Cycles represent natural systems in which matter and energy are continuously transferred between different spheres of the environment. Their study involves a recognition of stores, fluxes, and residence times, with hydrological, geological, and biogeochemical cycles providing the global context for landform science. Whereas cycles can be repeated, portions of cycles, as cascades or trajectories, are uni-directional. Temporal cycles include those in Milanković theory, as well as short-term cycles that enable different orders of magnitude of change to be identified, as cycles, or portions of cycles, that are more specifically geomorphic. Spatial cycles, usually referred to as cascades, involve erosion and deposition aspects of denudation, and geomorphology is central to understanding the temporal phasing of environmental flows.
Figure 8.1 The hydrological cycle (US Geological Survey)

A very good illustration of Milankovitch cycles is provided at http://www.globalwarmingart.com/wiki/File:Milankovitch_Variations.png
<table>
<thead>
<tr>
<th>Cycle</th>
<th>Stores or Reservoirs</th>
<th>Aspects of Transfers or Flux and Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geological:</strong> the</td>
<td><strong>Tectonic:</strong> Involves</td>
<td>Driven by geothermal energy and can provide pressure and thermal conditions to metamorphose rocks</td>
</tr>
<tr>
<td>creation and destruction of rocks, usually measured in hundreds of millions to billions of years</td>
<td>the movement of large plates in the lithosphere, produces ocean basins, continents, and mountains</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Rock:</strong> Igneous, sedimentary and metamorphic rocks</td>
<td></td>
</tr>
<tr>
<td><strong>Hydrological</strong> or water cycle, the continuous movement of water on, above and below the surface of the Earth</td>
<td>Oceans (c.94%), groundwater (&gt;4%), in ice sheets and glaciers (c.2%), with smaller amounts in the atmosphere, on land – in lakes and seas and rivers and in the soil</td>
<td>Evaporation, precipitation, runoff Solar energy, with about one third of that reaching the earth used in evaporating water and about 400,000 km$^3$ evaporated each year The entire contents of the oceans would take about 1 million years to pass through the hydrological cycle The ‘big six’ elements, carbon, nitrogen, phosphorous, hydrogen, oxygen and sulphur, are the building blocks of life Variations in residence times – calcium can average less than 109 years in tropical soils but 10–100 in temperate environments Photosynthesis fixes carbon dioxide from air and water; plants and animal respiration, decomposition Nitrogen fixation is the process of converting N$_2$ to nitrate or ammonia which can then be used: major processes in the global nitrogen cycle include nitrogen fixation (by both biological and industrial processes), uptake and release by organisms, denitrification (the conversion of nitrate back to N$_2$), soil erosion, runoff, and flux in rivers, and burial in marine sediments</td>
</tr>
<tr>
<td><strong>Biogeochemical cycling of elements, minerals and compounds</strong></td>
<td>The whole or part of the atmosphere, ocean, sediments and living organisms</td>
<td></td>
</tr>
<tr>
<td><strong>Carbon:</strong> Over 99% in carbonate rocks and organic deposits</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nitrogen:</strong> The nitrogen cycle is one of the most complicated material cycles in nature: the atmosphere (80% N$_2$) contains most of the nitrogen but there are also significant amounts in living organisms and in the soil</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>Cycle</th>
<th>Stores or Reservoirs</th>
<th>Aspects of Transfers or Flux and Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Eutrophication of lakes and rivers. Five main reactions in nitrogen cycling are: fixation, assimilation of nitrate to organic N, mineralization, nitrification oxidation process, and denitrification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Second to bicarbonate as the most abundant anion in rivers, major cause of acidity in natural and polluted rain water, a key ingredient in rock weathering, and the sulphur cycle is one of the most affected by human activity</td>
</tr>
<tr>
<td>Sulphur</td>
<td>Mainly in lithosphere, also in hydrosphere and vital in proteins</td>
<td>Unlike many other biogeochemical cycles, does not include a gas phase so that the atmosphere does not play a significant part, and the largest reservoir of phosphorus is in sedimentary rock: involves the uptake of phosphorus by organisms. After the decomposition of biological waste, it can accumulate in large amounts in soils and sediments. Phosphorus is used by humans as a fertilizer in farmlands and in detergents. Overuse of phosphorus can lead to eutrophication</td>
</tr>
<tr>
<td>Phosphorus</td>
<td></td>
<td>The transmission of hydrogen from water to carbohydrates etc. and back to water by living organisms. Differs from other biogeochemical cycles in that because of its low molecular weight hydrogen can leave Earth’s atmosphere. It has been suggested that this occurred on a grand scale in the past and that this is why today the Earth is mostly irreversibly oxidised</td>
</tr>
<tr>
<td>Oxygen</td>
<td></td>
<td>Three main reservoirs are the atmosphere, biosphere and the lithosphere in which silicate and oxide minerals are the main stores. Photosynthesis is the main driver producing sugars and free oxygen from carbon dioxide and water</td>
</tr>
</tbody>
</table>
Table 8.3  A channel classification framework compiled as a basis for river channel management (from Downs and Gregory, 2004, Table 3.3, page 58)

- Drainage basin/watershed/catchment
- Zones: production transfer deposition \( Schumm \text{ 1977b} \)
  - Boulder + floodway
  - Pastoral
  - Estuarine
- valley segments: bedrock
  - aliuval
  - coiluvial \( Montgomery \text{ 1993} \)
- Stream reaches: cascade
  - step-pool
  - plane-bed
  - pool-nflle
  - regime
  - braded \( Montgomery \text{ and Buffington 1993} \)
- channel unit:
  - fast water:
    - turbulent
    - nonturbulent \( Hawkins \text{ et al 1993} \)
  - slow water:
    - scour pools
    - dammed pools
- within channel:
  - aquatic habitats:
    - aquatic hapitates
    - aquatic communicates
    - sedimentary assembiage
- river environment at a point – incremental analysis

**BOX 8.1**


By 1968, J. Tuzo Wilson had identified three basic elements of geodynamics: plate tectonics, mantle plumes of deep origin, and the Wilson Cycle of ocean opening and closing, which provides evidence of plate tectonic behaviour in times before quantifiable plate rotations.

The rock cycle according to the Geological Society at www.geolsoc.org.uk/ks3/gsl/education/resources/rockcycle.html and on YouTube at www.youtube.com/watch?v=dwLRItCcyQo
RELEVANT ARTICLES IN PROGRESS IN PHYSICAL GEOGRAPHY:


UPDATES

Many papers can be cited to illustrate application of recent technique advances (see Table 1.4) but a particularly graphic demonstration of the use of use of cosmogenic nuclides is given by:


This illustrates the discussion in Section 8.2 (p. 82) and shows how bedrock erosion rates were determined for three evolution stages of fairy chimneys (mushroom-like structures or hoodoos) in the Central Anatolian Plateau of Turkey.

Another paper using technical advances in survey to reveal spatial patterning in landforms to good effect is:


The theme of sediment connectivity within sediment cascades is taken further in:

In practice, sediment cascades (or fluxes) can be very complex. This is well illustrated in a special issue of *Geomorphology*: