Lost in translation: how well do bacteria use each other's genes?

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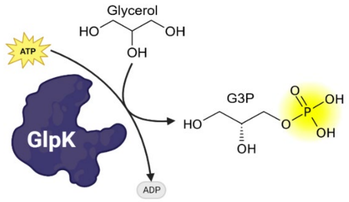
BACKGROUND: Human activity pollutes natural resources and contaminates ecosystems with harmful chemicals. "Bioremediation" occurs when bacteria degrade these pollutants, possibly for nutritional value or to detoxify their environment. To metabolize pollutants, bacteria may need evolve new metabolic pathways.

Horizontal gene transfer is a natural process wherein bacteria exchange genes across species boundaries, allowing rapid assembly of new metabolic pathways. Transfer of pollutant degradation genes has accelerated bioremediation in several cases.[1,2] However, bacteria have diverse preferences for how they encode their genes, which may cause transferred genes to function poorly in recipient bacterium.

QUESTION:
How useful are newly acquired genes, and does it correlate with their genetic diversity?

MODEL SYSTEM:
Glycerol kinase (*glpK*) is required for *E. coli* to use glycerol as a carbon source.

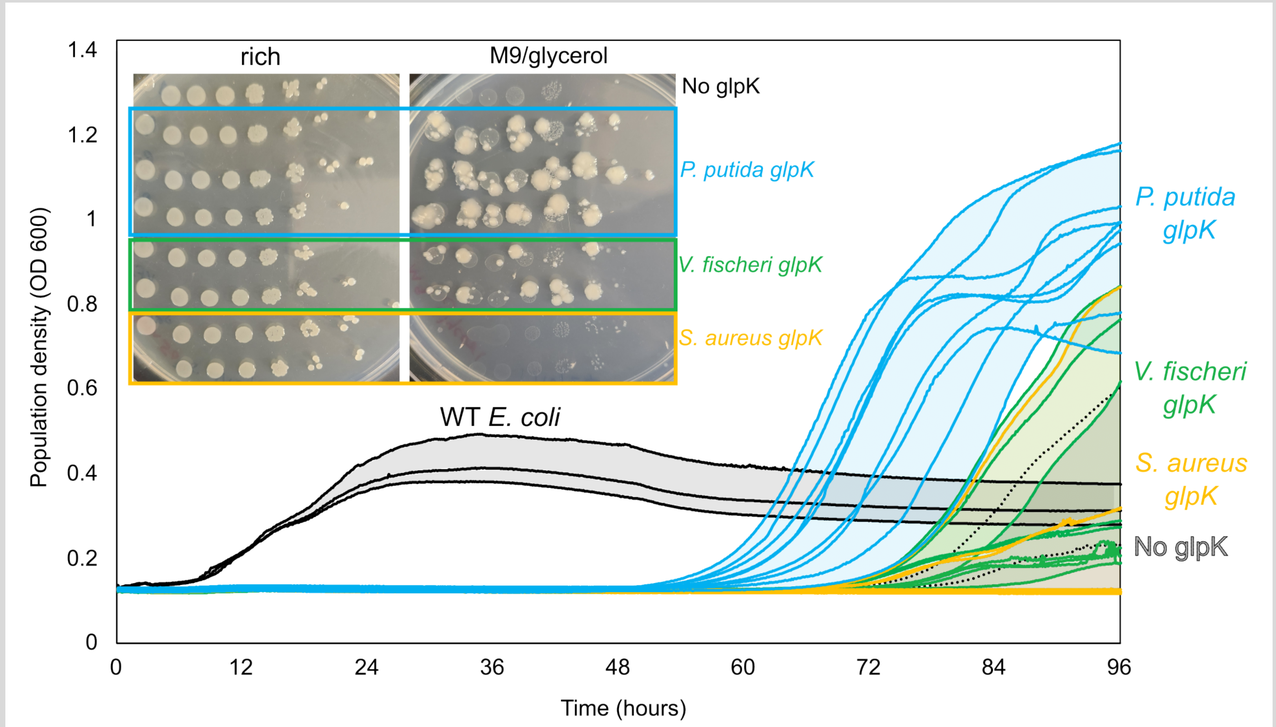


I replaced *E. coli*'s *glpK* with foreign *glpK*s from genetically diverse species:

Species	LCT	% glpK identity: Protein	% glpK identity: DNA	%GC	CAI
E. coli	--	--	--	54	0.79
S. enterica	Family	95.2	85.4	57	0.78
P. putida	Order	70.7	71.6	62	0.76
S. meliloti	Class	52.3	58.1	63	0.69
M. tuberculosis	Phylum	51.7	56.6	64	0.69
E. casseliflavus	Phylum	61.0	60.0	46	0.65
V. fischeri	Order	78.9	69.3	41	0.63
S. aureus	Phylum	56.0	59.5	37	0.61
E. anophelis	Phylum	58.6	57.5	41	0.59

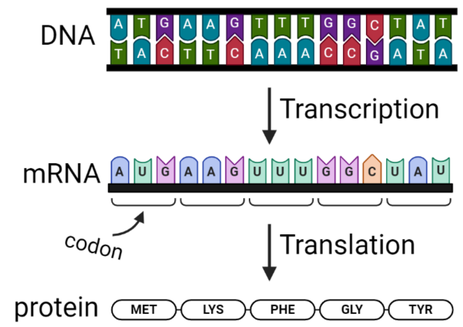
The functionality of foreign *glpK*s in *E. coli* determines how well they can grow on glycerol medium (M9/glycerol).

E. coli more effectively uses new genes that have preferred genetic properties.

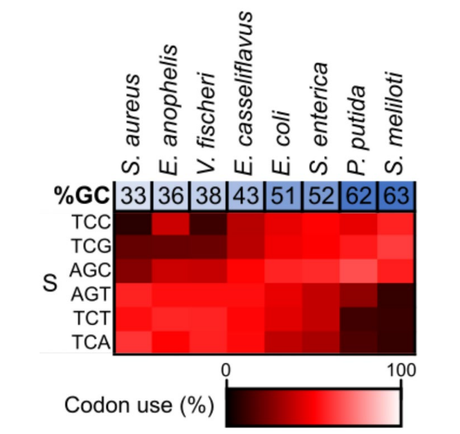


- All foreign *glpK* genes provide little to no growth for 48 hours. This may be due to incompatible promoter sequences that drive expression of foreign *glpK*s
- Spontaneous mutations likely allow *E. coli* with *Pseudomonas putida glpK* and *Vibrio fischeri glpK* to grow much better, but *Staphylococcus aureus glpK* confers little to no growth
- Better *glpK* function correlates with similar %GC, codon usage, and % identity with *E. coli glpK*

Why might a gene be incompatible?

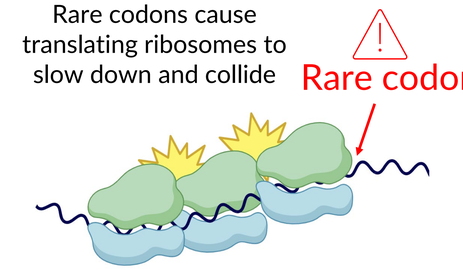


Gene expression relies on efficient transcription and translation.

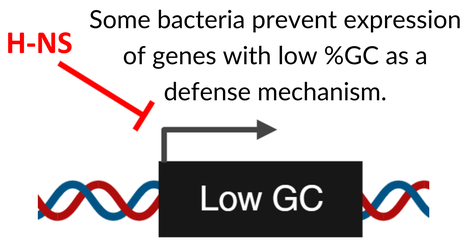


Several codons are used for the same amino acid during translation, and different species prefer different codons.

Rare codons cause translating ribosomes to slow down and collide



Some bacteria prevent expression of genes with low %GC as a defense mechanism.



Citations
1. Copley *et. al.* ***Genome Biology and Evolution*** (2012)
2. Ikuma *et. al.* ***Bioengineered*** (2012)

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