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Viruses of the Environment
Challenges in Viral Ecology and Evolution
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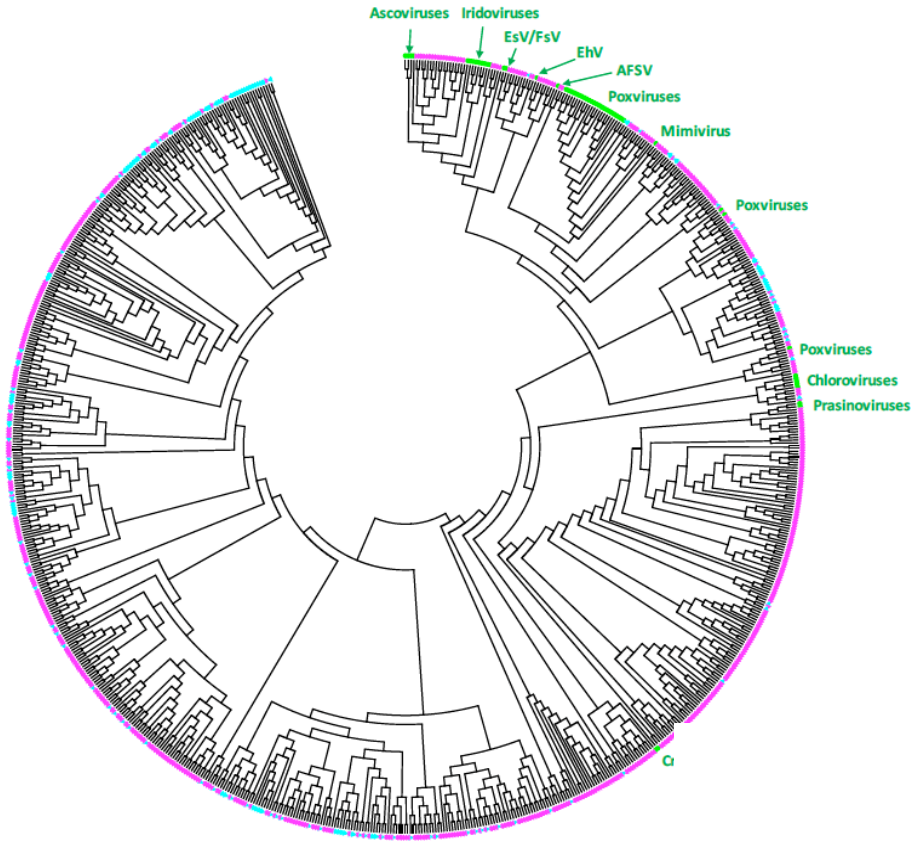
Viral Agents
have
Natural Genome Editing Competences

Guenther Witzany
Telos – Philosophische Praxis
5111-Buermoos, Austria

www.biocommunication.at

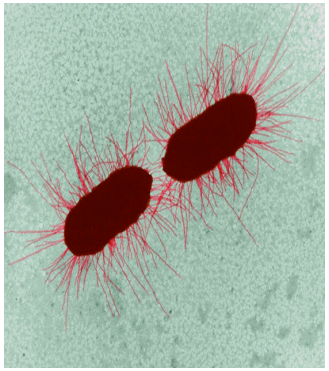


Biocommunication and Natural Genome Editing

The concept of biocommunication and natural genome editing investigates

1. **signal mediated interactions** between organisms in all domains (bacteria, animals (corals, bees), fungi, plants)

2. **viral-driven generation and integration** of nucleic acid sequences into pre-existing genomic content arrangements



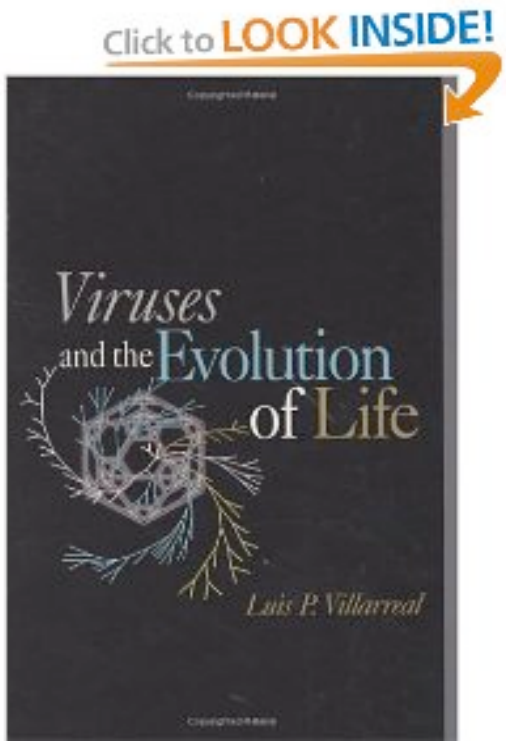
E. coli - rod prokaryote, division. Image copyright Dennis Kunkel Microscopy, Inc.

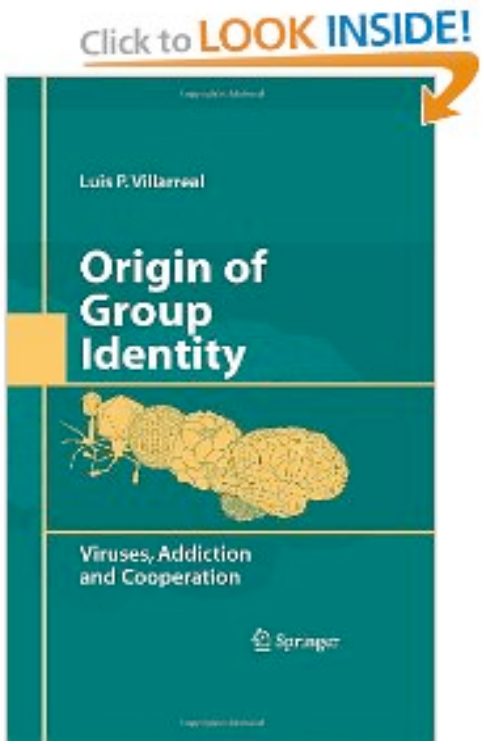
Hypothesis:

Major role in *de novo* generation and recombination of nucleic acid sequences in cells are not the result of chance mutations and selection, but

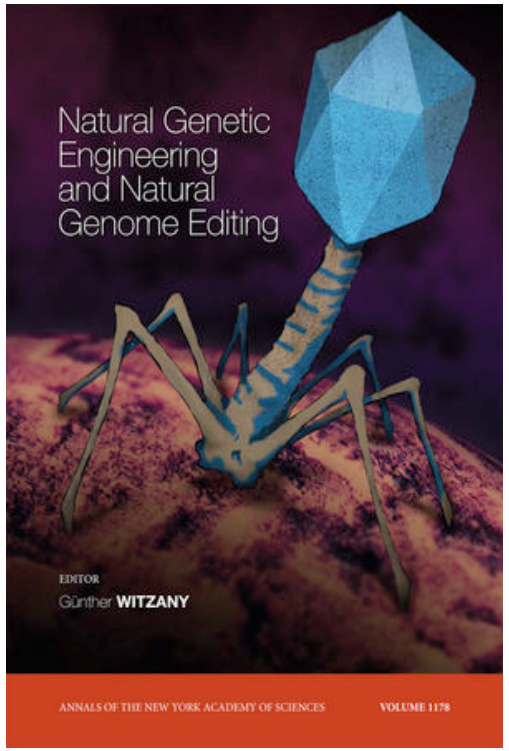
Viral and sub-viral agents **edit genetic code**

Biocommunication and Natural Genome Editing

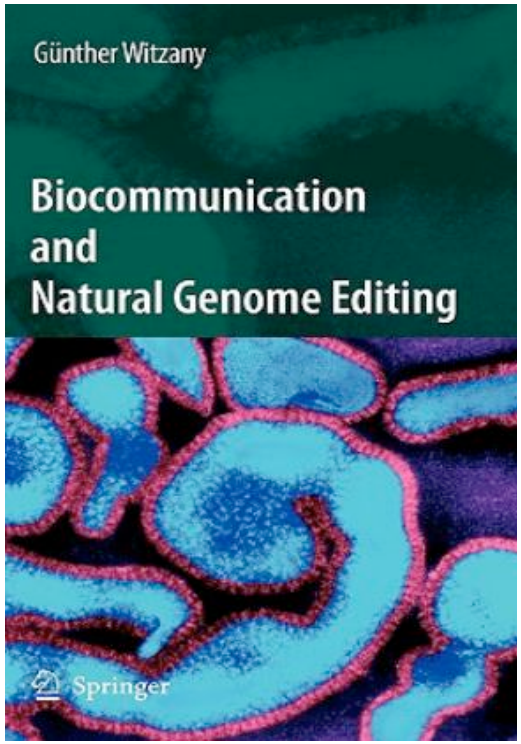




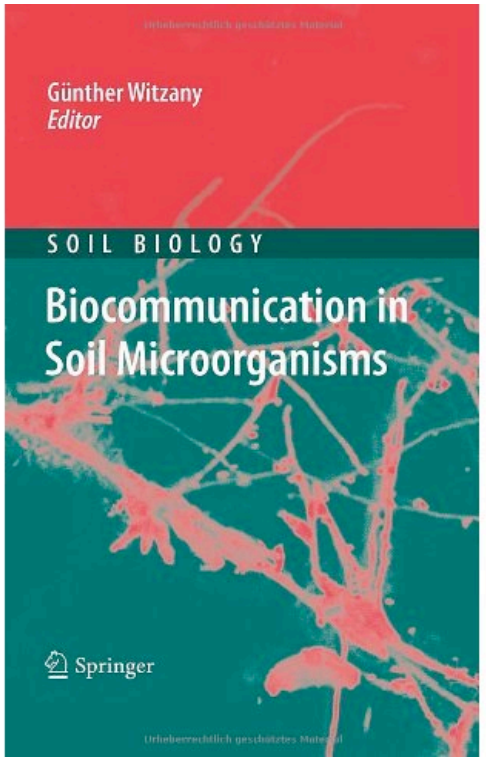
Biocommunication and Natural Genome Editing



2009

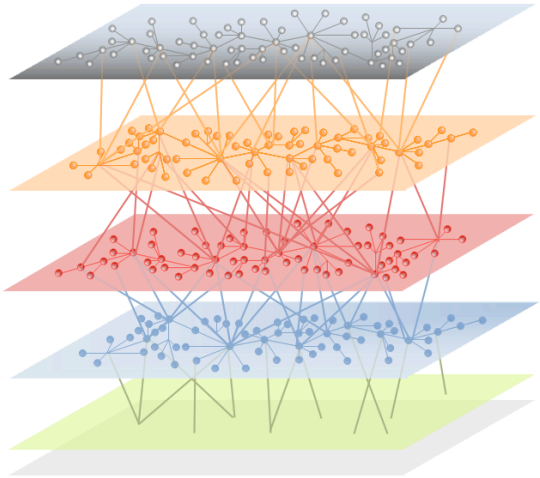


2010



2011

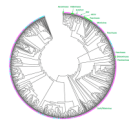
Natural Codes



- **Genetic code** (nucleic acid language)
- **Amino acid code** (protein language)
- **Behavioral codes** of organismic bodies

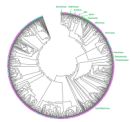
  (e.g., mating, attack, defense, altruistic behavior, mimicry…)
- **Symbolic codes**

  (Signs do not represent meaning by themselves but by consortia based conventions)



Natural Codes

- **No natural code codes itself** as no natural language speaks itself.
- In natural codes there must be **living agents** which are competent to edit these codes.
- Each code user follows **syntactic, semantic and pragmatic rules.**
- Rule-following is inherently a kind of **consortial interaction**



Manfred Eigen about the genetic code (1975):

- "The relative arrangement of the individual genes, the gene map, as well as the **syntax** and **semantics** of the molecular language are (…) largely known today".

- "All words of the molecular language are combined to a meaningful text, which can be broken down to sentences".

Manfred Eigen, Göttingen

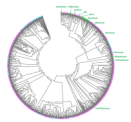
Manfred Eigen about the genetic code

- Manfred Eigen was deeply convinced that syntactic structures represent physical reality. If the syntax of a genetic sequence is known, the meaning (semantics) can be identified.

- Genetic syntax = physical reality = mathematics (formalizable sentences)

- Genetic syntax = protein semantics (meaning/function)

In natural codes/languages this is **NOT CORRECT**:
In natural codes **pragmatics (context)** determines meaning



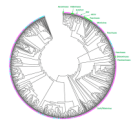
All natural code user follow syntactic, pragmatic, semantic rules

- **Syntax** (relation Sign to Sign)
  Rules that determine *combination* of vocabulatory elements, i.e. grammar

- **Semantics (**relation sign to signified something)
  Rules that determine *content* (meaning) of vocabulatory elements.

- **Pragmatics** (relation sign to sign user)
  Rules that determine how agents install code-based *interactions* according varying *contexts*

In contrast to former opinions the **meaning** of natural code sequences does not depend on syntax **but depends on contextual** (pragmatics**) use.**

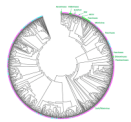


Context (pragmatics) Dependent Meaning
Optimizes Energy Cost

- In natural codes similar or identical sequences can transport different meanings dependent on varying (ecological) contexts:
  e.g. co-opted adaptation (optimizes energy cost)

- Through epigenetic marking it is possible to fix or even refix (=change) different meanings on the same genetic text sequence (optimizes energy cost)

- Memory: memory of context-determined patterns help to faster react on similar situations (optimizes energy cost)

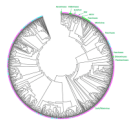


Essential Agents in Cellular Life

If the genetic code is really a natural code there must be **agents** that

- **generate** code sequences *de novo*
- **identify** sequence-specific target sites
- **integrate** in pre-existing genetic content arrangements
- **recombine** according adaptational purposes
- **mark** sequence sites to epigentically alter meaning

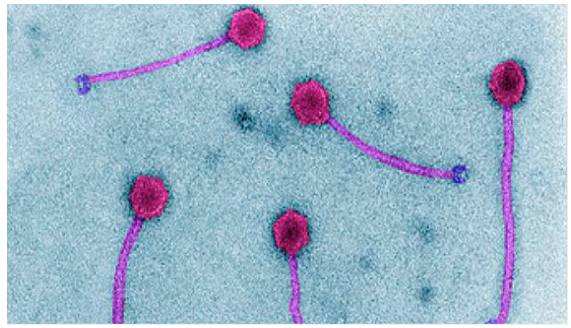
What are these agents?



Genetic Content Operators:
Persistent Viruses in Cellular Host

Examples of viruses/viral parts that **insert** into and **recombine** host genetic content

- Omnipresent phages in prokaryotes
- The eukaryotic nucleus has a variety of large dsDNA virus features
- Persistent viral parts in mitochondria and other organelles
- Endogenous retroviruses (active and/or defective)
- Intronic regions that are spliced out during exon assembly

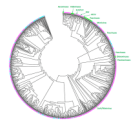


Listeria spp. Bacteriophage (DNA virus) Image copyright Dennis Kunkel Microscopy, Inc.

Essential Agents in Cellular Life

Some persistent viruses/virus-derived parts

- DNA-Viruses
- DNA-transposons
- non-retroviral RNA viruses
- endogenous retroviruses
- LTRs-retrotransposons
- non-LTRs (SINEs, LINEs, ALUs)
- group II introns
- group I introns
- non-coding RNAs

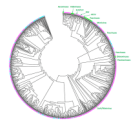


Essential Agents in Cellular Life

Retroagents are active in

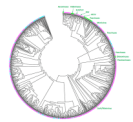
- Transcription
- Post-transcriptional RNA-Editing
- Translation
- DNA replication
- Chromatin organisation
- Epigenetic modifications
- DNA recombination

(Sternberg, R.v. and Shapiro, J.A. 2005.)



Essential Agents in Cellular Life

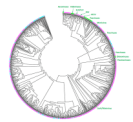
- Transcription
- Post-transcriptional RNA editing, splicing, ribosome-assembling
- Translation
- DNA-replication
- Chromatin organisation and epigenetic modification
- **DNA-recombination:** DNA transposons replicate by cut and paste
  Retrotransposons replicate by copy and paste



Non-Coding RNAs: Module-like Viral Parts

- Co-opted adaptations of former viral colonizers that now act as regulatory elements co- and post-transcriptionally

- Transcribed out of DNA sequences the activated non-coding RNAs act as modular tools for cellular needs



Summary

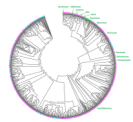
Natural genetic codes are **not randomly derived and selected mixtures** of nucleotides

Coherent with every natural code there must be **agents** that **generate, identify, integrate, recombine** and **mark** nucleic acid sequences

Natural genome editing occurs by **viral (and subviral) agents**

Natural genome editing is the result of **consortial interactions** of viral and subviral agents with cellular host

Natural genome editing agents follow syntactic, semantic **and pragmatic** rules (optimizes energy cost)



Conclusion

"**Life = physics + chemistry**" **(1944)**
(Erwin Schrödinger)

Life = physics + chemistry + (code-based) communication (2010)

Communication = consortial agents + signals + rules (syntactic, pragmatic, semantic)