HOW HORIZONTAL TRANSFER OF MOBILE ELEMENTS DRIVE BACTERIAL EVOLUTION

UNIT MICROBIAL EVOLUTIONARY GENOMICS
EDUARDO PC ROCHA
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1. Genome variability is driven by mobile elements
   *E. coli*, STs, pan-genomes

2. Mechanisms of transfer matter
   Plasmids, conjugation, integrative elements

3. Outlook: crossing borders & consequences
   Recombination, interconversion, functional consequences
E. coli’s large pan-genome

Escherichia coli
1305 natural isolates

Pan-genome: 76 221 gene families

Average genome: 4 685

No E. coli strain is a great model system for E. coli

(Touchon, Denamur, Gordon et al in prep)
Phages & plasmids increase genome size & especially variance in genome size.

(Touchon, Denamur, Gordon et al in prep)
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Different MGEs for distinct traits?

Conjugation

- Conjugative elements: Antibiotic resistance
  *Staphylococcus*, *Streptococcus*, enterobacteria.

- Prophages/plasmids: Toxins and other virulence factors
  Cholera, botulism, diphtheria, anthrax, shigellosis.

- Conjugative elements: Mutualism
  Rhizobia.

Virion-associated
Transmission: a variety of mechanisms

**Horizontal Transmission**
- Replication, Integration, excision
- Injection, Virion, packaging, lysis

**Vertical Transmission**
- Replication, partition
- Injection, Virion, packaging, lysis

**Conjugation/mobilization**
- Integration, excision
- Conjugation/mobilization

**Why so many mechanisms?**
- What are their relative advantages?
- Do they carry similar accessory traits?
To integrate or to self-replicate?

Conjugative plasmid (CP)
- 12% of Bacteria
- Partition
- Replication

Integrative Conjugative Element (ICE)
- 18% of Bacteria
- Integrase

(Guglielmini, PLoS Gen, 11; Cury, NAR, 17; Cury, MBE, 18)
Plasmids are more plastic

151 ICEs of Proteobacteria

139 CPs of the same genus

(Cury, NAR, 17; Cury, MBE, 18)
Genetic relatdeness vs Host phylogenetic distance

- **Distant taxa**
- **Close taxa**

Different elements

Similar elements

\[ \text{wGRR} = \frac{\%id \cdot \# \text{orthologues}}{\text{Smallest genome}} \]
Genetic relatedness (wGRR) vs Host phylogenetic distance

Very different taxa

Very similar elements
ICEs have broader host ranges

Very different taxa

Very similar elements

(Cury, NAR, 17; Cury, MBE, 18)
To integrate or to self-replicate?

Trade-off: genetic plasticity versus host range

(Cury, NAR, 17; Cury, MBE, 18)
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Distant transfer: Plasmids become ICEs

K-mer comparison with cognate chromosome:

- ICE more similar to host
- Plasmid more similar to host

ICEs in ICE/CP pairs are less similar to the chromosome:
- Confiming long range transfer of ICE
- Suggesting that CPs transferring to different taxa become ICE (because they can’t replicate).

(Cury, NAR, 17; Cury, MBE, 18)
Different elements, distinct functions

Comparison of functions across ICE and conjugative plasmids:

- Partition
- Replication
- Integrase
- Antibiotic resistance
- Toxin Antitoxin
- Integrons
- Entry Exclusion
- Restriction Modification
- Metabolism
- Cellular processes
- DNA Processing
- Poorly characterized
- Not annotated

- More likely in ICE
- Less likely in ICE

Relative probability in ICE

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(Cury, NAR, 17; Cury, MBE, 18)
Among 2200 plasmids:

- ~20% conjugative (CONJ)
- ~30% mobilizable (MOB)
- ~50% non-MOB

We don’t know how half of the plasmids transfer.
Resume and outlook

- MGEs drive variation in pangenomes.
- MGEs mobility mechanisms shape rates and range of transfer.
- Recombination and interconversion between MGEs may be frequent, allowing exchange of adaptive genes.
- Transfer mechanisms shape the traits carried by MGEs.
**Address**

**Date and place of birth**

11th May 1985, Oviedo (Spain)

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11th May 1985, Oviedo (Spain)

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**Languages**

- Native speaker English
- Bilingual English-French courses
- Other languages: German, Spanish

**Education**

- 2004–2005: BS Degree in the University of Hannover, Germany (ERASMUS Fellowship).
- 2005–2007: MS, specialising in Clinical Microbiology, in the University of Oviedo (Spain).

**Research Awards and Fellowships**

- 2010: EMBO Workshop, Heidelberg, Germany.
- 2012: EMBO Long-Term Fellowship Award.
- 2012: ETH Postdoctoral Fellowship Award (declined).
- 2014: EMBO Laboratory Management Course.

**RELEVANT COURSES**

  - Cell Signaling, infection and innate immunity
- 2012: 3 months fellowship from CSIC (Spanish National Research Council).
- 2013: 4 months fellowship from CSIC (Spanish National Research Council).
- 2013: Jury Award for Best Oral Talk in Young Researchers for Life Sciences (YRLS), Paris.

**Lab experience**

- DNA purification and analysis of genetic determinism
- Bacterial culture, minipreparation of plasmid DNA, Southern blot, and PCR.
- Analysis of nucleic acids and proteins
- Linkage disequilibrium analysis and tagging SNP identification
- Techniques: Cell growth analysis, fluorometer based assays, RNA-seq results

**Hobbies**

- Reading
- Running, gym
- Science Fiction, fantastic, fantasy
- Doctor Who, Sherlock, Black mirror
- Suits, Game of Thrones
- Watching TV shows

**Projects**

- Project title: Effect of various protonophores on growth and membrane potential

**Other tools used**

- NCBI tools
- HaploView, Cary Eclipse
- Other tools used for self-teaching
- R language: Bash basis, File management, Unix
- Collage analysis of nucleic acids and proteins

**Speciﬁcally relevant for this talk**

Microbial evolutionary genomics

- Escherichia coli
- Metagenomics
- HaploView, Cary Eclipse
- Other tools used for self-teaching
- R language: Bash basis, File management, Unix

**Collaborators**

- David Gordon (ANU/Canberra)
- Erick Denamur (AP-HP, U Paris)
- Fernando de la Cruz (U Cantabria)

- M Touchon
  - CR CNRS
- J Cury
  - Now at Saclay (FR)

- Highly motivated biology student in the first year of a Master’s degree, passionate about genetics and seeking a passion.