Glaciers

Glaciers are masses of ice formed on land by the compaction and recrystallization of snow. As snow gets buried by repeated snowfalls, snowflakes are converted to granular snow, then firn, and finally glacial ice in a process called pressure melting. The porosity is reduced from about 90 percent for freshly fallen snow to nearly 0 percent for ice with the transformation taking place within 30 meters of the surface.

Glaciers grow when the accumulation is greater than the losses during the summer melting. They are also influenced by the steepness and elevation of the topography. e.g., a steep mountain, even if above the snow line will not have a glacier since the snow can't stick and accumulate. Mountains at low elevations, likewise, will not have glaciers.

Types of glaciers

There are two primary types of glaciers:
**Continental:** Ice sheets are dome-shaped glaciers that flow away from a central region and are largely unaffected by underlying topography (e.g., Greenland and Antarctic ice sheets);
**Alpine or valley:** glaciers in mountains that flow down valleys. When two or glaciers meet and merge at the base of mountains, the new glacier is called a piedmont glacier. If the piedmont glacier flows to the sea, it's called a tidewater glacier.

1) cirque glacier - glacier confined by a valley; forms in a cirque (semicircular basin at head of valley formed by plucking of bedrock by glacier moving down hill).
2) valley glacier - form in a valley.
3) ice caps - cover mountain tops.

Structure of glaciers

The region near the head of the glacier where snow is converted to firn and then ice is called the **zone of accumulation**. The region near the foot of the glacier is called the **zone of ablation;** this is where ice is lost by melting, evaporation or calving (to make icebergs). Separating the accumulation zone from the ablation zone is the **equilibrium line.** The equilibrium line is located at the **equilibrium line altitude (ELA).**

Flow of glaciers

Near the top of the glacier, the ice can fracture due to stresses associated with flow. These fractures are called crevasses. In the lower parts of the glacier, the ice flows like a fluid; this region is called the zone of plastic flow. At the very base of the glacier, the ice slips over the surface (a process called basal
slip). Typical flow speeds for glaciers are a few mm to a couple meters per day. However, occasionally glacial surges occur; during these times, glaciers can move up 6 km/year. Many crevasses form during glacial surges.

**Glacial erosion**

Abrasion: grinding of surface;  
Glacial flour: silty powder that develops as glaciers ground down rocks and pebbles under them;  
Glacial striations: grooves and striations caused by rock fragments;  
Plucking: water freezes and cracks rocks, and these rock fragments and carried by the glacial ice;  
Roche moutonnée: The wavy structure formed by combined abrasion and plucking which is asymmetrical (steep side is down "stream");  
Whaleback: similar to a roche moutonnée, but on a larger scale.

**Glaciers and mountain landscapes**

Arête: sharp ridges between glacial valleys;  
Cirque: curved depressions formed at the head of glacial valleys (tarns are lakes in cirques);  
Col: low divide between two cirques produced by glacier erosion of the arête;  
Fjords: glacial troughs filled with ocean water;  
Glacial troughs: U-shaped glacial valleys;  
Hanging valley: valley produced by side glaciers entering main valley glacier. After retreat, or melting, the hanging valley floor will be above the main valley (e.g., Yosemite Falls);  
Horn: rock peak surrounded by cirques;  
Pater noster lakes: a chain of small glacial lakes in a valley;  
Tarn: a cirque lake.

**Depositional features (drift)**

Drumlin: rounded hill made of till; typically 2 km long, 300 m high;  
Esker: stream bed formed from streams below melting glacier;  
Glacial erratic: boulder deposited by melting ice;  
Ground moraine: "blanket" of till left by melting glacier;  
Kettle pond: depression formed after an isolated block of ice melts;  
Lateral moraine: till collected on valley sides by rock falls and plucking off valley walls;  
Medial moraine: formed by merging of lateral moraines as two glaciers meet;  
Moraine: features made of till;  
Outwash plain: region in front of a melting glacier; typically has braided streams;  
Terminal moraine: deposited at the furthest point of glacial advance;  
Till: unsorted sediment deposited directly by glaciers.

**Two final comments:**

The epoch named the Pleistocene is characterized by widespread glacial advance and retreat. The most recent epoch, the Holocene, is the time period since the last major glaciation.

Glaciers depress the surface because of their weight. Once they melt, the ground rebounds, in a process called postglacial rebound. The rate of rebound can be used to determine the viscosity of the mantle. The present rate of rebound is as high as 1 cm/year near Hudson's Bay in Canada.
**Ice Ages**

During ice ages, the cooler climate immediately surrounding the ice sheet or cap produces cool, rainy weather (like Oregon's) that resulted in more precipitation and less evaporation and the formation of pluvial lakes. Some of these lake basins are seen in the western United States - Lake Bonneville and Lahotan (near the current Great Salt Lake).

More water was also locked into the ice sheets lowering the sea level by ~130 meters. The lower sea level produced several land bridges that have since been submerged by the rising sea level (e.g., Bering land bridge and English Channel land bridge).

The advancing, and retreating, glaciers also forced flora and fauna to migrate south and north. This forced competition then relaxed it and opened new areas for some communities.

**Causes for Glaciation**

For glaciation to happen in the first place, we must have sizable land masses near the poles and those land masses must have high elevations.

The land masses get there via plate tectonics.

Once the land masses are situated correctly for glaciers to form, the average temperature must decrease so they do form. This is where the orbit of the earth and it's variations take over.

In ~1930 Milutin Milankovitch proposed that variations in three parameters of the earth's orbit caused glacial fluctuations:

1. Orbital eccentricity - the orbit of the earth around the sun is not a circle, but is elliptical and also varies. This eccentricity is a minor cause for seasons.
2. Tilt variations in the axis of rotation (obliquity) - the tilt of the earth's rotational axis varies with time. A tilted axis is the primary cause of seasons.
3. Precession - the earth's axis of rotation wobbles which results in minor fluctuations in the amount of solar radiation we receive.

These three factors account for only some of the reasons why the earth receives varying amounts of solar radiation. Other factors are dependent on solar-system and galaxy scale events.
A glacier is a large, permanent (non-seasonal) mass of ice that is formed on land and moves under the force of gravity. Glaciers may form anywhere that snow accumulation exceed seasonal melt.

Alpine glaciers form in the mountains.

Continental glaciers may cover large sections of continents as in Greenland and Antarctica. Recognition of past continental glaciation of North America and Europe was a major geological advance of the nineteenth century.

A valley glacier is one that occupies a valley, whereas an ice sheet is a mass of ice that covers a large area as in Greenland and an ice cap is a mass of ice that occupies a high mountain area and flows outward in several directions.

A typical valley glacier will add snow at its head and lose to melt at its foot. The snow line is the line below which the annual snow cover is lost in summer. The region above the snowline is the zone of accumulation; the region below the zone of wastage. If it gains more than it loses, its terminus will advance. It loses more than it gains, it will retreat.

Snowpatch Spire in the Bugaboos. Glacial erosion is a powerful force that leaves a terrain with very high relief. In this heavily glaciated terrain, we can see the dark-colored ice at the foot of the glacier in the background and the much lighter-colored snow. The dark ice is ablating or melting.
When a glacier encounters an increase in the slope of its bed, crevasses form where the surface is in tension and close where it is in compression. When a glacier encounters a very steep slope in its bed flow may become chaotic as in an icefall. The irregular ice blocks are called seracs and may be extremely unstable. Ice will not hold a vertical wall more than about 40m high (130ft). At the bottom of an icefall the surface may be in strong compression and periodic waves called ogives may form on the surface. The crevasse at the head of a glacier that separates the moving ice from the stationary ice is called a bergschrund.

Movement of valley glaciers varies from a few mm to as much as 15m per day. The very high rates of movement may develop in response to melt water in the basal layer and may give rise to a glacial surge ("galloping glacier").

Glaciers a powerful agents of erosion and leave characteristic land forms.

Rock entrained in the ice will accumulate as moraines. Lateral moraines are those at the sides of the glacier, the terminal moraine marks the furthest advance of the ice. Recessional moraines mark intermediate advances. Medial moraines are rock entrained in ten middle of a glacier by the coalescing of lateral moraines where glaciers flow together.

Other glacial landforms include drumlins (rounded, striated outcrop hills), eskers (low sinuous mounds of till left by subglacial streams), and kettles (depressions in outwash plain left by buried blocks of ice).

Glacial valleys have a characteristic U-shape with very little alluvial fill. They may have hanging tributaries. The steep-walled, semi-circular valley at the head of a glacier is a cirque. Where two cirques intersect the narrow ridge is called an arete. Aretes may intersect in a horn. A glacial valley that opens to the sea and has been flooded by ocean water is a fjord.