutan, India and Nepal. They cooperate on sustainable use of resources, environmental conservation and economic development. They map human-wildlife conflict hotspots.

They have also had a "Yaks Across Borders" exchange to encourage yak conservation. Yaks provide milk and meat. Their hides are used. Their dung is burned as fuel for cooking and heat. They are also used for transport. Yak herding has been important in this region for 4,500 years, but as borders were militarised between the countries, the herds couldn't mix anymore, and Yak herder communities suffered. Under this program, Bhutan gave yak bulls to India and Nepal, and it is hoped this transboundary interaction between the herders will be ongoing.

In many parts of the world, mountain economies are based on agriculture or mining, and the people living there tend to be poor. These areas have limited infrastructure, service, and opportunities. For many mountains, the issues are around farming and livestock and how to introduce best farming practices for sustainable food production. Or they're around mitigation of the impact of natural resource extraction, and the introduction of more sustainable enterprises to take its place.

Mountain tourism brings income and economic benefits to mountain communities, but the challenge is how to manage the environmental, social, and cultural impacts of that. Recreational tourism and associated infrastructure, commercial and residential development raise the question of how to prevent damage through over-activity; and particularly, how to share benefits from tourism to local populations, including indigenous peoples.

The question is whether economic growth happens in a socially and culturally appropriate and equitable way? Locations for second homes, such as in Nainitial, Uttarakhand, in India, and in Whistler, British Columbia, in Canada, put property prices and many local services beyond the means of local populations. And when land cover changes with development, is there the infrastructure to support it in terms of transit, clean water, sewage treatment, garbage and power? While tourism offers benefits in terms of employment opportunities and to the economy as a whole, the challenge is how to guard against over-exploitation and increasing dependence on low-wage jobs in tourism and pressure on local populations to out-migrate from the community. This is the case for Sherpas in Khumbu, Nepal, the gateway to Mount Everest, and in the Alps, and in the Rocky Mountains.

What are the solutions? Some employers provide staff housing. Will we need employer-paid supplements like a cost-of-living allowance you see in some expensive urban centres like London, or point of sale subsidies like to you see in remote wilderness regions like Canada's North?

When we think of mountains and people, we should also look at ethnogeology, how geological features are understood by indigenous communities. The Stawamus Chief Mountain right next to us was considered to be a longhouse turned to stone. There are traditional Quechua stories from the Andes of the most powerful spirits living on mountain summits. Mountains are often sacred sites, and many religions make pilgrimages to mountains: Wtai Shan and Emei Shan in China; Mount Sinai in Egypt; Gangotri in India; Meteora in Greece.

Legends and oral tradition are of cultural significance, but also of evidentiary significance. Oral histories of floods and volcanic eruptions are used by archaeologists, geographers, and geologists as corroborating evidence to piece together geological history. The Gunditjmara in Australia are an example of this. There is archaeological evidence of their occupation of 13,000 years, but they're telling stories describing the formation of the Budj Bim volcano, a geological event from 37,000 years ago. These indigenous archives of oral tradition as geological history are of great importance.

The good news is there are opportunities for cooperation and collaboration to protect and preserve our mountains and mountain. There are many international organizations doing this, for example, the Adaptations at Altitude program of the Swiss Agency for Development and Cooperation, GEO Mountains lead by the Mountain Research Initiative and the National Research Council of Italy, the Mountain Societies Research Institute of the University of Central Asia, the High Mountain Summit of the World Meteorological Organization, the Canadian Mountain Network, to name a few.

This course is a cooperative effort between Sea to Sky Gondola, the Mountain Research Institute and GEO Mountains at the University of Bern in Switzerland, the University of Calgary and the Arctic Institute. The teaching materials for this course are posted for public use on the GEO Mountains website as open source learning, so anyone, anywhere in the world, has access to them.

The question is how can you contribute to mountain sustainability?

Pick 3 Things-To-Do for yourself. Will it be to stay on the trail? Volunteer? Participate in Citizen Science (like iNaturalist https://www.inaturalist.org.) Watch your plastics; Try using a carbon emissions calculator?

Activity 6: What do mountains mean to you?

Individual work. 15 minutes to complete "What do mountains mean to you?"

We've come full circle, back to the question of what mountains mean to you: Write a poem, sketch, doodle, or explain why mountains matter or what they mean to you. Use the space on the back of you Field Guide for this. You may choose to keep your work private. If you would like, we can take a photo of your work to post (without your name) on social media with the hashtag #mountainsmatter. Or you can do this yourself. This will help increase awareness about the issues of mountain sustainability.