The Synthetic Biology Open Language (SBOL) Data Model

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on behalf of the SBOL community

University of Utah

SBOL Workshop
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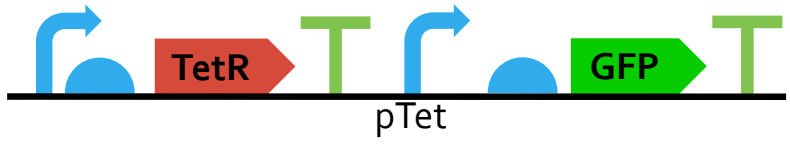
Sequence Data Standards

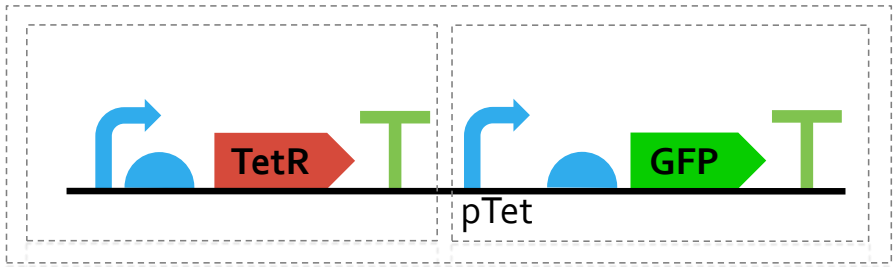
FASTA

ACTGTGCCGTTAAACGTGATTAAATCCGTACTGATAT...

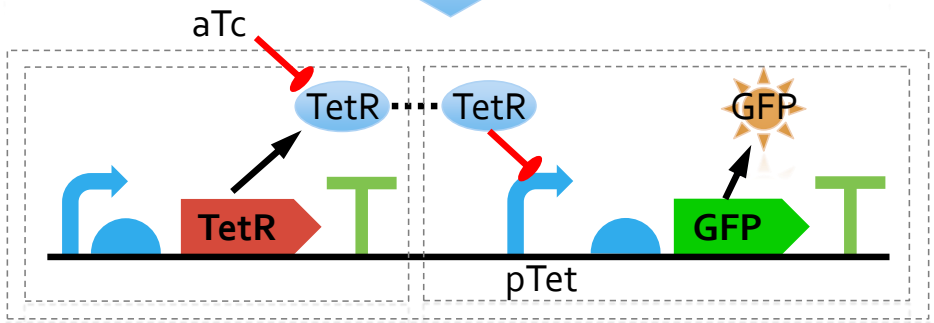
GenBank



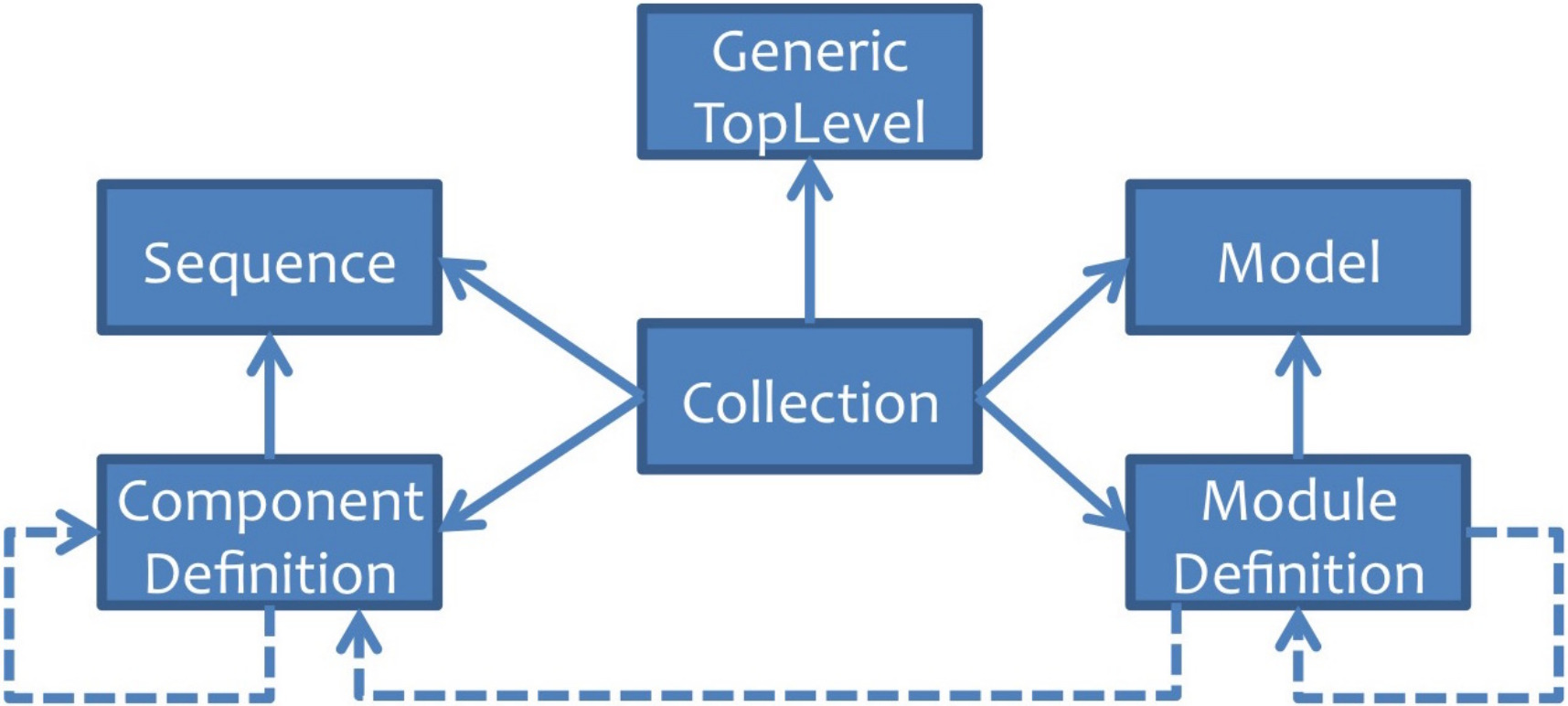
SBOL 1.1



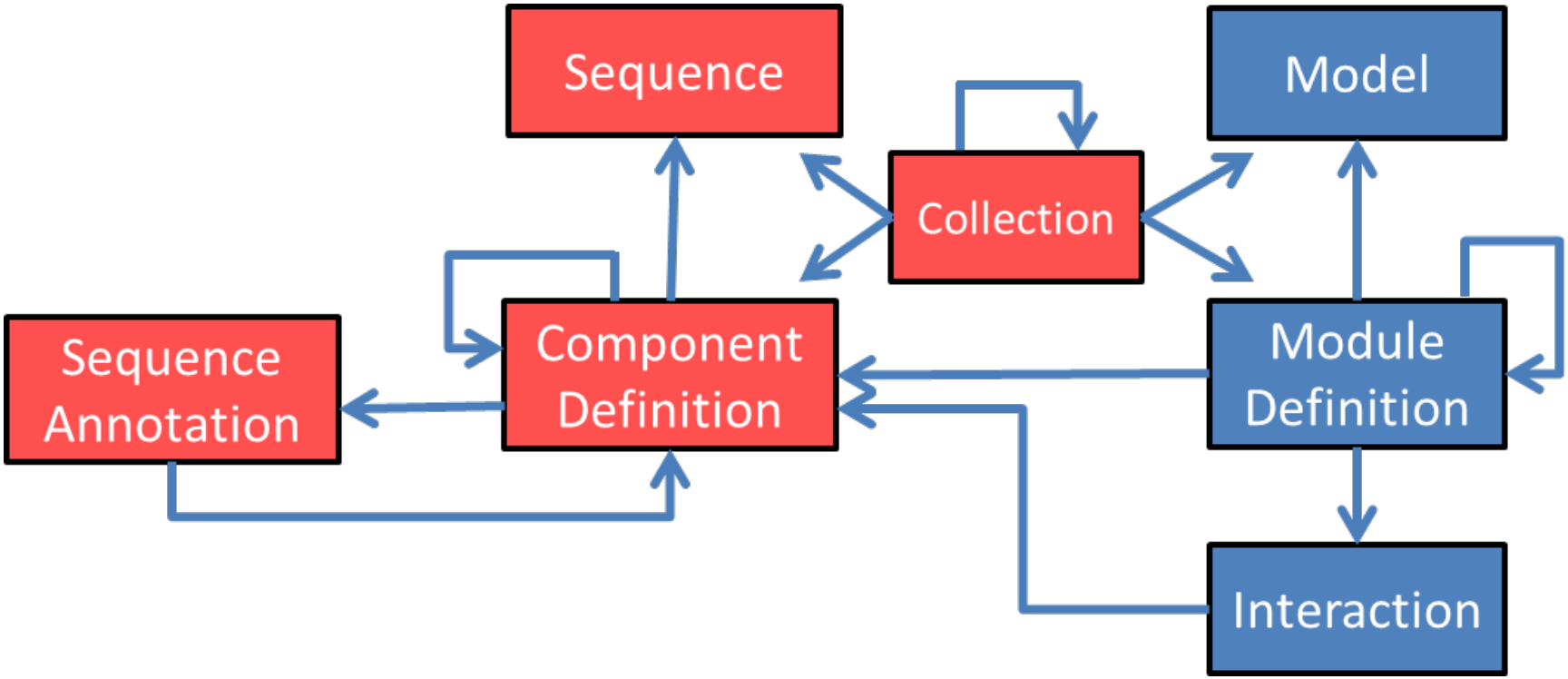
SBOL 2.0



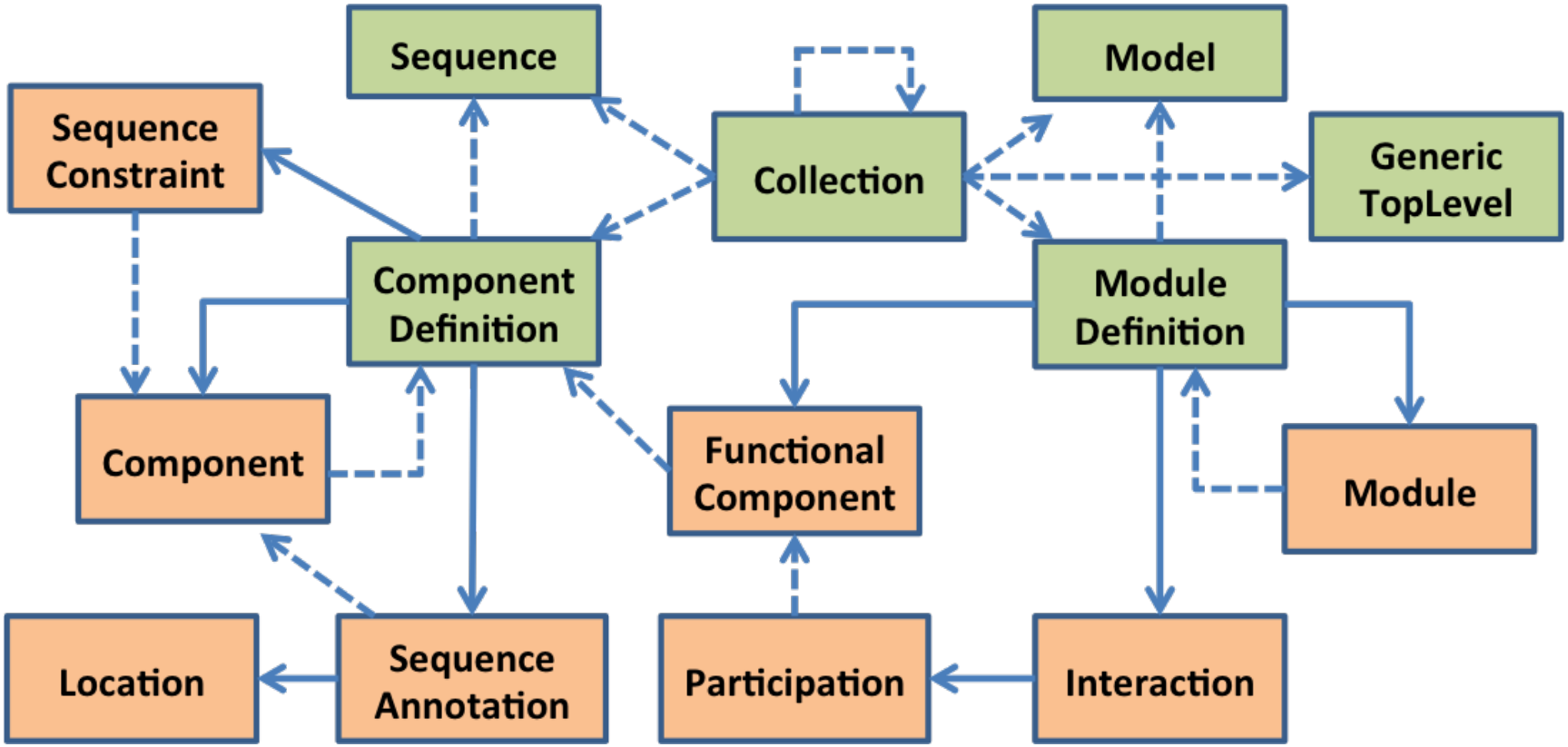
SBOL 2.0 Data Model



SBOL 2.0 Data Model



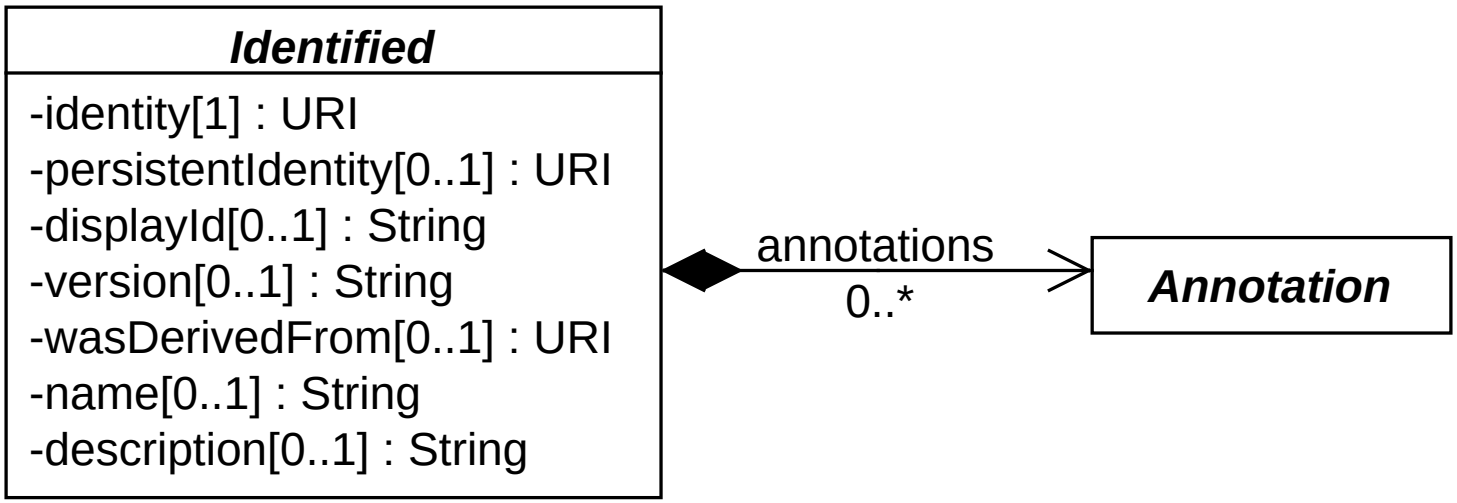
SBOL 2.0 Data Model



Understanding UML Diagrams

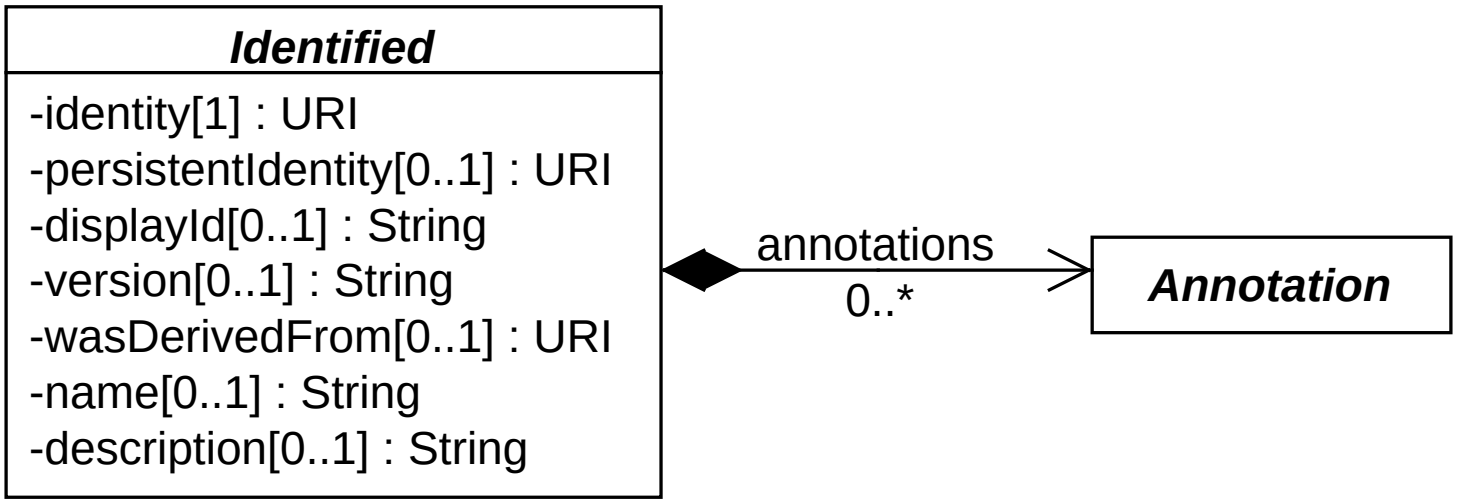
- Classes represented as boxes labeled with their member variables with types and cardinalities.
- Arrows with cardinality indicate associations between classes.
- A hollow diamond at the origin of an arrow represents shared aggregation (i.e., object is referenced and not owned).
- A solid diamond at the origin of an arrow represents composite aggregation (i.e., child object is owned by its parent object).
- Hollow arrows are used to represent inheritance.

Identified (Base Class for All SBOL Objects)



- *identity* - globally unique URI to identify this object (required).
- *persistentIdentity* - identity shared by multiple versions of the same object (optional).
- *displayId* - human-readable id composed of alphanumeric and underscore characters (optional).
- *version* - uses semantic versioning to identify multiple versions of the same object (optional).

Identified (Base Class for All SBOL Objects)



- *wasDerivedFrom* - identity of object that this is derived from (optional).
- *name* - human-readable String of arbitrary characters (optional).
- *description* - thorough text description of the object (optional).
- *annotations* - additional data about this object (more later).

Identified (Example)

```
<?xml version="1.0" ?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:dcterms="http://purl.org/dc/terms/"
 xmlns:prov="http://www.w3.org/ns/prov#"
 xmlns:sbol="http://sbols.org/v2#">
  <sbol:ComponentDefinition rdf:about="http://www.partsregistry.org/BBa_J23119/2">
    <sbol:persistentIdentity rdf:resource="http://www.partsregistry.org/BBa_J23119"/>
    <sbol:displayId> BBa_J23119 </sbol:displayId>
    <sbol:version> 2 </sbol:version>
    <prov:wasDerivedFrom rdf:resource="http://www.partsregistry.org/BBa_J23119/1"/>
    <dcterms:title> J23119 promoter </dcterms:title>
    <dcterms:description> Constitutive promoter </dcterms:description>
  </sbol:ComponentDefinition>
</rdf:RDF>
```

Compliant Top-Level URIs

$$\langle \textit{URI prefix} \rangle / \langle \textit{displayId} \rangle / \langle \textit{version} \rangle$$

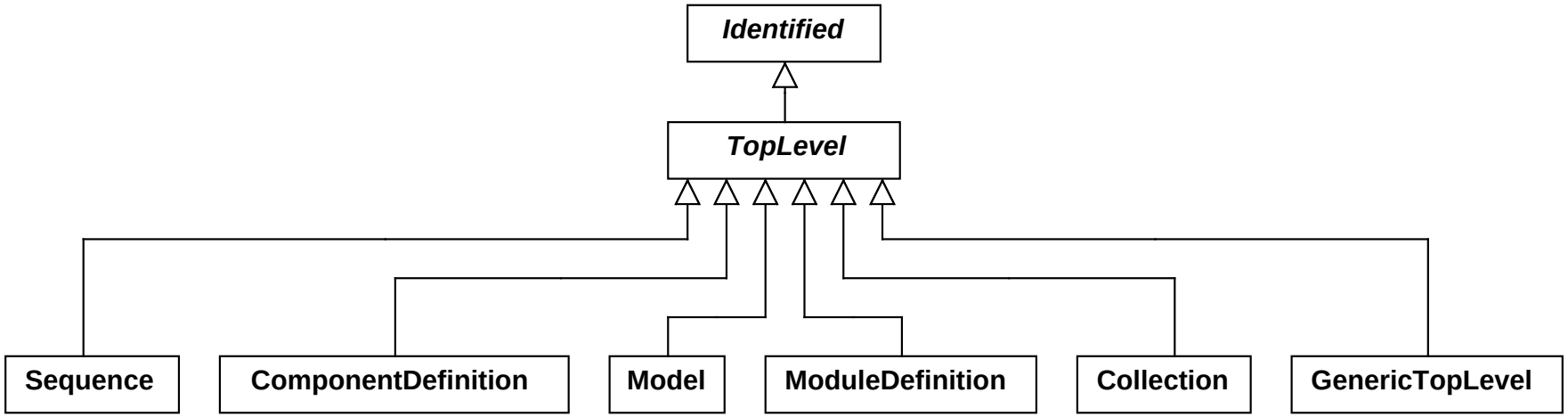
1. The *identity* MUST begin with a *URI prefix* that maps to a domain over which the user has control.
2. The *persistentIdentity* and *displayId* properties are REQUIRED.
3. The *persistentIdentity* MUST end with a delimiter (’/’, ’#’, or ’:’) followed by the *displayId* of the object.
4. If an object is not given a *version*, then its *identity* and *persistentIdentity* properties MUST contain the same *URI*.
5. If an object has a *version*, then its *identity* property MUST contain a *URI* of the form $\langle \textit{persistentIdentity} \rangle / \langle \textit{version} \rangle$".

Compliant Child URIs

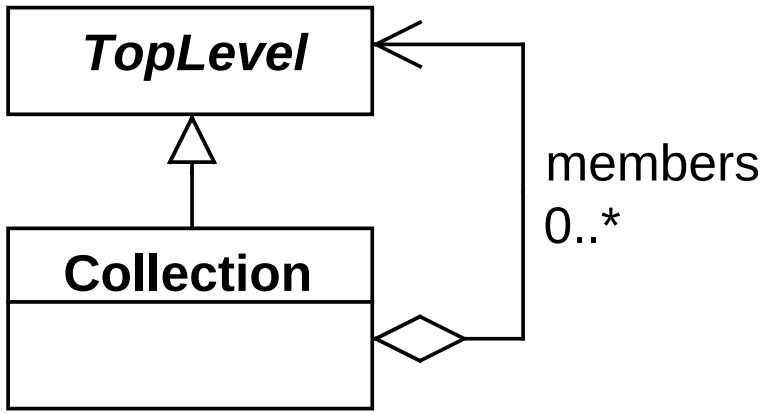
$$\langle parent\ persistentIdentity \rangle / \langle displayId \rangle / \langle parent\ version \rangle$$

1. The *persistentIdentity* MUST begin with the *persistentIdentity* of its parent object and be immediately followed by a delimiter (’/’, ’#’, or ’:’) and the *displayId* of the object.
2. The *version* MUST contain the same *String* as the *version* property of the object’s parent object.

TopLevel


Identified
TopLevel
Sequence
ComponentDefinition
Model
ModuleDefinition
Collection
GenericTopLevel

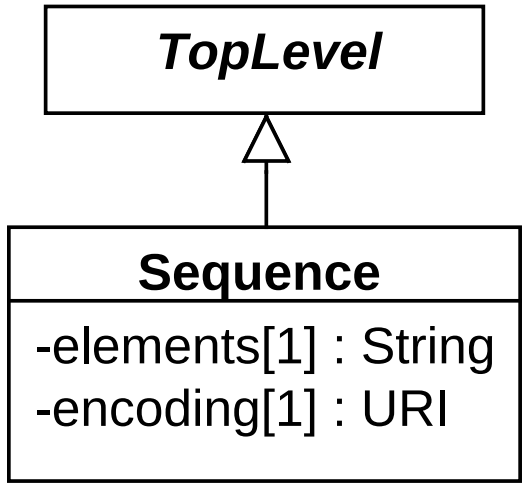
Collection



Collection (Example)

```
<?xml version="1.0" ?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:dcterms="http://purl.org/dc/terms/"
 xmlns:prov="http://www.w3.org/ns/prov#"
 xmlns:sbol="http://sbols.org/v2#">
  <sbol:Collection rdf:about="http://parts.igem.org/Promoters/Catalog/Anderson">
    <sbol:persistentIdentity rdf:resource="http://parts.igem.org/Promoters/Catalog/Anderson"/>
    <sbol:displayId> Anderson </sbol:displayId>
    <dcterms:title> Anderson promoters </dcterms:title>
    <dcterms:description> The Anderson promoter collection </dcterms:description>
    <sbol:member rdf:resource="http://partsregistry.org/Part:BBa_J23119"/>
    ...
    <sbol:member rdf:resource="http://partsregistry.org/Part:BBa_J23118"/>
  </sbol:Collection>
</rdf:RDF>
```

Sequence



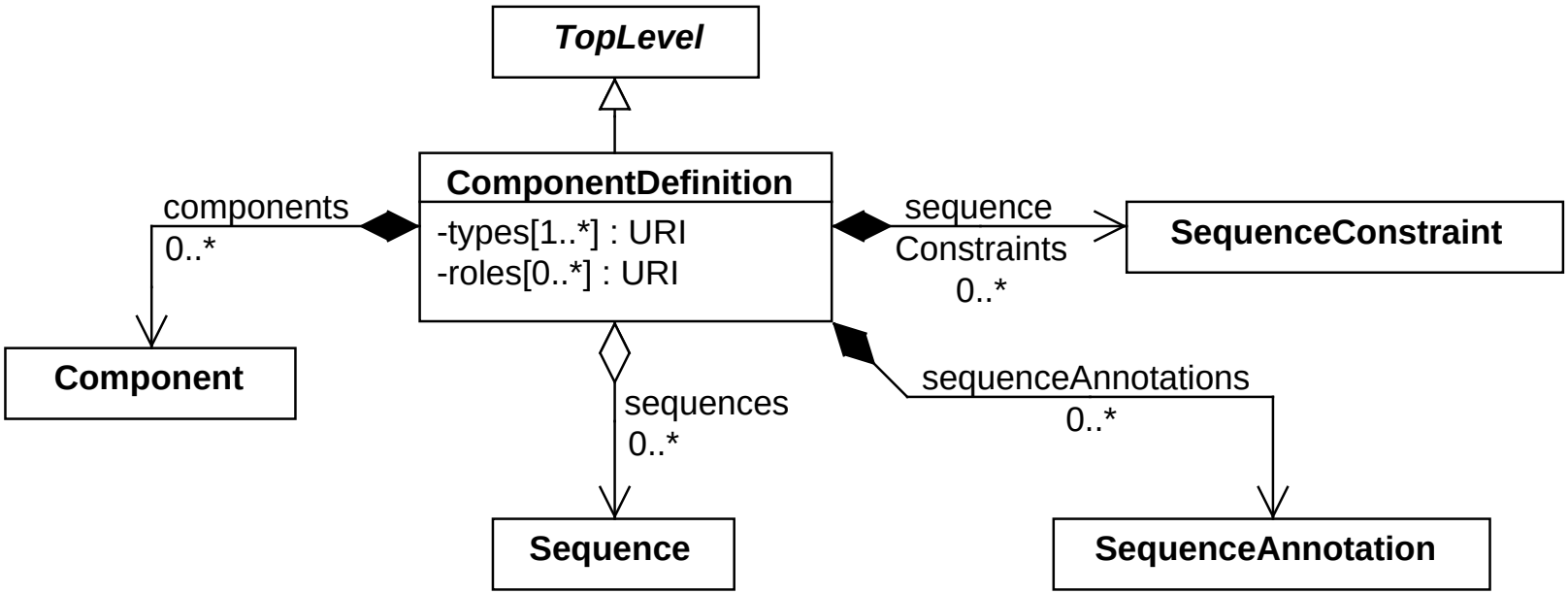
- *elements* - String of characters representing constituents of a biological or chemical molecule.
- *encoding* - URI indicating how elements are to be interpreted.

Encoding	**URI**	**CD Type**
IUPAC DNA, RNA	`http://www.chem.qmul.ac.uk/iubmb/misc/naseq.html`	DNA, RNA
IUPAC Protein	`http://www.chem.qmul.ac.uk/iupac/AminoAcid/`	Protein
SMILES	`http://www.opensmiles.org/opensmiles.html`	SmallMolecule

Sequence (Example)

```
<?xml version="1.0" ?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:dcterms="http://purl.org/dc/terms/"
 xmlns:prov="http://www.w3.org/ns/prov#"
 xmlns:sbol="http://sbols.org/v2#">
  <sbol:Sequence rdf:about="http://partsregistry.org/seq/BBa_J23119">
    <sbol:persistentIdentity rdf:resource="http://partsregistry.org/seq/BBa_J23119"/>
    <sbol:displayId> BBa_J23119 </sbol:displayId>
    <prov:wasDerivedFrom rdf:resource="http://parts.igem.org/Part:BBa_J23119:Design"/>
    <sbol:elements> ttgacagctagctcagtcctaggtataatgctagc </sbol:elements>
    <sbol:encoding rdf:resource="http://www.chem.qmul.ac.uk/iubmb/misc/naseq.html"/>
  </sbol:Sequence>
</rdf:RDF>
```

ComponentDefinition



ComponentDefinition (Types/Roles)

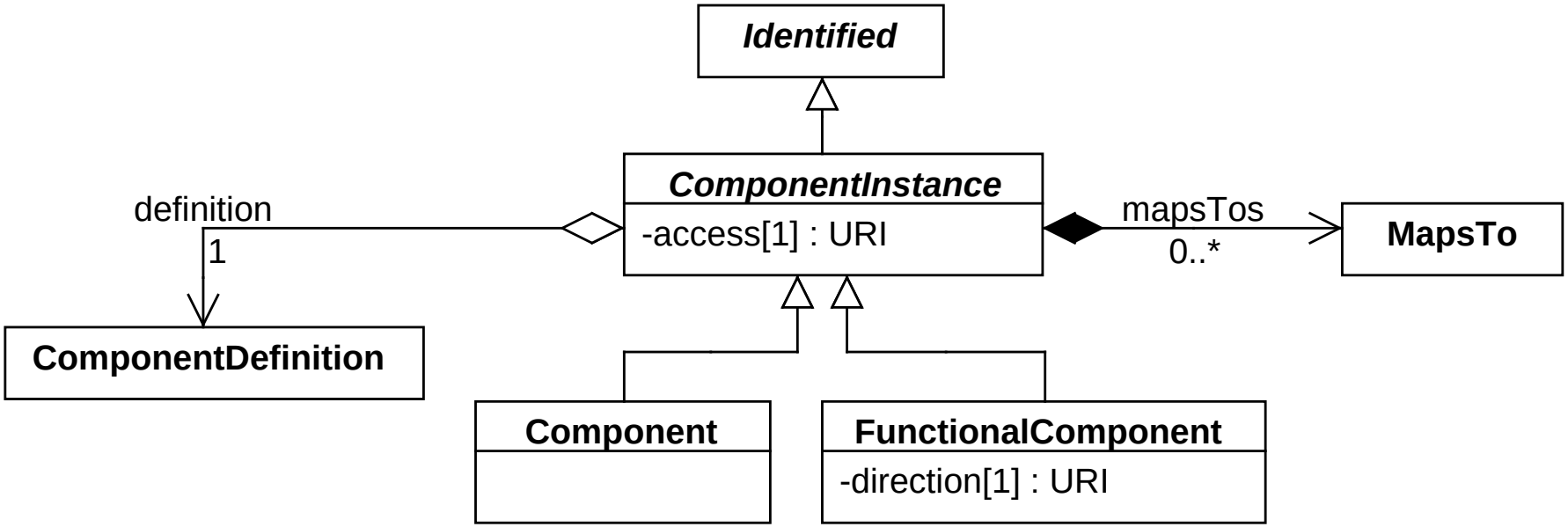
CD Type	URI for BioPAX Term
DNA	http://www.biopax.org/release/biopax-level3.owl#DnaRegion
RNA	http://www.biopax.org/release/biopax-level3.owl#RnaRegion
Protein	http://www.biopax.org/release/biopax-level3.owl#Protein
Small Molecule	http://www.biopax.org/release/biopax-level3.owl#SmallMolecule
Complex	http://www.biopax.org/release/biopax-level3.owl#Complex

CD Role	URI for SequenceOntology Term	CD Type
Promoter	http://identifiers.org/so/SO:0000167	DNA
RBS	http://identifiers.org/so/SO:0000139	DNA
CDS	http://identifiers.org/so/SO:0000316	DNA
Terminator	http://identifiers.org/so/SO:0000141	DNA
Gene	http://identifiers.org/so/SO:0000704	DNA
Operator	http://identifiers.org/so/SO:0000057	DNA
Engineered Gene	http://identifiers.org/so/SO:0000280	DNA
mRNA	http://identifiers.org/so/SO:0000234	RNA

ComponentDefinition (Example)

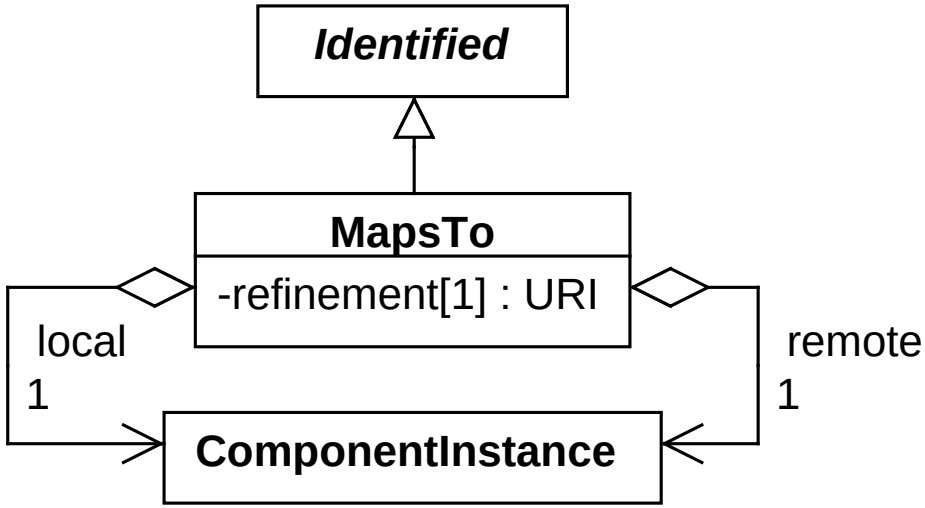
```
<?xml version="1.0" ?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:dcterms="http://purl.org/dc/terms/"
 xmlns:prov="http://www.w3.org/ns/prov#"
 xmlns:sbol="http://sbols.org/v2#">
  <sbol:ComponentDefinition rdf:about="http://partsregistry.org/cd/BBa_J23119">
    <sbol:persistentIdentity rdf:resource="http://partsregistry.org/cd/BBa_J23119"/>
    <sbol:displayId> BBa_J23119 </sbol:displayId>
    <dcterms:title> J23119 promoter </dcterms:title>
    <dcterms:description> Constitutive promoter </dcterms:description>
    <sbol:type rdf:resource="http://www.biopax.org/release/biopax-level3.owl#DnaRegion"/>
    <sbol:role rdf:resource="http://identifiers.org/so/SO:0000167"/>
    <sbol:sequence rdf:resource="http://partsregistry.org/seq/BBa_J23119"/>
  </sbol:ComponentDefinition>
</rdf:RDF>
```

Component (Child of ComponentDefinition)



Access URI	**Description**
`http://sbols.org/v2#public`	MAY be referred to by remote **MapsTo** objects.
`http://sbols.org/v2#private`	MUST NOT be referred to by remote **MapsTo** objects.

MapsTo (Child of ComponentInstance)



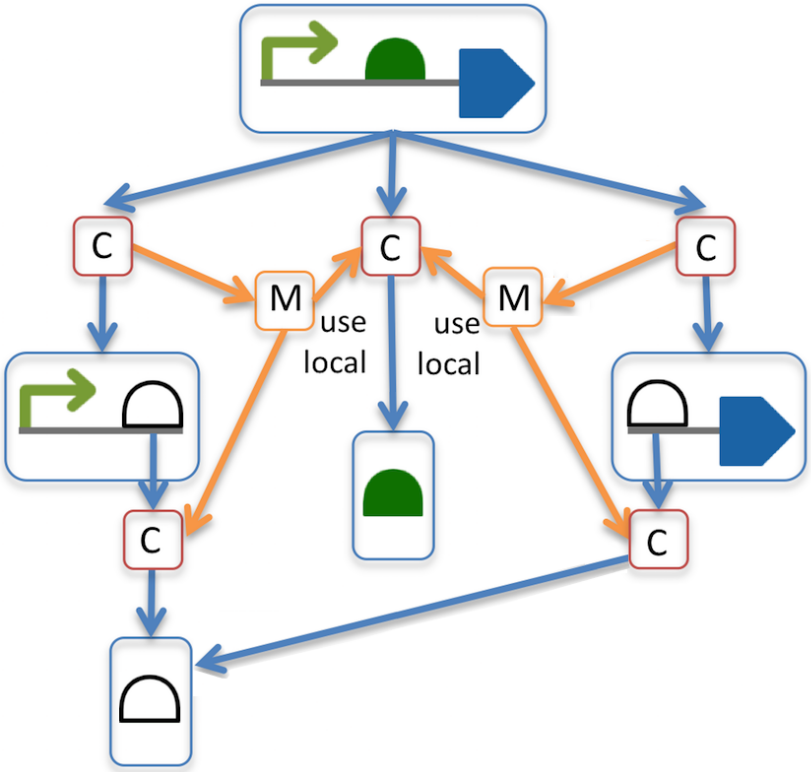
Refinement URI

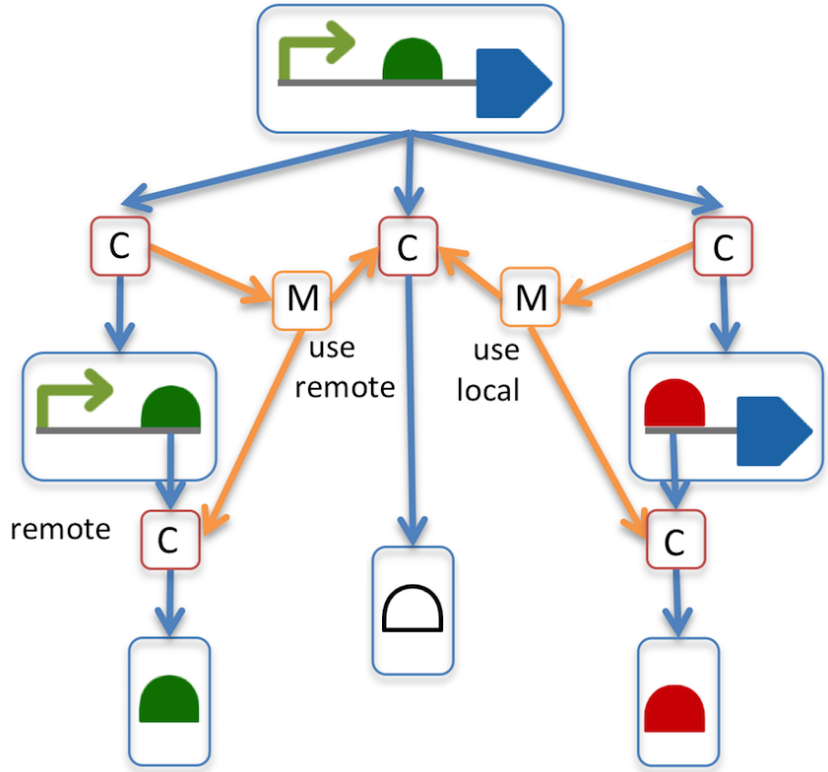
`http://sbols.org/v2#useRemote`
`http://sbols.org/v2#useLocal`
`http://sbols.org/v2#verifyIdentical`
`http://sbols.org/v2#merge`

Description

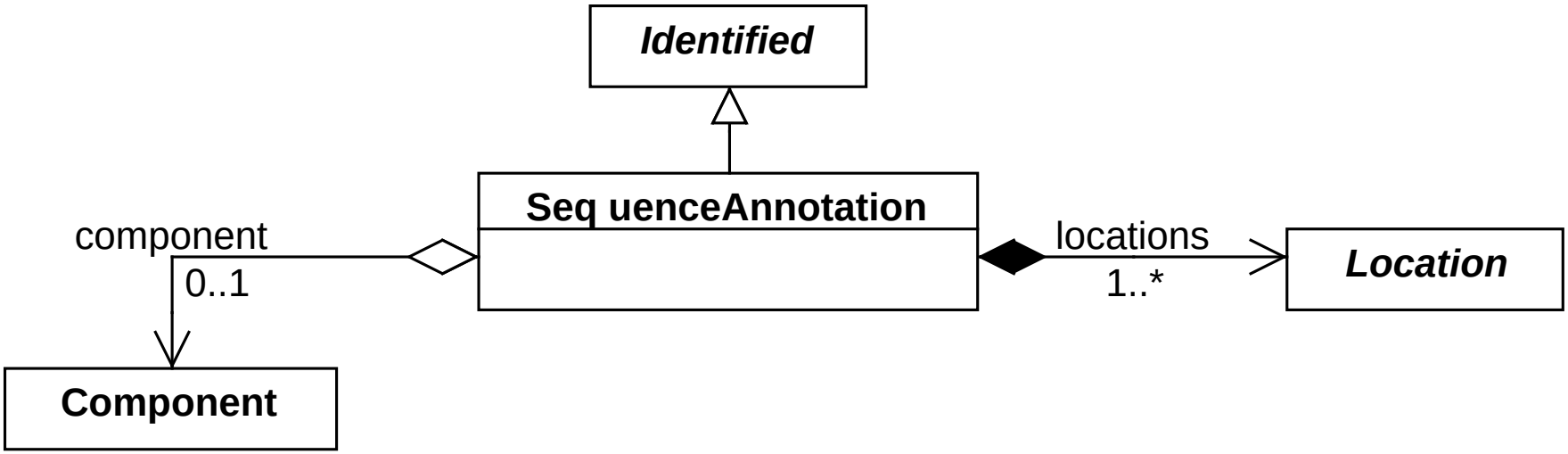
All references MUST dereference to the *remote* **CI**.
All references MUST dereference to the *local* **CI**.
The *definition* of the *local* and *remote* MUST be same **CD**.
All references MUST dereference to both objects.

MapsTo (Example)

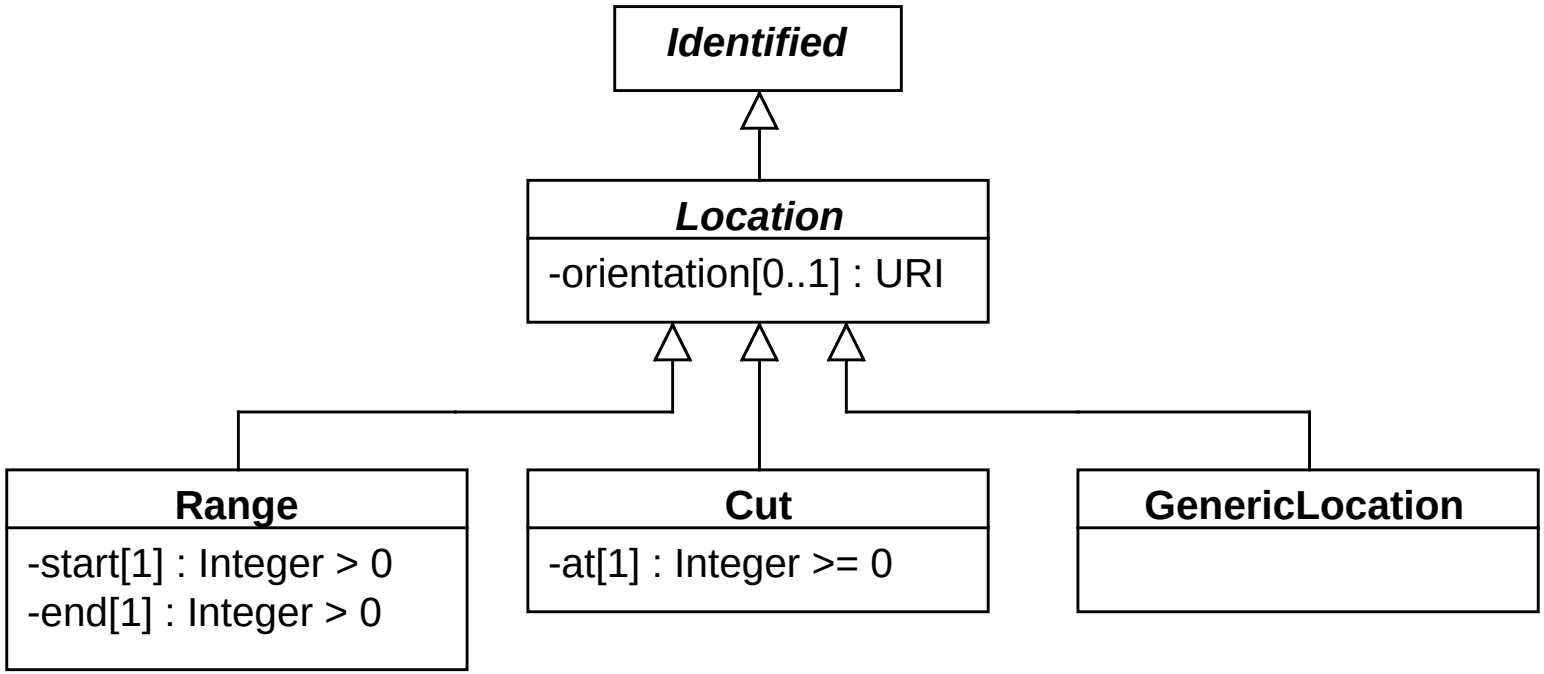




SequenceAnnotation (Child of ComponentDefinition)



Location (Child of SequenceAnnotation)



Orientation URI

`http://sbols.org/v2#inline`

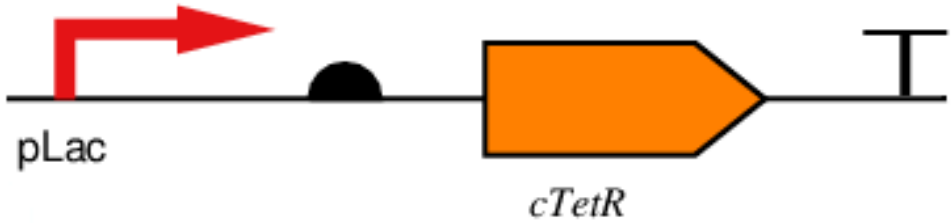
`http://sbols.org/v2#reverseComplement`

Description

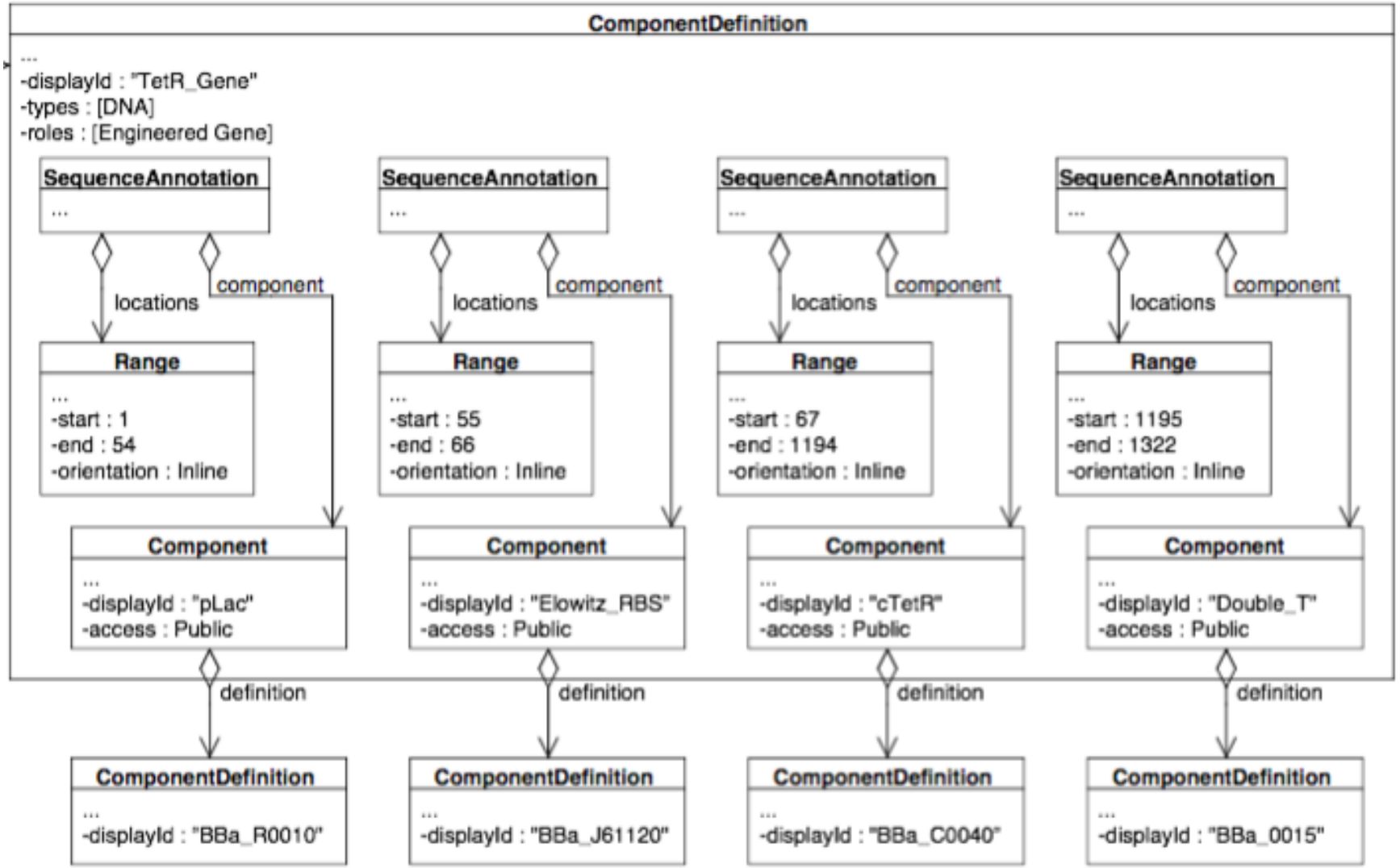
The region is inline with the sequence.

The region is on the reverse-complement translation.

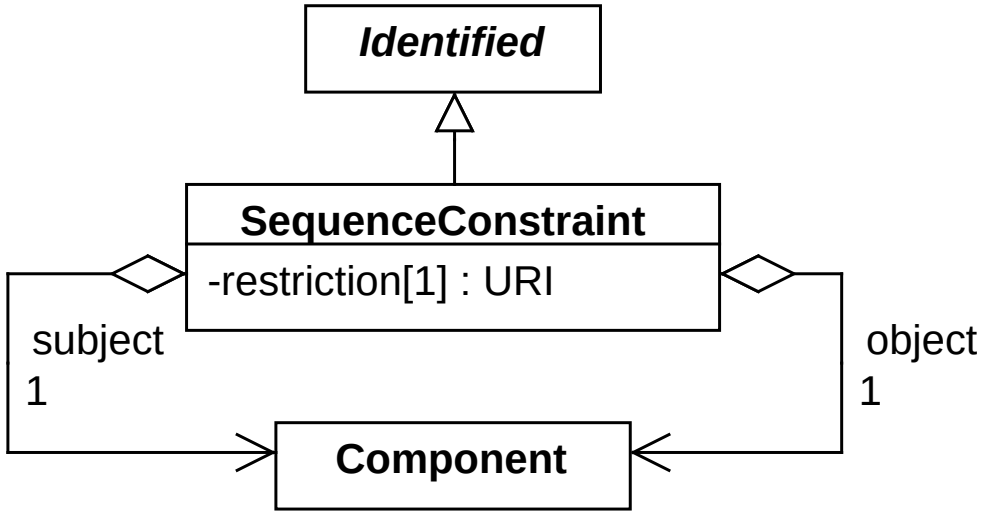
LacI Inverter



LacI Inverter (SBOL)



SequenceConstraint (Child of ComponentDefinition)



Restriction URI

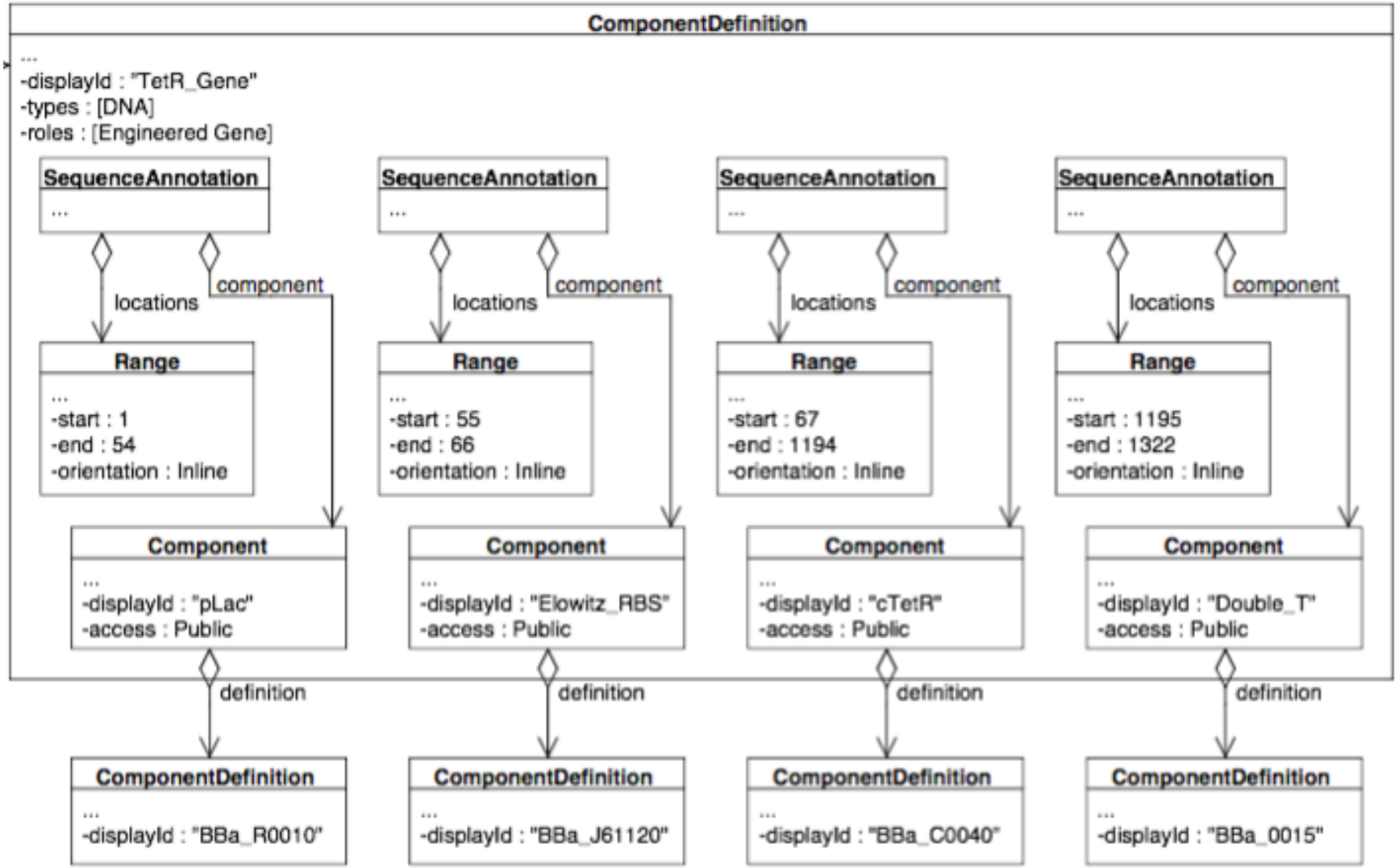
`http://sbols.org/v2#precedes`
`http://sbols.org/v2#sameOrientationAs`
`http://sbols.org/v2#oppositeOrientationAs`

Description

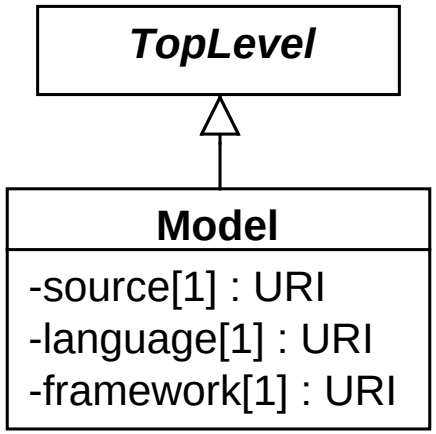
subject MUST precede *object* **Component**.
subject & *object* MUST have same orientation.
subject & *object* MUST have opposite orientations.

SequenceConstraint (Question)

QUESTION: Redrew the UML diagram below using SequenceConstraints rather than SequenceAnnotations.



Model



- *source* - URI reference to the source file for the model.
- *language* - URI that species language in which the model is implemented.

Model Language	URI for EDAM Term
SBML	`http://identifiers.org/edam/format_2585`
CellML	`http://identifiers.org/edam/format_3240`
BioPAX	`http://identifiers.org/edam/format_3156`

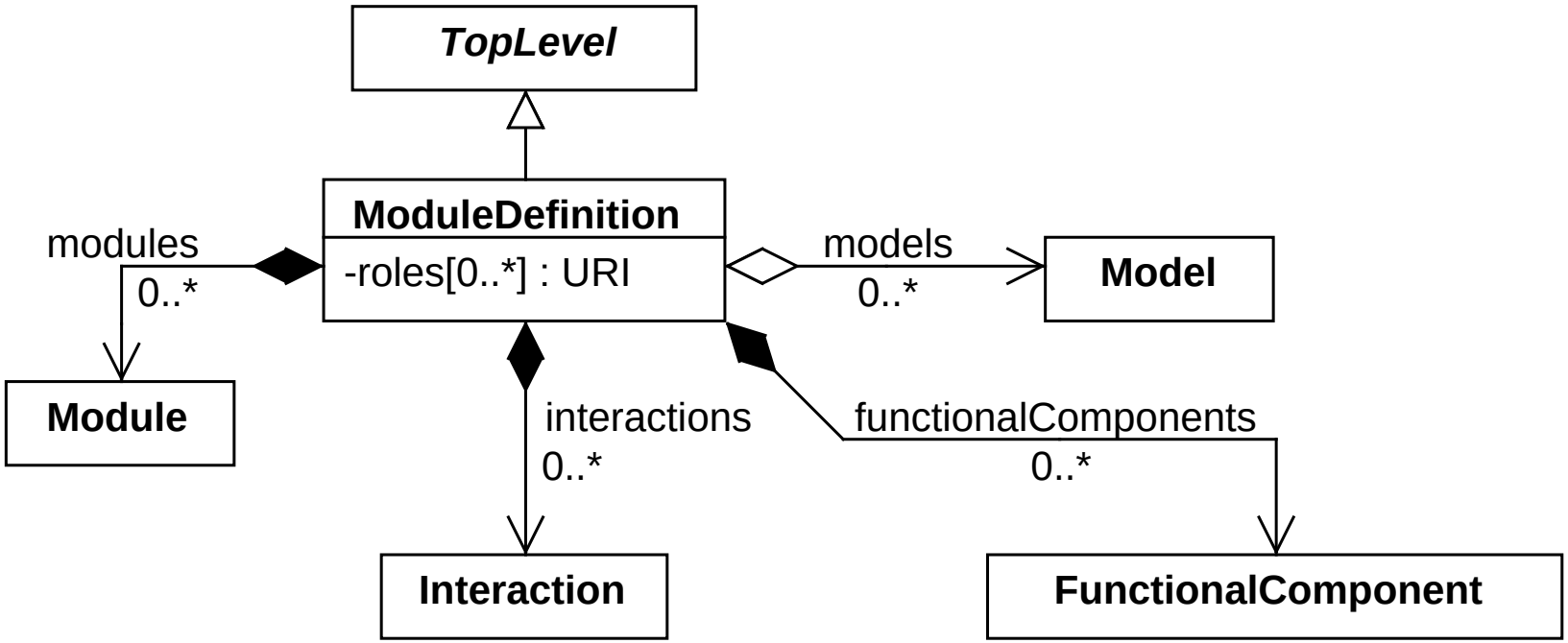
- *framework* - URI that species modeling framework used.

Framework	URI for SBO Term
Continuous	`http://identifiers.org/biomodels.sbo/SBO:0000062`
Discrete	`http://identifiers.org/biomodels.sbo/SBO:0000063`

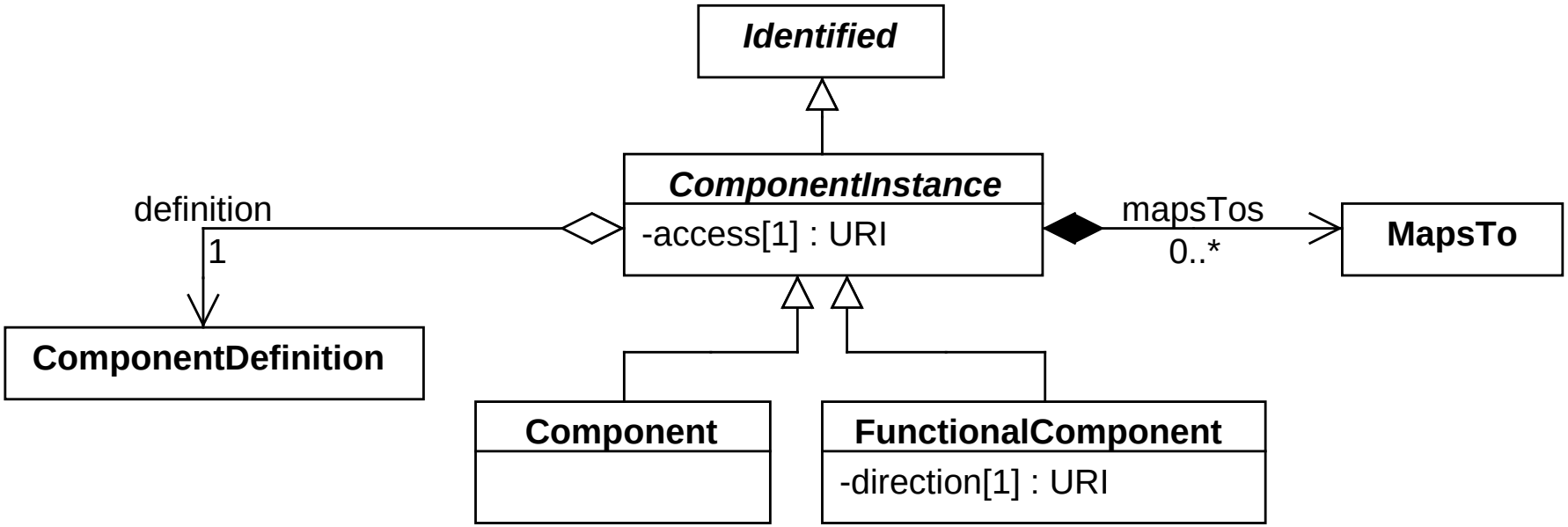
Model (Example)

```
<?xml version="1.0" ?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:dcterms="http://purl.org/dc/terms/"
 xmlns:prov="http://www.w3.org/ns/prov#"
 xmlns:sbol="http://sbols.org/v2#">
  <sbol:Model rdf:about="http://www.sbolstandard.org/examples/pIKE_Toggle_1">
    <sbol:persistentIdentity rdf:resource="http://www.sbolstandard.org/examples/pIKE_Toggle_1"/>
    <sbol:displayId> pIKE_Toggle_1 </sbol:displayId>
    <dcterms:title> pIKE_Toggle_1 toggle switch </dcterms:title>
    <sbol:source rdf:resource="http://virtualparts.org/part/pIKE_Toggle_1"/>
    <sbol:language rdf:resource="http://identifiers.org/edam/format_2585"/>
    <sbol:framework rdf:resource="http://identifiers.org/biomodels.sbo/SBO:0000062"/>
  </sbol:Model>
</rdf:RDF>
```

ModuleDefinition

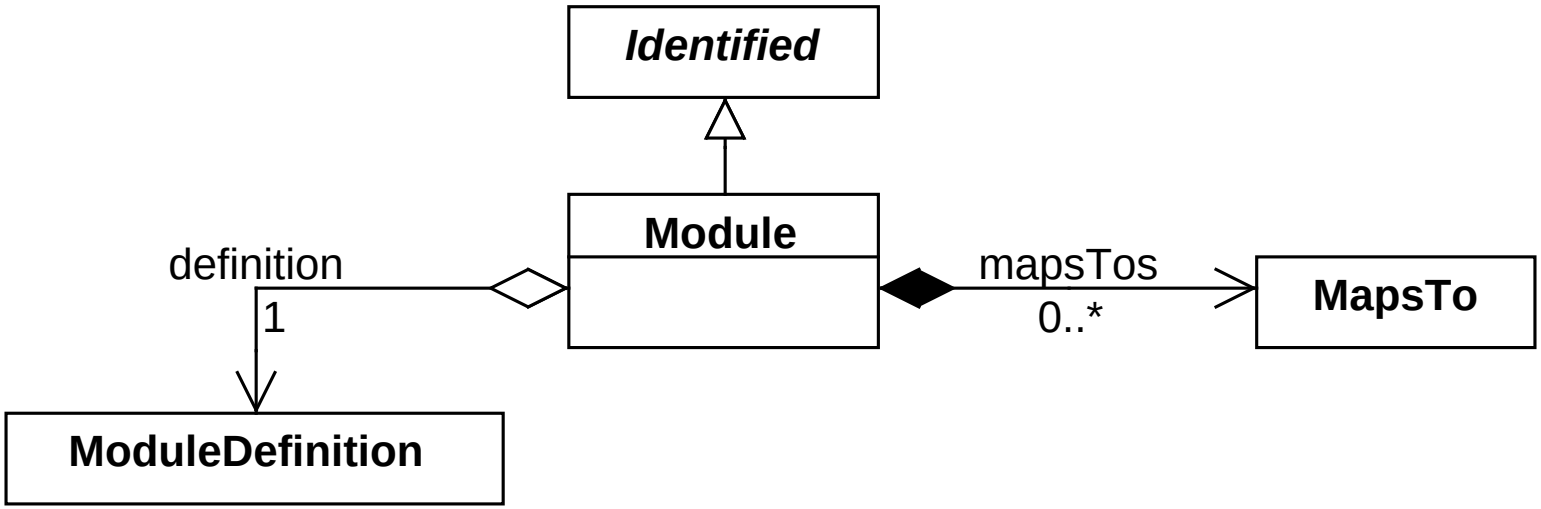


FunctionalComponent (Child of ModuleDefinition)

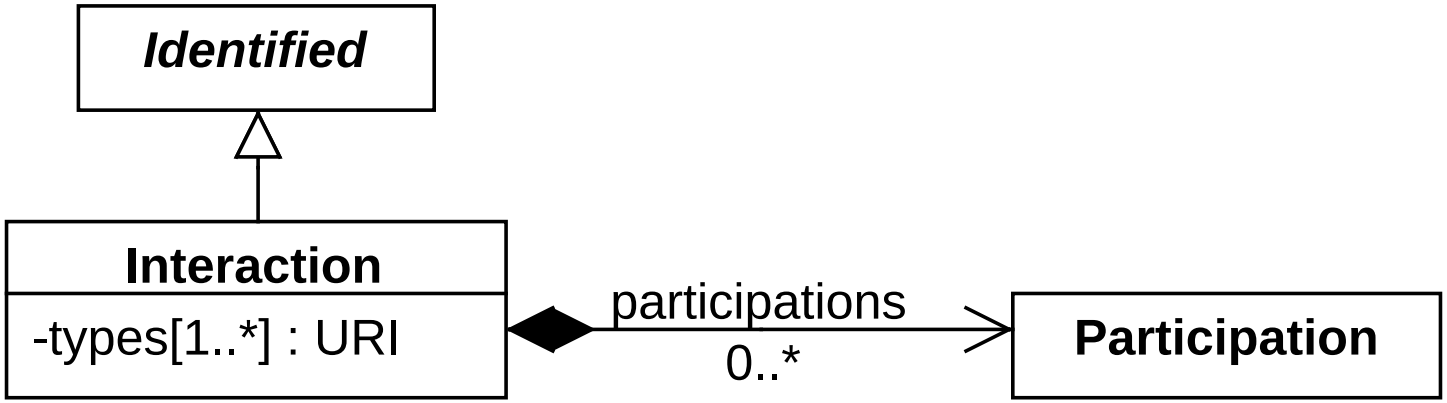


Direction URI	Description
`http://sbols.org/v2#in`	Indicates that it is an input.
`http://sbols.org/v2#out`	Indicates that it is an output.
`http://sbols.org/v2#inout`	Indicates that it is both an input and output
`http://sbols.org/v2#none`	Indicates that it is neither an input nor output.

Module (Child of ModuleDefinition)

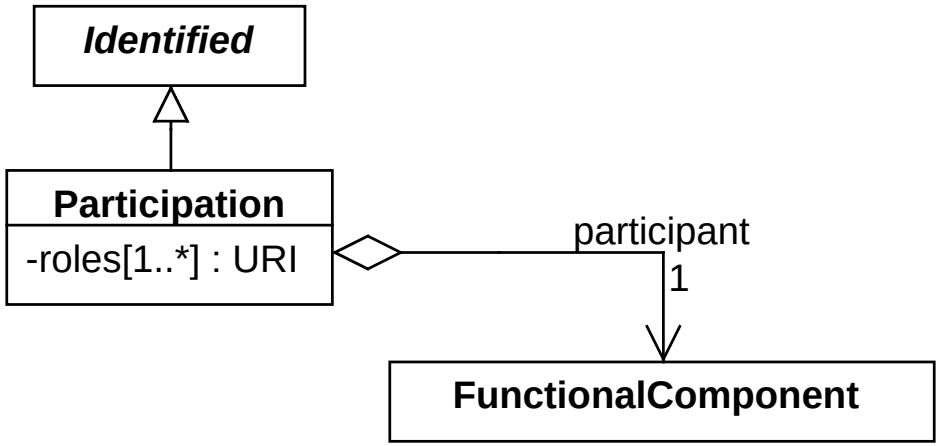


Interaction (Child of ModuleDefinition)



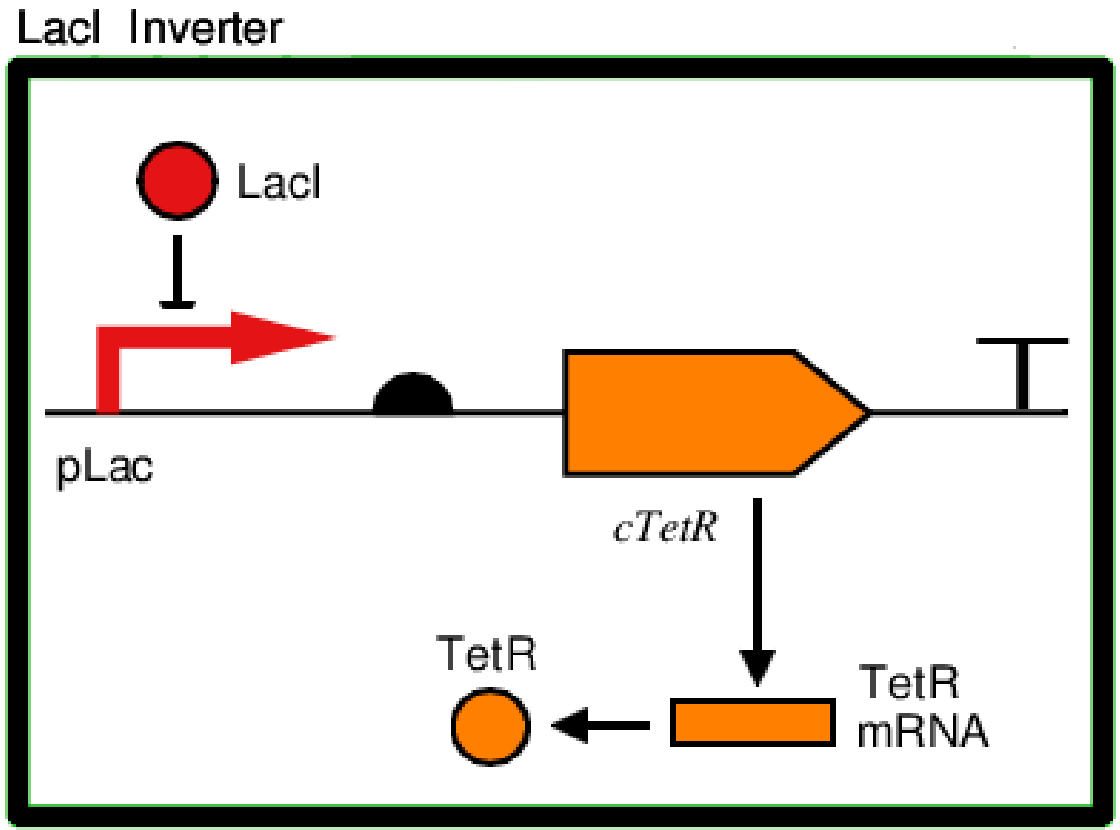
Interaction Type	**URI for SystemsBiologyOntology Term**
Inhibition	`http://identifiers.org/biomodels.sbo/SBO:0000169`
Stimulation	`http://identifiers.org/biomodels.sbo/SBO:0000170`
Biochemical Reaction	`http://identifiers.org/biomodels.sbo/SBO:0000176`
Non-Covalent Binding	`http://identifiers.org/biomodels.sbo/SBO:0000177`
Degradation	`http://identifiers.org/biomodels.sbo/SBO:0000179`
Genetic Production	`http://identifiers.org/biomodels.sbo/SBO:0000589`

Participation (Child of Interaction)

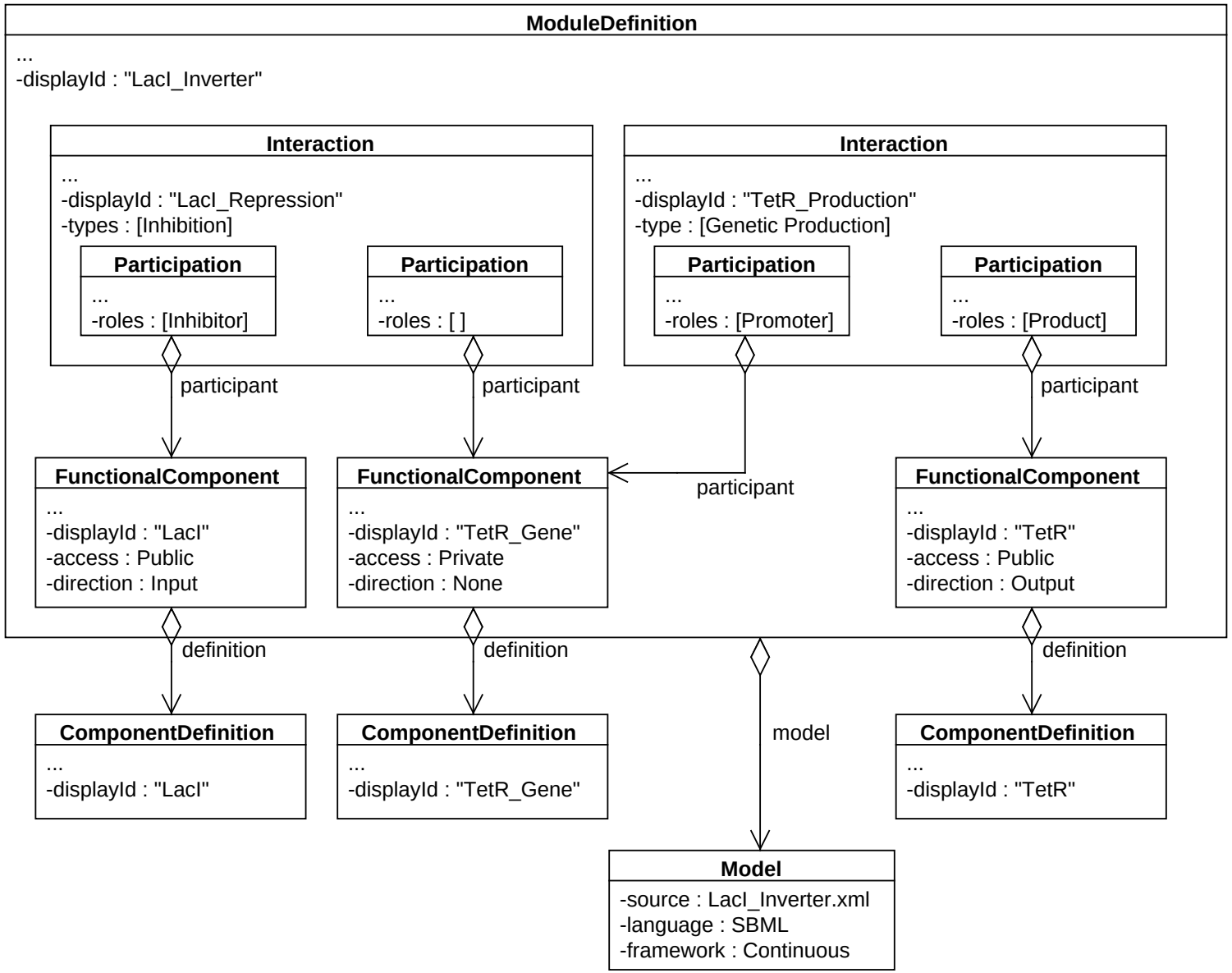


Part. Role	URI for SBO Term	Interaction Types
Inhibitor	http://identifiers.org/biomodels.sbo/SBO:0000020	Inhibition
Stimulator	http://identifiers.org/biomodels.sbo/SBO:0000459	Stimulation
Reactant	http://identifiers.org/biomodels.sbo/SBO:0000010	Non-Covalent Binding, Degradation Biochemical Reaction
Product	http://identifiers.org/biomodels.sbo/SBO:0000011	Non-Covalent Binding, Genetic Production, Biochemical Reaction
Promoter	http://identifiers.org/biomodels.sbo/SBO:0000598	Inhibition, Stimulation, Genetic Production
Modifier	http://identifiers.org/biomodels.sbo/SBO:0000019	Biochemical Reaction

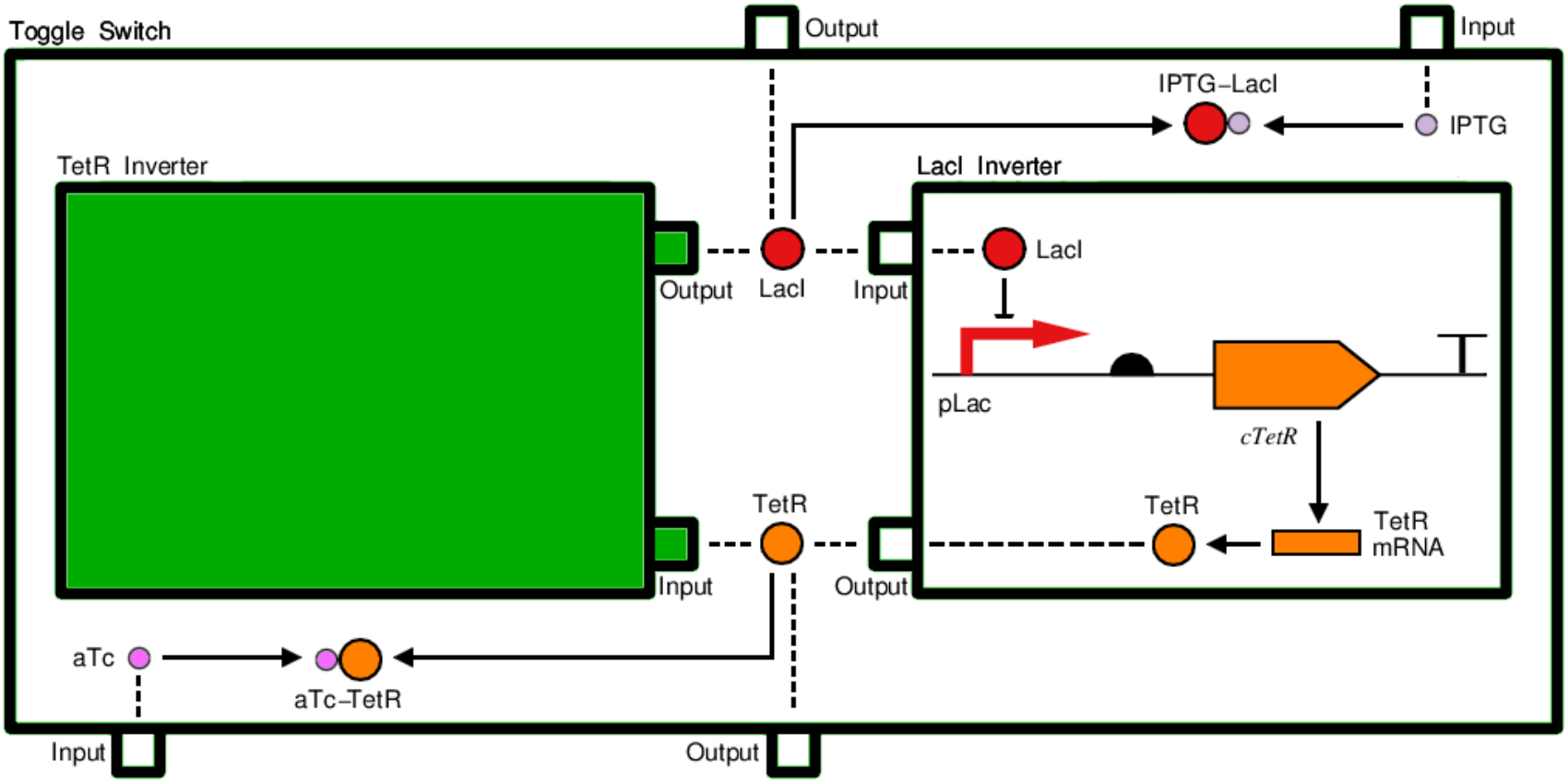
LacI Inverter



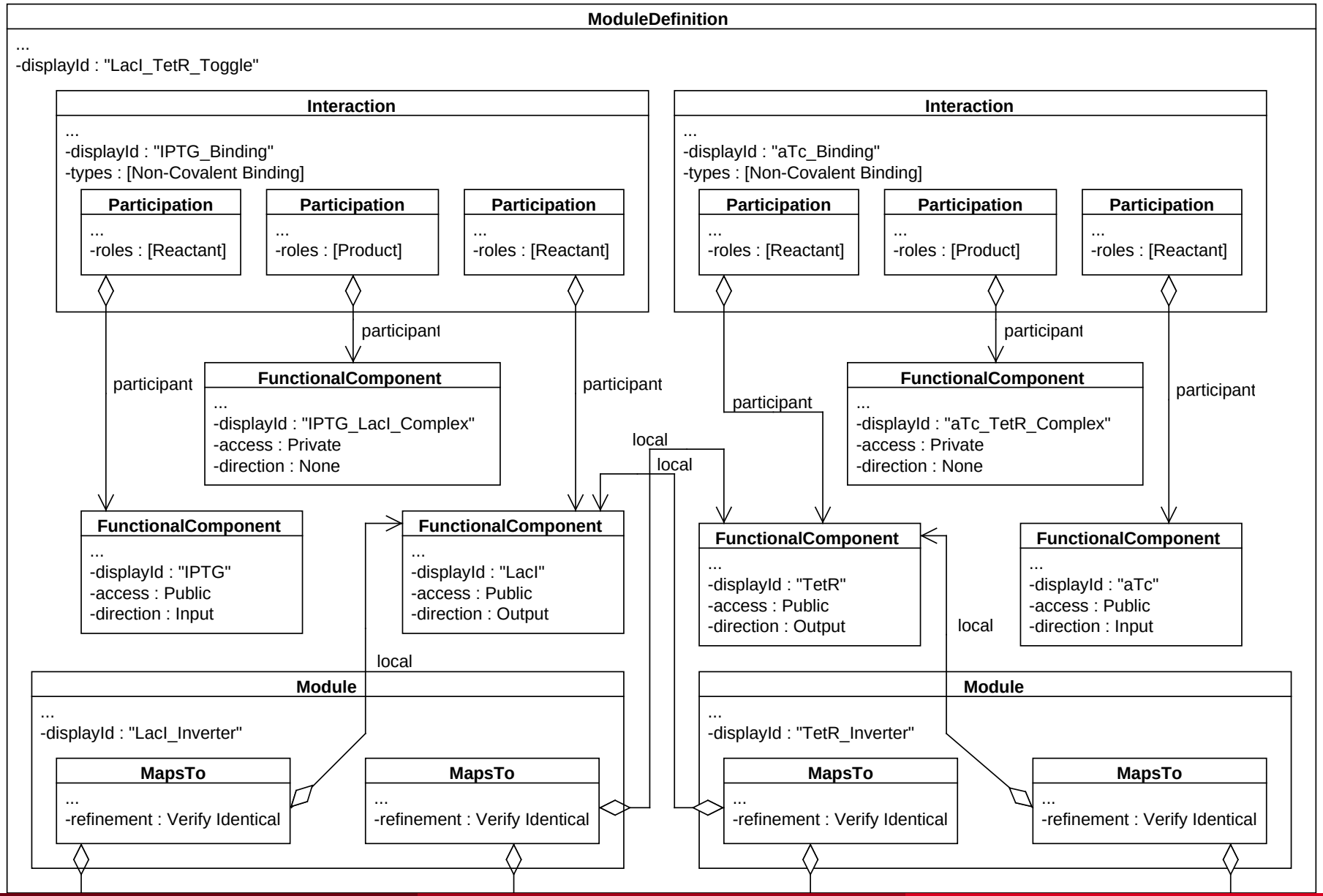
LacI Inverter (SBOL)



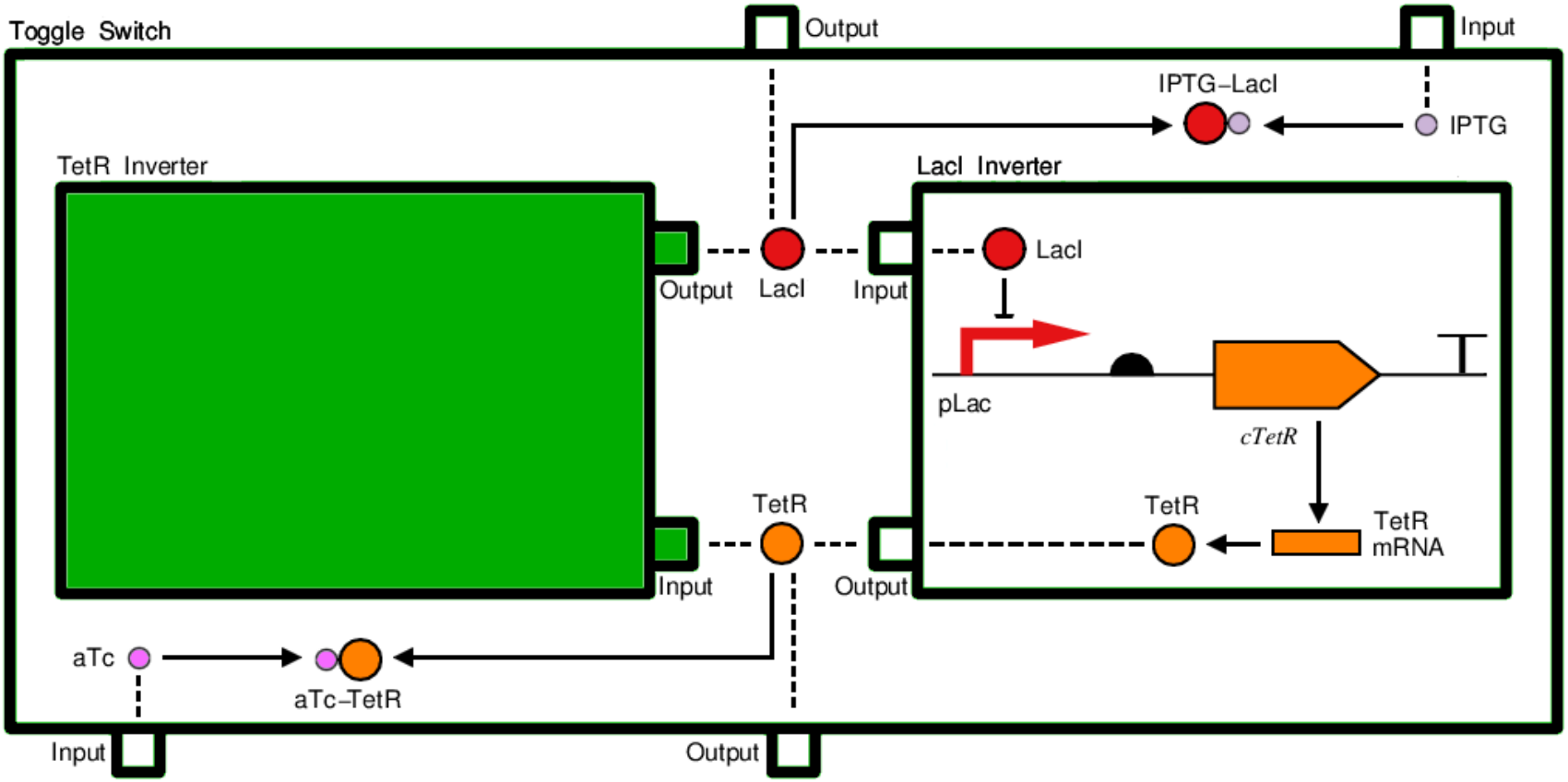
Genetic Toggle Switch



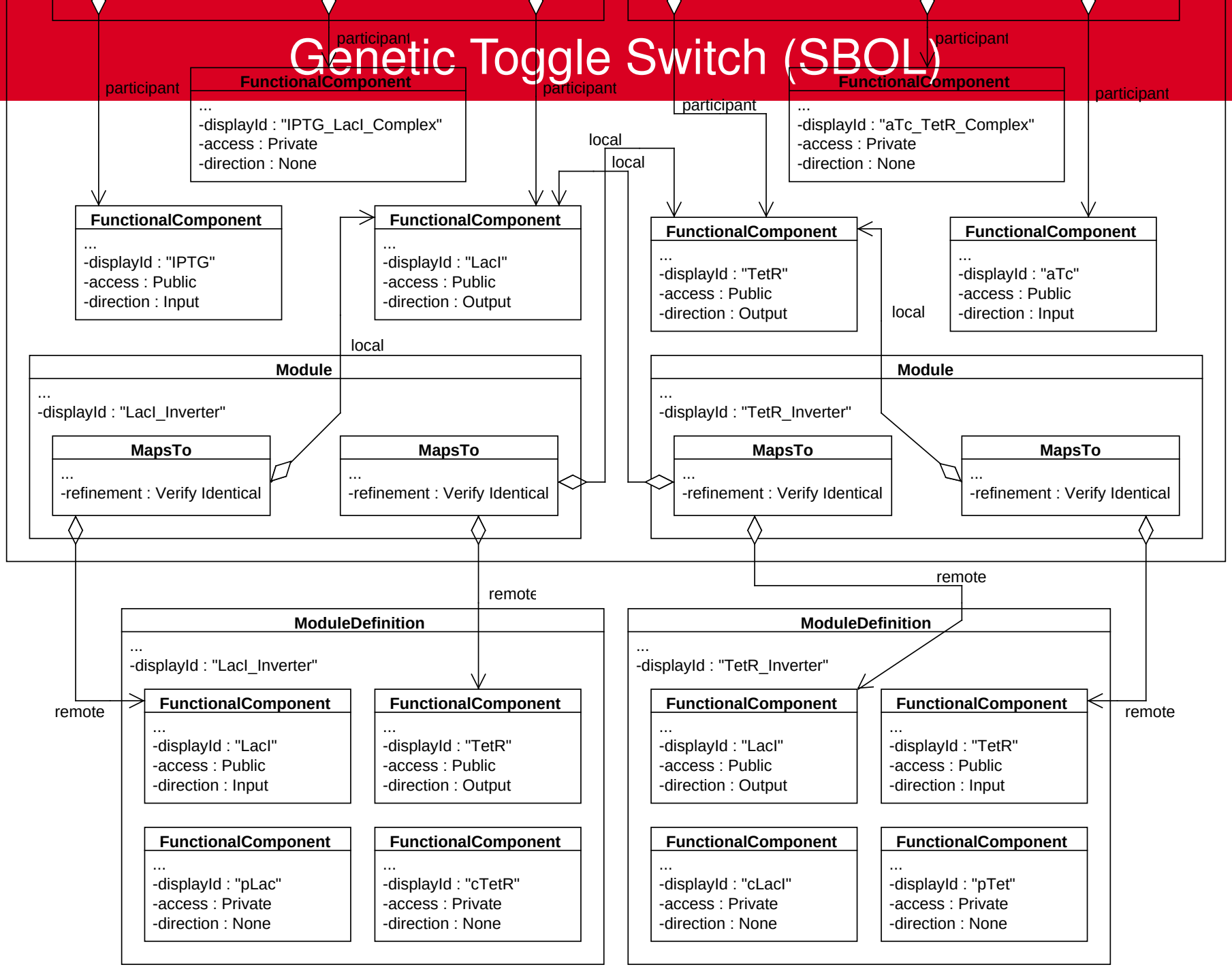
Genetic Toggle Switch (SBOL)



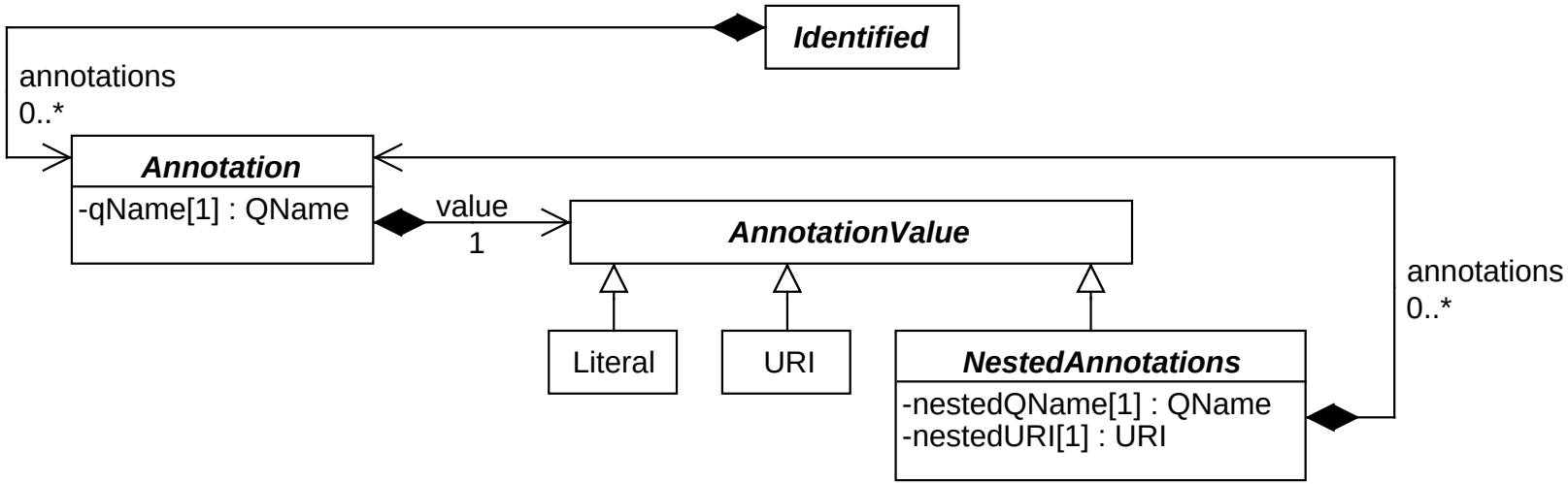
Genetic Toggle Switch



Genetic Toggle Switch (SBOL)



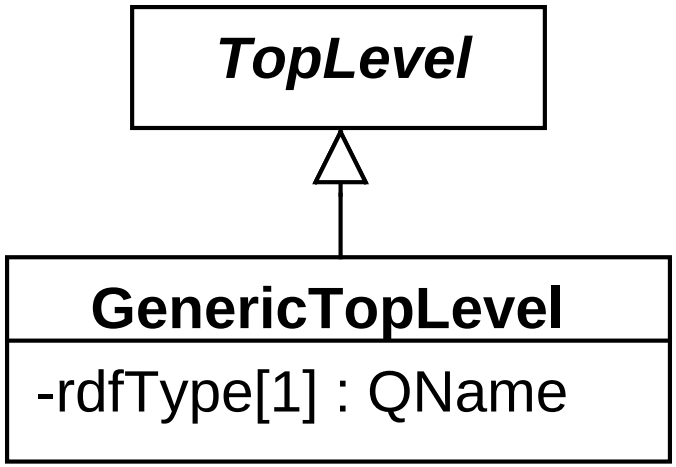
Annotations (Child of Identified)



Annotations (Example)

```
<?xml version="1.0" ?>
<rdf:RDF xmlns:pr="http://partsregistry.org"
 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:dcterms="http://purl.org/dc/terms/"
 xmlns:prov="http://www.w3.org/ns/prov#"
 xmlns:sbol="http://sbols.org/v2#">
  <sbol:ComponentDefinition rdf:about="http://partsregistry.org/cd/BBa_J23119">
    <sbol:persistentIdentity rdf:resource="http://partsregistry.org/cd/BBa_J23119"/>
    <sbol:displayId> BBa_J23119 </sbol:displayId>
    <pr:group> iGEM2006_Berkeley </pr:group>
    <pr:experience rdf:resource="http://parts.igem.org/cgi/partsdb/part_info.cgi?part_name=BBa_J23
    <pr:information>
      <pr:Information rdf:about="http://parts.igem.org/cgi/partsdb/part_info.cgi?part_name=BBa_J23
        <pr:sigmafactor> //rnap/prokaryote/ecoli/sigma70 </pr:sigmafactor>
        <pr:regulation> //regulation/constitutive </pr:regulation>
      </pr:Information>
    </pr:information>
    <dcterms:title> J23119 </dcterms:title>
    <dcterms:description> Constitutive promoter </dcterms:description>
    <sbol:type rdf:resource="http://www.biopax.org/release/biopax-level3.owl#DnaRegion"/>
    <sbol:role rdf:resource="http://identifiers.org/so/SO:0000167"/>
  </sbol:ComponentDefinition>
</rdf:RDF>
```

GenericTopLevel



GenericTopLevel (Example)

```
<?xml version="1.0" ?>
<rdf:RDF xmlns:myapp="http://www.myapp.org/"
 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:dcterms="http://purl.org/dc/terms/"
 xmlns:prov="http://www.w3.org/ns/prov#"
 xmlns:sbol="http://sbols.org/v2#">
  <sbol:ComponentDefinition rdf:about="http://www.partsregistry.org/cd/BBa_J23119">
    <sbol:persistentIdentity rdf:resource="http://www.partsregistry.org/cd/BBa_J23119"/>
    <sbol:displayId> BBa_J23119 </sbol:displayId>
    <prov:wasDerivedFrom rdf:resource="http://www.partsregistry.org/Part:BBa_J23119"/>
    <myapp:datasheet rdf:resource="http://www.partsregistry.org/gen/datasheet1"/>
    <dcterms:title> J23119 </dcterms:title>
    <dcterms:description> Constitutive promoter </dcterms:description>
    <sbol:type rdf:resource="http://www.biopax.org/release/biopax-level3.owl#DnaRegion"/>
    <sbol:role rdf:resource="http://identifiers.org/so/SO:0000167"/>
  </sbol:ComponentDefinition>
  <myapp:Datasheet rdf:about="http://www.partsregistry.org/gen/datasheet1">
    <sbol:persistentIdentity rdf:resource="http://www.partsregistry.org/gen/datasheet1"/>
    <sbol:displayId> datasheet1 </sbol:displayId>
    <myapp:characterizationData rdf:resource="http://www.myapp.org/measurement/1"/>
    <myapp:transcriptionRate> 1 </myapp:transcriptionRate>
    <dcterms:title> Datasheet 1 </dcterms:title>
  </myapp:Datasheet>
</rdf:RDF>
```

Conclusion (SBOL Compliant Software)

- Can either support all classes or only its structural subset.
- Can support import of SBOL, export of SBOL, or both (lossy/lossless).
- SBOL Test Suite is currently under development here:
  `https://github.com/SynBioDex/SBOLTestSuite`
- Validate SBOL files generated using the SBOL Validator found here:
  `http://www.async.ece.utah.edu/sbol-validator/`
- Report SBOL-compliant software to the SBOL editors (editors@sbolstandard.org), so it can be listed on the SBOL website.