

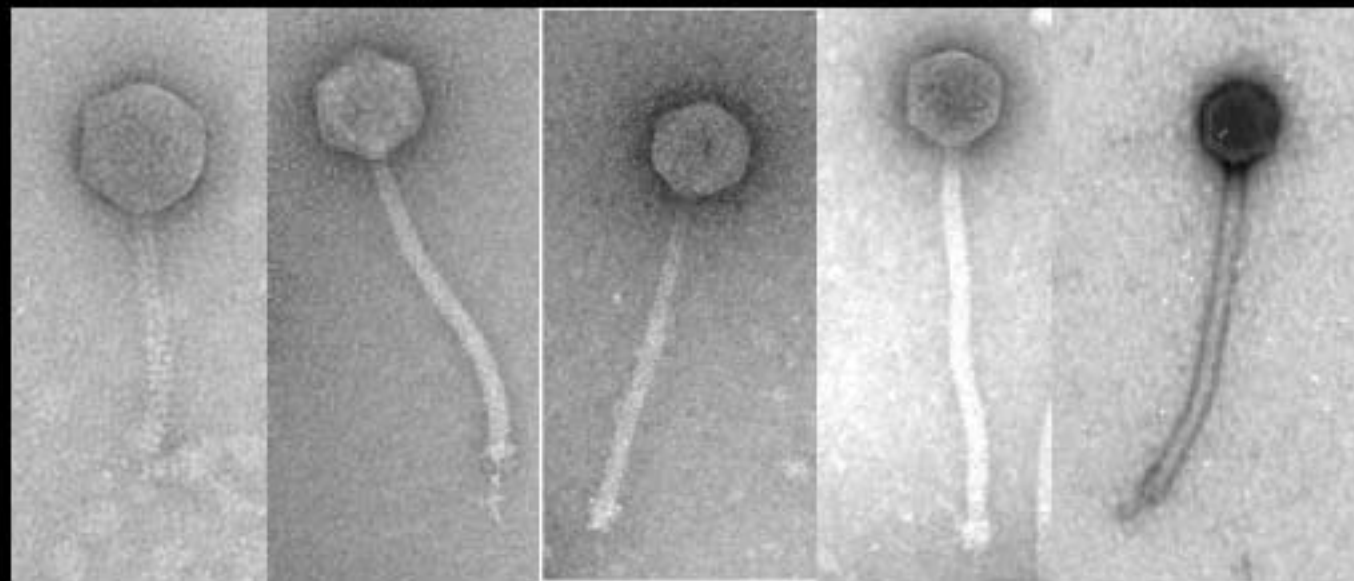
Bacteriophages: Genes and Genomes

Part 2. Bacteriophages: Genomic insights

Graham F. Hatfull
University of Pittsburgh

Bacteriophage genomes and genome evolution

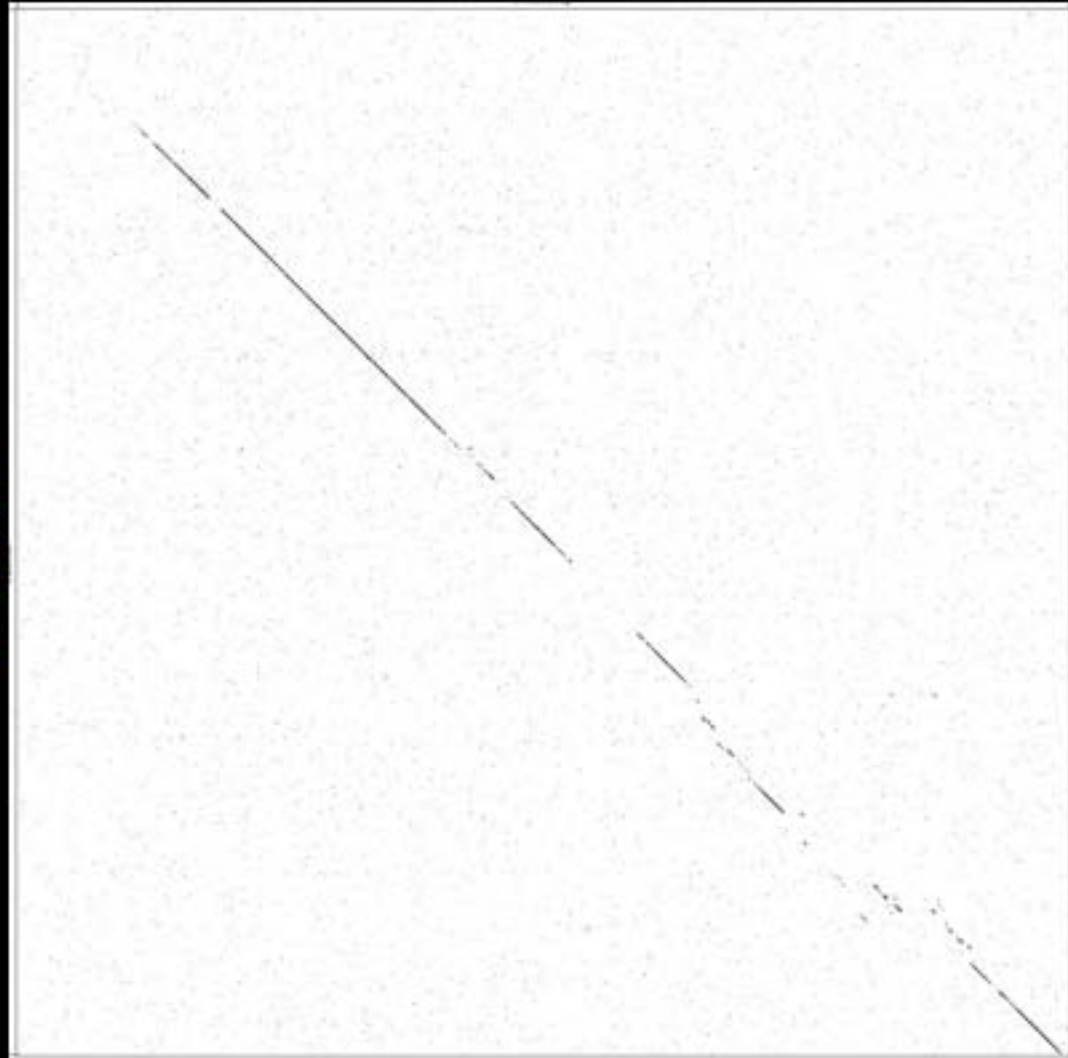
Virion morphology does not necessarily reflect evolutionary relationships



Phage genomics reveals evolutionary histories and mechanistic insights

Fruitloop

Boomer



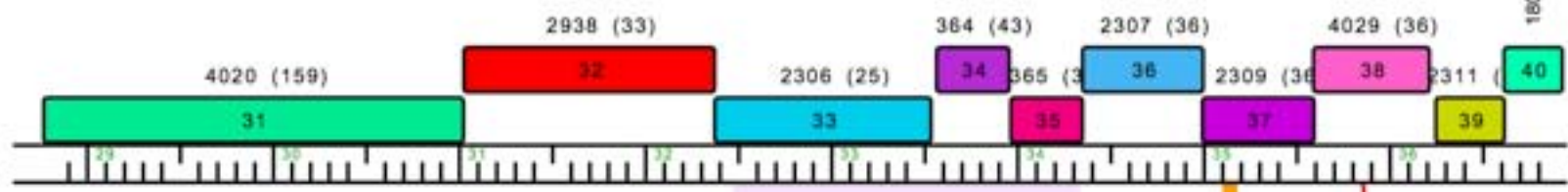
Dotplot comparison of Fruitloop and Boomer genomes

What do phage genomes look like?

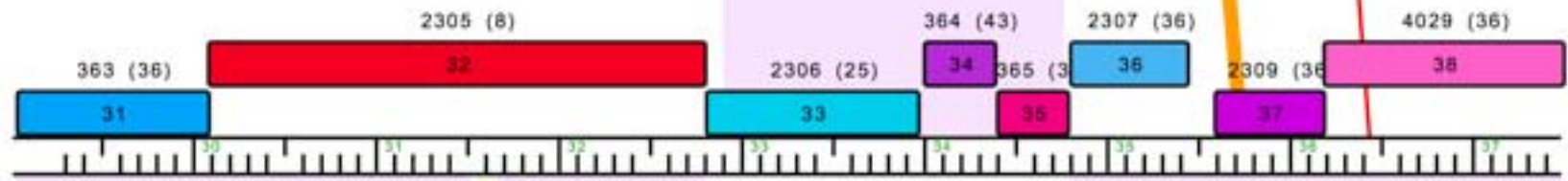
1. Phage DNA isolated from virions is linear
2. Genome have either defined or terminally redundant circularly permuted ends
3. Size range: ~ 5 - 500 kbp
4. Phage genomes are densely packed with genes
5. Phages infecting bacteria from different genera are typically unrelated at DNA level

The characteristic architectural feature: mosaicism

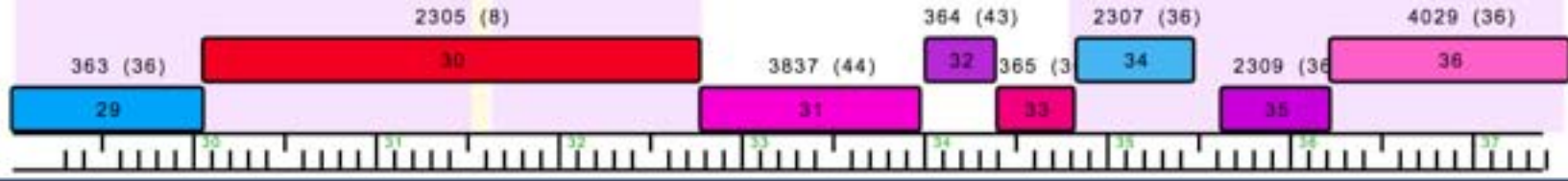
PG1



Rosebush




Qyrzula



Module boundaries correspond with gene boundaries

ACT: Cjw1gb.txt vs 244genbank.txt

W P Q T S G S A T C T E S N D Q P Q Q A E G H R I R D P H H E R S D R S P
G P R R V G P Q P V R S R M T N R S K Q K G T E F E T R I T N G L I E A I
M A P D E W V R N L Y C V E * D P T A A S R R A P N S R P A S R T V * S K P
T C C C C C A C A C C A C T C C G T C C C C A A D C T G T A C C C A C T C C A T C A C C A A D C C A C C A A D C A C A W C C C A C C C A A T T C C A C A C C C C A T C A C C A A C C C T C T C A T C C A A D C C C T
53410 | 53420 | 53430 | 53440 | 53450 | 53460 | 53470 | 53480 | 53490 | 53500 | 53510 |
A C C G G G G T C T C C T C A C C C A C C G T T C C A C A T C C C T C A C C T A C T O G T T C G G G T C G T T C G T C T T C C C G T G C C T T A A G C T C T C G G G T A G T C C T T C C C A C A C T A C C T T C G G G
H G W V L P D A V Q V S D F S W G C C A S P C R I R S G C * S R D S R L G
P G L R T P G C G T R L R I V L R L L C F P V S N S V R M V F P R I S A R
A G S S H T R L R Y P T S H G V A A L L L A G F E L G A D R V T Q D F G E
21



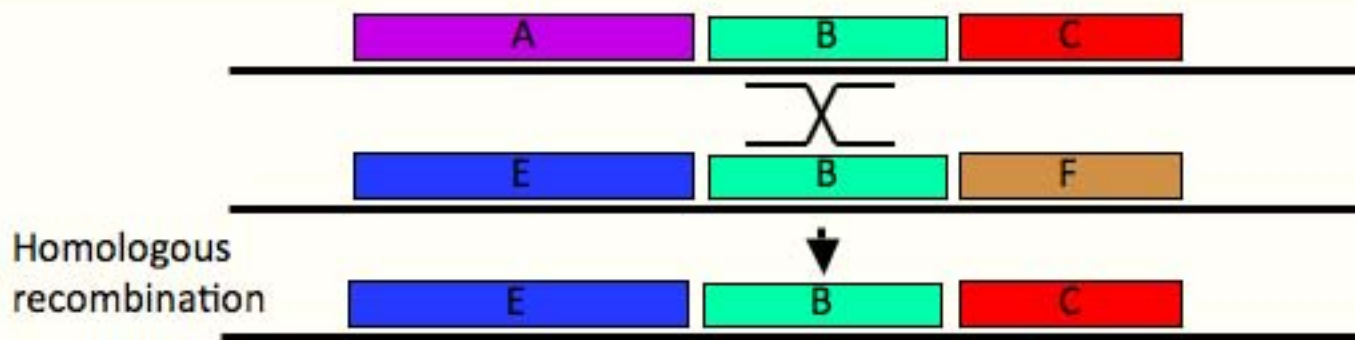
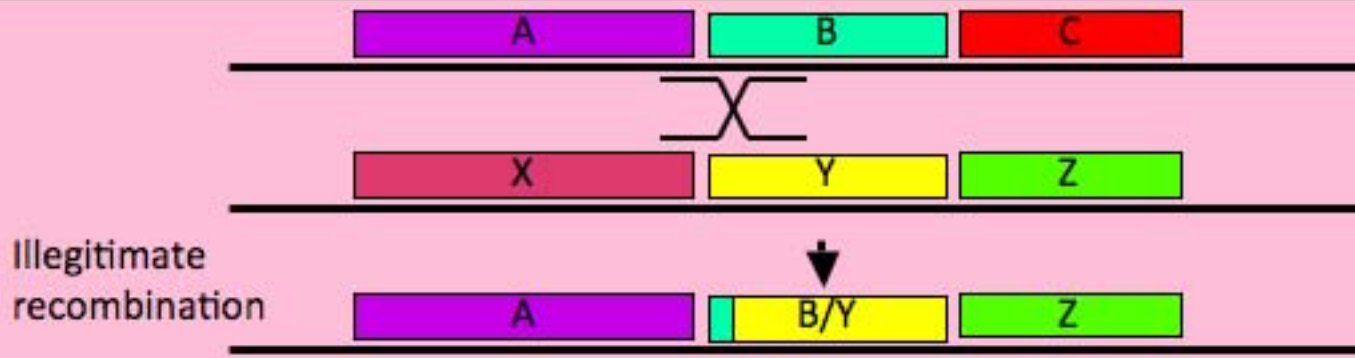
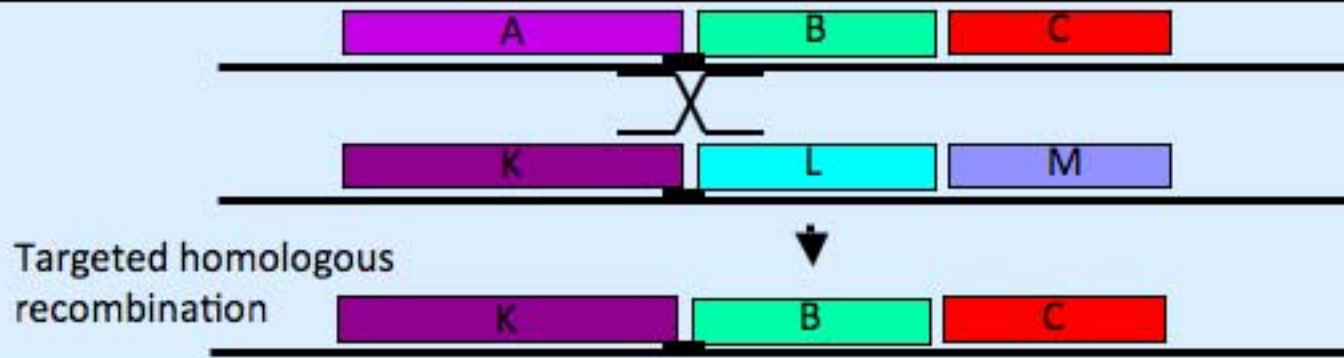
P C T S S V D G S T G S G L D E P Q Q A E G H R I R D P H H E R S D R S P
H V P P R S M A R Q A L V L T N R S K Q K G T E F E T R I T N G L I E A I
A M Y L L G R W L D E L W S * D R T A A S R R A P N S R P A S R T V * S K P
C C A T C T A C C T C C T C C G T C C A T C C C T C C A C A C C C T C T C C T C T C C C A A D C C A C C A A C C A C A C C C C A C C C A A T T C C A C A C C C C A T C A C C A A C C C T C T C A T C C A A D C C C T
52300 | 52310 | 52320 | 52330 | 52340 | 52350 | 52360 | 52370 | 52380 | 52390 | 52400 |
O G T A C A T G C A C C A C C C A G C T A C C C A C C T G T C C G A G A C C A C A C T C C T T O G G T C G T T O G T C T T C C C G T G C C T T A A G C T C T C G G G T A G T C C T T C C C A C A C T A C C T T C G G G
W T G G R D I A R C A R T K V F R L L C F P V S N S V R M V F P R I S A R
M Y R R P R H S S L S Q D Q R V A A L L L A G F E L G A D R V T Q D F G E
G H V E E T S P E V P E P R S S G C C A S P C R I R S G C * S R D S R L G

How does genomic mosaicism arise?

Two models:

1. By targeting of homologous recombination to conserved boundary sequences
2. By illegitimate recombination at random sequences

How does genomic mosaicism arise?



Proposed role of illegitimate recombination has important consequences

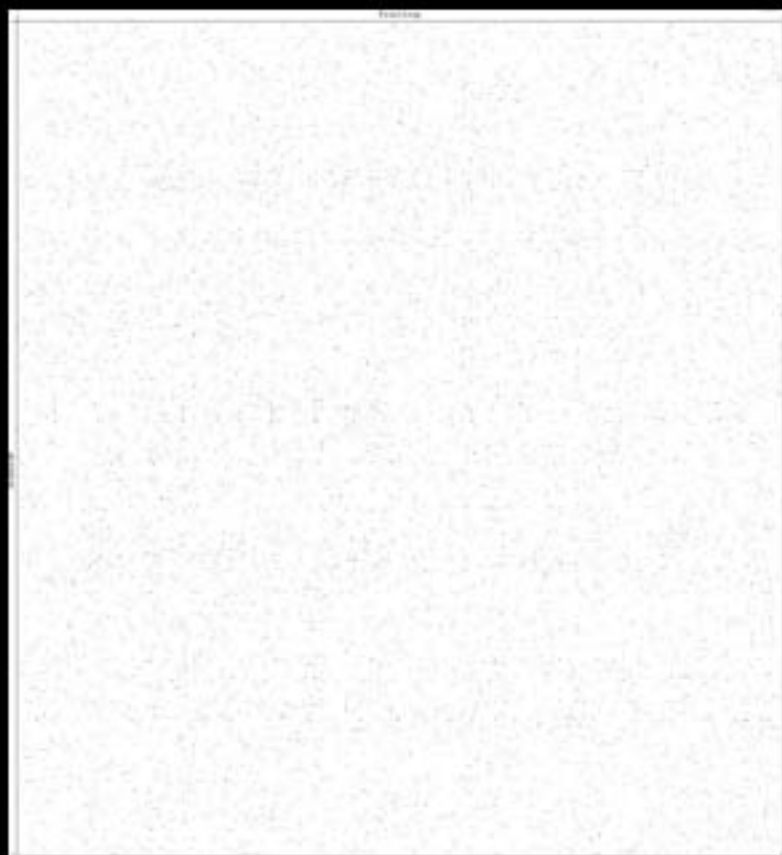
1. Illegitimate recombination happens at low frequency
2. Occurs at random positions
3. Most recombination events generate genomic trash
4. Multiple low frequency events are likely needed to generate survivors

Proposed role of illegitimate recombination has important consequences

4. Phage genomes will recombine with the bacterial chromosome
5. It is highly creative: joining DNA segment not previously joined
6. Recombinant joints can survive as fossilized relics of recombination
7. Many phages encode recombinases that could facilitate recombination between very short sequences

Zooming in on phage genome comparisons

Because phages of distantly-related bacteria are very different to each other.....



It is harder to learn about how they evolved

In conclusion...

- Phage genomes are architecturally mosaic
- Mosaicism is fueled by illegitimate recombination
- Genome segments can be reassorted by homologous recombination