ELSI Virus workshop

(ver. 0906)

Spotlighting viruses in evolution: 4 billion years of coevolution with cells

ELSI Hall (ELSI-1 bldg. Tokyo Tech Univ)

Friday Sep. 9. 2016 13:30-17:00

Organizer/Chair:

Tomohiro Mochizuki (ELSI)

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13:30-13:35 **Tomohiro Mochizuki (ELSI-Titech)**

Opening comment and introduction

13:35-14:00 **Masaharu Takemura (Tokyo Univ. Sci., Japan)**

Giant viruses inhabiting aquatic environments: how did they emerge and come?

14:00-14:25 **David Prangishvili (Institut Pasteur, France)**

Viruses of hyperthermophilic Achaea

14:25-14:50 **Mart Krupovic (Institut Pasteur, France)**

Assembly and budding of the archaeal enveloped virus SSV1

14:50-15:15 **Ken Stedman (Portland State Univ., USA)**

Chimeric viruses and insights into transitions between RNA and DNA

*15:15-15:30 *** Pause café ****

Coffee and snacks provided at the 2nd floor (Agora)

15:30-16:15 **Eugene Koonin (NCBI, USA)**

Origin of cells: from Geochemistry to Virology

16:15-17:00 **Patrick Forterre (Institut Pasteur, France)**

Origins

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* No preregistration required, but external visitors will be asked to sign their names at the entrance

* Temporary WIFI will be provided

ABSTRACTS

13:35-14:00

Masaharu Takemura (Tokyo Univ. Sci.)

Giant viruses inhabiting aquatic environments: how did they emerge and come?

So-called "giant viruses" in the narrow sense, include two families and several other individual viruses: Family Mimiviridae, Family Marseilleviridae, Pandoraviruses, Pithovirus, Mollivirus, and Faustovirus. The Mimiviridae and Marseilleviridae families are distributed worldwide in oceans, rivers, lakes, and various artificial bodies of water. Recently we isolated a new Marseilleviridae family member, Tokyovirus, from the Arakawa River in Tokyo, followed by other new Mimiviridae family members isolated from pond, river, and some sea molluscs. Researchers have just begun to embark on a discussion of the biological significance of giant viruses, exploring various aspects such as their genomes, structures, and evolution. How did these giant viruses emerge at ancient times and how have they come to our familial circumstances and affected the evolution of life?

14:00-14:25

David Prangishvili (Institut Pasteur, France)

Viruses of hyperthermophilic Achaea

In my talk I will summarize the state of art of our studies on hyperthermophilic archaeal viruses, focusing on their virion structure and genomic properties.

14:25-14:50

Mart Krupovic (Institut Pasteur, France)

Eukaryotic-like Virus Budding in Archaea

Similar to many eukaryotic viruses (and unlike bacteriophages), viruses infecting archaea are often encased in lipid-containing envelopes. However, the mechanisms of their morphogenesis and egress remain unexplored. Here, we used dual-axis electron tomography (ET) to characterize the morphogenesis of Sulfolobus spindle-shaped virus 1 (SSV1), the prototype of the family Fuselloviridae and representative of the most abundant archaea-specific group of viruses. Our results show that SSV1 assembly and egress are concomitant and occur at the cellular cytoplasmic membrane via a process highly reminiscent of the budding of enveloped viruses that infect eukaryotes. The viral nucleoprotein complexes are extruded in the form of previously unknown rod-shaped intermediate structures which have an envelope continuous with the host membrane. Further maturation into characteristic spindle-shaped virions takes place while virions remain attached to the cell surface. Our data also revealed the formation of constricted ring-like structures which resemble the budding necks observed prior to the ESCRT machinery-mediated membrane scission during egress of various enveloped viruses of eukaryotes. Collectively, we provide evidence that archaeal spindle-shaped viruses contain a lipid envelope acquired upon budding of the viral nucleoprotein complex through the host cytoplasmic membrane. The proposed model bears a clear resemblance to the egress strategy employed by enveloped eukaryotic viruses and raises important question as of how the archaeal single-layered membrane composed of tetraether lipids can undergo scission.

14:50-15:15

<u>Ken Stedman (Portland State Univ, USA)</u>

Chimeric viruses and insights into transitions between RNA and DNA

Until recently it was thought that viruses only recombined with close relatives; DNA viruses only recombine with DNA viruses and RNA viruses only recombine with RNA viruses. We found a virus genome in a metagenomic study of an acidic hot lake that appears to have arisen by recombination between a ssDNA and RNA virus (1). Similar hybrid or chimeric genomes have been found in many environments, from deep sea sediments, to Korean air samples (2-3). These novel ssDNA virus genomes only contain 2 conserved genes, a capsid protein gene similar to plant virus protein genes and a replication initiation protein similar to other ssDNA viruses and some plasmids. We have proposed a number of theories for the origins of these viruses (2, 4), are isolating proteins, and are applying novel micro-fluidic techniques to isolate viruses and their hosts.

1. G. S. Diemer and K. M. Stedman. A Novel Virus Genome Discovered in an Extreme Environment Suggests Recombination between Unrelated Groups of RNA and DNA Viruses. (2012) *Biology Direct*, **7(1):**13. doi:10.1186/1745-6150-7-13
2. K. Stedman. Mechanisms for RNA capture by ssDNA viruses: Grand Theft RNA! (2013) *J. Mol. Evol.*, **76/6** 359-364. doi: 10.1007/s00239-013-9569-9
3. Roux et al.. Chimeric viruses blur the borders between the major groups of eukaryotic single-stranded DNA viruses. (2013) *Nat. Comm.* **4** doi: 10.1038/ncomms3700
4. K.M. Stedman. Deep Recombination: RNA and ssDNA virus genes in DNA virus and host genomes. (2015) *Annu. Rev. Virol.* **2**:10.1-10.15. doi: 1-/1146/annurev-virology-100114-055127.

15:30-16:15

<u>Eugene V. Koonin (NCBI, USA)</u>

Origin of cells: from Geochemistry to Virology

It is often hypothesized that first cells evolved in oceanic environments, in particular in the vicinity of hydrothermal vents. However, comparison of the ionic compositions of modern cells and various environments, based on ‘chemistry conservation principle’ suggest otherwise. All cells contain much more potassium, phosphate, and transition metals than modern (or reconstructed primeval) oceans, lakes, or rivers. Cells maintain ion gradients by using sophisticated, energy-dependent membrane enzymes (membrane pumps) that are embedded in elaborate ion-tight membranes. The first cells could possess neither ion-tight membranes nor membrane pumps, so the concentrations of small inorganic molecules and ions within protocells and in their environment would equilibrate. Hence, the ion composition of modern cells most likely reflects the inorganic ion composition of the habitats of protocells. The ‘hatcheries’ of the first cells can be reconstructed by combining geochemical analysis with phylogenomic scrutiny of the inorganic ion requirements of universal components of modern cells. These ubiquitous, and by inference primordial, proteins and functional systems show affinity to and functional requirement for K^+, Zn^{2+}, Mn^{2+}, and phosphate. Thus, protocells should have evolved in habitats with a high K^+/Na^+ ratio and relatively high concentrations of Zn, Mn, and phosphorous compounds. Geochemical reconstruction shows that the ionic composition conducive to the origin of cells could not have existed in marine settings but is compatible with emissions of vapor-dominated zones of inland geothermal systems. Under the anoxic, CO_2-dominated primordial atmosphere, the chemistry of basins at geothermal fields would resemble the internal milieu of modern cells. The precellular stages of evolution could have transpired in shallow ponds of condensed and cooled geothermal vapor that were lined with porous silicate minerals mixed with metal sulfides and enriched in K^+, Zn^{2+}, and phosphorous compounds. In parallel to the (geo)chemical reconstructions that reveal salient aspects of the habitats and the biochemistry of primordial cells, comparative analysis of cellular and viral genomes implies a scenario of precellular evolution that involves cohesion of the genomes of the emerging cellular life forms from primordial pools of small genetic elements that eventually segregated into hosts and parasites.

References

Mulkidjanian AY, Bychkov AY, Dibrova DV, Galperin MY, Koonin EV. Origin of first cells at terrestrial, anoxic geothermal fields. Proc Natl Acad Sci U S A. 2012;109:E821-30

Koonin EV. The origins of cellular life. Antonie Van Leeuwenhoek. 2014 106:27-41

16:15-17:00

Patrick Forterre (Institut Pasteur, France)

Origins

I will briefly present my currents ideas about different origins: origin of life, of cells, of viruses (virocells), of LUCA (its nature) and of the three cellular domains (origins of hyperthermophiles and origin of eukaryotes). I will also emphasize our recent data supporting the Woese versus the eocyte tree.