

SBOL Visual aids rapid communication of variant synthetic DNA designs.

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Abstract

Synthetic Biology Open Language (SBOL) Visual is an effort to standardize visual representations of synthetic biological constructs, and is a human-readable counterpart to the SBOL standard data format for representing construct design. SBOL Visual 1.0 consists of a set of standardized glyphs for representing designs of synthetic genetic systems as contiguous constructs. Each symbol corresponds to a sequence element in physical DNA, including simple regulatory elements such as promoters and DNA construction features like restriction sites. The symbols can be used as stencils to make illustrations on at the computer or by hand, for rendering in a web browser, as images for software design, or as a formal set of symbols for communication and instruction.

SBOL Visual symbols are currently used by a number of commercial and academic software tools. SBOL Visual is particularly well suited to represent the design of multi-component artificial genetic constructs, and we present examples where SBOL Visual has been employed for scientific descriptions of such constructs. SBOL Visual is developed by members of SBOL Developers Group to ensure cross-compatibility with other biological standards. **SBOL Visual is a free and open standard with resources made available for the broadest possible use under the Creative Commons CC0 “public domain” license.** The symbols are provided for personal, academic, and commercial use in a variety of image formats, including PNG and SVG. We encourage any interested practitioners to download the images, use and modify them freely, suggest changes, and join the SBOL Visual community to participate in developing the standard:

<http://www.sbolstandard.org/visual>

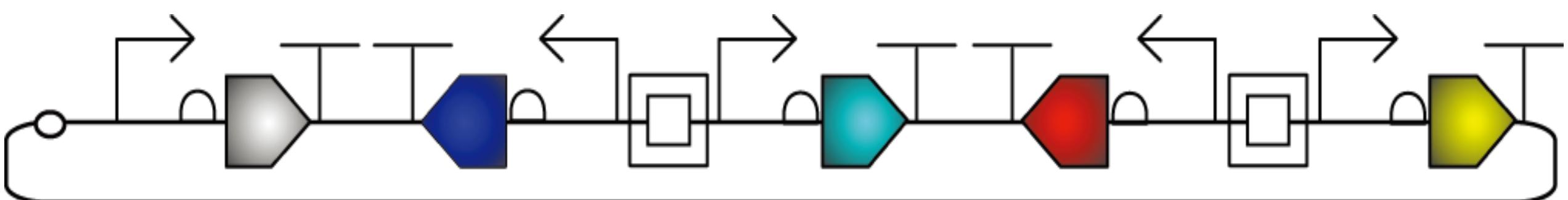
The SBOLv Glyphs and their Meanings

Current SBOL Visual Core Glyphs	
↗ promoter	X ribonuclease site
□ cds	O rna stability element
⌇ ribosome entry site	X protease site
T terminator	O protein stability element
□ operator	O origin of replication
□ insulator	□ user defined

Glyphs for DNA Construction	
O	Origin of Replication SBOL UID: org.sbols.origin_of_replication SO Accession: SO:0000296
→	Primer Binding Site SBOL UID: org.sbols.primer_binding_site SO Accession: SO:0005850
	Restriction Enzyme Recognition Site SBOL UID: org.sbols.restriction_enzyme_recognition_site SO Accession: SO:0000061*
=	5' Overhang / 5' Sticky restriction site SBOL UID: org.sbols.five_prime_overhang SO Accession: SO:0001932
=	3' Overhang / 3' Sticky restriction site SBOL UID: org.sbols.three_prime_overhang SO Accession: SO:0001933
	Restriction Site Resulting in No Overhang / Blunt restriction site SBOL UID: org.sbols.restriction_site_no_overhang SO Accession: SO:0001954*
=	Assembly Junction / Assembly Scar SBOL UID: org.sbols.assembly_junction SO Accession: SO:0001953
X	Signature / Barcode SBOL UID: org.sbols.signature SO Accession: SO:0001978*

Sequence Ontology	
↗	Promoter The sequence at the beginning of a gene required for transcription initiation. SBOL UID: org.sbols.promoter SO Accession: SO:0000167
□	Operator / User defined A transcription factor binding site. SBOL UID: org.sbols.operator SO Accession: SO:0000057
▷	Coding Dependent Sequence (CDS) A complete coding dependent sequence, inclusive of the start and stop codons. A sequence of codons which encode an oligopeptide, often folds into a protein. May also include untranslated regions (e.g. introns). SBOL UID: org.sbols.cds SO Accession: SO:0000316
⌇	Ribosome Entry Site This symbol represents a ribosome binding site in prokaryotes, an IRES in viruses, and Kozak sequence in eukaryotes. SBOL UID: org.sbols.ribosome_entry_site SO Accession: SO:0000139
T	Terminator A sequence which halts transcription, usually found at the end of a gene. SBOL UID: org.sbols.terminator SO Accession: SO:0000141
□	Insulator / Spacer A sequence that provides genetic isolation between two or more contiguous components. SBOL UID: org.sbols.insulator SO Accession: SO:0000627
X	Ribonuclease Site SBOL UID: org.sbols.ribonuclease_site SO Accession: SO:0001977*
O	RNA Stability Element SBOL UID: org.sbols.rna_stability_element SO Accession: SO:0001546*
X	Protease Site SBOL UID: org.sbols.protease_site SO Accession: SO:0001956
O	Protein Stability Element SBOL UID: org.sbols.protein_stability_element SO Accession: SO:0001955*

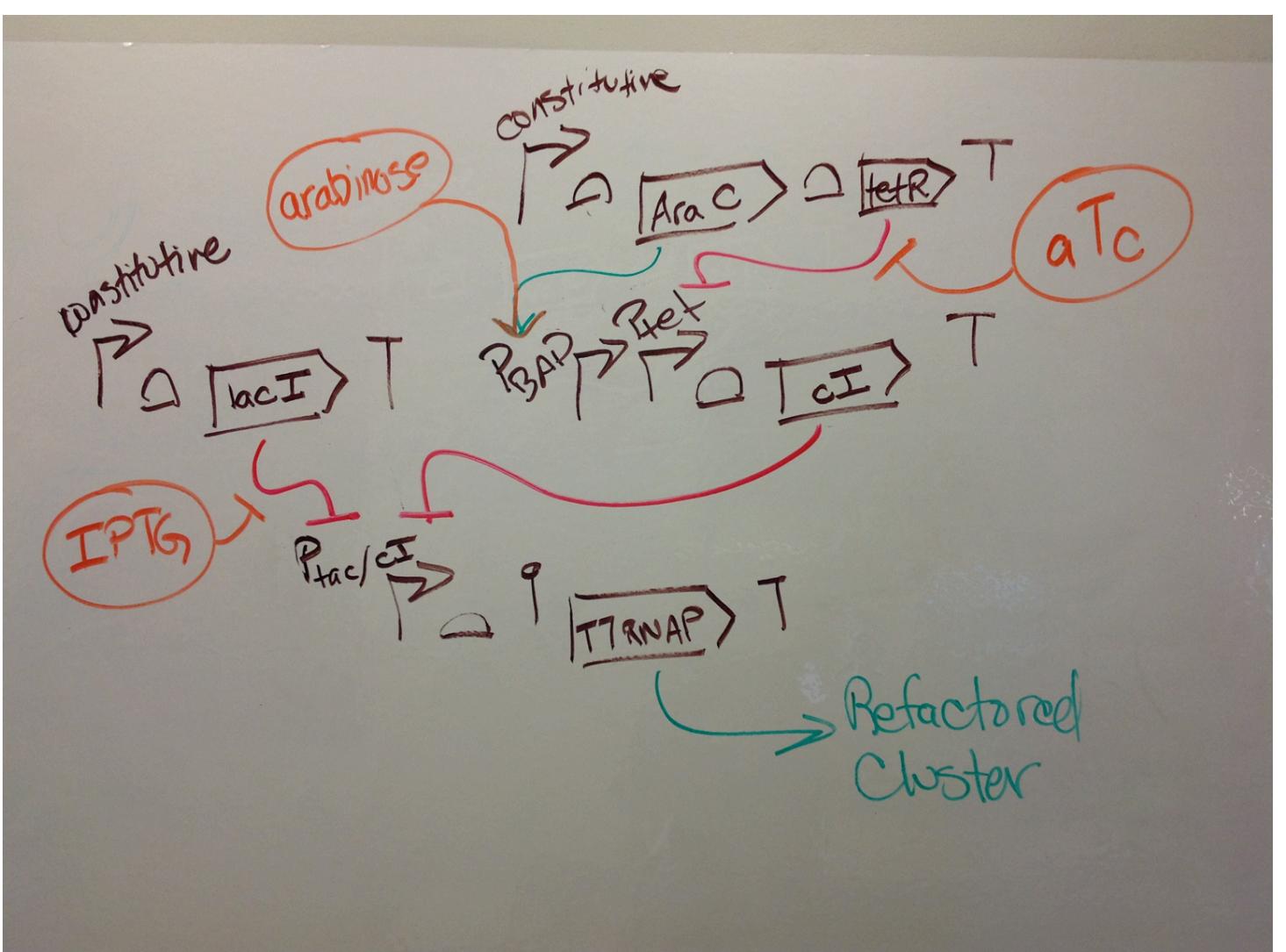
Example: Four color genetic reporter on plasmid



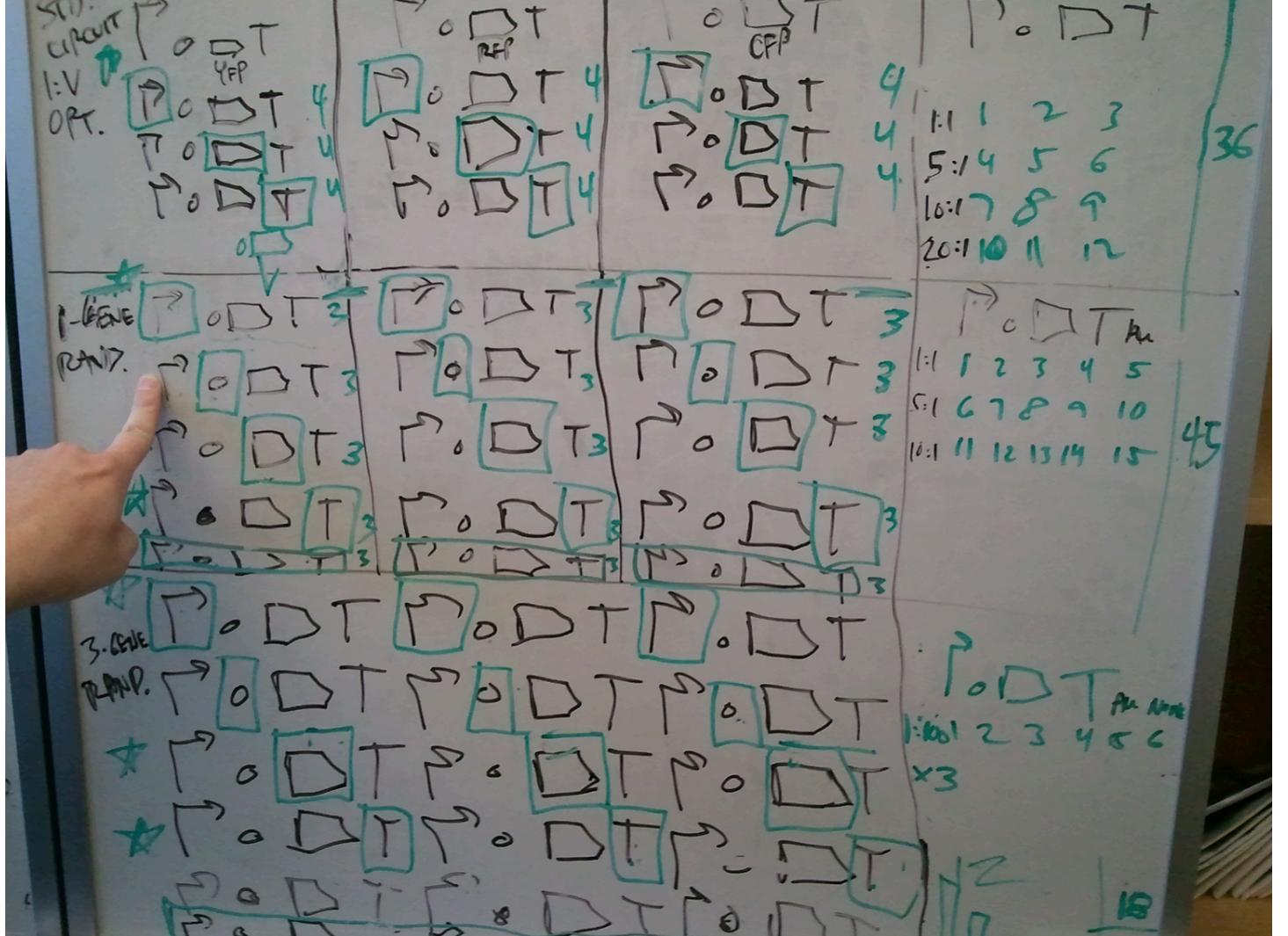
SBOL Visual in Use

Whiteboard Discussions

Design of Genetic Circuits



Combinatorial Designs

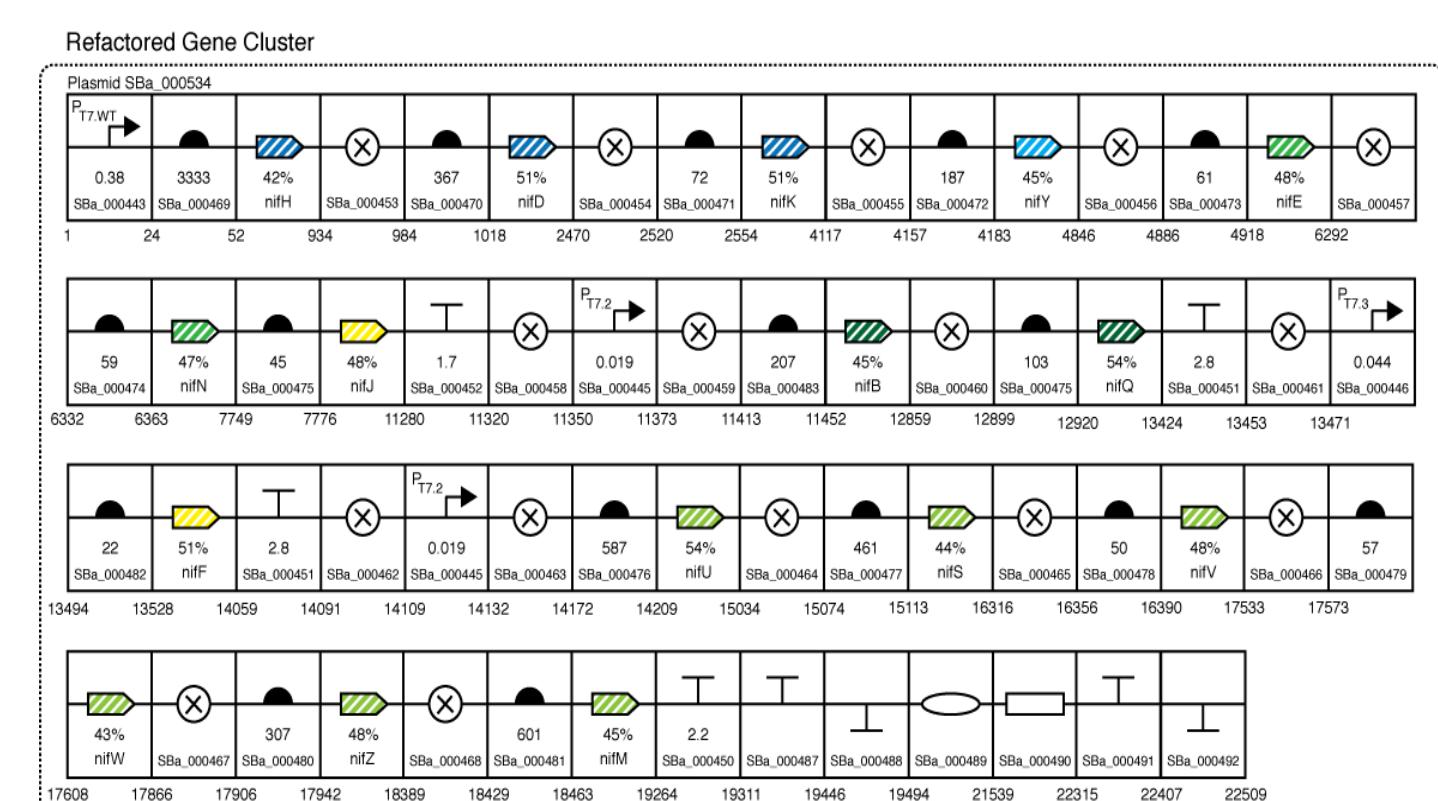


Scientific Publications

Cox, III, Sidney R et al. A synthetic three-color scaffold for monitoring genetic regulation and noise. *J Biol Eng. Biomed Central Ltd; 2010;4: 10.* doi:10.1186/1754-1611-4-10

Dunlop MJ, Cox, III, Sidney R, Levine JH, Murray RM, et al. Regulatory activity revealed by dynamic correlations in gene expression noise. *Nat Genet. Nature Publishing Group; 2008;40: 1493–1498.* doi:10.1038/ng.281

Kosuri S et al., Composability of regulatory sequences controlling transcription and translation in *Escherichia coli*. doi:10.1073/pnas.1301301110

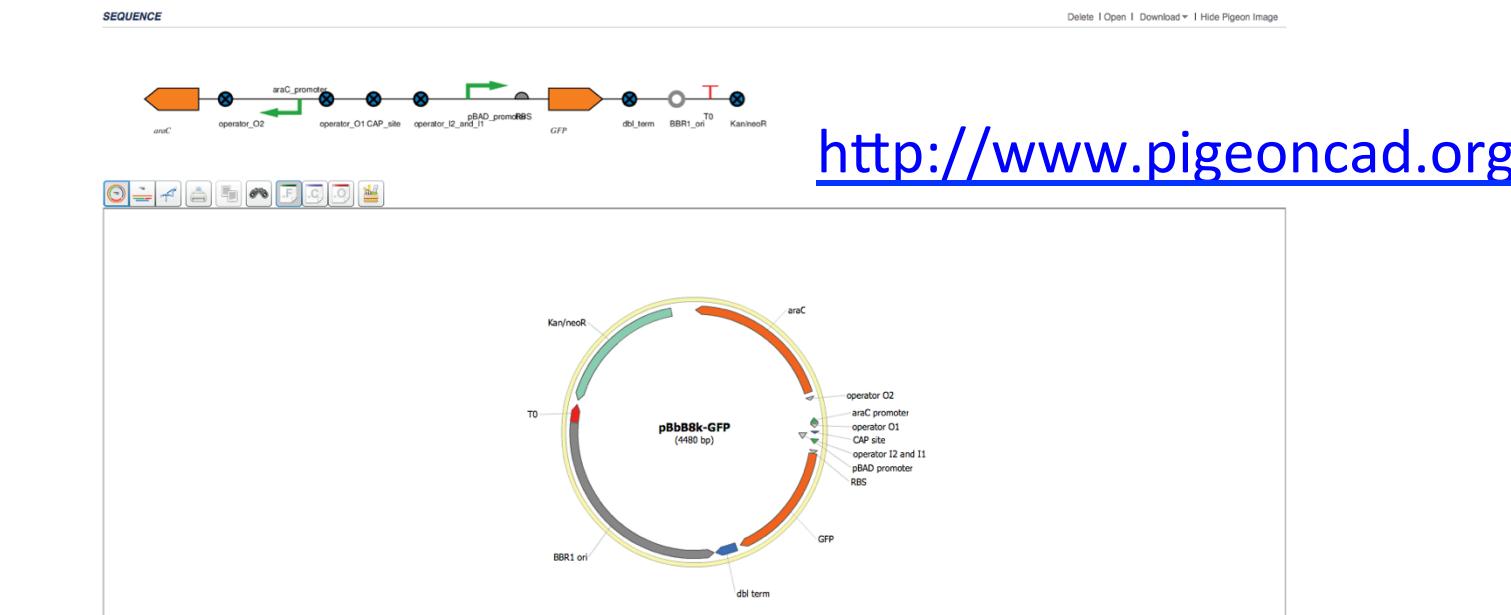


Kiani et al., CRISPR transcriptional repression devices and layered circuits in mammalian cells, *Nature Methods*, 11(7), July 2014

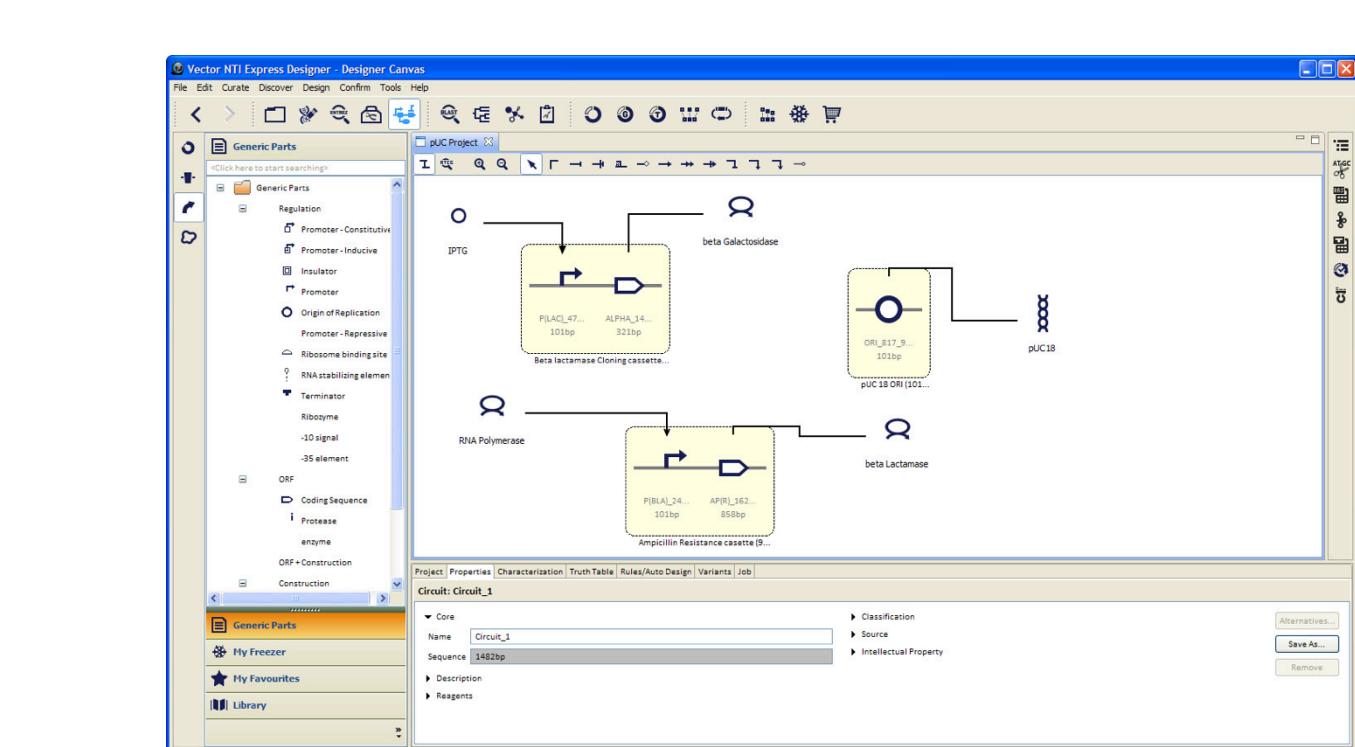
Temme et al. Refactoring the nitrogen fixation gene cluster from *Klebsiella oxytoca*. *Proc Natl Acad Sci U S A. 2012;109: 7085–7090.* doi:10.1073/pnas.1120788109

Software/CAD Tools

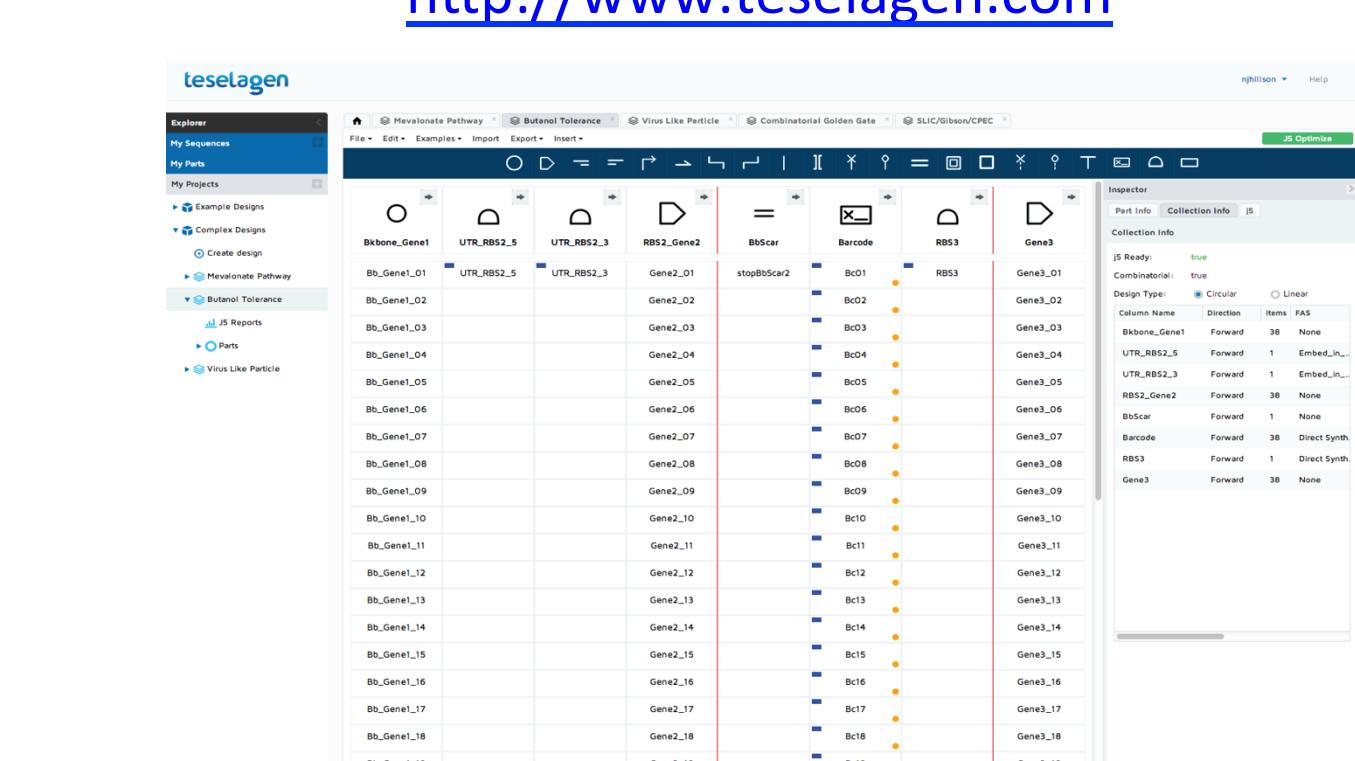
JBEI ICE Registry



Life Technologies VectorNTI Express Designer



<http://www.teselagen.com>



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