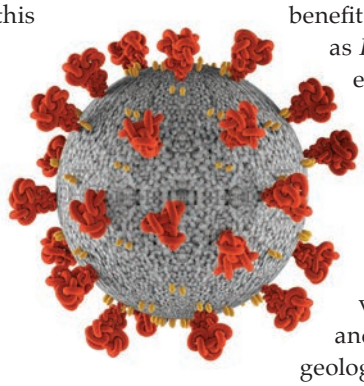
The Year of (What Is?) Life

With life altered irrevocably by the pandemic, **Michael A. Rosen** asks whether viruses might be geological agents.

When our Society designated 2020 the "Year of Life", who could have predicted how life would be transformed by COVID-19? Businesses and institutions closed. Millions became unemployed. The UK economy shrank by a fifth. Confirmed COVID-19 cases have surpassed 30 million globally and over a million people have died. All this from a virus.

Many biologists do not classify viruses as 'life'. Simply composed of nucleic acids enveloped by a protein, viruses cannot metabolise or reproduce without a host cell. Their evolution may lack the "last universal common ancestor" (LUCA) that is theorised for cellular life.



Yet life can appear subordinate to viruses. For example, the sea slug, *Elysia chlorotica* long puzzled scientists. It grazes on algae, from which it incorporates chloroplasts into its tissues, then stops eating to live solely by photosynthesis. How the chloroplasts remain intact within *E. chlorotica* lacking plant cell metabolism was baffling until discovery that the slugs produce essential plant proteins. How did this process evolve?

After laying eggs to propagate the species, a generation of *E. chlorotica* dies, synchronously. But not before a retrovirus blooms inside them. Millions of virus particles are released as the slugs decay. Not only does this explain how photosynthesis evolved in a sea slug (by virus-aided horizontal gene transfer) but the retrovirus may control *E. chlorotica's* full life cycle.

Viruses in the biosphere

Alive or not, viruses arguably are Earth's most successful biological entities. Virus genomic expression and replication vary greatly. Conversely, cellular life has a universal genome, DNA, and only one method of replication. A few genes are common among viruses but missing from cellular organisms. So not all viruses began as genetic material "escaped" from cells. Instead they might be ancient, originating alongside the cellular LUCA.

Every environment harbours viruses. Nearly all cellular organisms host them. They jump between hosts, as we know well from coronaviruses and bats. All viruses are parasitic but not all are pathogens. Some benefit their hosts, as *E. chlorotica's* retrovirus enables photosynthesis.

Viruses outnumber cellular life ten to a hundred-fold. The average litre of seawater contains a billion viral particles, a kilogram of sediment contains a million viruses. With such abundance and influence, do viruses affect geology? Are we overlooking their signature in the geological record?

Viruses in the geosphere?

Photosystems are proven to be transferred among modern cyanobacteria by viruses and recently calcispheres discovered in Neoproterozoic stromatolites are postulated to be virus fossils. Did viruses help oxygenate the atmosphere? They control metabolism, blooms and demise in modern coccoliths. Have viruses affected chalk deposition? Viruses kill 80% of benthic bacteria. What is their influence on ocean productivity? On sedimentation? On source rock accumulation? Viral material is abundant in modern microbial mats. Did they help form fossil lagerstätten? They are documented nucleation sites for iron precipitation in acid mine water. Might viruses play a role in mineralisation?

Our Society designated this "Year of Life" to highlight modern and geological links between the biosphere and geosphere. Will the events of 2020 also trigger the study of viruses as geological agents equal to or in concert with (other) life?

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Further Reading list available online.

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Pictures should be of print quality – please take photographs on the largest setting on your camera, with a plain background.

Precedence will always be given to more topical contributions. Any one contributor may not appear more often than once per volume (once every 12 months).

> "ALIVE OR NOT, VIRUSES ARE POWERFUL AGENTS WITHIN THE BIOSPHERE. TO WHAT EXTENT DO VIRUSES ALSO AFFECT THE GEOSPHERE?"