Physical Geography

- 4 subdisciplines for 4 spheres of environment:
  - Lithosphere → Geomorphology
  - Atmosphere → Climatology
  - Hydrosphere → Hydrology
  - Biosphere → Biogeography

Geomorphology

- the scientific study of landforms and the processes that shape them
- Geomorphologists seek to understand:
  - why physical landscapes look the way they do
  - landform history and dynamics
- Also seek to predict future changes through a combination of field observation, physical experiment, and numerical modeling
**Catastrophism**

- idea that Earth was shaped by sudden, short-lived, violent events over relatively short period
  - dominant scientific beliefs in Europe founded on the biblical narratives of Creation and flood of Noah
  - Anglican Archbishop James Ussher published a widely-accepted chronology in 1648 based on the Bible and historical texts
    - Fixed moment of creation as the night preceding October 23, 4004 BC

**Uniformitarianism**

- idea that natural laws and processes we see now, have always operated in the past
  - slow incremental changes (e.g. erosion) shaped the Earth's appearance
  - James Hutton (1785) popularized idea in geology
- Extended time frame of earth’s physical history back to millions, eventually billions of years (current estimate 4.55 billion years)
Modern consensus

- Today most combine catastrophist and uniformitarianist standpoints
  - The Earth's history is a slow, gradual story punctuated by occasional natural catastrophic events that have affected Earth and its inhabitant
- Most mass extinction events have been result of catastrophic events (e.g., 10 km wide asteroid at end of Cretaceous Period 65 million BP) or large scale volcanos
Geological Time as a 24 Hour Day

Earth's Physical History as a 24-Hour Day

Origin of Earth
(4.55 billion years ago)
Collision with asteroid creates moon

First atmosphere (90%) First life forms (single-cell)
1st atmosphere (NY)
2nd atmosphere (9%) 2nd atmosphere (NY)
3rd atmosphere (oxygen buildup) 12:00
8:00

Geoepochs: Eons (modern humans) appear 3.5 seconds before midnight, and all written human culture appears in the last 3 seconds of this 24-hour day.

Geomorphology

- Evolved out of Geology late 19th century
- William Morris Davis (1850-1934)
  - "father" of American geography (founded Geography Department at Harvard)
  - Association of American Geographers 1st President
- Strongly influenced by Darwin and uniformitarian ideas
Davis -- Cycle of Erosion theory

- "it seems most probable, that the many pre-existent streams in each river basin concentrated their water in a single channel of overflow, and that this one channel survives - a fine example of natural selection."
- theory of how mountains/landforms are created and evolve
- cycle begins with the uplift of mountains
  - "youth" - relief steepest and most irregular.
  - "maturity" - over time, the streams carve wider valleys
  - "old age" - meandering rivers flowing thru flat, level plains at the lowest elevation possible ("base level" or "peneplain")
- cycle starts over with "rejuvenation", another uplift of mountains and the cycle repeats.

Cycle of Erosion
Cycle of Erosion

- Davis' theory is not entirely accurate, but revolutionary in its time, and helped modernize physical geography and create the field of geomorphology.
- The real world is not quite as orderly as Davis' cycles. Most rivers show all stages of his model at once, but he could not explain why "uplift" took place.

Geomorphologic Processes

- Geomorphologists now believe variation in landforms is produced by two types of processes based on source of energy that drives them:
  - **Energy Internal to the Earth** (Endogenic):
    - Plate movements
    - Volcanism
  - **Energy External to the Earth** (Exogenic):
    - Weathering
    - Mass Wasting
    - Erosion
Internal (Endogenic) Forces

- **Diastrophic:**
  - pressures that slowly transform the earth’s crust

- **Volcanism:**
  - transports heated material towards the earth’s surface

Diastrophic Forces

- The pressures that slowly transform the earth’s crust include:
  - Folding: layers of rock buckle due to pressure
    - Creates ridges and folds in concave waves
  - Faulting: fractures in the surface of a plate
    - Creates escarpments, separation, fault block mountains
  - Earthquakes: whenever movement occurs crust is reshaped
Layers of the Earth

- **Inner Core**
  - Solid iron and nickel core, 6,378 - 5,100 km
- **Outer Core**
  - Liquid iron, 5,100 - 2,900 km
- **Lower Mantle**
  - Mostly solid, 2,900 - 700 km
- **Upper Mantle (Asthenosphere)**
  - Partly molten, 100-700 km
- **Lithosphere**
  - Crust and most solid mantle, 0 to 100 km

Continental Drift

- Developed in 1906 by Alfred Wegener:
  - All of earth’s land masses were once a super continent called Pangaea (200 million years ago)
  - Land masses slowly broke away from each other to form today’s continents
  - Theory rejected because he couldn’t explain why this would occur
  - Also dismissed because he was a meteorologist
In the 1960s, geoscientists reworked Wegener’s theory to explain why continents move.

Movement explained by earth’s interior composition:
- Landforms are part of thin, rigid crust (17 km deep)
- Supported by deeper partially molten layer (mantle)
- Extremely high temperatures in the centre
- Plates (solid) move on convection currents in semi-molten mantle

identified 7 major plates (and 9+ more smaller ones)
Plate Boundaries

- three types of boundaries between plates:
  - Divergent: plates move away from each other
  - Convergent: plates move toward each other (mountains)
    - subduction - one plate forced under another in ocean trenches
  - Transform: plates pass each other

- Cause earthquakes, formation of deep sea trenches and ridges, mountain ranges, and Wegener’s continental drift
Divergent boundaries

- Rifts / trenches formed
  Mid-Atlantic Ridge; African Rift Valley
**Transform Boundaries**

- Plates move past each other
- (most earthquakes)
  - San Andreas Fault
  - Creates no new crust

**Convergent Boundaries**

- Lighter continental plates pushed up by denser oceanic plates
- Produces trenches / mountains / volcanos
  - "Ring of Fire" - Pacific plate pushing on both coasts
Hot Spots

- where crust is weak, molten materials rise to surface, sometimes in middle of plates
- As plates move, location of hot spot shifts (Hawaiian islands)
  - Other examples Iceland, Galapagos, Yellowstone
- Canadian geophysicist Tuzo Wilson proposed to solve one anomaly of plate tectonics theory

Hawaiian Hotspot

- Over 70 million years, has shifted over 6000 km from Aleutians to Hawaii
Earthquakes

- a sudden release of energy in the Earth’s crust that creates seismic waves
- There are around 500,000 earthquakes each year. 100,000 of these can actually be felt
- Most of the world’s earthquakes (90%, and 81% of the largest) take place along the Pacific Ring of Fire
Preliminary Determination of Epicenters
358,214 Events, 1963 - 1998

Magnitude

Earthquakes

Chile (1960)
San Francisco (1989)
Kobe (1995)
California (1989)

Energy Equivalents

Krakatoa Eruption
World's Largest Nuclear Test (USSR)
Hiroshima Atomic Bomb

Number of Earthquakes per Year (worldwide)
Tsunami
Volcanism

- Rock melting inside the earth generates magma that rises to the surface where there are fractures and weaknesses

- four main types:
  - **Cinder cone** small, common
  - **Composite** Mt. Fuji, St. Helen’s
  - **Shield** Mauna Loa
  - **Lava Dome** Mt. Pelee
Eyjafjallajökull (Iceland)
Airspace completely (red) or partially (orange) closed to air traffic 18 April 2010
Largest Volcanos

- Yellowstone - 2 million BP volcanic eruptions
  - ash and volcanic debris covered western half of US over 1m
  - 2500 km$^3$ of material thrown into the atmosphere
- Lake Toba, Indonesia - supervolcano 69,000-77,000 BP
  - largest explosive eruption on Earth in last 25 million years
  - global consequences: killed most humans alive, volcanic winter -
    temp. decline of 3-5°C, 15°C in high latitudes
- Tambora, Indonesia 1815
  - 10 000 direct deaths, 82 000 indirect (starvation, disease, hunger)
  - "Year without a Summer" -- Daily low temperatures abnormally low
    in northern hemisphere, famine widespread due to crop failures.

Reading: The Tragedy of St. Pierre

- Describes eruption of Mt. Pelee in Martinique in 1902 (worst eruption of 20th century)
- killed about 30,121 people (only two survivors)
- most deaths caused by pyroclastic flows
  - fast-moving currents of hot gas and rock (tephra), which
    travel away from the volcano at up to 700 km/h
  - gas can reach temperatures of about 1,000 °C
  - flows normally hug the ground and travel downhill, or
    spread laterally under gravity
**Exogenic (External) Forces**

- **Weathering:**
  - a set of processes that,
    - Separate particles of rock from larger rocks
    - Prepare rocks for creation of soil and deposition

- **Mass Wasting:**
  - the pulling of loose objects towards the earth

- **Erosion:**
  - the processes that move small particles of gravel, dust, sand and silt across the earth’s surface

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**Weathering**

- **Two types of weathering:**
  - **Mechanical Weathering:**
    - disintegration of materials at or near surface
      - frost action
      - salt crystals
Weathering

- **Chemical Weathering**
  - decomposition of rocks due to chemical reactions of minerals with heat and moisture
  - Rock breaks down into components through oxidation (oxygen), hydrolysis (water), carbonation (carbon dioxide)

Mass Wasting

- pull of gravity alters landforms
- Large and small materials pulled toward the earth’s surface, creating new land forms
- Can be rapid or slow:
  - Avalanches and landslides: quickly change the shape of mountains and deposit materials at the base
  - Soil creep and mud-flows slowly change slopes and deposit materials at their base
Landslide

- La Conchita, California
- 1995

St. Jude QC
May 2010
Erosion

- Erosion caused by agents that carve landforms, move earth materials
  - **Running Water**: run-off picks up particles that act as abrasives, them dump material creating new landforms
    - High water volume, rapid flow, steep slope = rapid erosion
    - Slow flows = deposition of load-creating deposition
  - Follows classic Davis cycle of erosion model

Ground Water: decomposes rocks and creates sinkholes, especially in areas of limestone rock
Guatemala City -- May 2010

Erosion

- Ice
  - weight of glacier breaks up rock and glacier transports ‘till’ as it moves
    - Leaves behind large troughs and lakes, Deposits glacial till as it melts
Continental Glaciation

Alpine Glacier

Lateral Moraine
End Moraine
Erosion

- **Waves and Currents**
  - deposit sand/gravel on shore, backwash pulls away
  - Creates sandy beaches and spits, causes cliff erosion

- **Wind Erosion**: sand and dust particles blown against rock surfaces
  - More severe in dry areas
  - “Dust Bowl” 1930s