

Synthetic Biology Open Language

SBOL Chair: Chris J. Myers ([University of Utah](#))

SBOL Editors: Hasan Baig (Habib), Vishwesh Kulkarni (Warwick),
Curtis Madsen (Sandia), James McLaughlin (Newcastle), Zach Palchick (Zymergen)

[IWBDA SBOL Workshop 2019](#)

Cambridge, UK

July 8, 2019

SYNTHETIC BIOLOGY



Drew Endy

Standards are a foundational principle of synthetic biology

Synthetic biology adds:

- Standards
- Abstraction
- Decoupling

to genetic engineering.

SYNTHETIC BIOLOGY OPEN LANGUAGE (SBOL)

VERSION 1 RELEASED IN 2011



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NATURE BIOTECHNOLOGY | COMPUTATIONAL BIOLOGY | PERSPECTIVE



[日本語要約](#)

The Synthetic Biology Open Language (SBOL) provides a community standard for communicating designs in synthetic biology

Michał Galdzicki, Kevin P Clancy, Ernst Oberortner, Matthew Pocock, Jacqueline Y Quinn,
Cesar A Rodriguez, Nicholas Roehner, Mandy L Wilson, Laura Adam, J Christopher Anderson,
Bryan A Bartley, Jacob Beal, Deepak Chandran, Joanna Chen, Douglas Densmore, Drew
Endy, Raik Grünberg, Jennifer Hallinan, Nathan J Hillson, Jeffrey D Johnson, Allan Kuchinsky,
Matthew Lux, Goksel Misirli, Jean Peccoud, Hector A Plahar, Evren Sirin, Guy-Bart Stan, Alan
Villalobos, Anil Wipat, John H Gennari, Chris J Myers & Herbert M Sauro

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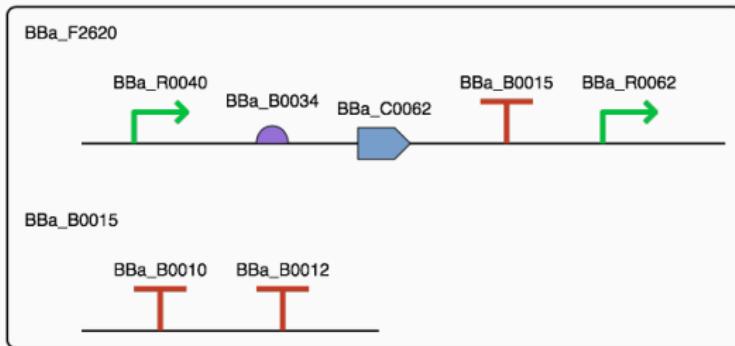
Nature Biotechnology 32, 545–550 (2014) | doi:10.1038/nbt.2891

Received 09 November 2013 | Accepted 20 December 2013 | Published online 06 June 2014

COMMUNITY PAGE

SBOL Visual: A Graphical Language for Genetic Designs

Jacqueline Y. Quinn^{1*}, Robert Sidney Cox III^{2*}, Aaron Adler³, Jacob Beal³, Swapnil Bhatia⁴, Yizhi Cai⁵, Joanna Chen^{6,7}, Kevin Clancy⁸, Michal Galdzicki⁹, Nathan J. Hillson^{6,7}, Nicolas Le Novère¹⁰, Akshay J. Maheshwari¹¹, James Alastair McLaughlin¹², Chris J. Myers¹³, Umesh P¹⁴, Matthew Pocock^{12,15}, Cesar Rodriguez¹⁶, Larisa Soldatova¹⁷, Guy-Bart V. Stan¹⁸, Neil Swainston¹⁹, Anil Wipat¹², Herbert M. Sauro^{20*}



Sharing Structure and Function in Biological Design with SBOL 2.0

Nicholas Roehner,^{*†} Jacob Beal,[‡] Kevin Clancy,[§] Bryan Bartley,[⊥] Goksel Misirlı,^{||} Raik Grünberg,[¶] Ernst Oberortner,[#] Matthew Pocock,[▽] Michael Bissell,[⊗] Curtis Madsen,^{||} Tramy Nguyen,[■] Michael Zhang,[■] Zhen Zhang,[■] Zach Zundel,[▲] Douglas Densmore,[†] John H. Gennari,[●] Anil Wipat,^{||} Herbert M. Sauro,[⊥] and Chris J. Myers[■]

SEE ALSO:

- Roehner et al., *ACS Synthetic Biology* (2014)
- Bartley et al., *Journal of Integrative Bioinformatics* (2015)
- Beal et al., *Journal of Integrative Bioinformatics* (2016)
- Cox et al., *Journal of Integrative Bioinformatics* (2017)

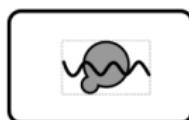
SBOL V VERSION 2: NUCLEIC ACID GLYPHS (2017)

Nucleic Acid Glyphs

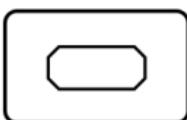
Aptamer	Assembly Scar	Blunt Restriction Site	(recommended) CDS	(alternate) CDS	Composite	Engineered Region	3' Overhang Sticky End
5' Overhang Sticky End	3' Sticky Restriction Site	5' Sticky Restriction Site	Insulator	No Glyph	Non-Coding RNA	Omitted Detail	Operator
ORI	ORI-T	Poly-A Site	Primer Binding Site	Promoter	Ribosome Entry Site	Signature	Recombination Site
Terminator	(recommended) Unspecified	(alternate) Unspecified	(recommended) DNA Location	(recommended) RNA Location	(recommended) Protein Location	(alternate) DNA Location	(alternate) RNA Location
(alternate) Protein Location	DNA Cleavage Site	RNA Cleavage Site	Protein Cleavage Site	DNA Stability Element	RNA Stability Element	Protein Stability Element	

SBOLv VERSION 2: MOLECULAR SPECIES GLYPHS (2017)

Molecular Species Glyphs



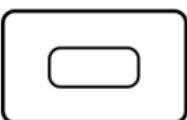
Superpose
Glyphs Complex



(alternate)
Complex



(recommended)
Macromolecule



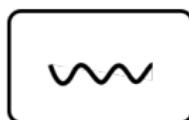
(alternate)
Macromolecule



No Glyph



Nucleic Acid
(Generic)



Nucleic Acid
(1-Strand)



Nucleic Acid
(2-Strand)



Small Molecule



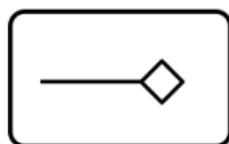
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Unspecified



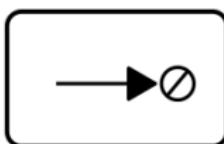
(alternate)
Unspecified

SBOL V VERSION 2: INTERACTION GLYPHS (2017)

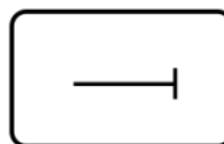
Interaction Glyphs



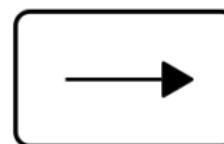
Control



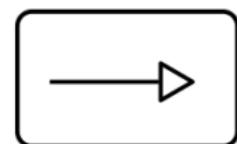
Degradation



Inhibition



Process



Stimulation

Improving Synthetic Biology Communication: Recommended Practices for Visual Depiction and Digital Submission of Genetic Designs

Nathan J. Hillson,^{*,†,‡,§,||} Hector A. Plahar,^{†,‡,||} Jacob Beal,^{*,‡,⊥} and Ranjini Prithviraj,[#]

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[‡]Biological Systems and Engineering Division, Lawrence Berkeley National Lab, Berkeley, California 94720, United States

[§]DOE Joint Genome Institute, Walnut Creek, California 94598, United States

^{||}Synthetic Biology Engineering Research Center, Emeryville, California 94608, United States

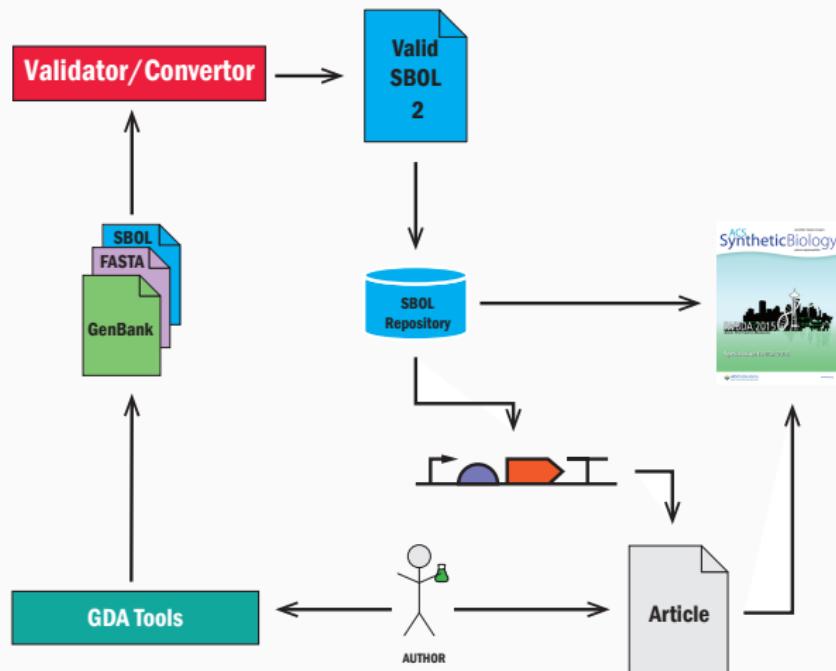
[⊥]Raytheon BBN Technologies, Cambridge, Massachusetts 02138, United States

[#]ACS Synthetic Biology, American Chemical Society, Washington, D.C. 20036, United States

ABSTRACT: Research is communicated more effectively and reproducibly when articles depict genetic designs consistently and fully disclose the complete sequences of all reported constructs. *ACS Synthetic Biology* is now providing authors with updated guidance and piloting a new tool and publication workflow that facilitate compliance with these recommended practices and standards for visual representation and data exchange.



ACS SYNTHETIC BIOLOGY SBOL WORKFLOW



Hillson et al., *ACS Synthetic Biology* (2016)

Zundel et al., *ACS Synthetic Biology* (2017)

Received 3 December 2015; accepted 27 February 2016. Date of publication 24 March 2016;
date of current version 14 April 2016.

Digital Object Identifier 10.1109/LLS.2016.2546546

libSBOLj 2.0: A Java Library to Support SBOL 2.0

**ZHEN ZHANG¹, TRAMY NGUYEN¹, NICHOLAS ROEHNER², GÖKSEL MISIRLI³,
MATTHEW POCOCK⁴, ERNST OBERORTNER⁵, MEHER SAMINENI¹, ZACH ZUNDEL¹,
JACOB BEAL⁶, KEVIN CLANCY⁷, ANIL WIPAT³, AND CHRIS J. MYERS¹**

¹University of Utah, Salt Lake City, UT 84112 USA

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⁶Raytheon BBN Technologies, Cambridge, MA 02138 USA

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CORRESPONDING AUTHOR: C. J. MYERS (myers@ece.utah.edu).

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in part by the Engineering and Physical Sciences Research Council under Grant EP/J02175X/1.

Native Java library for SBOL Version 2

ACS Synthetic Biology

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ACS Synth. Biol.

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Technical Note

 [Prev](#)

pySBOL: A Python Package for Genetic Design Automation and Standardization

Bryan A. Bartley^{*†} , Kiri Choi[‡], Meher Samineni[§], Zach Zundel[§] , Tramy Nguyen[§] , Chris J. Myers[§], and Herbert M. Sauro[‡]

† Raytheon BBN Technologies, Cambridge, Massachusetts 02138, United States

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§ Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, Utah 84112, United States

ACS Synth. Biol., Article ASAP

DOI: 10.1021/acssynbio.8b00336

Publication Date (Web): November 13, 2018

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*E-mail: bryan.a.bartley@raytheon.com.

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Cite this: *ACS Synth. Biol.* XXXX, XXX, XXX-XXX

RIS Citation

GO

Python library that SWIG wraps a C++ library

SBOLJS VERSION 2 RELEASED IN 2016

The screenshot shows the homepage of the ACS Synthetic Biology journal. At the top right is a search bar with the placeholder "Enter search text" and a dropdown menu showing "ACS Synth. Biol.". Below the header is a navigation bar with links: "Browse the Journal", "Articles ASAP", "Current Issue", "Submission & Review", "Open Access", and "About the Jou". The main content area features a "Technical Note" titled "sboljs: Bringing the Synthetic Biology Open Language to the Web Browser" by James Alastair McLaughlin†, Chris J. Myers‡, Zach Zundel‡, Nathan Wilkinson‡, Christian Atallah†, and Anil Wipat*. Below the title is a note about the School of Computing at Newcastle University and the Department of Electrical and Computer Engineering at the University of Utah. A citation link is provided: "Cite this: ACS Synth. Biol. 2019, 8 (1), pp 191–193". At the bottom left is an email address: "E-mail: anil.wipat@ncl.ac.uk".

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Technical Note

◀ Previous

sboljs: Bringing the Synthetic Biology Open Language to the Web Browser

James Alastair McLaughlin[†], Chris J. Myers[‡], Zach Zundel[‡], Nathan Wilkinson[‡], Christian Atallah[†], and Anil Wipat^{*}

[†] School of Computing, Newcastle University, Newcastle upon Tyne NE4 5TG, U.K.
[‡] Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, Utah 84112, United States

ACS Synth. Biol., 2019, 8 (1), pp 191–193
DOI: 10.1021/acssynbio.8b00338
Publication Date (Web): November 7, 2018
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*E-mail: anil.wipat@ncl.ac.uk.

Cite this: ACS Synth. Biol. 2019, 8 (1), pp 191–193

RIS Citation GO

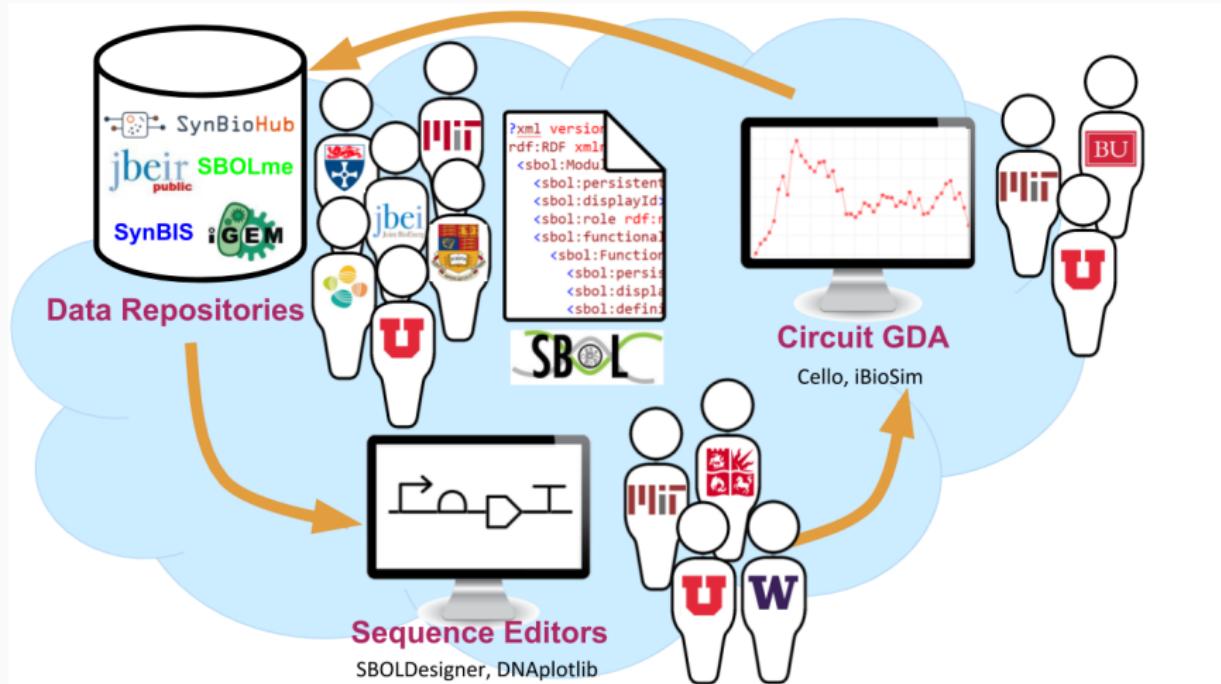
Native Javascript library

SOFTWARE SUPPORTING SBOL

Name	Function					SBOL		
	R	S	V	G	M	1	2	v
Benchling		•				•		
BOOST		•				•	•	
Cello				•		•	•	
DeviceEditor	•		•			•		•
DNAPlotLib			•			•		•
Eugene	•					•		•
Finch	•	•	•	•		•	•	
GenoCAD	•	•	•					•
GeneGenie	•					•		
Graphviz			•					•
ICE	•		•			•	•	•
iBioSim	•	•	•	•	•	•	•	•
j5	•	•						
MoSeC	•				•	•		
Pigeon			•					•
Pinecone	•							•
Pool Designer	•					•	•	
Proto BioCompiler			•	•		•		•
SBOLDesigner	•	•	•			•	•	•
SBOLme	•							
ShortBol	•	•		•			•	
SynBioHub	•		•			•	•	•
Tellurium					•		•	
TeselaGen	•	•				•		•
TinkerCell	•	•	•	•	•	•	•	
VisBOL			•				•	•
VirtualParts	•				•		•	•

<http://sbolstandard.org/software/tools/>

SYNTHETIC BIOLOGY WORKFLOW USING SBOL



WORD OF WARNING

HOW STANDARDS PROLIFERATE:
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC)

SITUATION:
THERE ARE
14 COMPETING
STANDARDS.

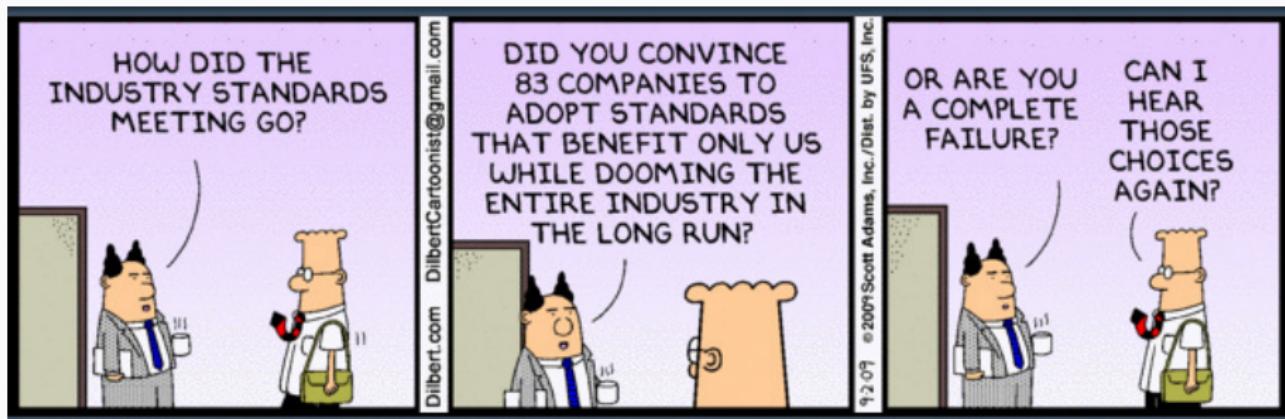
14?! RIDICULOUS!
WE NEED TO DEVELOP
ONE UNIVERSAL STANDARD
THAT COVERS EVERYONE'S
USE CASES.



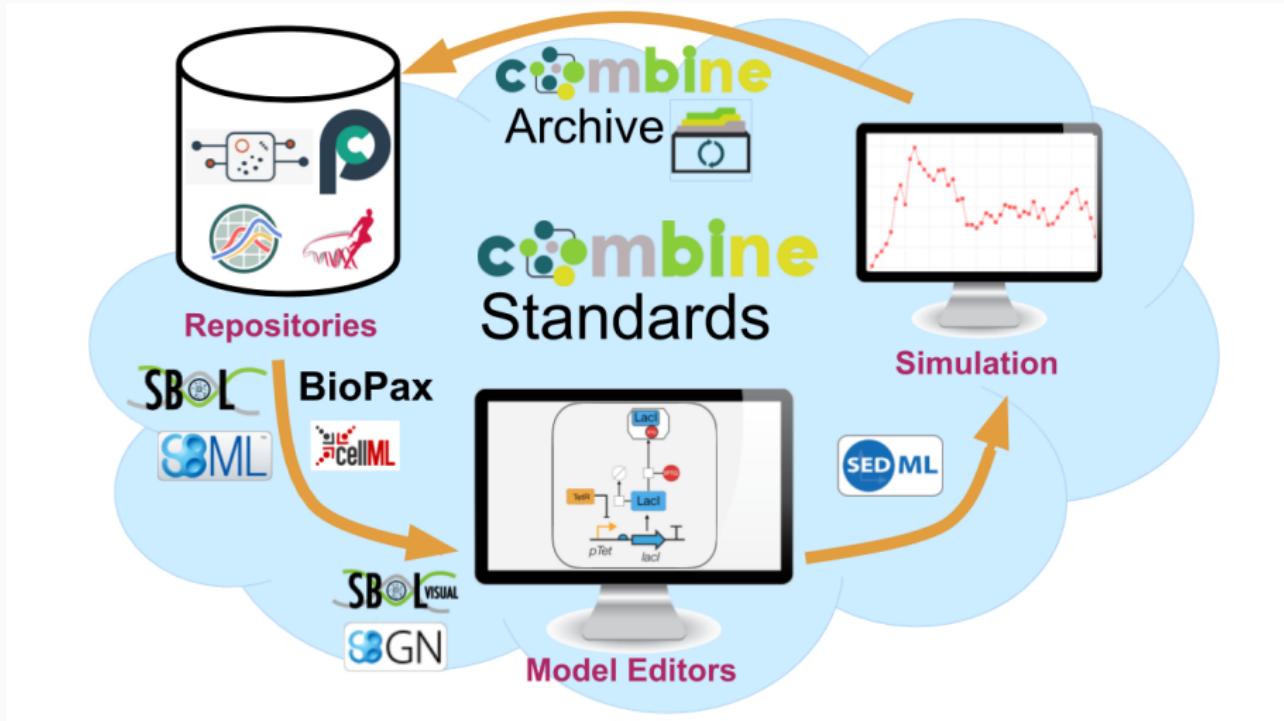
SOON:

SITUATION:
THERE ARE
15 COMPETING
STANDARDS.

PROPRIETARY STANDARDS

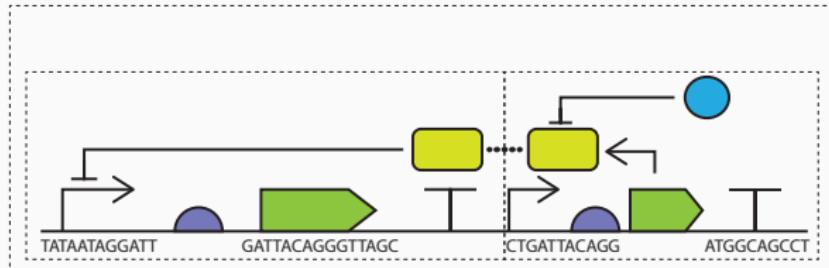


STANDARD ENABLED SYSTEMS/SYNTHETIC BIOLOGY WORKFLOW

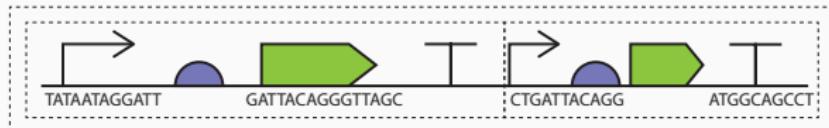


SBOL EVOLUTION

SBOL 2



SBOL 1



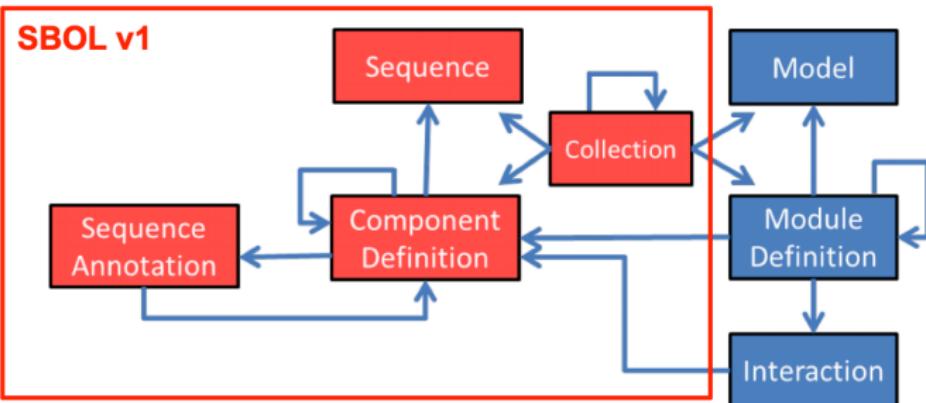
GenBank

Promoter	RBS	CDS	Terminator	Promoter	RBS	CDS	Terminator
TATAATAGGATT	CCGCAATGGATTACAGGGTTAGCAAATGGCAGCCTGATTACAGGGTTAGCAAATGGCAGCCT						

FASTA

TATAATAGGATTCCGCAATGGATTACAGGGTTAGCAAATGGCAGCCTGATTACAGGGTTAGCAAATGGCAGCCT

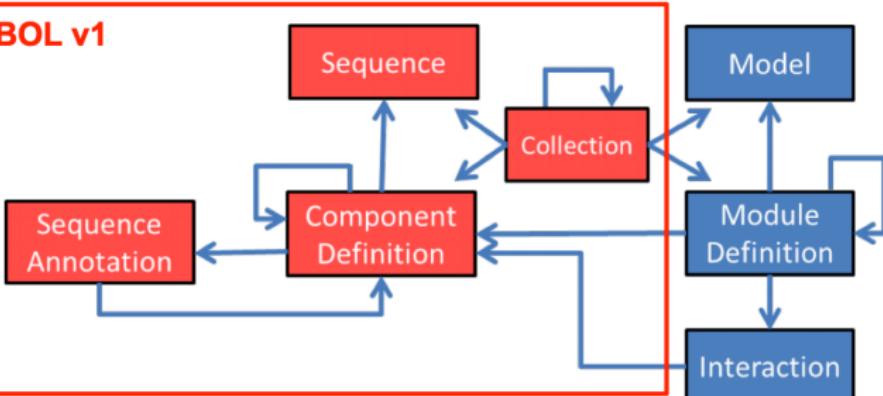
SBOL DATA MODEL



SBOL DATA MODEL

SBOL v2.0

SBOL v1

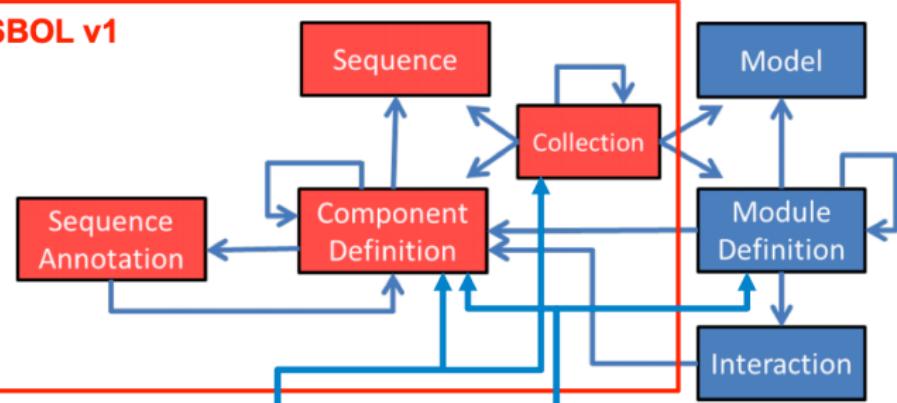


SBOL DATA MODEL

SBOL v2.2

SBOL v2.0

SBOL v1



Provenance

Combinatorial
Derivation

Implementation

Attachment

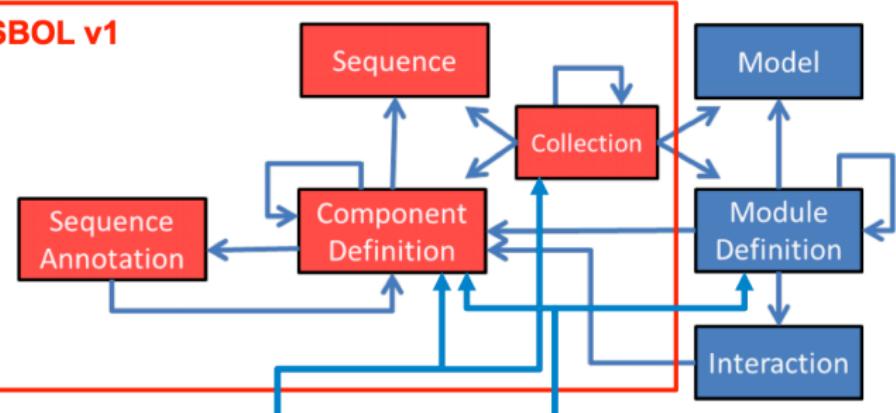
SBOL DATA MODEL

SBOL v2.3

SBOL v2.2

SBOL v2.0

SBOL v1



Provenance

Combinatorial
Derivation

Implementation

Attachment

Experiment

Experimental
Data

Measure

COMPONENT DEFINITIONS

ComponentDefinition

identity: iGEM#l13504

name: "iGEM 2016 interlab reporter"

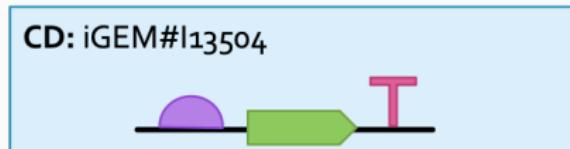
description: "GFP expression cassette
used for 2016 iGEM interlab"

type: biopax#DnaRegion

role: SO:0000804 (Engineered Region)



COMPONENTS



Component

Component

Component

definition

definition

definition

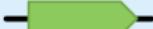
ComponentDefinition

identity: iGEM#Boo34
name: RBS (Elowitz 1999)
type: biopax#DnaRegion
role: SO:oooo0139
(Ribosome Entry Site)



ComponentDefinition

identity: iGEM#Eoo40
name: GFP
type: biopax#DnaRegion
role: SO:oooo316 (CDS)

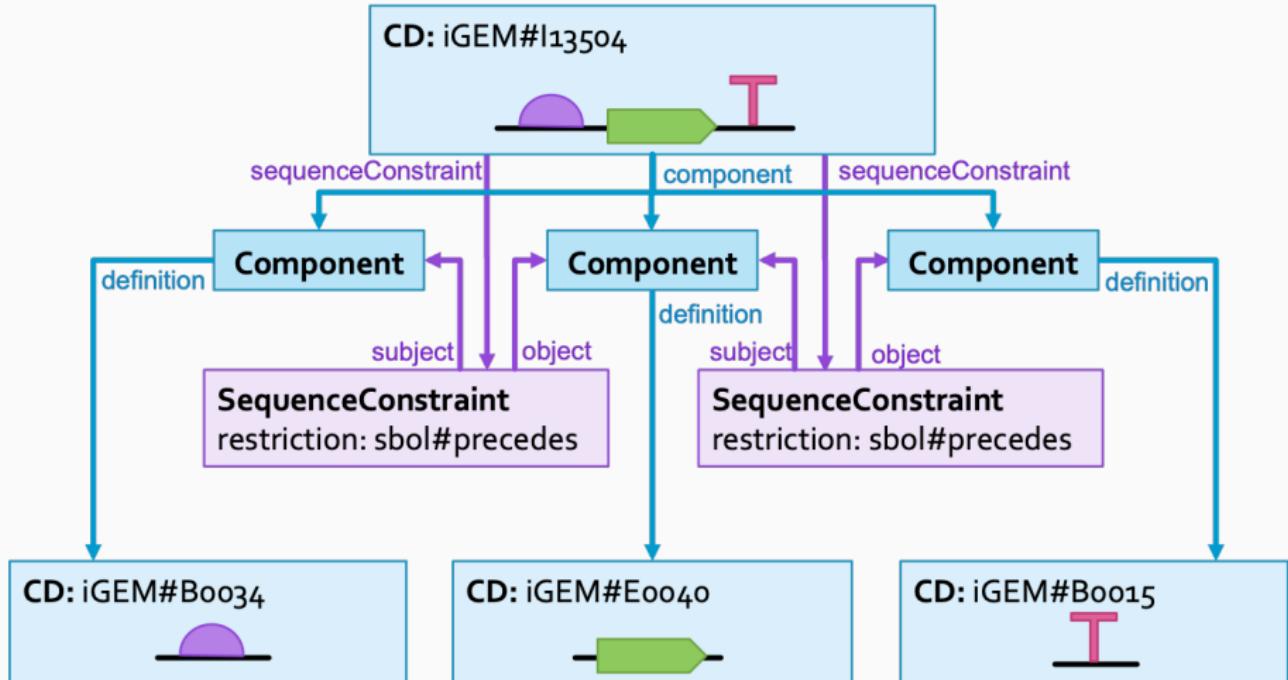


ComponentDefinition

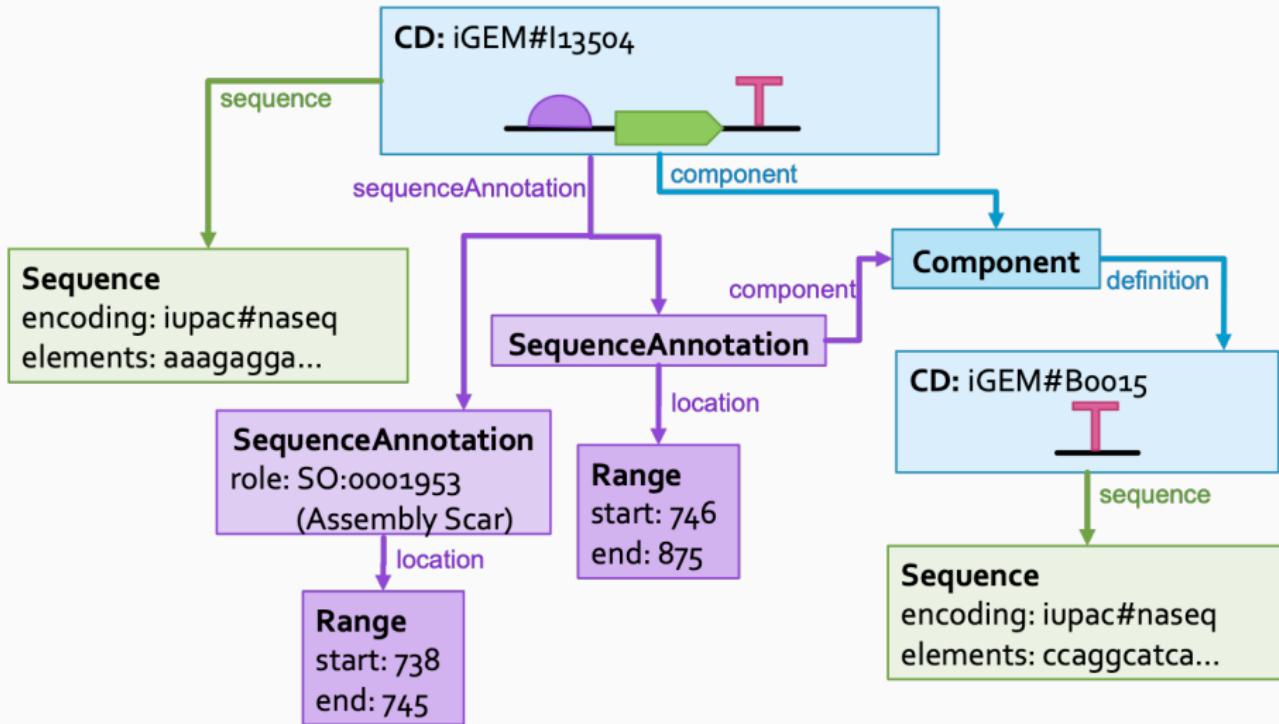
identity: iGEM#Boo15
name: double terminator
type: biopax#DnaRegion
role: SO:oooo141
(Terminator)



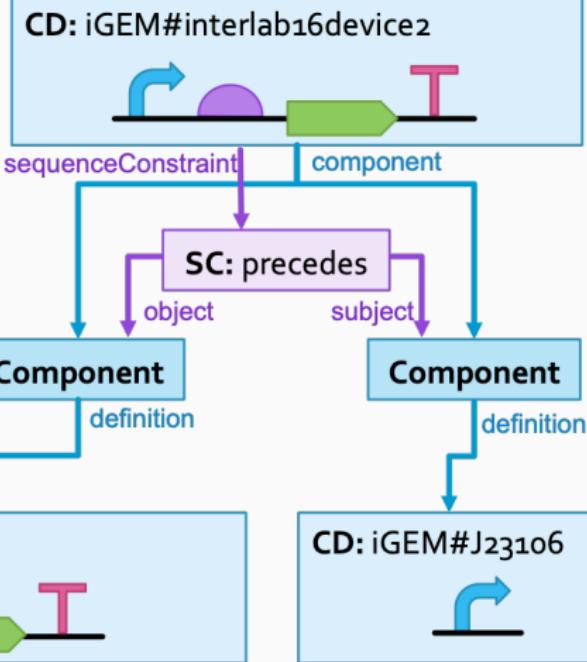
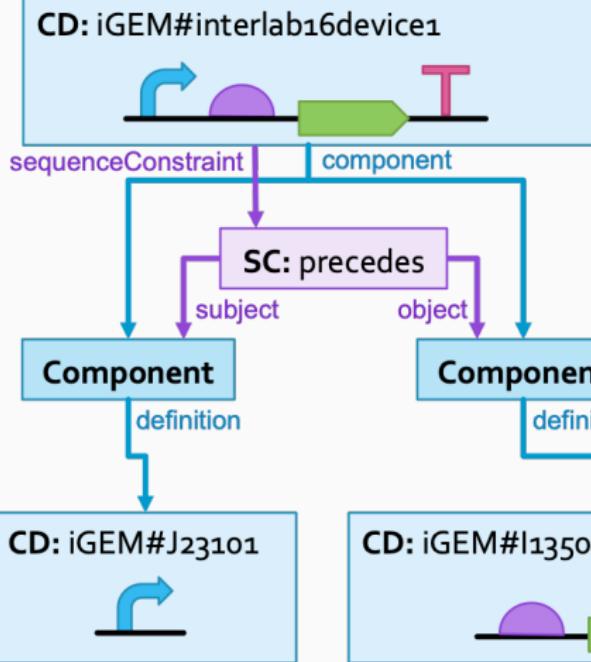
SEQUENCE CONSTRAINTS



SEQUENCES/SEQUENCE ANNOTATIONS



REUSING COMPONENTS



COMBINATORIAL DERIVATIONS

Overview

pBAD pHlylR RBS AmtR Ter

Combinatorial Design Variants: RBS

Variant operator: one

Derivation strategy: None

Derivation display ID: RBS_CombinatorialDerivation

Derivation name: [empty field]

Derivation description: [empty field]

Variant count (5)

Type	Display Id	Name	Version	Description
Part	A1	A1	1	
Part	B1	B1	1	
Part	E1	E1	1	
Part	R1	R1	1	
Part	B3	B3	1	

Add Variant Remove Variant Add new Combinatorial Derivation Save

COLLECTIONS

Collection:

identity: iGEM#interlab16

name: "iGEM 2016 interlab parts"

description: "Collection of parts used
for 2016 iGEM interlab"

member

CD: iGEM#interlab16device1



CD: iGEM#interlab16device2



CD: iGEM#interlab16device3



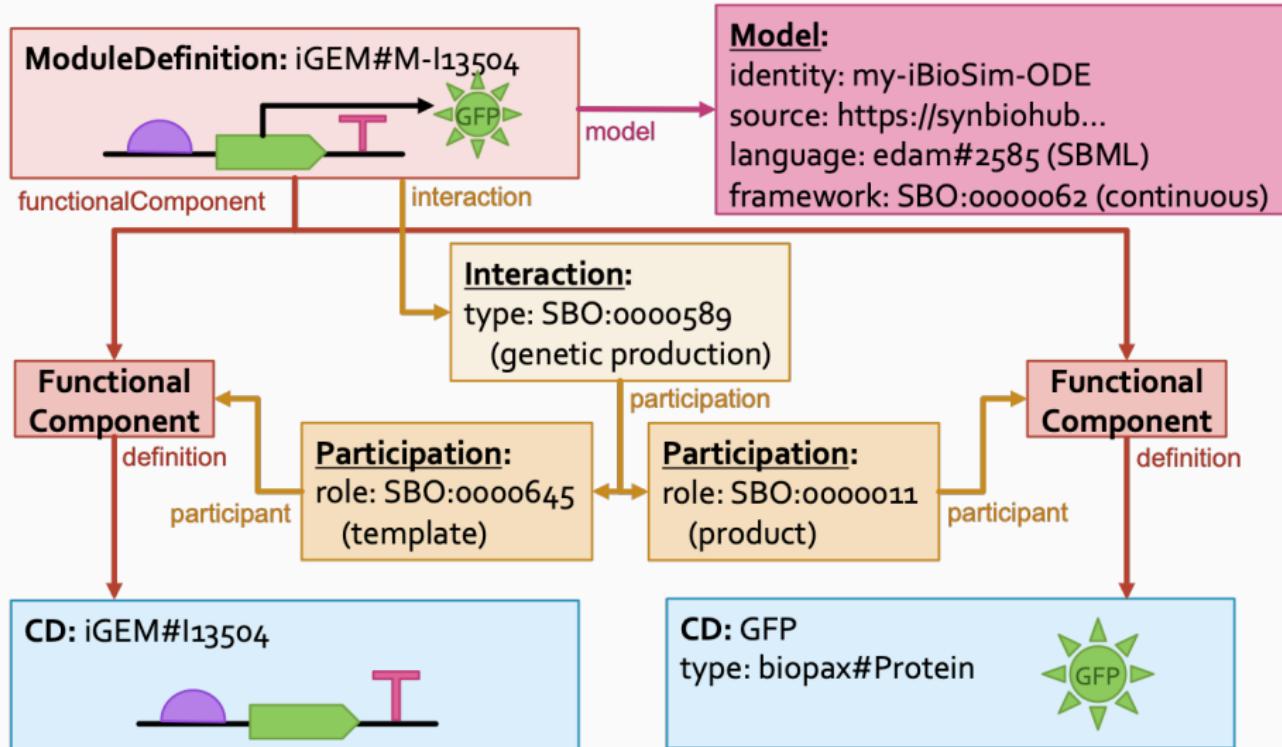
CD: iGEM#interlab16positiveControl



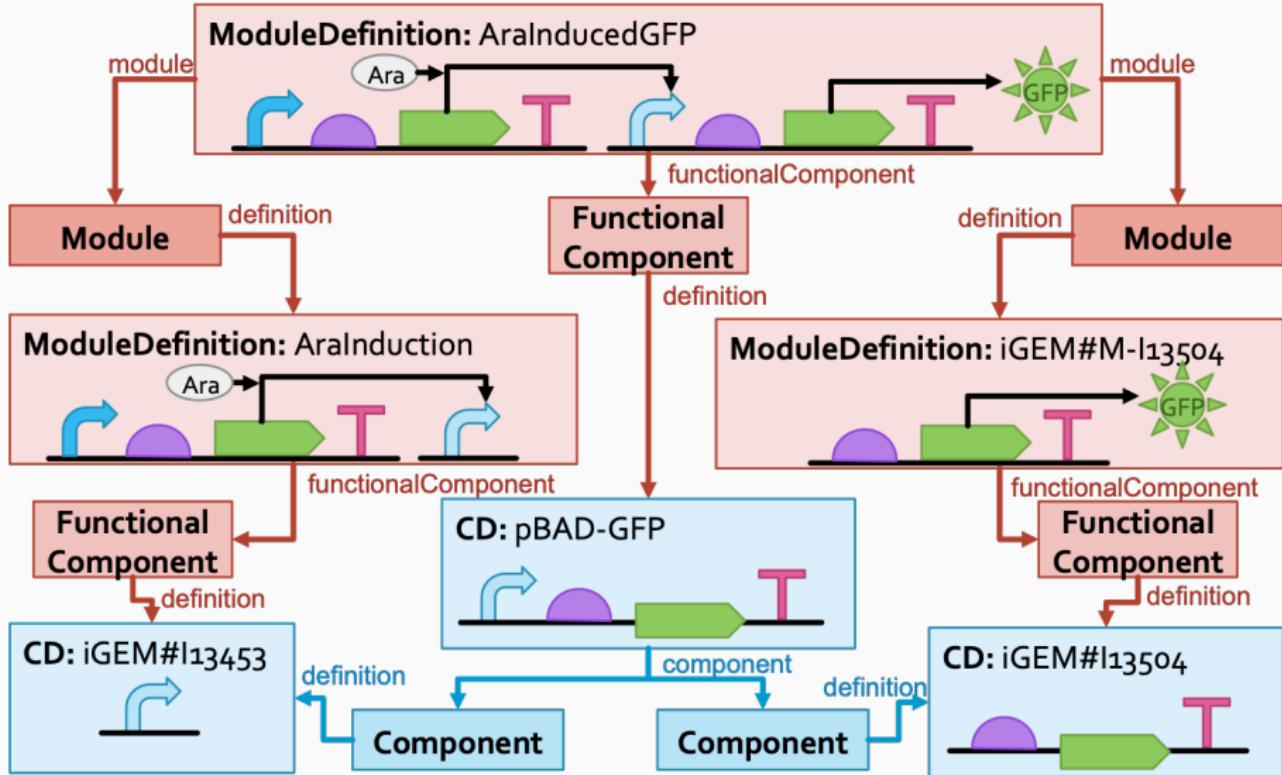
CD: iGEM#interlab16negativeControl



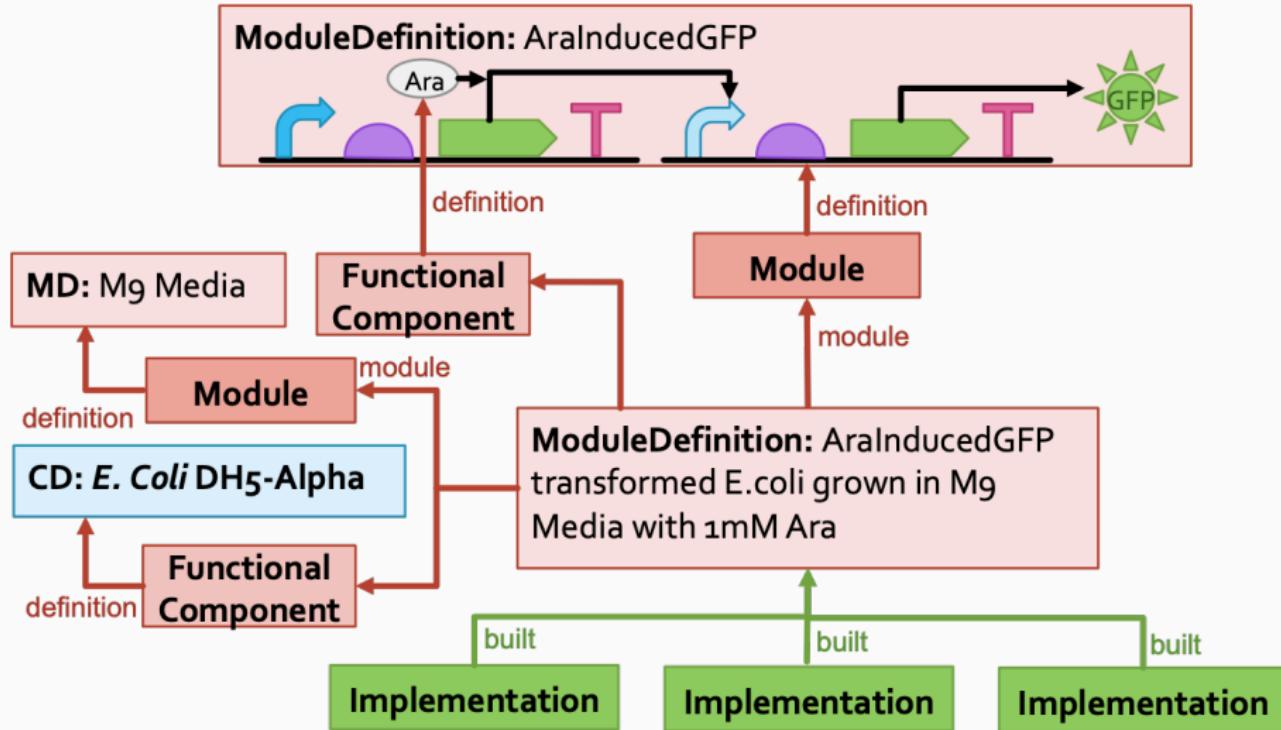
MODULE DEFINITIONS



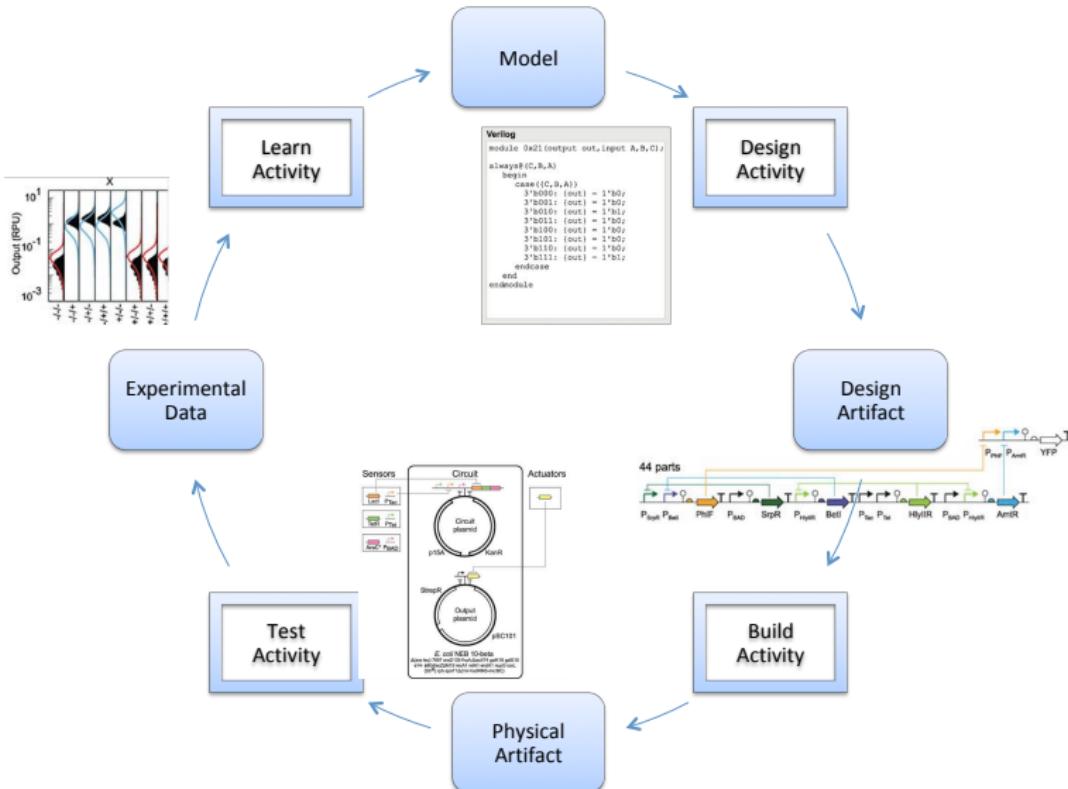
COMPOSING MODULES



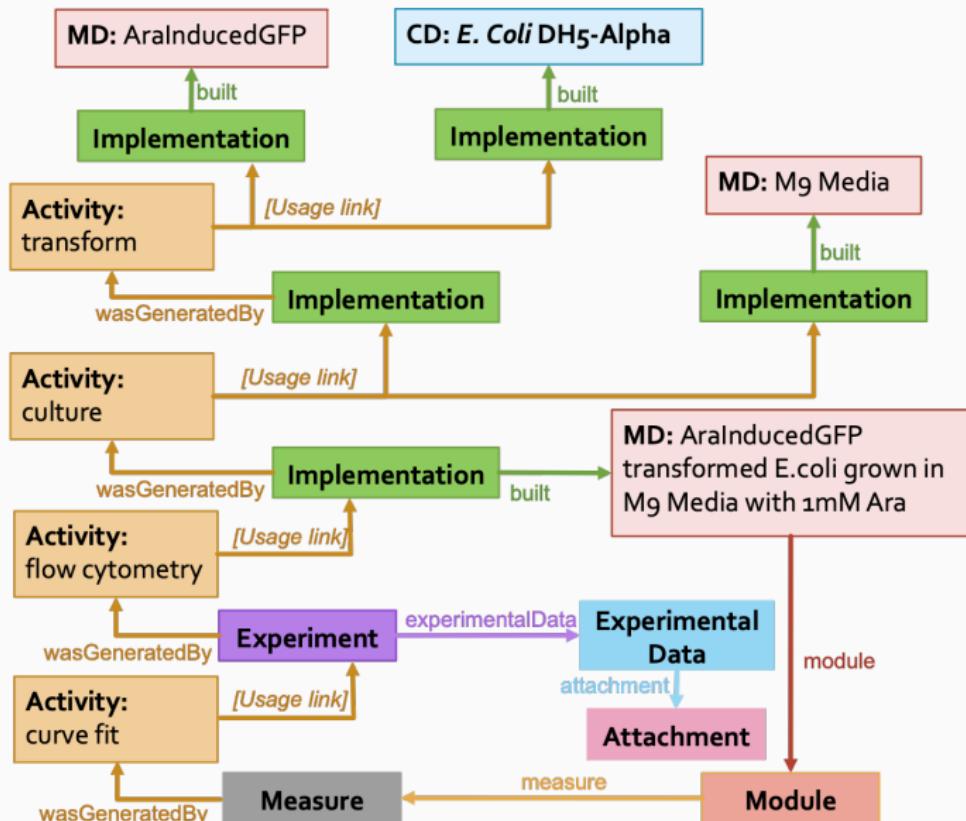
IMPLEMENTATIONS



DESIGN-BUILD-TEST-LEARN (PROV-O)



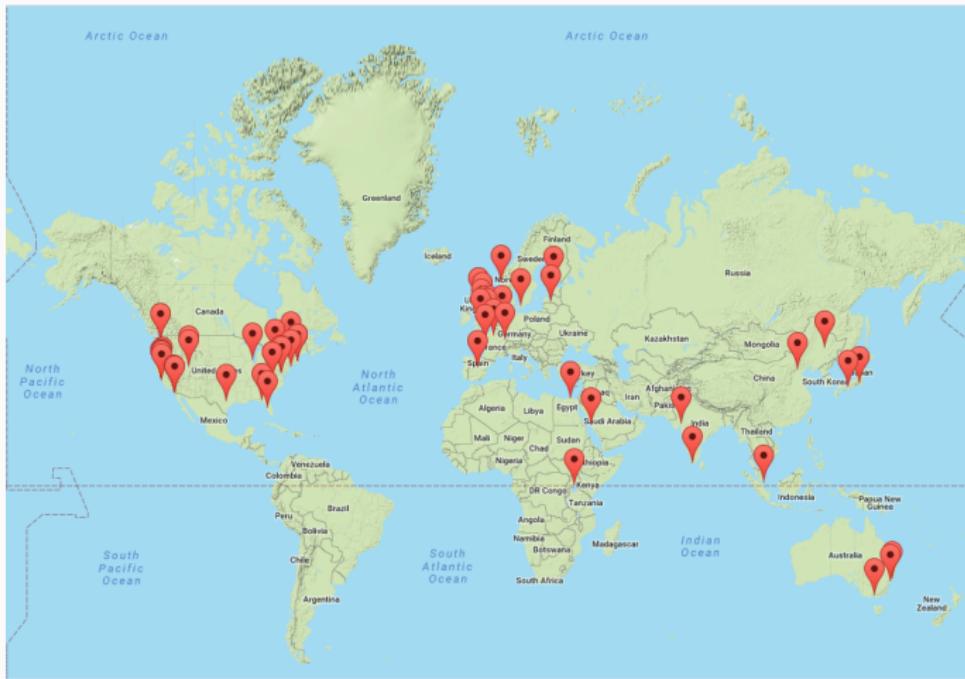
DESIGN-BUILD-TEST-LEARN (PROV-O)



MORE INFORMATION

- Standards are an important enabler for data sharing and reproducibility.
- Ultimate goal should be a complete standard-enabled workflow.
- Much more information is available from:
<http://www.sbolstandard.org/>.
- Check out the SBOL Standard Youtube channel.
- SBOL is also on Facebook, Twitter, and Vimeo.

SBOL COMMUNITY



145+ people from 17 countries

Representing 42 universities and 28 companies and government labs

ORGANIZATIONS SUPPORTING SBOL



Previous support for the development of SBOL provided by National Science Foundation Grants DBI-1356041 and DBI-1355909, and the Engineering and Physical Sciences Research Council under Grant Number EP/J02175X/1.