

# Synthetic Biology Open Language Visual: An Open-Source Graphical Notation for Synthetic Biology

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## 1. INTRODUCTION

The Synthetic Biology Open Language Visual (SBOL Visual) project is an effort toward developing a community-driven open standard for visual representation of genetic designs. Standardized visual notation for communicating designs has proven to be useful in many engineering disciplines. A de facto visual notation does exist in synthetic biology; however, it is incomplete, is often extended ad hoc, and exists as a poorly defined, voluntary, communal convention rather than an explicit standard. Because synthetic biology endeavors often require a multidisciplinary team, a common visual system of communication with well-defined semantics is vital. It is also important that the emerging ecosystem of biological design tools converge upon a common visual language to maximize adoption and minimize ambiguity in results. Given the central role and rich history of visual representation in the life sciences, a well-defined visual notation will also prompt the construction of the formal infrastructure needed to support effective ontologies, meaningful models, and tools tailored to community needs.<sup>1</sup>






















 promoter	 primer binding site
 cds	 restriction site
 ribosome entry site	 blunt restriction site
 terminator	 5' sticky restriction site
 operator	 3' sticky restriction site
 insulator	 5' overhang
 ribonuclease site	 3' overhang
 rna stability element	 assembly scar
 protease site	 signature
 protein stability element	 user defined
 origin of replication	

Figure 1: SBOL Visual version 1.0.0 symbols

## 2. RELATIONSHIP TO SBOL STANDARD

SBOL Visual comprises a set of symbols, shown in figure 1, used to visually depict functional information encoded by nucleic acid sequences [1]. It serves as a human-readable counterpart to the Synthetic Biology Open Language data exchange standard [2]. The way in which SBOL Visual relates to the SBOL standard is depicted in Figure 2. Sequences of one or more SBOL Visual symbols can be used to depict DNA Components in the SBOL data model. Each symbol represents one or more ontological terms, which are used in the SBOL data model to establish DNA Component type, often referred to as part type. Currently, both SBOL Standard and SBOL Visual use terms from the Sequence Ontology (SO) [3].

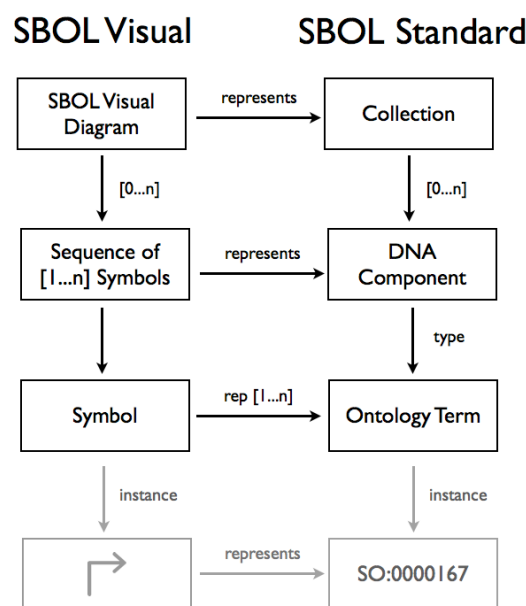
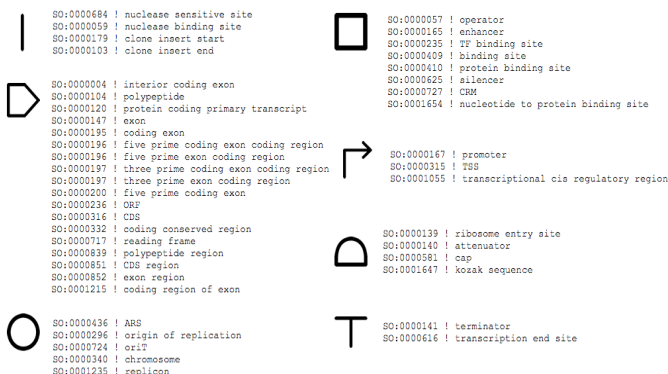


Figure 2: Relationship between SBOL Visual and SBOL Standard

In the specification of SBOL Visual version 1.0.0, each symbol is linked to a single SO term, which serves as a definition for the symbol. In April 2013, during a meeting of the SBOL Developers Group in Newcastle University, changes to the relationship between SBOL Visual symbols and ontological terms were explored. While use of a single ontological term to serve as a definition for a particular symbol allows for tighter design representation, allowing symbols represent of multiple terms widens the flexibility and range of the standard. As a proof of concept, terms in the Sequence Ontology Feature Annotation (SOFA), a subset of the SO containing only locatable sequence feature, were assigned to SBOL Visual symbols, displayed in Figure 3. Creating this mapping enables software tools to more

<sup>1</sup> The introduction section was submitted as an abstract and will be presented as poster at SB6.0. Figures in this abstract overlap with figures in a paper submitted to the Bio-Ontologies 2013.

readily generate diagrams to depict annotated sequences by expanding the number of terms that can be represented by SBOL Visual. Further work is yet to be done to refine the mechanics for serialization of symbol-term mappings and how to avoid conflicts in potential interpretation of symbols.



**Figure 3: Draft mapping from SOFA to SBOL Visual symbols**

### 3. ADOPTION OF SBOL VISUAL

SBOL Visual is intended for use in a range of circumstances and formalities, from casual whiteboard brainstorming to formal scientific publication. The standard is presently being used by synthetic biologists to depict genetic designs in peer-reviewed publications and presentations. Software developers in academia and industry are also adopting SBOL Visual in computer-aided design tools for synthetic biology. The tools that adopt SBOL Visual are listed in Table 1.

**Table 1. Software tools that adopt SBOL Visual**

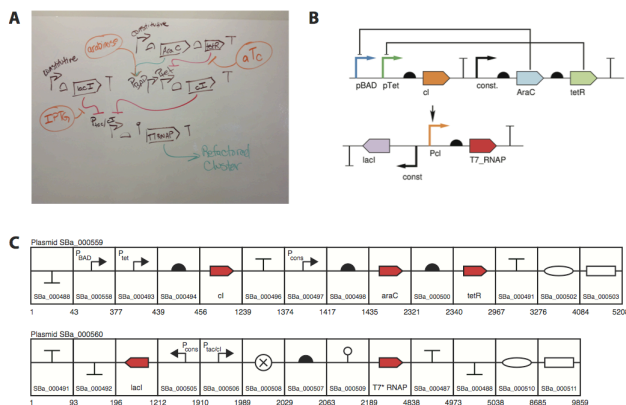
Tool Name	Link
Tinker Cell	<a href="http://tinkercell.com">tinkercell.com</a>
GenoCAD	<a href="http://genocad.org">genocad.org</a>
DeviceEditor	<a href="http://j5.jbei.org">j5.jbei.org</a>
BioCompiler	<a href="http://synbiotools.bbn.com">synbiotools.bbn.com</a>
SBOL Designer	<a href="http://clarkparsia.github.io/sbol">clarkparsia.github.io/sbol</a>
Pigeon	<a href="http://pigeoncad.org">pigeoncad.org</a>
GraphViz	<a href="http://graphviz.org">graphviz.org</a>
Vector NTI® Express Designer	<a href="http://lifetechnologies.com">lifetechnologies.com</a>
Teselagen	<a href="http://teselagen.com">teselagen.com</a>

SBOL Visual can be used alongside other notation systems, such as Systems Biology Graphical Notation and with user generated symbols in order to depict aspects of design such as genetic regulation, as shown in Figure 4.

### 4. GROWTH OF SBOL VISUAL

The next step for SBOL Visual is the creation of a framework for supporting the synthetic biology community's involvement in growing and maturing SBOL Visual. While the symbols specified in the current version of SBOL Visual are drawn from the de

facto visual notation of the synthetic biology community, SBOL Visual must ultimately be community driven if it is to meet the needs of synthetic biologists. The infrastructure for adding new symbols and term mappings to SBOL Visual is yet to be built.



**Figure 4: Use of SBOL Visual to represent an ANDN controller, designed by Temme, et al. [4] (A) as drawn on a whiteboard, (B) as produced by web-based SBOL Visual generator Pigeon [5], and (C) as formatted and by Temme for publication.**

### 5. CONCLUSION

SBOL Visual is an open-source, community-driven response to the need for standardization of graphical notation for synthetic biology. It is a set of symbols to represent ontological terms related to functionality of nucleic acid sequences, focused on forward engineering of genetic systems. SBOL Visual is being used on whiteboards, slide presentations, scientific posters and publications, and in several CAD tools. The next steps for the SBOL Visual effort is to develop a consistent methodology for adding new symbols and ontological associations to the standard, so that SBOL Visual can leverage the input of the greater synthetic biology community and cover more use cases. Through active input from the synthetic biology community, SBOL Visual will mature into a foundational tool for the communication of genetic design.

### 6. AUTHOR AFFILIATIONS

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