

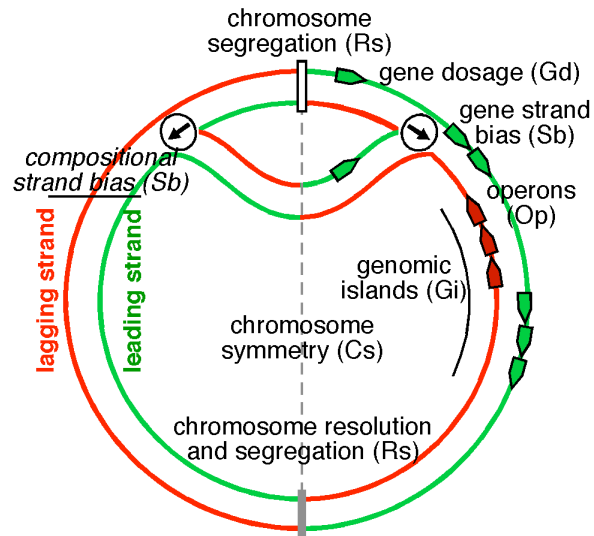
The dilemma of the bacterial genome between organisation and creativity

Eduardo Pimentel Cachapuz Rocha

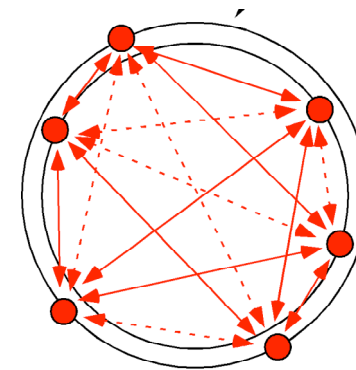
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Summary

Genome organization



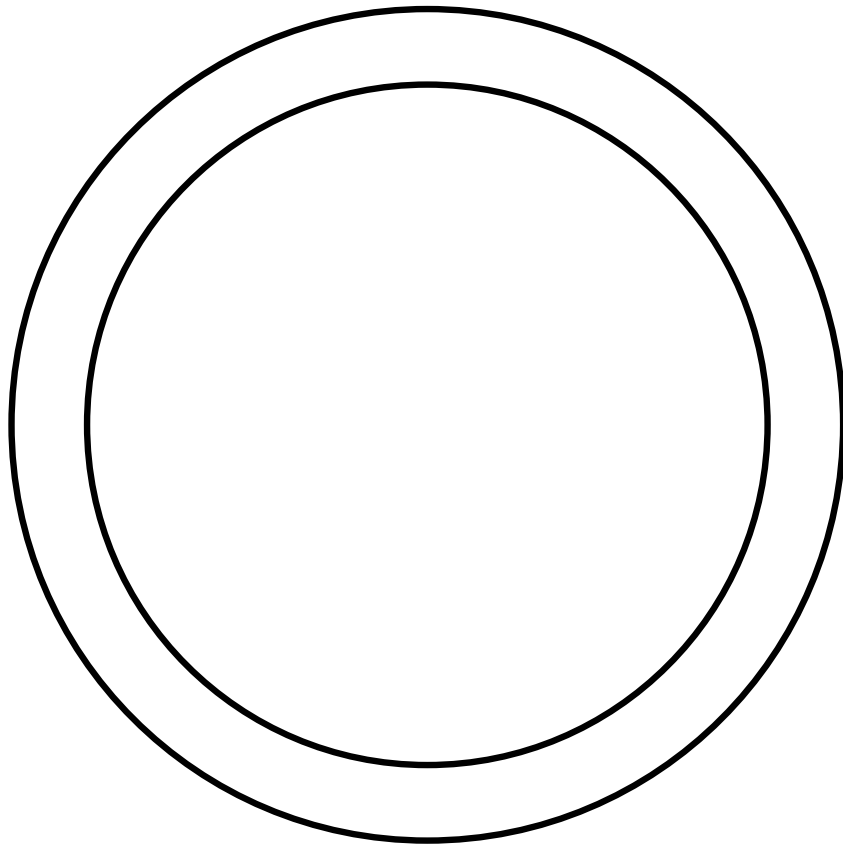
Genome dynamics



Conflicts

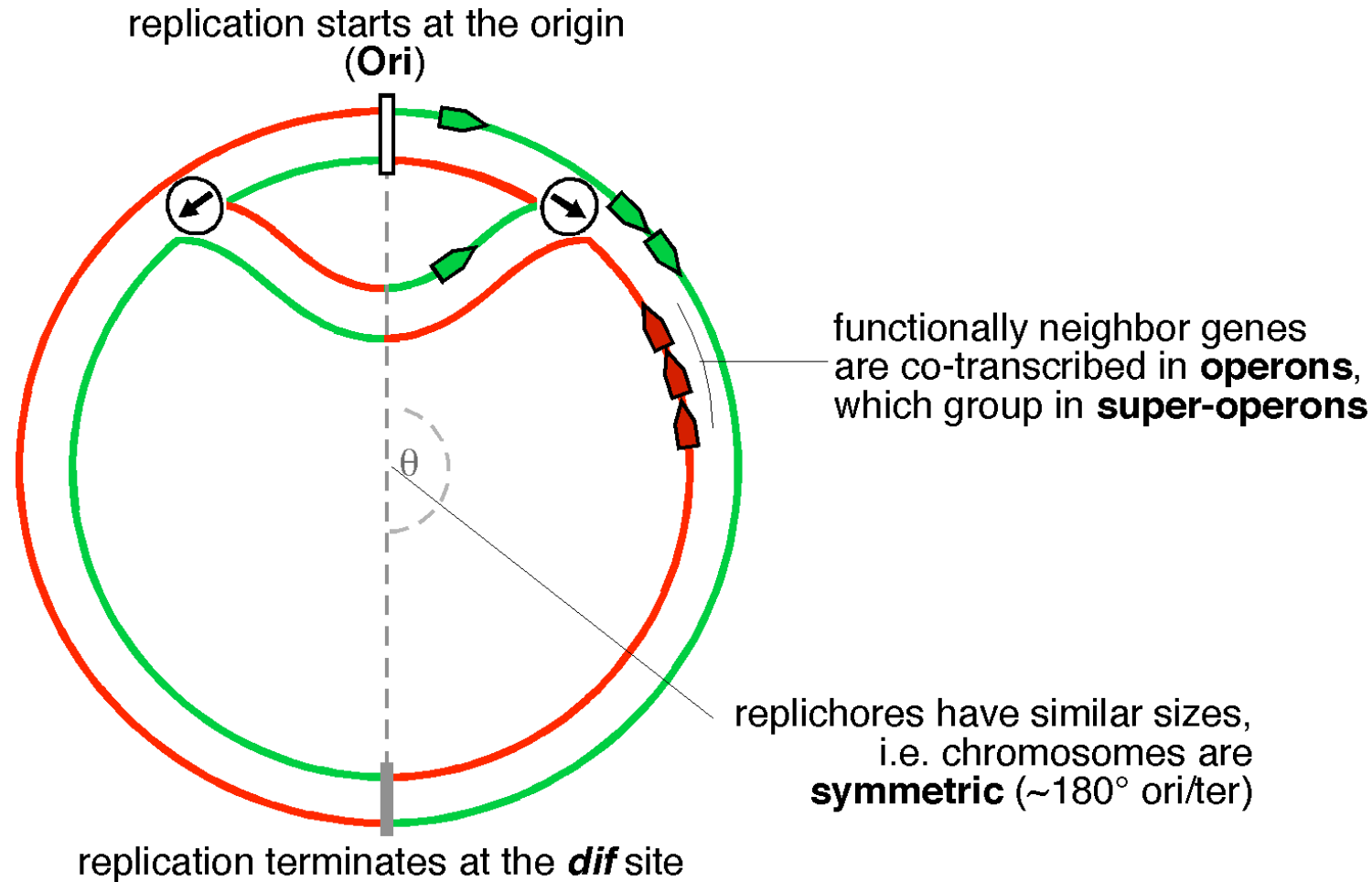


Genome organisation

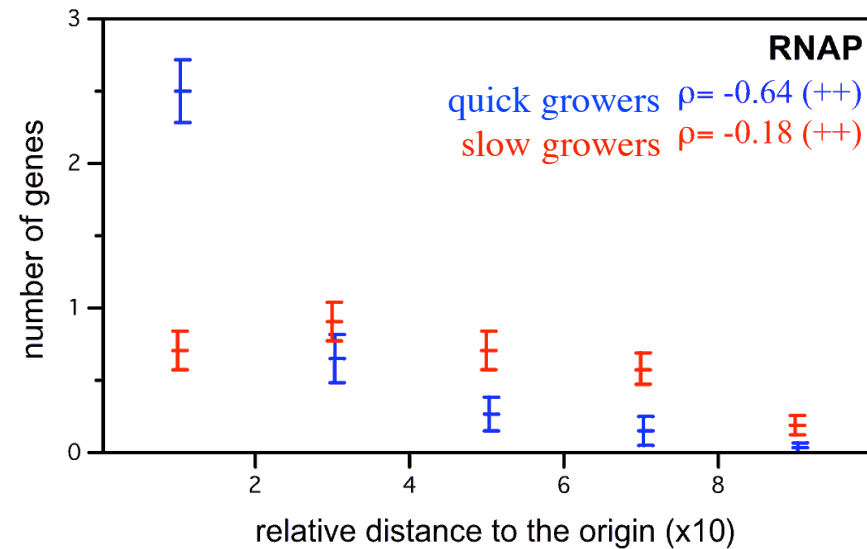
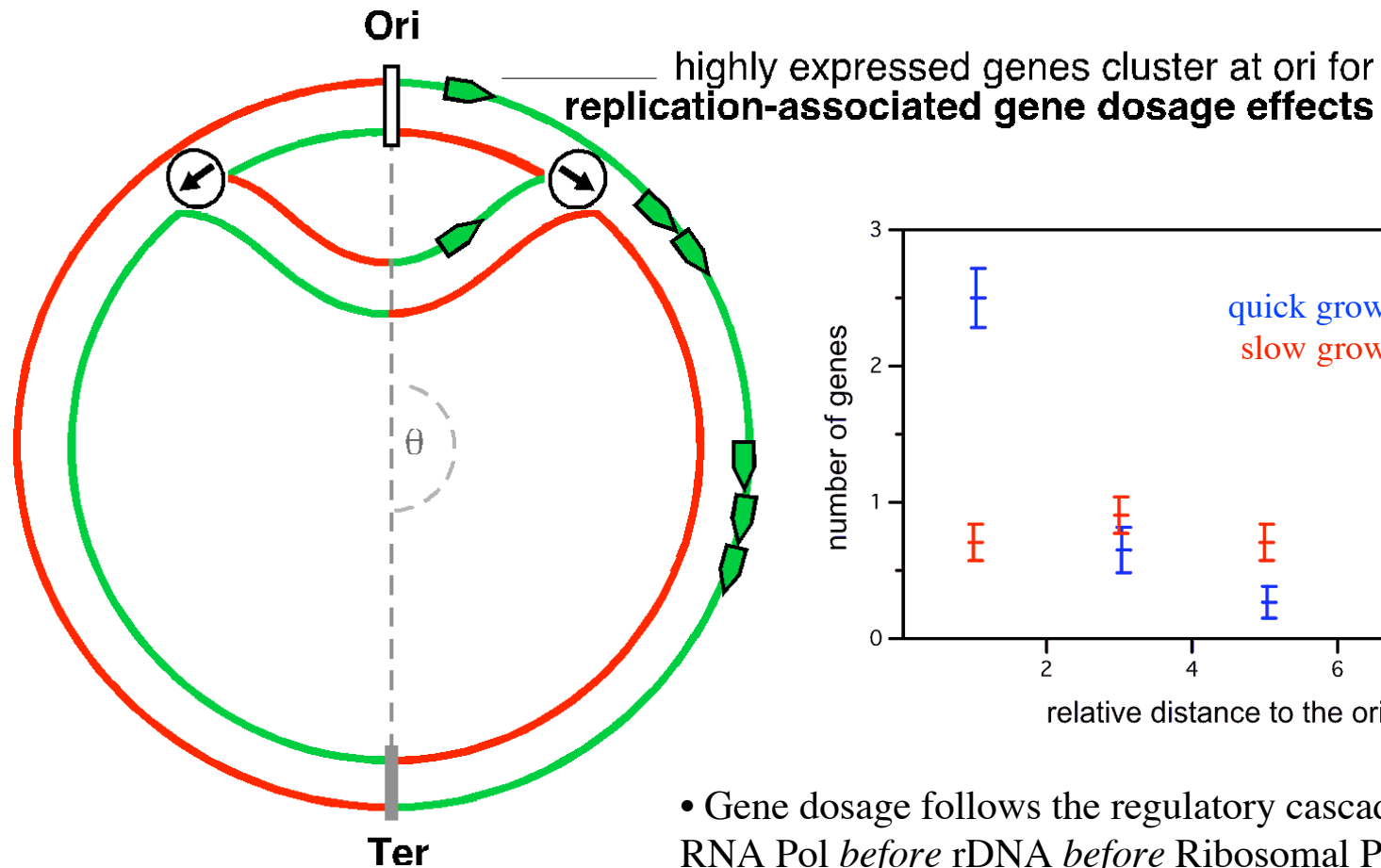


The cellular processes that interact with the chromosome shape its organisation.

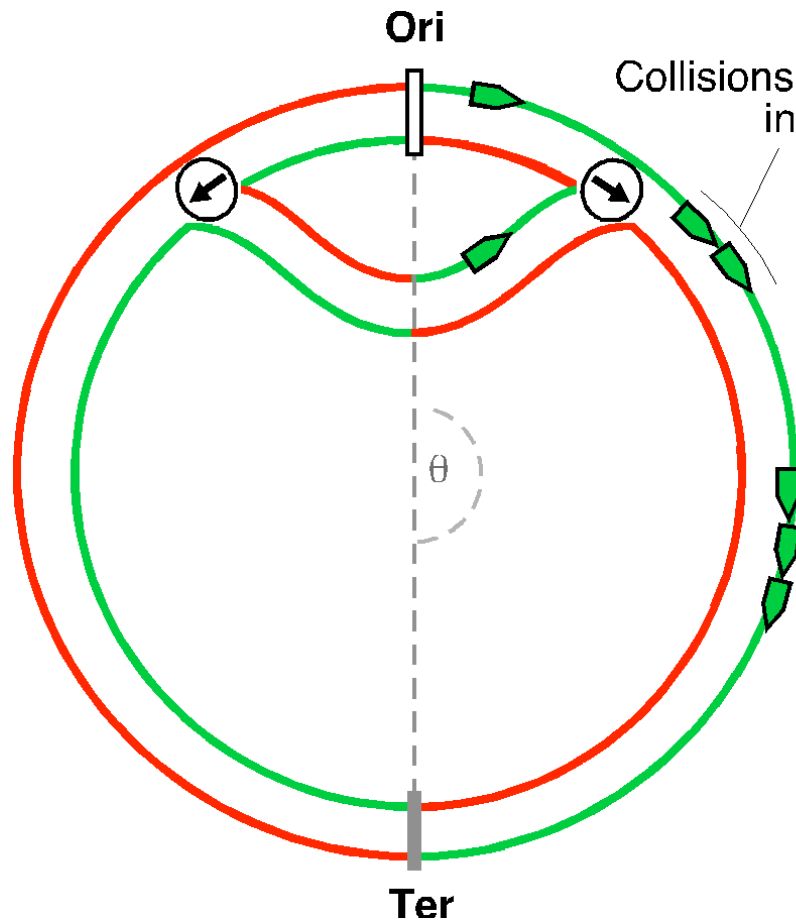
Replication & transcription



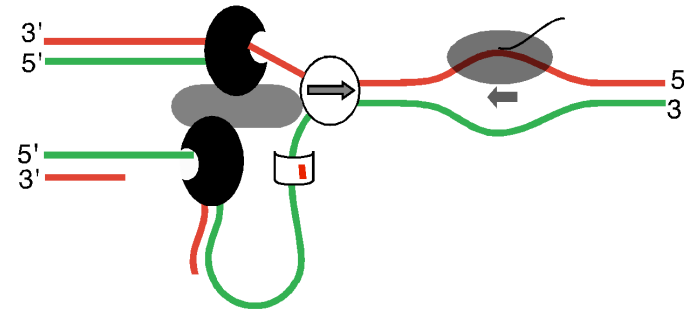
Mutualist interactions



Antagonistic interactions

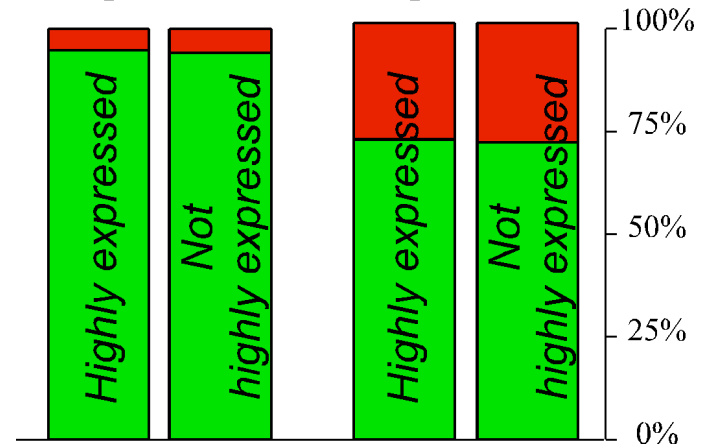


Collisions between polymerases result in **gene strand bias**, i.e. more genes in the leading strand



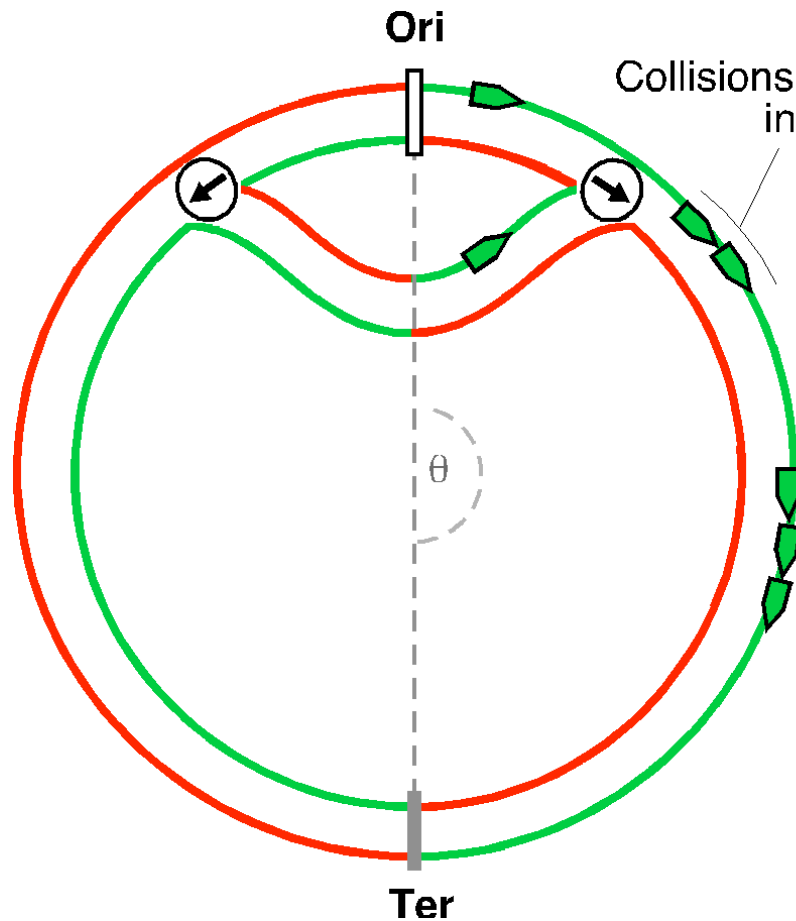
Essential genes

Non-essential genes

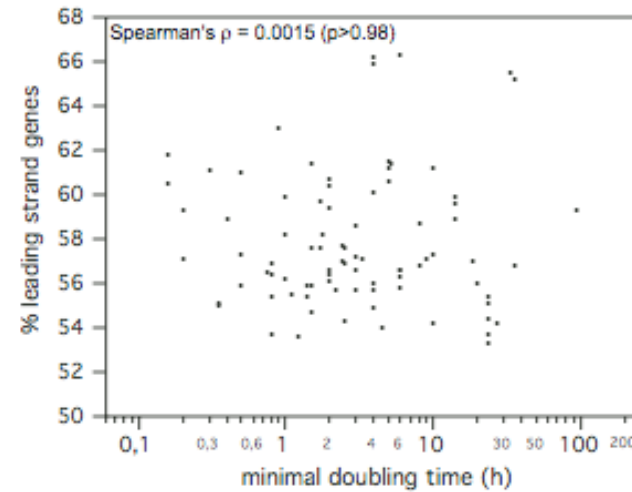
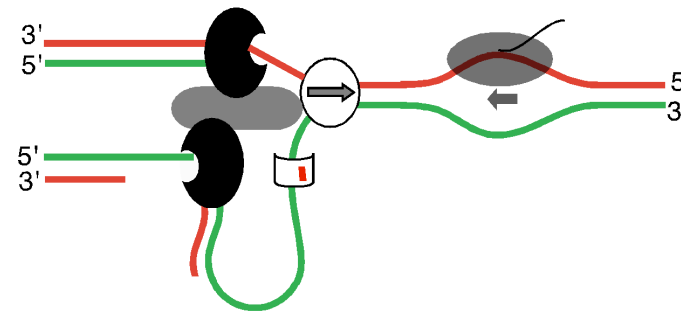


(Rocha, Nature Genet, 03)

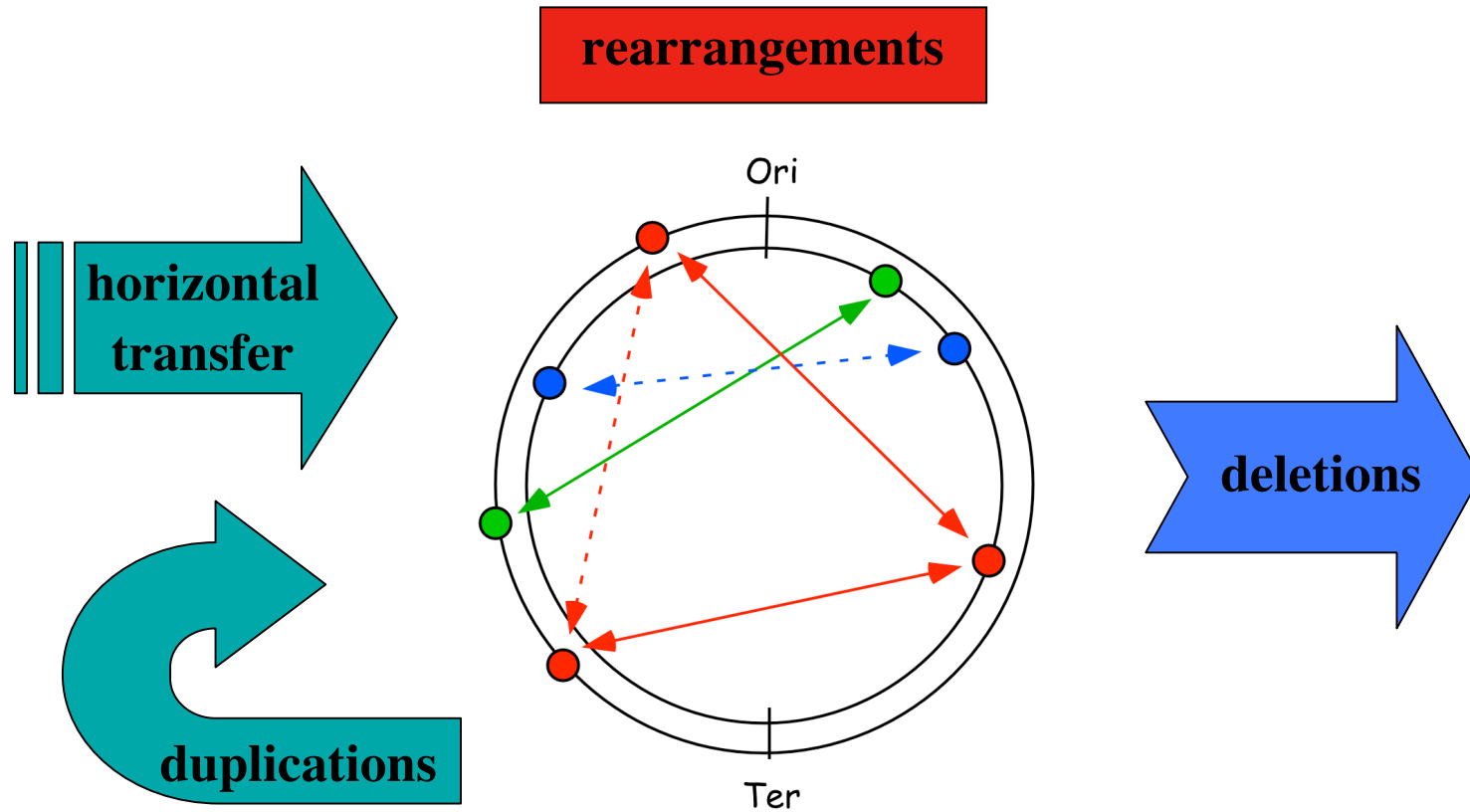
Antagonistic interactions



Collisions between polymerases result in **gene strand bias**, i.e. more genes in the leading strand

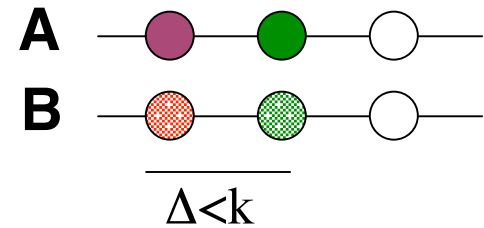


But the genome changes ...

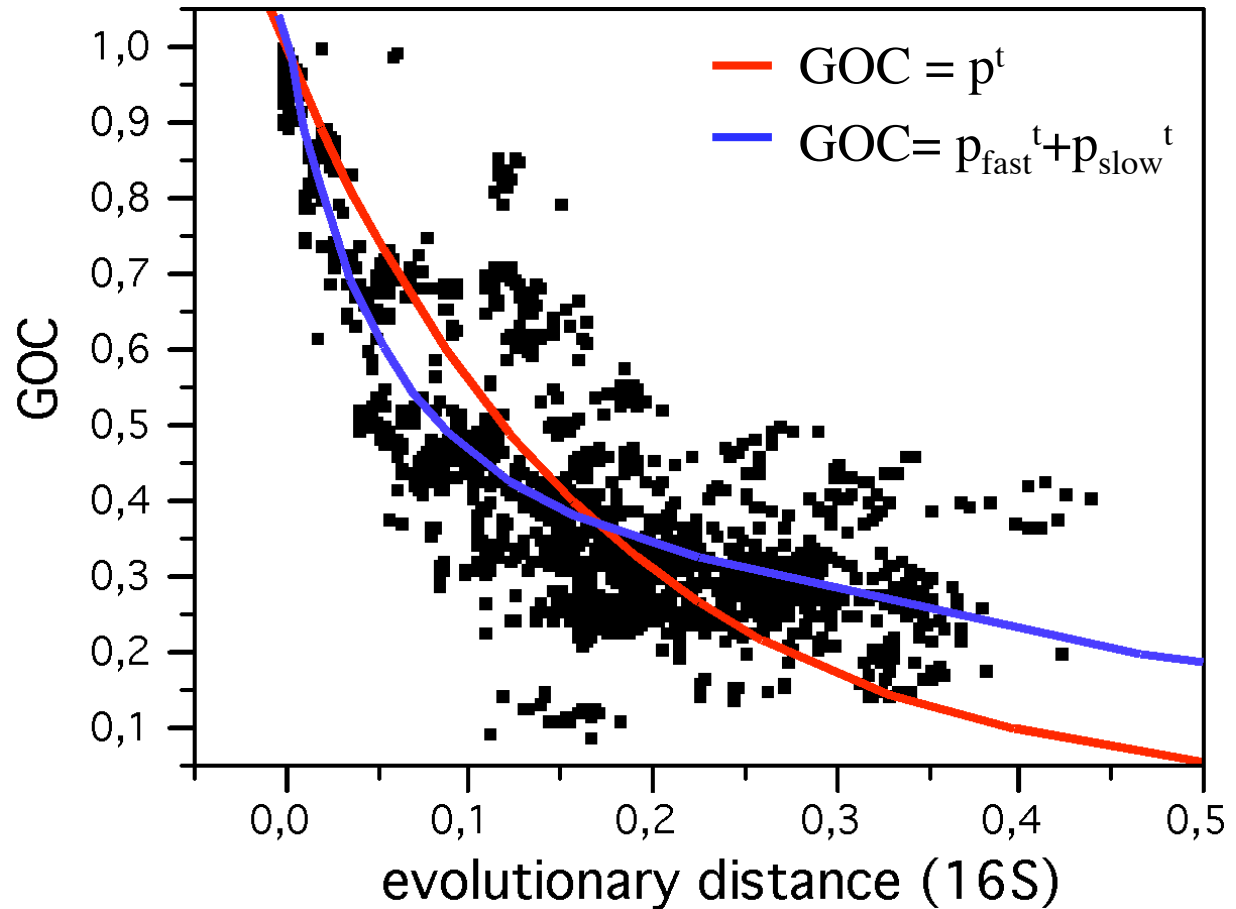
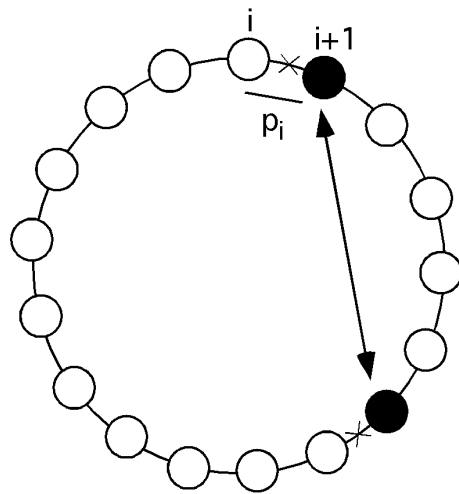


(adapted from Mira, TIG, 01)

Gene order conservation (GOC)

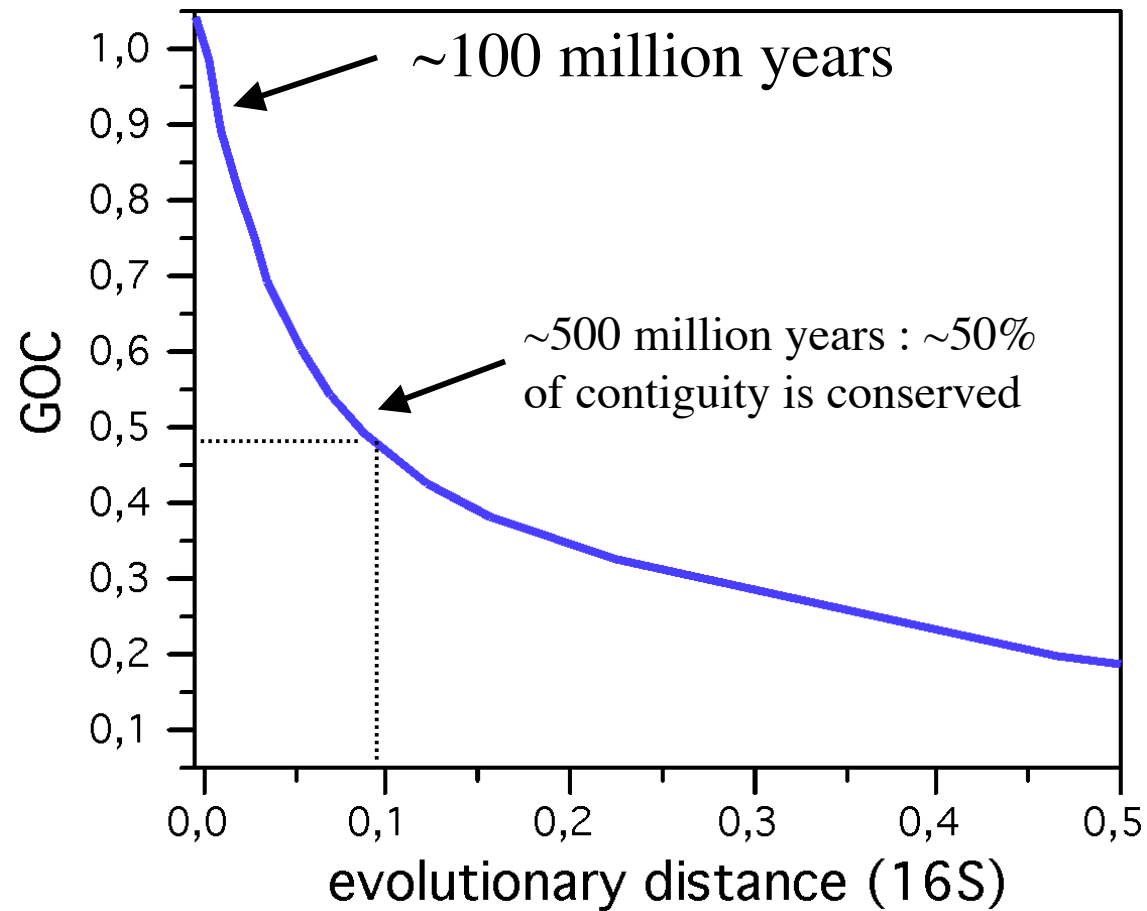


$$GOC = \frac{\sum_{i \in genes} GOC_i}{N}$$

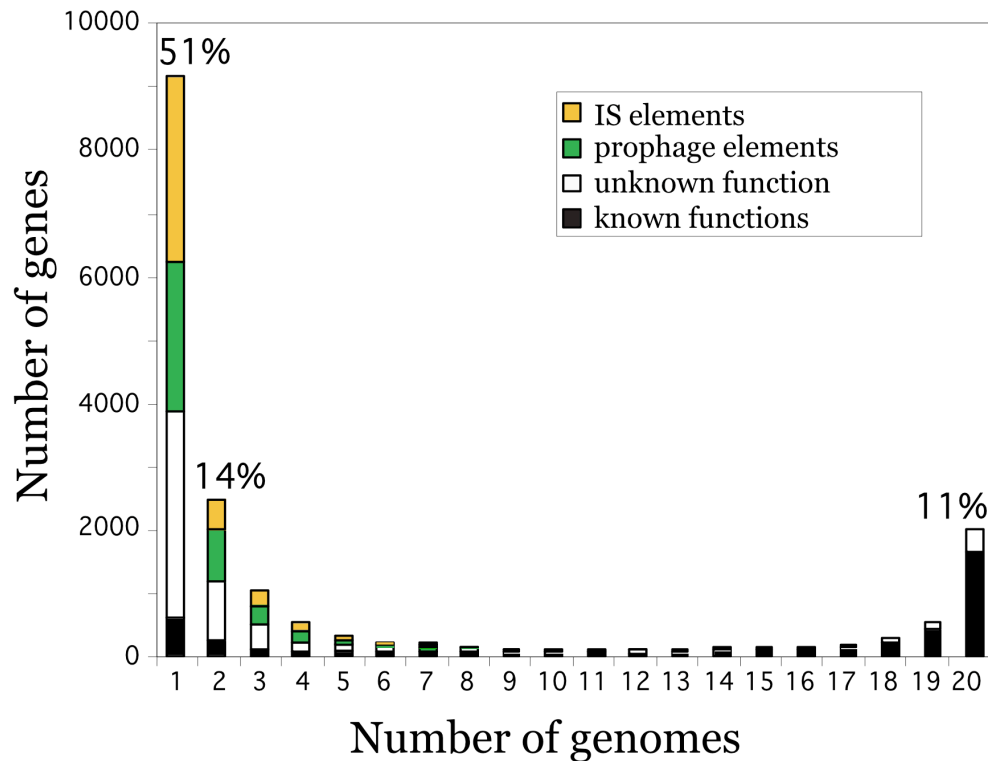


p - probability that two contiguous genes have contiguous orthologs
 Data: 126 genomes of 6 clades, 16S rDNA distances (HKY+ Γ)

Genome backbones are stable



The paradox of bacterial genomes



Among 20 genomes of the same species (*E. coli*):

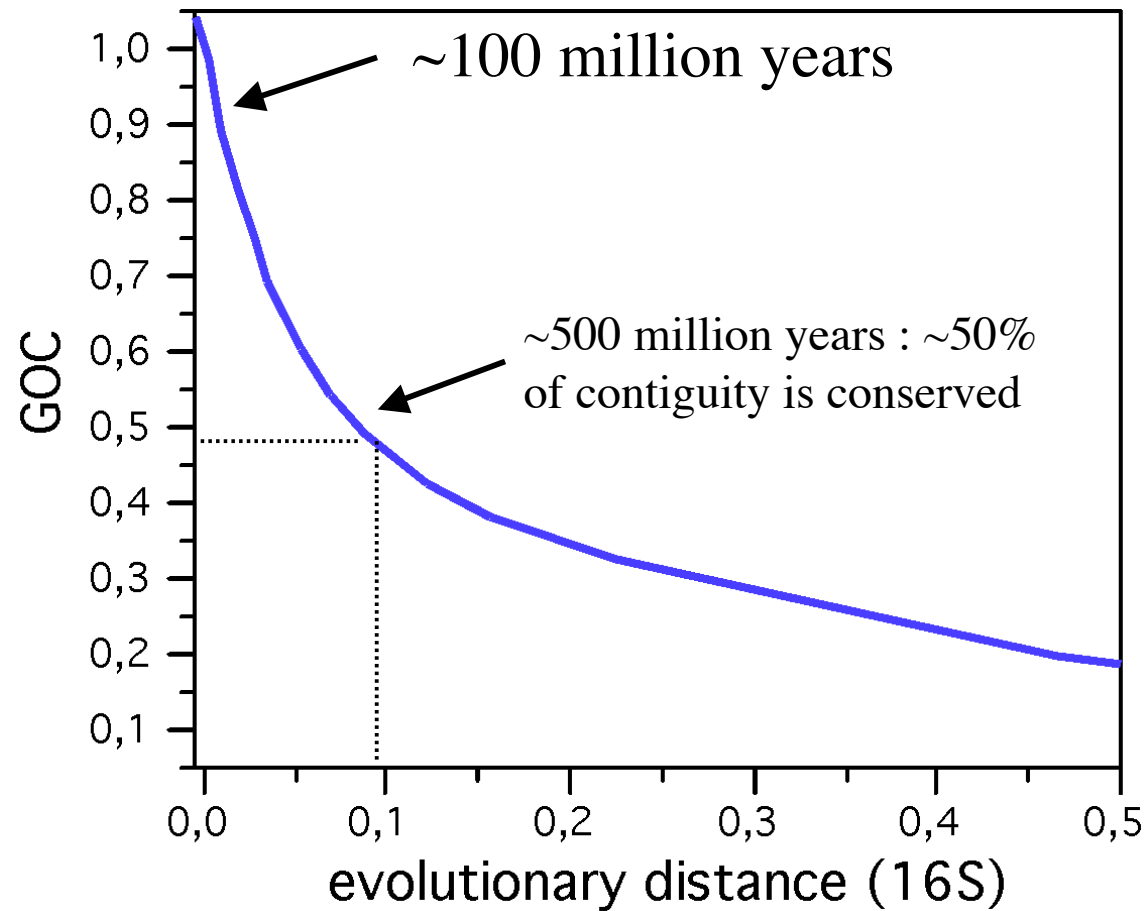
~4 600 genes on average/genome

~1 900 ubiquitous genes

~18 000 different sets of orthologs

Bacterial genomes are organized and plastic. How is that possible?

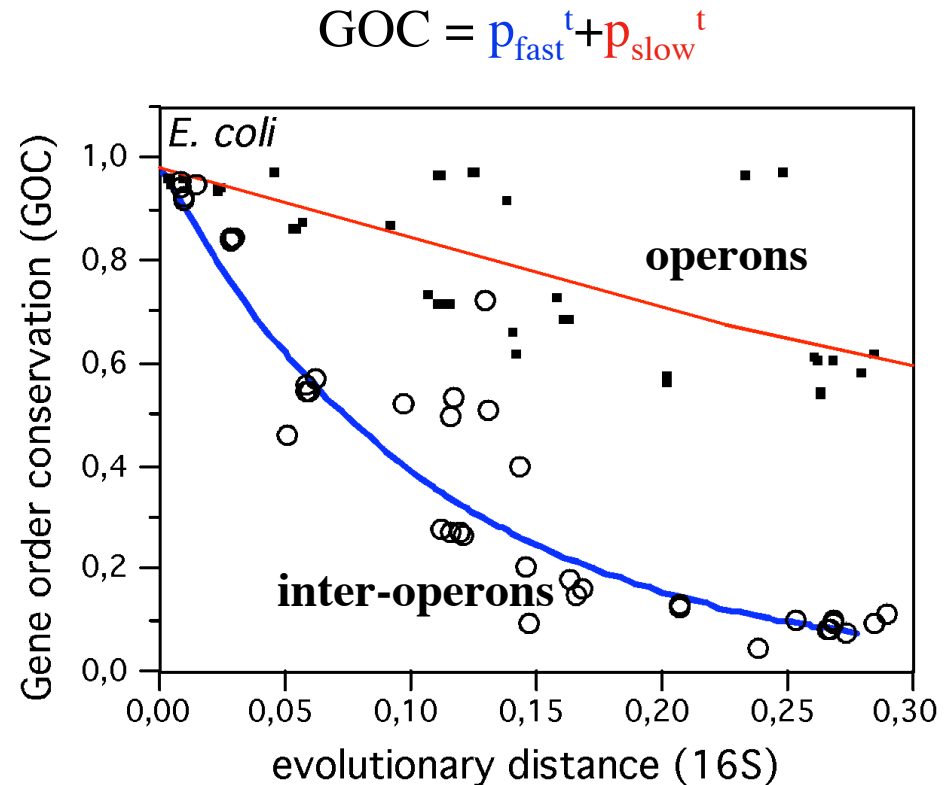
Genome backbones are stable



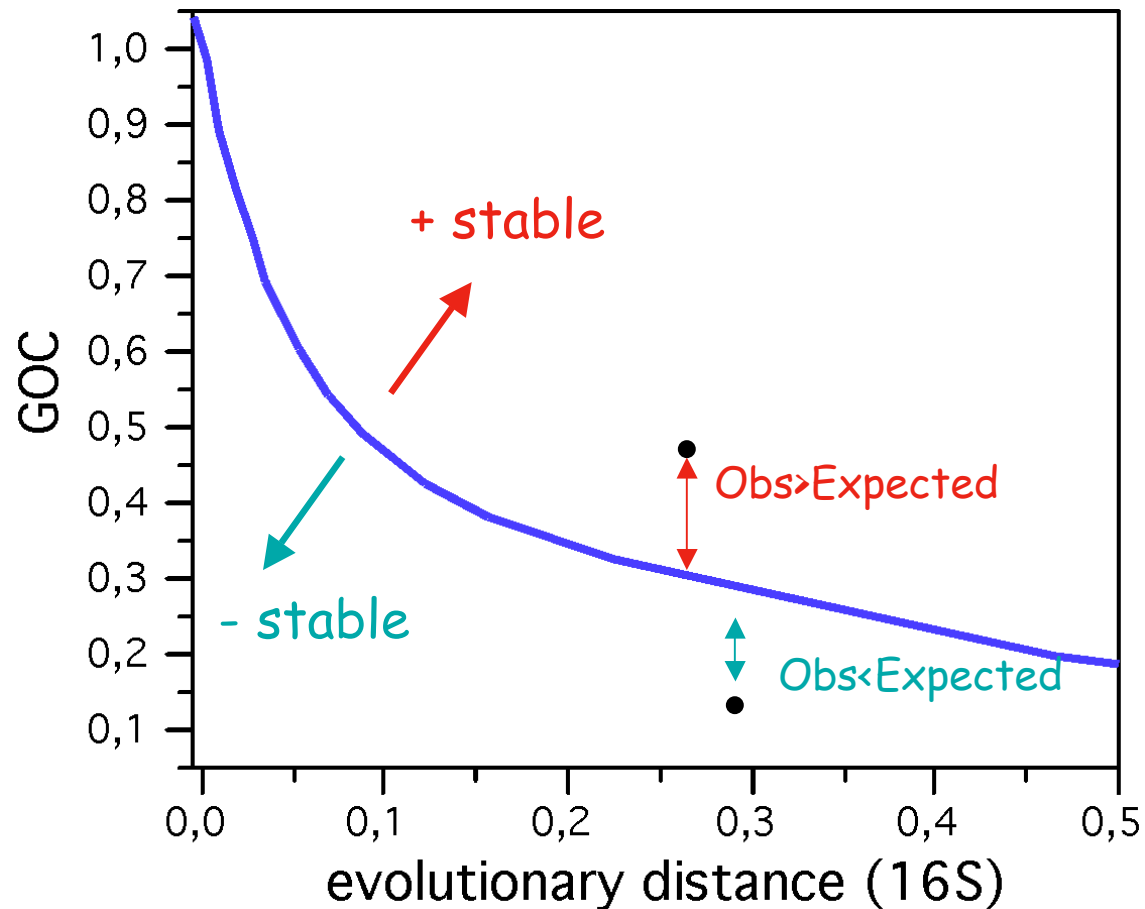
Operons organize genomes locally

E. coli rearrangement rates for inter-operon pairs :
⇒ observed $10^{-7}/\text{gen}$
⇒ expected (lab) $> 10^{-4}/\text{gen}$

Selection for supra-operonic organization.

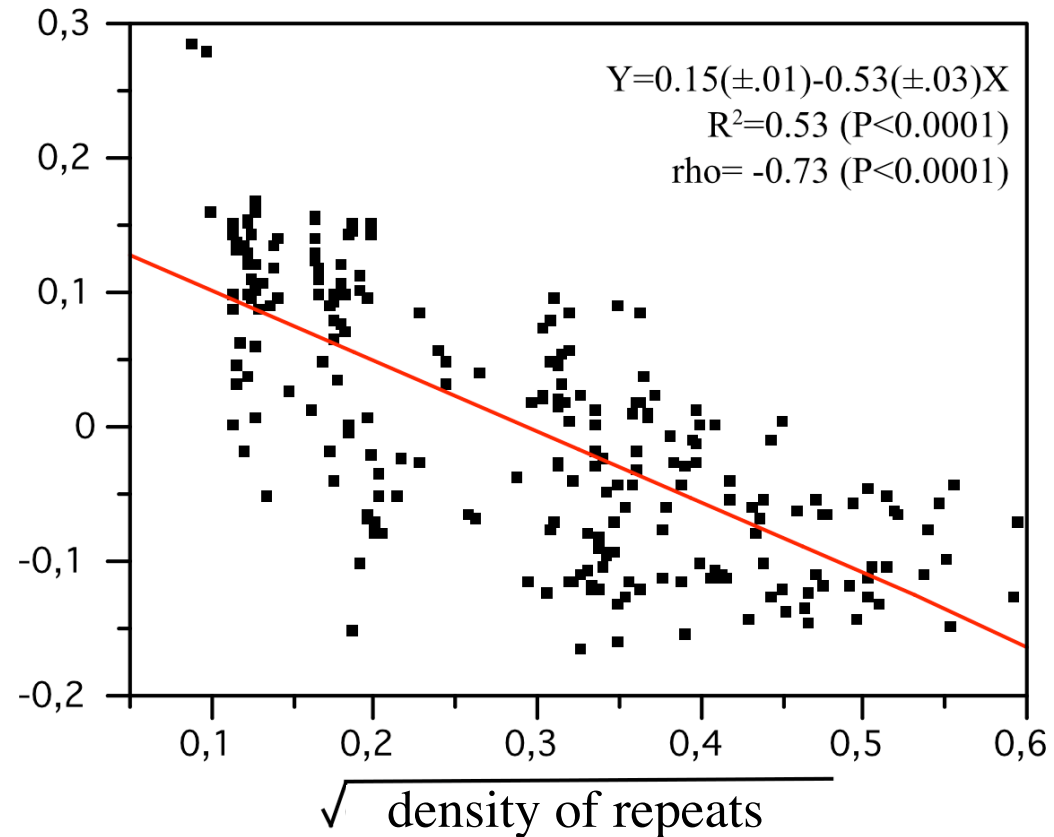
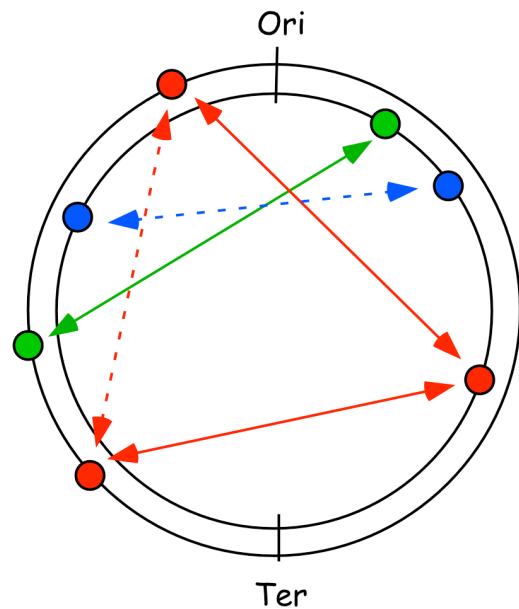


Defining genome stability



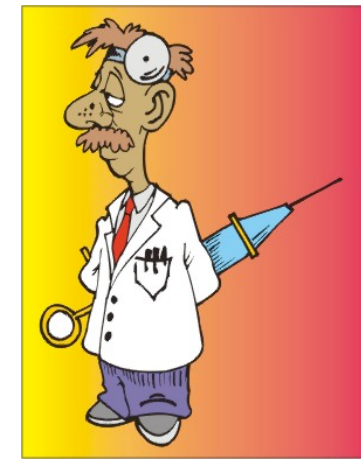
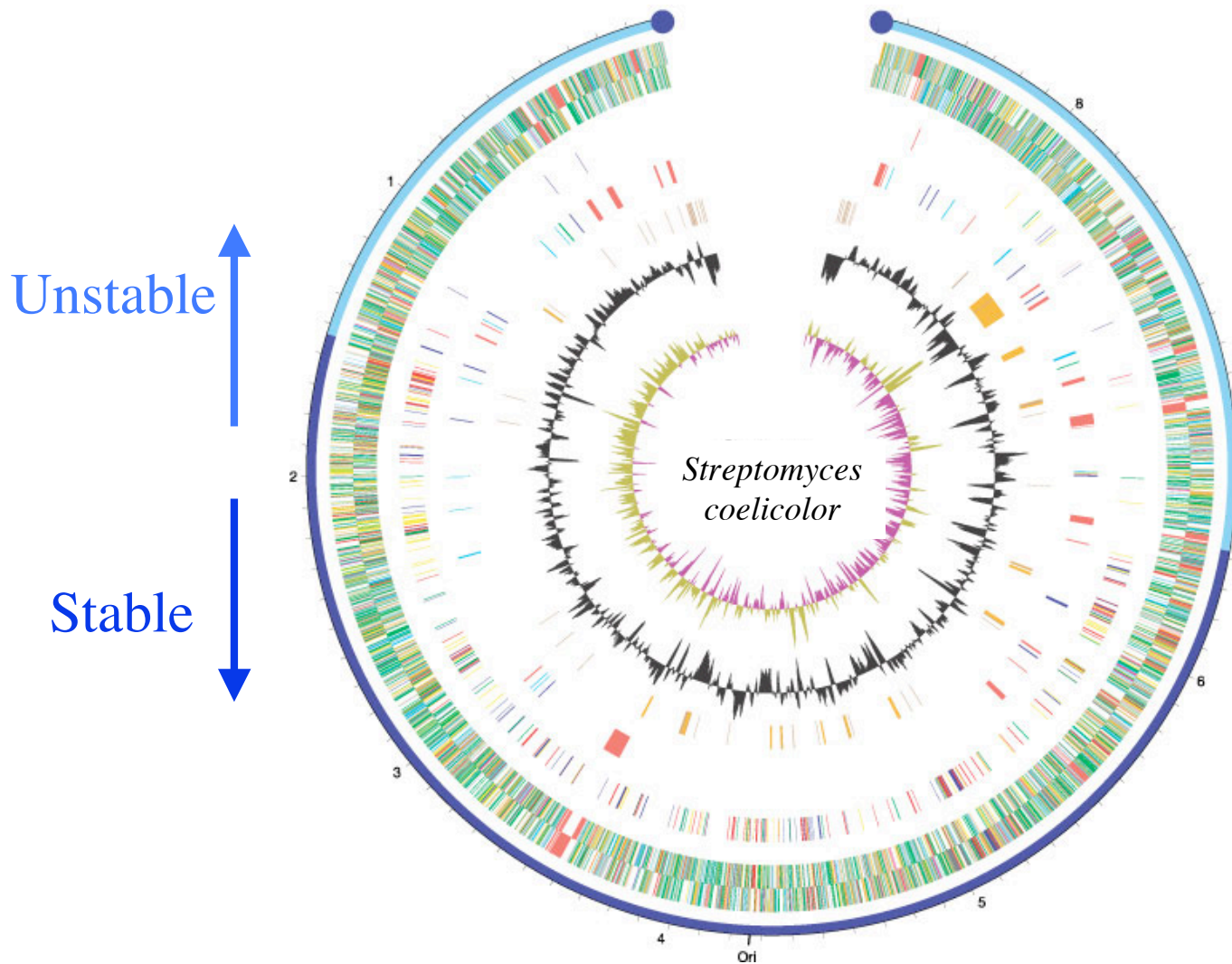
Genome stability can be defined as the average of the residuals for the comparisons in which the genome participates.

Repeats decrease stability



The type and distribution of repeats in genomes suggest counter-selection for rearrangements leading to chromosome disorganisation.

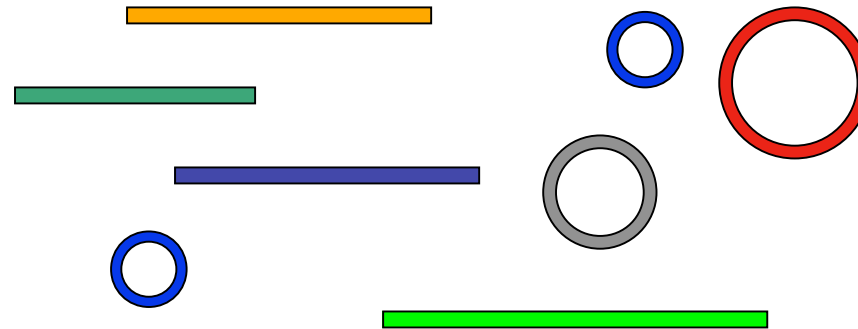
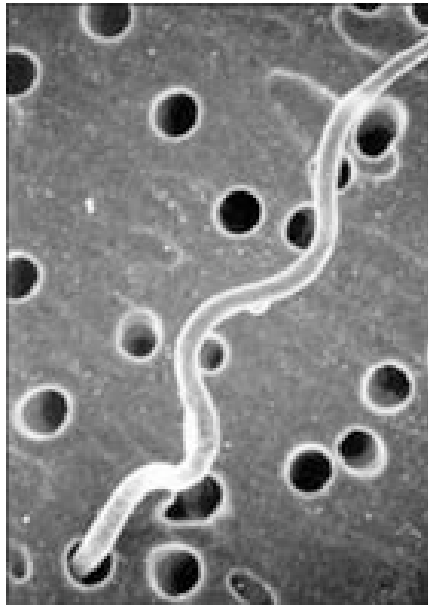
Regionalization



(Bentley, Nature, 02)

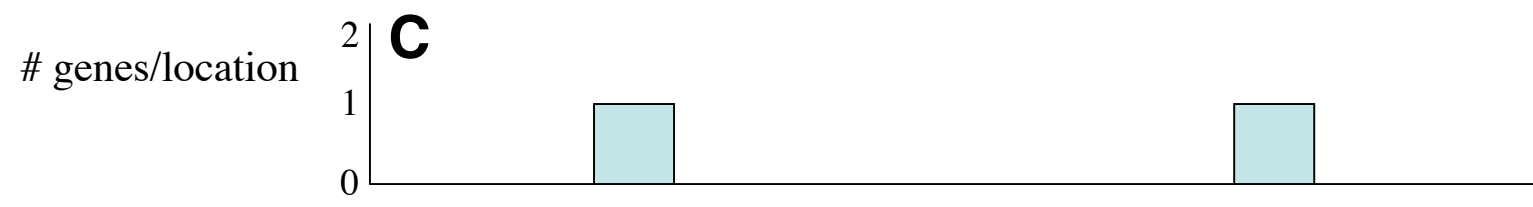
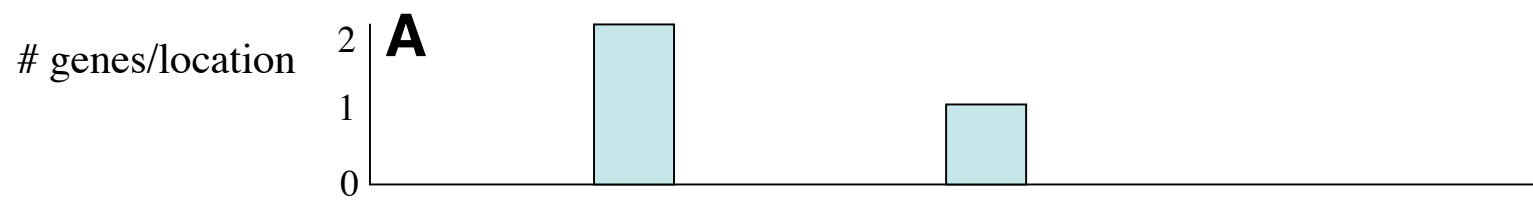
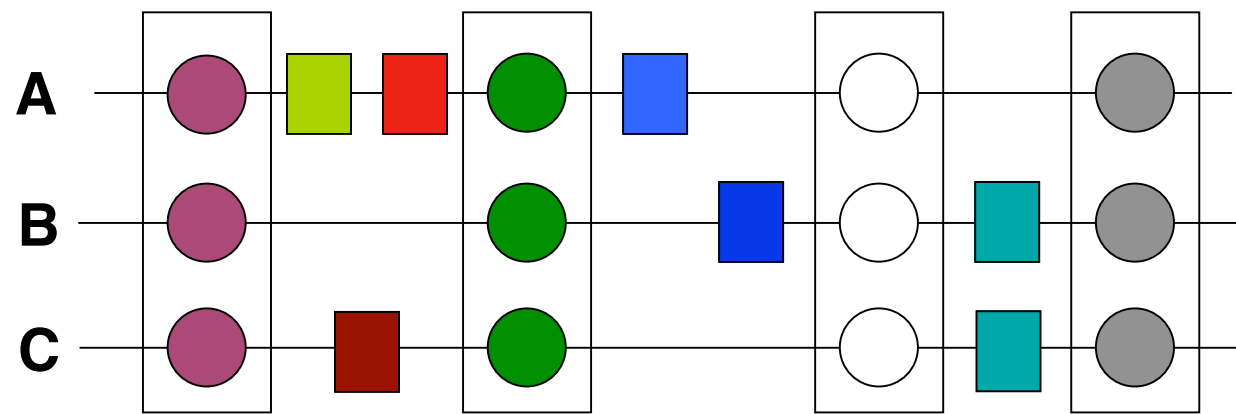
Delocalization

Borrelia burgdorferi



- Plasmids (600 kb) : 1256 repeats

-
- Chromosome (900 kb) : 21 repeats



Take Home Message

- Genomes are organized by their interaction with cellular processes.
- Typical genomic rearrangement rates are high (~mutation rates), but rearrangements are rarely fixed because of natural selection.
- One cannot have the best of two worlds ... but one can try. Stabilization of the core genome often involves confining gene dynamics into a restricted set of locations.
- Therefore, in spite of extensive dynamics, the bacterial core genome is typically stable.

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Atelier de



He who wants to have right without wrong, order without disorder [...] does not know how things hang together.

Chuang-Tzu (300 BC) « Forgetting about preferences »