Geomorphology: Mechanics and Evolution of Landscapes
(GES 206.2.5401)

• Instructor: Itai Haviv, haviv@bgu.ac.il, room 331, building 58, office hours: Tuesday 11:15-13:15

• Teaching assistant: May-Tal Sadeh, toolylooly@gmail.com, Room 127, building 58, office hours: Wednesday 09:00-11:00

• Your info inputs:
  - Degree, Year, Department
  - background in Math, Physics, Geomorphology
  - software experience (Excel, Matlab, ArcGIS)
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• Course focus

• Assignments and grading
  Labs and problem sets 30%
  Field work reports 20%
  Critical review 10%
  Exam 40%
  ALL MANDATORY!

• Field trips:
  Sunday 18.12
  Sunday 08.01
  During the field trip weeks Labs will be held on Thursday from 17:00 to 19:00
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- Course materials will be posted in Highlearn
Why study geomorphology? Grand challenges in earth surface processes

1. What Does Our Planet’s Past Tell Us About Its Future?
2. How Do Geopatterns on Earth’s Surface Arise and What Do They Tell Us About Processes?
3. How Do Landscapes Influence and Record Climate and Tectonics?
4. How Does the Biogeochemical Reactor of the Earth’s Surface Respond to and Shape Landscapes from Local to Global Scales?
5. What Are the Transport Laws That Govern the Evolution of the Earth’s Surface?
6. How Do Ecosystems and Landscapes Coevolve?
7. What Controls Landscape Resilience to Change?
8. How Will Earth’s Surface Evolve in the “Anthropocene”?
9. How Can Earth-Surface Science Contribute Toward a Sustainable Earth Surface?

USA National Research Council, 2010
Landscapes on the Edge: New Horizons for Research on Earth’s Surface
Landscapes are the interface for lithosphere-atmosphere interactions
Late Cenozoic uplift of mountain ranges and global climate change: chicken or egg?

Peter Molnar & Philip England

Molnar, 2004
Interacting processes

- Bedrock Channel Erosion
- Landsliding and Rockfall
- "Diffusive" Hillslope Transport
- Bedrock Weathering
- Fluvial Erosion, Transport and Deposition
- Tectonic Uplift
Guiding principles

- *Conservation* (of mass, energy, momentum)
- *Transport Rules* (flow of water and ice, transport of sediment, etc)
- *Event Size, Frequency and Duration* (storms, floods, climate variations, etc)

![Conservation of Mass on a Hillslope Element](image)

*Fig. 1.*—Relations between rate of transport, applied stress, and frequency of stress application.
An exiting era for Geomorphology

1. New geochronologic methods
2. Highly improved computational efficiency
3. Wide spread availability of high resolutions datasets including satellite imagery and Digital Elevation Models (DEM’s). The ability to measure and quantify geomorphic features on all scales.
4. Data on extra-terrestrial landscapes
LIDAR
(Light Detection and Ranging)
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The Mars Orbiter Laser Altimeter (MOLA)
reconstruct Earth’s past in increasing detail including aspects of its geochemistry, biotic processes, topography, and particle and solute fluxes.
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\[ \frac{\partial Z}{\partial t} = D \frac{\partial^2 Z}{\partial x^2} - K A^m \frac{\partial Z}{\partial x} + U \]

\[ 1 = \frac{K L_c^{2m+1}}{D} \]

\[ L_c = \left( \frac{D}{K} \right)^\frac{1}{2m+1} \]

Perron et al., 2009, Nature
Hasbergen and Paola, 2000. *Geology*
Hasbergen and Paola, 2000. *Geology*
How Do Landscapes Influence and Record Climate and Tectonics?

Lave and Avouac, 2001, JGR
Are long-term exhumation rates correlated with monsoon precipitation?
How Do Landscapes Influence and Record Climate and Tectonics?

Egholm et al., 2009, *Nature*
3. Are long-term exhumation rates correlated with monsoon precipitation?

Stolar, Roe and Willett, 2007 (JGR)
Whipple (2009), *Nature* modified from Willett (1999), *JGR*
How Does the Biogeochemical Reactor of the Earth's Surface Respond to and Shape Landscapes from Local to Global Scales?

Tree throw

Gophers burrowing

Gabet et al., 2003
What Are the Transport Laws That Govern the Evolution of the Earth's Surface?

\[
\bar{q}_z = -K_1 \nabla z
\]

\[
\bar{q}_z = -K_2 h \cos \theta \nabla z
\]

\[
\bar{q}_z = \frac{K_3 \nabla z}{1 - \left(\frac{\nabla z}{S_c}\right)^2}
\]

\[
\bar{q}_z = \frac{K_4 (h) \nabla z}{1 - \left(\frac{\nabla z}{S_c}\right)^2}
\]

Roering (2008)
Grove Karl Gilbert (1843-1918, USGS director):
1877- The geology of the Henry mountains. “Equality of action” and dynamic equilibrium, graded rivers
1890 - Lake Bonneville, discovered crustal flexure due to isostatic rebound and calculated mantle viscosity.
1909 – The convexity of Hilltops
Early concepts and prominent figures

William Morris Davis (1850-1934, Harvard Professor):
1899 – The geographical cycle
The erosion cycle: Mountains evolve to peneplains.
Structure, Process and Time dictate landscape evolution.
Historical approach. Used evolution to explain natural cycles of landscapes. Assumed rapid (instantaneous) uplift.

Davis, 1899
A. In the initial stage, relief is slight, drainage poor.

B. In early youth, stream valleys are narrow, uplands broad and flat.

C. In late youth, valley slopes predominate but some interstream uplands remain.

D. In maturity, the region consists of valley slopes and narrow divides.

E. In late maturity, relief is subdued, valley floors broad.

F. In old age, a peneplain with monadnocks is formed.
Early concepts and prominent figures

Walther Penck (1888-1923, Austrian)
1924 - Morphological Analysis of Landforms (in German)
1953 - (English version)

Both Davis himself and his followers have made and still make the tacit assumption that uplift and denudation are successive processes, whatever part of the earth is being considered.

It is essential, when investigating the origin and development of denudational forms as they appear at the earth's surface, to ascertain the relationship between the intensity of the endogenetic and of the exogenetic processes, in short, between uplift and denudation; and it is necessary to follow out how this changes as time goes on. None of the present methods used in morphology brings us nearer to achieving this end; none even attempts to do so. The assumption generally introduced, that uplift and denudation were successive processes, or could at any rate be treated as such, has stood in the way.
**Orographic Precipitation**

Topography -> Climate

Hillslope transport:
- Creep, sheetwash, gullies, landslides, debris flows
- Runoff hydrology

Weathering/soil production

Debris-flow incision/deposition; Glacial erosion

"Bedrock" channel incision, aggradation

Alluvial fans: Fluvial and debris flow deposition
- Channelization, avulsion, segmentation

Uplift

Isostacy, flexure, deformation
- Erosion -> Tectonics

Subsidence

=> Hillslope form, gradient, length
- Drainage density
- Sediment supply (rate/size)

=> River profiles, topographic skeleton
- Valley form, channel morphology
- Fill and strath terraces

=> Fan size, slope, texture
- Hazard, sediment facies

Alluvial rechannelization, aggradation, incision
- Sediment transport, flooding
- Lateral migration, avulsion

=> Channel slope, width, form, floodplain
- Hazard, facies