Frank T. Bergmann[1,2] / Sarah M. Keating[3] / Ralph Gauges[4] / Sven Sahle[1] / Katja Wengler[5]

SBML Level 3 package: Render, Version 1, Release 1

[1] BioQuant/COS, Heidelberg University, Heidelberg, Germany. http://orcid.org/0000-0001-5553-4702.
[2] Department of Computing and Mathematical Sciences, California Institute of Technology, Pasadena, CA, USA. http://orcid.org/0000-0001-5553-4702.
[3] European Bioinformatics Institute (EMBL-EBI), Hinxton, Cambrigeshire, United Kingdom of Great Britain and Northern Ireland, E-mail: skeating@caltech.edu. https://orcid.org/0000-0002-3356-3542.
[4] Hochschule Albstadt-Sigmaringen, Sigmaringen, Germany
[5] University of Hertfordshire, Hertfordshire, United Kingdom of Great Britain and Northern Ireland

Abstract:
Many software tools provide facilities for depicting reaction network diagrams in a visual form. Two aspects of such a visual diagram can be distinguished: the layout (i.e.: the positioning and connections) of the elements in the diagram, and the graphical form of the elements (for example, the glyphs used for symbols, the properties of the lines connecting them, and so on). This document describes the SBML Level 3 *Render* package that complements the SBML Level 3 Layout package and provides a means of capturing the precise rendering of the elements in a diagram. The SBML Level 3 *Render* package provides a flexible approach to rendering that is independent of both the underlying SBML model and the *Layout* information. There can be one block of render information that applies to all layouts or an additional block for each layout. Many of the elements used in the current render specification are based on corresponding elements from the SVG specification. This allows us to easily convert a combination of layout information and render information into a SVG drawing.

Keywords: SBML, Render, Visualisation
DOI: 10.1515/jib-2017-0078
Received: December 14, 2017; **Accepted:** February 1, 2018

Automatically generated rough PDF by *ProofCheck* from River Valley Technologies Ltd

Sarah M. Keating is the corresponding author.
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SBML Level 3 Package: Render ('render')

Frank T. Bergmann
fbergman@caltech.edu
Computing and Mathematical Sciences
California Institute of Technology
Pasadena, CA, US

Sarah M. Keating
skeating@ebi.ac.uk
European Bioinformatics Institute
(EMBL-EBI)
Hinxton, Cambridgeshire, UK

Ralph Gauges
gauges@hs-albsig.de
Hochschule Albstadt-Sigmaringen
Sigmaringen, Germany

Sven Sahle
sven.sahle@bioquant.uni-heidelberg.de
Modelling of Biological Processes
University of Heidelberg
Heidelberg, Germany

Katja Wengler
k.wengler@herts.ac.uk
University of Hertfordshire
Computer Science
Hatfield, UK

Version 1, Release 1

December 5, 2017

The latest release, past releases, and other materials related to this specification are available at
http://sbml.org/Documents/Specifications/SBML_Level_3/Packages/Rendering_(render)

This release of the specification is available at
http://co.mbine.org/specifications/sbml.level-3.version-1.render.version-1.release-1

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1 Introduction and motivation

1.1 Proposal corresponding to this package specification

This specification for Rendering in SBML Level 3 Version 1 is based on the proposal, by this documents authors, located at the following URL:

http://sbml.org/Community/Wiki/SBML_Level_3_Proposals/Rendering

The tracking number in the SBML issue tracking system (SBML Team, 2010) for Render package activities is 234. The version of the proposal used as the starting point for this specification is the version of May 2011. Previous versions of the current proposal are:

Version 5 (May 2011)

http://otto.bioquant.uni-heidelberg.de/sbml/level2/20110525/sbml-render-specification-20110525.pdf

Version 4 (October 2009)

http://otto.bioquant.uni-heidelberg.de/sbml/level2/20091029/SBMLRenderExtension-20091029.pdf

Version 3 (January 2008)

http://otto.bioquant.uni-heidelberg.de/sbml/level2/20080130/RenderExtensionDraft-20080130.pdf

Version 2 (March 2007)

http://otto.bioquant.uni-heidelberg.de/sbml/level2/20070309/RenderExtensionDraft-20070309.pdf

Version 1 (October 2006)

http://otto.bioquant.uni-heidelberg.de/sbml/level2/20061012/RenderExtensionDraft-20061012.pdf

Version 0.2 (October 2003)

http://otto.bioquant.uni-heidelberg.de/sbml/level2/20031028/SBMLRenderExtension-20031028.pdf

Version 0.1 (September 2003)

http://otto.bioquant.uni-heidelberg.de/sbml/level2/20030911/sbml-render-extension-20030918.pdf

Details of earlier independent proposals are provided in Section 2.

1.2 Tracking number

As initially listed in the SBML issue tracking system under:
http://sourceforge.net/p/sbml/sbml-specifications/234/.

1.3 Package dependencies

The Render package adds additional classes to SBML Level 3 Version 1 Core and extends the SBML Level 3 Layout package.

1.4 Document conventions

Following the precedent set by the SBML Level 3 Core specification document, we use UML 1.0 (Unified Modeling Language; Eriksson and Penker 1998; Oestereich 1999) class diagram notation to define the constructs provided by this package. We also use color in the diagrams to carry additional information for the benefit of those viewing the document on media that can display color. The following are the colors we use and what they represent:

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- *Black*: Items colored black in the UML diagrams are components taken unchanged from their definition in the SBML Level 3 Core specification document.
- *Green*: Items colored green are components that exist in SBML Level 3 Core, but are extended by this package. Class boxes are also drawn with dashed lines to further distinguish them.
- *Blue*: Items colored blue are new components introduced in this package specification. They have no equivalent in the SBML Level 3 Core specification.
- *Red*: Items colored red are new components introduced in this package specification. The color red indicates that these items are not fully defined in the particular UML diagram in which they appear. Full definitions, including appropriate UML diagrams, are located elsewhere in the text.

We also use the following typographical conventions to distinguish the names of objects and data types from other entities; these conventions are identical to the conventions used in the SBML Level 3 Core specification document:

AbstractClass: Abstract classes are classes that are never instantiated directly, but rather serve as parents of other object classes. Their names begin with a capital letter and they are printed in a slanted, bold, sans-serif typeface. In electronic document formats, the class names defined within this document are also hyperlinked to their definitions; clicking on these items will, given appropriate software, switch the view to the section in this document containing the definition of that class. (However, for classes that are unchanged from their definitions in SBML Level 3 Core, the class names are not hyperlinked because they are not defined within this document.)

Class: Names of ordinary (concrete) classes begin with a capital letter and are printed in an upright, bold, sans-serif typeface. In electronic document formats, the class names are also hyperlinked to their definitions in this specification document. (However, as in the previous case, class names are not hyperlinked if they are for classes that are unchanged from their definitions in the SBML Level 3 Core specification.)

`SomeThing`, `otherThing`: Attributes of classes, data type names, literal XML, and generally all tokens *other* than SBML UML class names, are printed in an upright typewriter typeface. Primitive types defined by SBML begin with a capital letter; SBML also makes use of primitive types defined by XML Schema 1.0 (Biron and Malhotra, 2000; Fallside, 2000; Thompson et al., 2000), but unfortunately, XML Schema does not follow any capitalization convention and primitive types drawn from the XML Schema language may or may not start with a capital letter.

For other matters involving the use of UML and XML, we follow the conventions used in the SBML Level 3 Core specification document.

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2 Background

In 2003 the authors proposed an extension to the SBML file format that allowed programs to include layout and render information in SBML files to store one or more graphical representations of the SBML model. During the discussions on the SBML mailing list, it soon became evident that a consensus for both layout and render information would not be reached easily, therefore the layout specification was separated from the render part of the specification and concentrated on the inclusion of layout information into SBML files. The Layout Specification has since been publicly accepted as SBML Level 3 Package.

This document describes now an extension to the SBML Layout Package that describes the precise rendering of elements. Where the Layout package only describes the size and location if objects, the Render package complements this description by detailing precisely how they are to be rendered.

2.1 Design decisions

The render extension is based on the existing layout extension. Secondly, the render extension is made as flexible as possible in order to not impose any artificial limits on how programs can display their reaction networks.

The render extension is independent of the underlying SBML model as well as of the layout extension, thus the render information will be stored as one or more separate blocks. There can be one block of render information that applies to all layouts and an additional block for each layout. For SBML Level 2 this render information will be stored in the annotation of the `listOfLayouts` element or the annotation of a `layout` element respectively.

The render information consists of a set of styles that are associated with objects from the Layout Package either by a list of `id`s of layout objects or by roles of layout objects or `id`s of their corresponding model elements. For example, a style can be defined that applies to all **SpeciesReference** objects or to all objects that have the `role product`.

Global render information included in the annotation of the `listOfLayouts` element will only be able to define styles that associate render information with roles of elements, it cannot associate styles with individual objects from a layout via their `id`s.

Many of the elements used in the current render specification are based on corresponding elements from the SVG specification. This allows us to easily convert a combination of layout information and render information into a SVG drawing. At the same time we profit from the work that has already been done while creating the SVG specification.

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3 Package syntax and semantics

In this section, we define the syntax and semantics of the Render package for SBML Level 3 Version 1 Core. We expound on the various data types and constructs defined in this package, then in Section 4 on page 38, we provide complete examples of using the constructs in example SBML models.

3.1 Namespace URI and other declarations necessary for using this package

Every SBML Level 3 package is identified uniquely by an XML namespace URI. For an SBML document to be able to use a given SBML Level 3 package, it must declare the use of that package by referencing its URI. The following is the namespace URI for this version of the Render package for SBML Level 3 Version 1:

"`http://www.sbml.org/sbml/level3/version1/render/version1`"

In addition, SBML documents using a given package must indicate whether understanding the package is required for complete mathematical interpretation of a model, or whether the package is optional. This is done using the attribute `required` on the `<sbml>` element in the SBML document. For the Render package the value of the required attribute is "`false`".

The following fragment illustrates the beginning of a typical SBML model using SBML Level 3 Version 1 and this version of the Render package (note, that the Layout package is also needed):

```
<?xml version="1.0" encoding="UTF-8"?>
 <sbml xmlns="http://www.sbml.org/sbml/level3/version1/core" level="3" version="1"
   xmlns:layout="http://www.sbml.org/sbml/level3/version1/layout/version1" layout:required="false"
   xmlns:render="http://www.sbml.org/sbml/level3/version1/render/version1" render:required="false"
  >
```

Originally the layout and render extension were developed for use with SBML Level 2 files, where the information was stored in annotations to SBML models, layout lists and layouts. The namespace for the version of the SBML render extension for SBML Level 2 is:

"`http://projects.eml.org/bcb/sbml/render/level2`"

An example using the render extension in this context would look like this:

```
<?xml version="1.0" encoding="utf-8"?>
<sbml xmlns="http://www.sbml.org/sbml/level2" level="2" version="1">
  <model id="model1" name="Model␣with␣L2␣Render␣Annotation">
    <annotation>
      <listOfLayouts xmlns="http://projects.eml.org/bcb/sbml/level2">
        <layout id="layout1">
          <annotation>
            <listOfRenderInformation xmlns="http://projects.eml.org/bcb/sbml/render/level2">
              ...
            </listOfRenderInformation>
          </annotation>
          ...
        </layout>
        ...
      </listOfLayouts>
      ...
    </annotation>
    ...
  </model>
</sbml>
```


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3.2 Primitive data types

Section 3.1 of the SBML Level 3 specification defines a number of primitive data types and also uses a number of XML Schema 1.0 data types (Biron and Malhotra, 2000). We assume and use some of them in the rest of this specification, specifically `boolean`, `integer`, `double`, `ID`, `SId`, `SIdRef`, and `string`. The Render package defines other primitive types; these are described below.

3.2.1 *Type* `StyleType`

The type `StyleType` is used by **LocalStyle** and **GlobalStyle** elements, in order to apply a particular **Style** to a **GraphicalObject**. This is done via the `typeList` attribute that uses the `StyleType` as its data type.

A valid **StyleType** instance is a combination of one or more of the following values separated by white spaces:

- "`COMPARTMENTGLYPH`",
- "`SPECIESGLYPH`",
- "`REACTIONGLYPH`",
- "`SPECIESREFERENCEGLYPH`",
- "`TEXTGLYPH`",
- "`GENERALGLYPH`",
- "`GRAPHICALOBJECT`"
- "`ANY`"

The `ANY` keyword specifies that this styles applies to any type of glyph and would be equivalent to listing all the other keywords.

3.2.2 *Type* `GradientSpreadMethod`

The type **GradientSpreadMethod** is being used by **GradientBase** elements to decide how gradients propagate over the whole element they are applied to. It is an enumeration consisting of the following three values called `pad`, `reflect` or `repeat`:

- `pad`: the gradient color at the endpoint of the vector defines how the gradient is continued beyond that point (default value).
- `reflect`: the gradient continues from end to start and then from start to end again and again.
- `repeat`: the gradient pattern is repeated from start to end over and over again.

3.2.3 *Type* `FillRule`

The type FillRule describes how a surface created by connecting points on a **Polygon** are to be filled when rendered.

Allowed values for a valid instance of type `FillRule` are:

- `nonzero`
- `evenodd`

This property is implemented in all graphics libraries. They detect whether a point is to be filled by casting a ray from the point to the outside of the object (in an arbitrary direction). Along that ray all crossings with the polygon lines are counted. In the case of `evenodd` if the line count is even, the point is outside (and to be not filled), if the line count is odd, the point is inside, and to be drawn filled.

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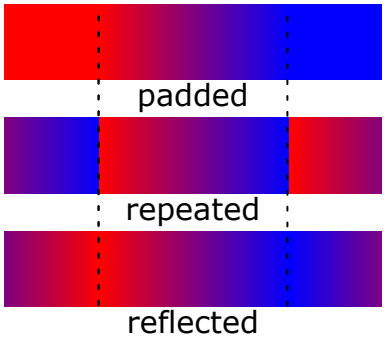

Figure 1: *example of different SVG spreadMethod values*

For the `nonzero` fill rule, the directionality of the line segments are taken into account. If along the ray a line is crossed that goes from left to right, the current line count will be lowered by one, if a line is being crossed going from right to left, then the line count will be incremented by one. If a the end the line count is non-zero then the point is considered inside the shape and to be drawn filled. Sometimes this fill rule is also called *winding*.

For a detailed description on how these values should be applied, we would like to refer you to the corresponding documentation in the SVG specification[1].

3.2.4 *Type* `FontFamily`

The **FontFamily** type gives a hint as to which font is to be used when rendering **Text** elements. This type extends the type `string`. The following values are pre-defined:

- `serif`
- `sans-serif`
- `monospace`

However, applications are free to use the **FontFamily** to store the name of the font the writing application used as a string. It has not been an issue for reading applications to find a similar font.

3.2.5 *Type* `FontWeight`

The type **FontWeight** indicates whether the font is to be used in its normal form, or in its bold form. Consequently, the only values allowed for this enumeration are:

- `bold`
- `normal`

3.2.6 *Type* `FontStyle`

The type **FontStyle** determines whether a font is to be drawn use italic or normal styles. Thus the only allowed values are:

- `italic`
- `normal`

3.2.7 *Type* `VTextAnchor`

The type **VTextAnchor** allows models to specify how text elements are to be vertically aligned within their bounding box. This enumeration has the following allowed values:

[1] http://www.w3.org/TR/SVG/painting.html#FillRuleProperty

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- `top`,
- `middle`
- `bottom`
- `baseline`

Examples illustrating the use of the different **VTextAnchor** values are given in Appendix A on page 65 .

3.2.8 *Type* `HTextAnchor`

The type **HTextAnchor** defines the horizontal alignment of text elements. This enumeration can use the following values:

- `start`
- `middle`
- `end`

Examples illustrating the use of the different **HTextAnchor** values are given in Appendix A on page 65 .

3.2.9 *Type* `RelAbsVector`

The position and size of render elements can be specified as a combination of an absolute value and a relative value. The absolute value is a numerical value in units of "`pt`" (1/72 inch) indicating the position of the object. The relative value is a percentage indicating the size of the object. All values are relative to the bounding box of the corresponding element in the layout. This bounding box basically specifies a canvas for the render elements to be drawn on.

In order to avoid populating the resulting XML with numerous attributes the Render package encodes this information in the **RelAbsVector** class with the two attributes `abs` and `rel` by extending the `string` such that it encodes optionally an absolute number first followed by an optional relative number followed by a `%` sign. Adding spaces between the coordinates is encouraged, but not required.

Examples of the **RelAbsVector** construct for the `x` coordinate are shown in the table below.

`string`	Coordinate
$-5+100\%$	5 points left of the right edge of the current bounding box.
50%	50% from the left edge of the current bounding box.
2	2 points from the left edge of the bounding box.

It should be noted that when applying transformations to elements with relative values, the relative values have to be converted to absolute values first.

3.2.10 *Type* `doubleArray`

The **doubleArray** primitive type is a comma and space delimited set of `double` values in a single string as shown in the following example:

```
"1.0, 2.1, 3.2, 4.0, 5.3"
```

3.2.11 *Type* `colorString`

The **colorString** primitive type is a string encoding the hexidecimal color code. Color values are specified as a six or eigth digit hex string which defines the RGBA value of the color. The string is formatted as "`#`" followed by the

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six or eight digits "`0-9 a-f A-F`". If only the first six digits for the RGB value are given, the alpha value (also known as transparency or opacity of the color) is assumed to be 0xFF which means that the color is totally opaque.

The following defines an opaque dark red color, with a red component of 0x20, green component of 0x00, and blue component of 0x00.

```
"#200000ff"
```

This is equivalent to

```
"#200000"
```

where not specifying the alpha component means it will have the value of 0xff.

3.2.12 Type `xsi:type`

In a similar fashion to the SBML Layout specification the `xsi:type` attribute from the XML Schema instance (XSI) namespace is used. The namespace is:

"`http://www.w3.org/2001/XMLSchema-instance`"

For this purpose, the attribute `xsi:type` is set to the following fixed values: "`RenderPoint`" for line segments and "`RenderCubicBezier`" for splines.

3.3 General features

The render extension provides two locations where styles can be defined. First each layout can have its own set of render information located as a child element of the **Layout** element (Figure 2). This is considered to be **local** render information. Secondly, **global** render information objects can be located as child elements of the **ListOfLayouts** element (Figure 3).

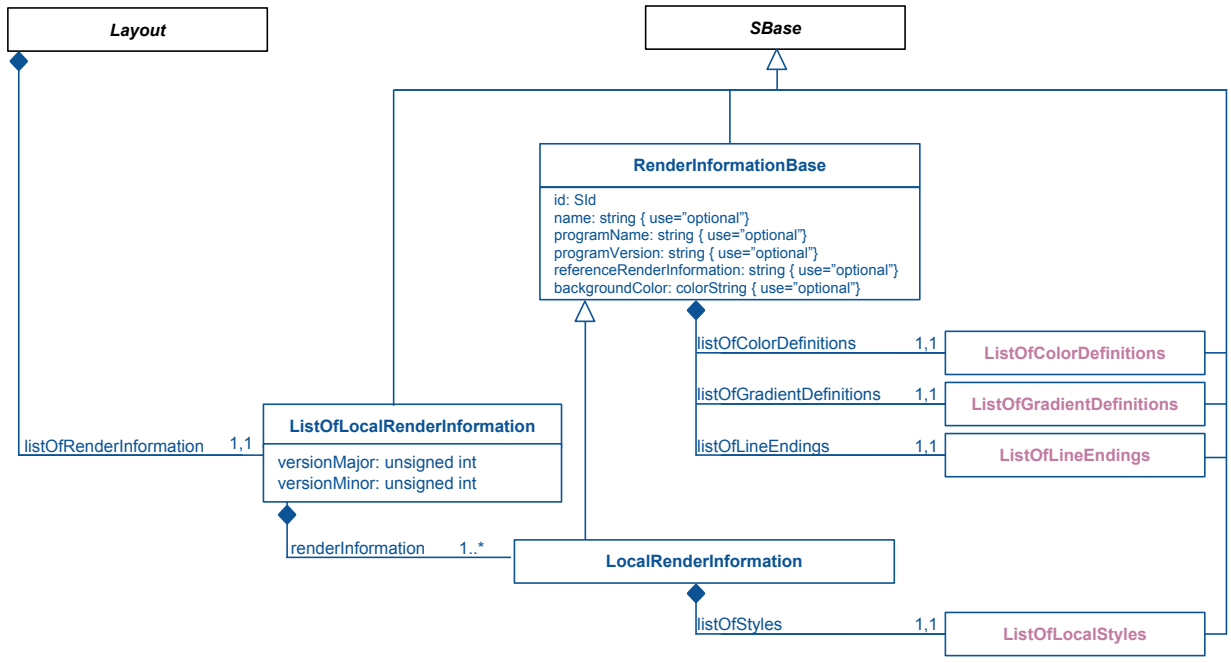

Figure 2: *A UML representation of the extended* ***Layout*** *class for the Render package. See Section 1.4 for conventions related to this figure.*

It is important to note that each layout can have more than one set of local render information and that it is also

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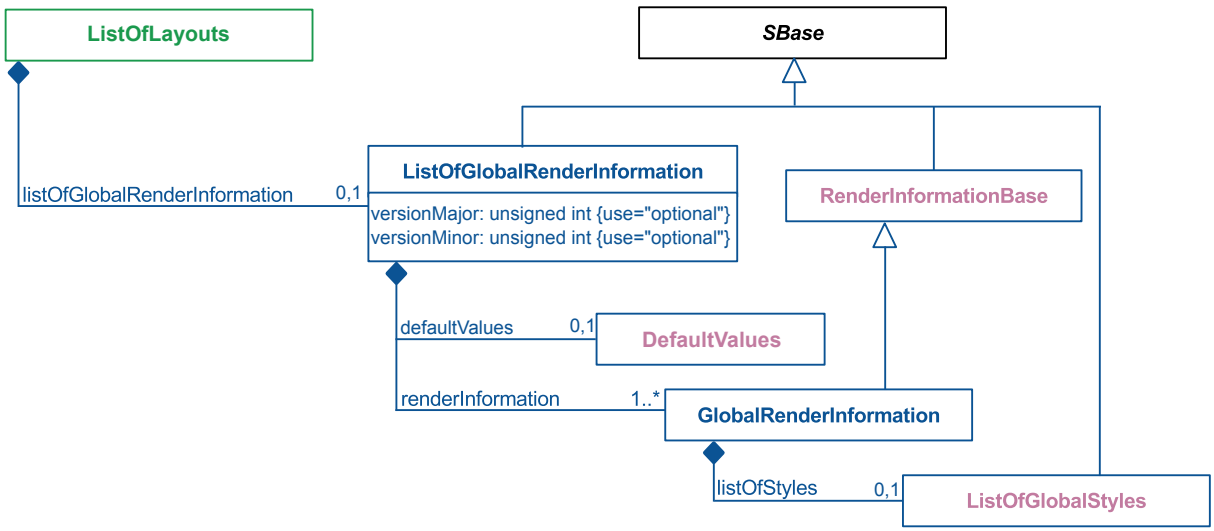

Figure 3: *A UML representation of the extended* ***ListOfLayouts*** *object for the Render package. See Section 1.4 for conventions related to this figure.*

possible to define more than one global style. Each style can also reference another style that complements it. This way the user can create styles that are based on other styles. In contrast to local styles, the global styles can not reference individual layout elements by an id, they can only define role based or type based styles.

3.3.1 Uniqueness of ids

Local and global render information objects can reference other render information objects. Items are then resolved by looking up the ids. This also makes it possible to override elements specified in the referenced render information by defining a new object in its render information object with the same id.

When overriding elements, the object type have to remain compatible. So **LineEnding** definitions on the other hand can only be replaced by other **LineEnding** definitions and **Style** objects only with style objects. An exception to the rule is that **ColorDefinitions** in the referenced render information may also be replaced by a gradient definition (that is either a **LinearGradient** or a **RadialGradient**) and vice versa.

3.3.2 Default Values

Previously, the render package specified default values and inheritance in a similar fashion to the specification used by SVG. However, in order to comply with the **SBML** development guidelines for Level 3 packages, we introduced a new class **DefaultValues** to encode these values within the model. The **DefaultValues** class can occur as a child of either the **ListOfGlobalRenderInformation** or a **ListOfLocalRenderInformation**.

The values from the **DefaultValues** class are to be taken as default source for the values of any optional attribute that is not explicitly declared. An example on how to use the **DefaultValues** class is below. For the meaning of the individual attributes, please see the corresponding sections later in this document. If an attribute has not been declared, either explicitly on an element or using the **DefaultValues** class then software reading the XML may chose how they handle the attribute.

Note that the **DefaultValues** associated with a **ListOfLocalRenderInformation** will override **DefaultValues** declared on the **ListOfGlobalRenderInformation**.

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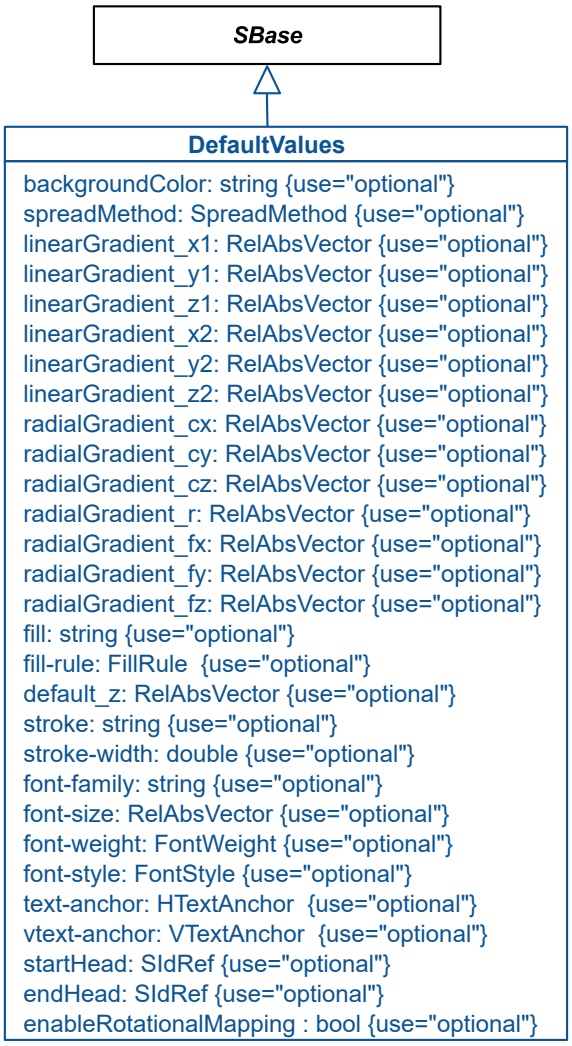

Figure 4: *A UML representation of the* ***DefaultValues*** *class for the Render package. See Section 1.4 for conventions related to this figure.*

```
<defaultValues
  backgroundColor = "#FFFFFFFF"
  spreadMethod="pad"

  linearGradient_x1 = "0%"
  linearGradient_y1 = "0%"
  linearGradient_z1 = "0%"
  linearGradient_x2 = "100%"
  linearGradient_y2 = "100%"
  linearGradient_z2 = "100%"

  radialGradient_cx = "50%"
  radialGradient_cy = "50%"
  radialGradient_cz = "50%"
  radialGradient_r  = "50%"
  radialGradient_fx = "50%"
  radialGradient_fy = "50%"
  radialGradient_fz = "50%"

  stroke="none" stroke-width="0"
```


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```
  fill="none" fill-rule="nonzero"

  font-family  = "sans-serif"
  font-size    = "0"
  font-weight  = "normal"
  font-style   = "normal"
  text-anchor  = "start"
  vtext-anchor = "top"

  enableRotationalMapping = "true"

  default_z = "0.0"
/>
```

3.4 Extended elements from the Layout package

3.4.1 The extended GraphicalObject class

The Render package extends the **GraphicalObject** object from the Layout package with the addition of the `objectRole` attributes.

The `objectRole` *attribute*

A **GraphicalObject** has an optional attribute `objectRole` of type `string`. This attribute specifies with which **Style** the object should be rendered. In the example below a **SpeciesGlyph** is tagged with the role "`SBO-0000285-clone`" later on a style in a **GlobalRenderInformation** element includes that role in its `roleList` attribute and will be applied.

```
  <speciesGlyph id="sGlyph_9" render:objectRole="SBO-0000285-clone"
   species="NAD" xmlns:render="http://www.sbml.org/sbml/level3/version1/render/version1">
    <boundingBox>
      <position x="138" y="247" />
      <dimensions width="36" height="24" />
    </boundingBox>
  </speciesGlyph>

  ...

  <style roleList="SBO-0000285-clone␣NO-SBO-clone">
    <g stroke="black" stroke-width="2" fill="EPNBackgroundGradient">
      <ellipse cx="50%" cy="50%" cz="0.0" rx="50%" ry="50%" />
      <ellipse cx="50%" cy="50%" cz="0.0" rx="50%" ry="50%" />
    </g>
  </style>
```

3.4.2 The extended ListOfLayouts class

The Render package extends the **ListOfLayouts** object from the Layout package with the addition of an optional **ListOfGlobalRenderInformation** object (Figure 3).

The ListOfGlobalRenderInformation class

The **ListOfGlobalRenderInformation** object inherits the core attributes and subobjects from the **SBase** class. It contains one or more objects of type **GlobalRenderInformation**.

In addition, the **ListOfGlobalRenderInformation** object has the optional attributes `versionMajor` and `versionMinor` as well as an optional **DefaultValues** element that provides the default values for the **GlobalRenderInformation** objects contained in the list.

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The `versionMajor` *attribute*

A **ListOfGlobalRenderInformation** has an optional attribute `versionMajor` of type `unsigned integer` which specifies the major version of the render information. Note this attribute is included to preserve backward compatibility with software using the Render package as a Level 2 annotation. If used it is recommended that the value is set to "`1`".

The `versionMinor` *attribute*

A **ListOfGlobalRenderInformation** has an optional attribute `versionMinor` of type `unsigned integer` which specifies the minor version of the render information. Note this attribute is included to preserve backward compatibility with software using the Render package as a Level 2 annotation. If used, it is recommended that the value is set to "`0`".

3.4.3 The extended Layout class

The Render package extends the **Layout** object from the Layout package with the addition of an optional **ListOfLocalRenderInformation** object (Figure 2).

The ListOfLocalRenderInformation class

The **ListOfLocalRenderInformation** object inherits the core attributes and subobjects from the **SBase** class. It contains one or more objects of type **LocalRenderInformation**.

In addition, the **ListOfLocalRenderInformation** object has the optional attributes `versionMajor` and `versionMinor` as well as an optional **DefaultValues** element that provides the default values for the **LocalRenderInformation** objects contained in the list.

The `versionMajor` *attribute*

A **ListOfLocalRenderInformation** has an optional attribute `versionMajor` of type `unsigned integer` which specifies the major version of the render information. Note this attribute is included to preserve backward compatibility with software using the Render package as a Level 2 annotation. If used it is recommended that the value is set to "`1`".

The `versionMinor` *attribute*

A **ListOfLocalRenderInformation** has an optional attribute `versionMinor` of type `unsigned integer` which specifies the minor version of the render information. Note this attribute is included to preserve backward compatibility with software using the Render package as a Level 2 annotation. If used, it is recommended that the value is set to "`0`".

3.5 Render Information

The render information classes hold all information about the rendering. The information is stored between three classes: **RenderInformationBase**, the base class with common features; **GlobalRenderInformation** a class applying to types and roles of elements on a global level; and **LocalRenderInformation** that provides additional information that can be applied to individual elements from the Layout package. These classes are illustrated in Figure 2 and Figure 3.

3.5.1 The RenderInformationBase class

The **RenderInformationBase** class is an abstract class that holds all the information that is common to both local and global render information objects. It derives from the ***SBase*** class and thus inherits any attributes and elements that are present on this class. In addition the **RenderInformationBase** has the required attribute `id` and the optional attributes `name`, `programName`, `programVersion`, `referenceRenderInformation` and `backgroundColor`. Additionally, it may contain a **ListOfColorDefinitions**, **ListOfGradientDefinitions** and / or a **ListOfLineEndings**. These

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lists are optional, however if present may not be empty. There may only be one of each of those lists.

The `id` attribute

A **RenderInformationBase** has a required attribute `id` of type `SId`. This `id` may be used to reference this **RenderInformation** object from other elements within the Render package.

The `name` attribute

A **RenderInformationBase** has an optional attribute `name` of type `string`. This `name` attribute can be used to give the object a more user friendly identifier.

The `programName` attribute

A **RenderInformationBase** has an optional attribute `programName` of type `string` which can be used to store the name of the program that was used to create the render information.

The `programVersion` attribute

A **RenderInformationBase** has an optional attribute `programVersion` of type `string` which can be used to store the version number of the program used to create the render information.

The `referenceRenderInformation` attribute

A **RenderInformationBase** has an optional attribute `referenceRenderInformation` of type `SIdRef` which can be used to specify the `id` of another local or global render information object that complements the current render information object. A program reading and interpreting the render information can use this information to access another render information object, should the current object contain unsuitable information (i.e., information that the reading software cannot render).

A **LocalRenderInformation** object may reference any **GlobalRenderInformation** object but may only reference **LocalRenderInformation** objects defined within the same parent **Layout** object. A **GlobalRenderInformation** object may only reference other **GlobalRenderInformation** objects. Cyclical references are not allowed.

The `backgroundColor` attribute

A **RenderInformationBase** has an optional attribute `backgroundColor` of type **colorString** which defines the background color for rendering.

The ListOfColorDefinitions class

The **ListOfColorDefinitions** object inherits the core attributes and subobjects from the **SBase** class. It contains one or more objects of type **ColorDefinition** which are used to predefine a set of colors to be referenced by **Styles**.

The ListOfGradientDefinitions class

The **ListOfGradientDefinitions** object inherits the core attributes and subobjects from the **SBase** class. It contains one or more objects of type **GradientBase** which are used to define either **LinearGradient** or **RadialGradient** objects to be used in **Styles**.

The ListOfLineEndings class

The **ListOfLineEndings** object inherits the core attributes and subobjects from the **SBase** class. It contains one or more objects of type **LineEnding** which can be used to define a set of **LineEndings** that can be applied to path objects.

3.5.2 The LocalRenderInformation class

The **RenderInformation** element of type **LocalRenderInformation** is the primary container that holds the render information for a **Layout** instance.

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The **LocalRenderInformation** object derives from the **RenderInformationBase** class and thus inherits any attributes and elements that are present on this class. A **LocalRenderInformation** may contain exactly one element named `listOfStyles` of type **ListOfLocalStyles**.

The ListOfLocalStyles class

The **ListOfLocalStyles** object inherits the core attributes and subobjects from the **SBase** class. It is optional but if present has to contain one or more objects of type **LocalStyle**.

3.5.3 The GlobalRenderInformation class

Global render information is specified in a very similar way as local render information. The attributes and elements of **GlobalRenderInformation** objects and **LocalRenderInformation** objects are the same with the exception of the `listOfStyles` element. In the case of a **GlobalRenderInformation** object the `listOfStyles` element is of type **ListOfGlobalStyles**.

It should be noted that another difference between **GlobalRenderInformation** and **LocalRenderInformation** is the fact that **GlobalRenderInformation** objects may only reference ids of other **GlobalRenderInformation** objects in their `referenceRenderInformation` attribute.

The ListOfGlobalStyles class

The **ListOfGlobalStyles** object inherits the core attributes and subobjects from the **SBase** class. It contains one or more objects of type **GlobalStyle**.

The following snippet shows the general outline of a **ListOfGlobalRenderInformation** object:

```
<layout:listOfLayouts>
   <render:listOfGlobalRenderInformation>
      <render:renderInformation render:id="FancyRenderer_GlobalDefault"
                          render:name="default␣global␣style"
                          render:programName="FancyRenderer"
                          render:programVersion="0.1.1">
        <render:listOfColorDefinitions>
             ...
        </render:listOfColorDefinitions>
        <render:listOfGradientDefinitions>
             ...
        </render:listOfGradientDefinitions>
        <render:listOfLineEndings>
             ...
        </render:listOfLineEndings>
        <render:listOfStyles>
             ...
        </render:listOfStyles>
      </render:renderInformation>
   </render:listOfGlobalRenderInformation>
</layout:listOfLayouts>
```

3.6 Styles

3.6.1 The Style class

The **Style** class that holds all the information that is common to both local and global styles (Figure 5). The **Style** object derives from the ***SBase*** class and thus inherits any attributes and elements that are present on this class. A **Style** element may contain exactly one **RenderGroup** element. In addition, the **Style** object has the optional attributes `id`, `name`, `roleList` and `typeList`.

The **RenderGroup** element, "`g`", is used to specify how the elements covered by this **Style** object are to be rendered

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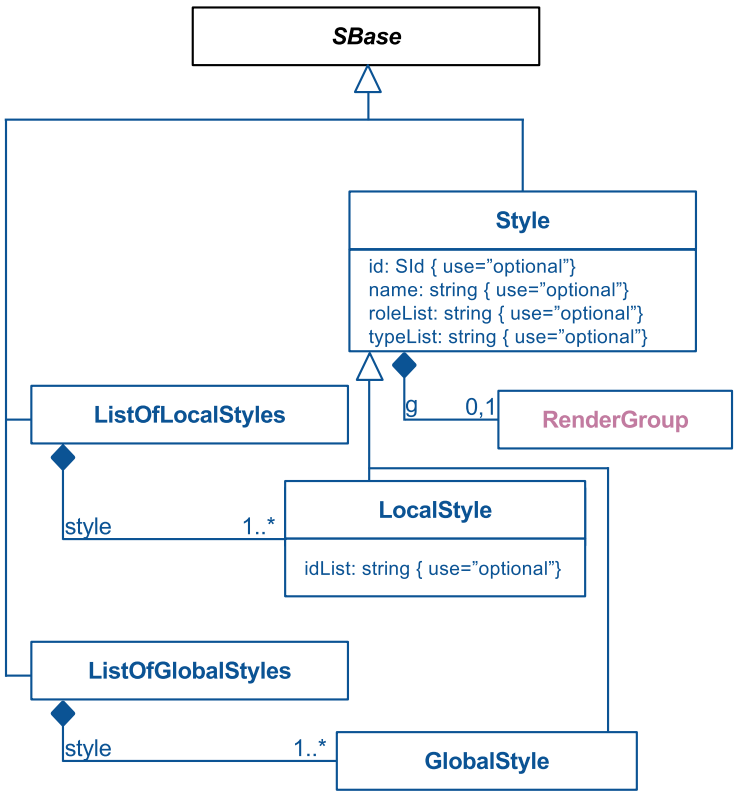

Figure 5: *A UML representation of the* ***Style*** *object for the Render package. See Section 1.4 for conventions related to this figure.*

and is discussed fully in Section 3.10.6.

The `id` *attribute*

A **Style** has an optional attribute `id` of type `SId` which can be used to uniquely identify this **Style** object.

The `name` *attribute*

A **Style** has an optional attribute `name` of type `string` which can be used to provide a more user friendly identifier.

The `roleList` *attribute*

A **Style** has an optional attribute `roleList` of type `string`. The string value of the `roleList` attribute contains a space-separated list of all the roles to which this **Style** should be applied.

This attribute can be used in conjunction with the `objectRole` attribute that is used to extend the **GraphicalObject** class from the Layout package. If the string given as an `objectRole` value appears in the `roleList` attribute of some render information object, then that render information object applies to the graphical object as shown in the snippet below. Note this relationship is only valid if there is no render information object that is more specific. For example, another **LocalStyle** could be defined with `idList` that references the `layout:id="go1"` explicitly, in which case that style would be chosen. For more information see also Appendix C.2 on page 74.

```
<layout:layout>
   <layout:listOfAdditionalGraphicalObjects>
      <layout:graphicalObject layout:id="go1" render:objectRole="Parameter">
         ...
      </layout:graphicalObject>
```


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```
   </layout:listOfAdditionalGraphicalObjects>
   <render:listOfLocalRenderInformation>
      <render:renderInformation render:id="FancyRenderer_GlobalDefault">
            ...
        <render:listOfStyles>
            <render:style render:id="style_1" render:roleList="Parameter">
               <g> ... </g>
            </render:style>
        </render:listOfStyles>
      </render:renderInformation>
   </render:listOfLocalRenderInformation>
</layout:layout>
```

The `typeList` *attribute*

A **Style** has an optional attribute `typeList` of type `string`. The string value of the `typeList` attributes contains a space-separated list of one or more of the values from the **StyleType** enumeration. The example snippet shows a particular style that is to be applied to both **SpeciesGlyph** and **SpeciesReferenceGlyph** objects from the Layout package.

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```
<layout:listOfLayouts>
   <render:listOfGlobalRenderInformation>
      <render:renderInformation render:id="FancyRenderer_GlobalDefault">
            ...
        <render:listOfStyles>
            <render:style render:id="style_1" render:typeList="SPECIESGLYPH_SPECIESREFERENCEGLYPH">
               <g> ... </g>
            </render:style>
        </render:listOfStyles>
      </render:renderInformation>
   </render:listOfGlobalRenderInformation>
</layout:listOfLayouts>
```

3.6.2 The GlobalStyle class

The **GlobalStyle** object derives from the **Style** class and thus inherits any attributes and elements that are present on this class. The **GlobalStyle** class is used for objects in the **ListOfGlobalStyles** element of a **GlobalRenderInformation** object.

3.6.3 The LocalStyle class

The **LocalStyle** object derives from the **Style** class and thus inherits any attributes and elements that are present on this class. It is identical to the **GlobalStyle** object but has an additional optional `idList` attribute.

The **LocalStyle** class is used for objects in the **ListOfLocalStyles** element of a **LocalRenderInformation** object.

The `idList` *attribute*

A **LocalStyle** has an optional attribute `idList` of type `string` which is a space-separated list of ids of layout objects to which this **Style** should be applied.

3.7 Colors and Gradients

All **RenderInformation** objects may contain a **ListOfColorDefinitions** containing objects of type **ColorDefinition** and a **ListOfGradientDefinitions** containing objects of type **GradientBase**. Gradients consist of continuously smooth color transitions along a vector from one color to another, possibly followed by additional transitions along the same vector to other colors. Here the Render package borrows heavily from the SVG specification. These are described in more detail in this section.

3.7.1 The ColorDefinition class

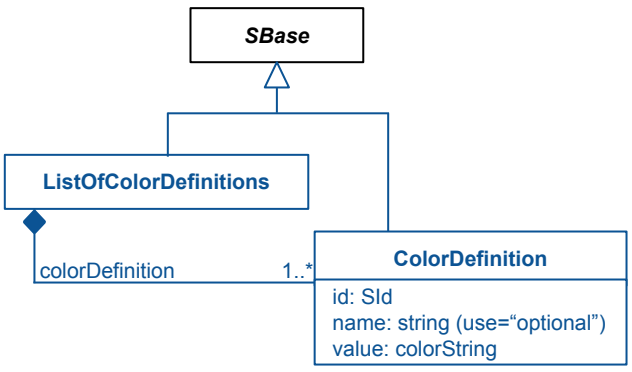

Figure 6: *A UML representation of the* ***ColorDefinition*** *object for the Render package. See Section 1.4 for conventions related to this figure.*

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The **ColorDefinition** object derives from the ***SBase*** class and thus inherits any attributes and elements that are present on this class. In addition, the **ColorDefinition** object has the required attributes `id` and `value` and the optional attribute `name`.

The `id` *attribute*

A **ColorDefinition** has a required attribute `id` of type `SId` which is used to give the **ColorDefinition** an unique identifier within the **RenderInformation** object.

The `name` *attribute*

A **ColorDefinition** has an optional attribute `name` of type `string`. This `name` attribute can be used to give the object a more user friendly identifier.

The `value` *attribute*

A **ColorDefinition** has a required attribute `value` of type **colorString**. Instead of specifying a color value, the value "`none`" can be given which is equivalent to no drawing at all.

The example snippet defines a dark red color, with a red component of 0x20, green component of 0x00, and blue component of 0x00. Since it is not specifying the alpha component, it will have the value of 0xff.

```
<listOfColorDefinitions>
  <colorDefinition id="darkred" value="#200000" />
       ...
</listOfColorDefinitions>
```

3.7.2 The GradientBase class

GradientBase is an abstract class that holds all the information that is common to both **RadialGradient** and **LinearGradient** objects (Figure 5).The **GradientBase** object derives from the ***SBase*** class and thus inherits any attributes and elements that are present on this class. A **GradientBase** may contain one or more **GradientStop** elements. In addition, the **GradientBase** object has a required `id` attribute and two optional attributes: `name` and `spreadMethod`.

The `id` *attribute*

A **GradientBase** has a required attribute `id` of type `SId` which is used to uniquely identify or reference a gradient within an **RenderInformation** object.

The `name` *attribute*

A **GradientBase** has an optional attribute `name` of type `string`. This `name` attribute can be used to give the object a more user friendly identifier.

The `spreadMethod` *attribute*

A **GradientBase** has an optional attribute `spreadMethod` of type **GradientSpreadMethod** that specifies the method that is used to continue the gradient pattern if the vector points do not span the whole bounding box of the object to which the gradient is applied.

3.7.3 The GradientStop class

As the name suggests the **GradientStop** object is used to define "gradient stops" which are used in line with the SVG specification. The **GradientStop** object derives from the ***SBase*** class and thus inherits any attributes and elements that are present on this class. In addition, the **GradientStop** object has the required attributes `offset` and `stop-color`. Note, unlike most SBML elements, the XML element name does not match the class name. The name of a **GradientStop** element is "`stop`" to preserve backward compatibility with render used in Level 2 annotations.

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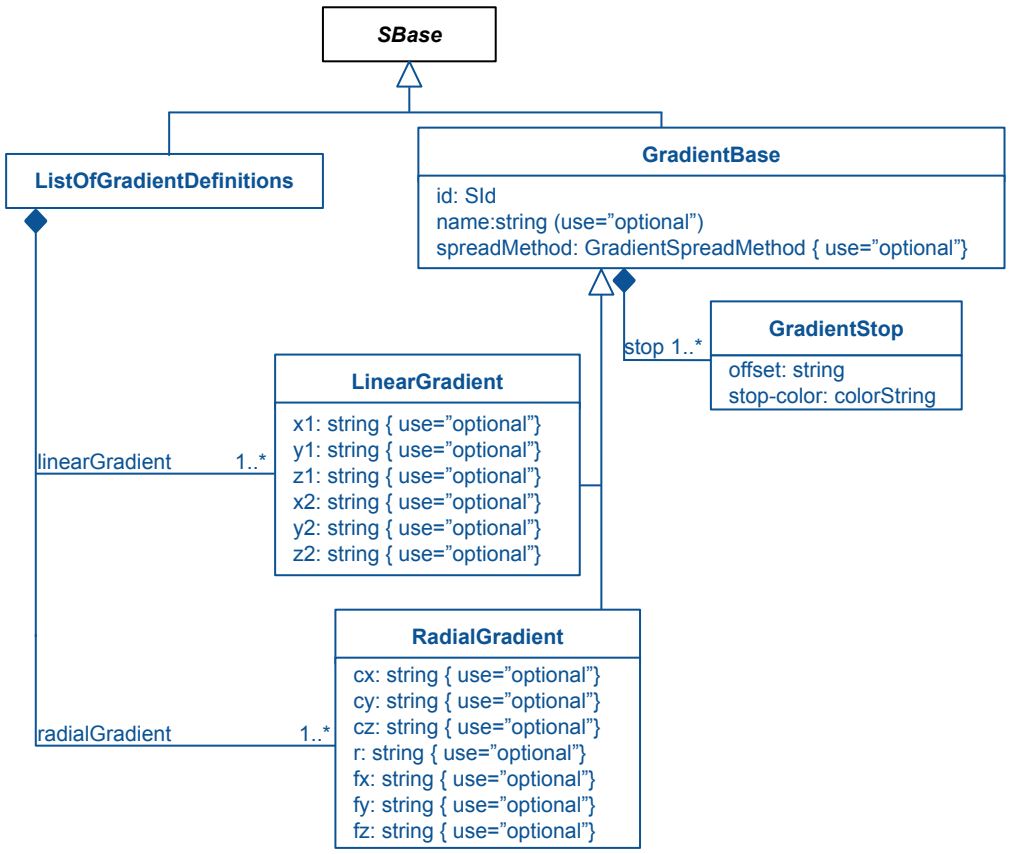

Figure 7: *A UML representation of the gradient objects for the Render package. See Section 1.4 for conventions related to this figure.*

The `offset` *attribute*

A **GradientStop** has a required attribute `offset` of type **RelAbsVector** which represents the relative distance from the starting point of the gradient. Depending on the type of gradient, this is either the point defined by the `x1`,`y1` and `z1` attributes (**LinearGradient**) or the `fx`, `fy` and `fz` attributes (**RadialGradient**). This value is given as a positive percentage value. Note, when using 2 dimensions the z values `z1` or `fz` are not required.

The `stop-color` *attribute*

A **GradientStop** has a required attribute `stop-color` of type `string` which defines the color for the given gradient stop. The attributes value can either be given as a hexadecimal color value (i.e., type **colorString**) or as the id of a **ColorDefinition** object from the **ListOfColorDefinitions** (i.e., type `SIdRef`).

The `id` of a **ColorDefinition** specifying "`none`" as its `value` cannot be used as a `stop-color`. It is also considered an error to specify the id of another gradient as the value of a `stop-color` attribute. In the case where the two points that define the gradient vector are identical, the area is to be painted with a single color taken from the last gradient stop element.

There are a few rules that need to be considered when working with gradient stops.

1. The offset value of a gradient stop should be between 0% and 100%.
2. The absolute part in any offset value is ignored, meaning it is considered to be 0.0 even if specified otherwise in a gradient stop.

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3. The offset of any gradient stop should to be greater than the offset of the preceding gradient stop.

Historically, the render specification applied the same rules as the SVG specification. The above is a simplification of these rules but users should be aware that existing implementations and models apply the following defaults when encountering models that do not comply with the rules above.

- An offset that is less that 0% is adjusted to be 0%.
- An offset that is greater than 100% is adjusted to be 100%.
- If an offset has a value less than that of the preceding stop, the offset is adjusted to have the same value as the preceding stop.
- If there are multiple stops with the same offset, the color used is that of the final stop with the duplicate offset value.

3.7.4 The LinearGradient class

The **LinearGradient** provides the vector points that define the start and end points to which the **GradientStop** elements should be mapped.

The **LinearGradient** object derives from the **GradientBase** class and thus inherits any attributes and elements that are present on this class. In addition, the **LinearGradient** object has the attributes `x1`, `y1`, `z1`, `x2`, `y2` and `z2`. As the names suggest these represent the x, y and z coordinates in a three dimensional Cartesian system. If only the x and y attributes are used a two dimensional viewport is assumed.

Note that these attributes are all considered optional. This is to preserve compatibility with the historical render specification that used default values (see Section 3.3.2 on page 12). The current recommendation is that the `x` and `y` values are considered required.

Since the value for the vector can be specified as an absolute value or one that is relative to the current viewport these attributes all have values of type **RelAbsVector**.

The `x1`*,* `y1` *and* `z1` *attributes*

The attributes `x1`, `y1` and `z1` define the start point of the gradient in either two (`z1` undefined) or three dimensions.

The `x2`*,* `y2` *and* `z2` *attributes*

The attributes `x2`, `y2` and `z2` define the end point of the gradient in either two (`z2` undefined) or three dimensions.

Example of specifying the LinearGradient shown in Figure 8.

```
<listOfGradientDefinitions>
  <linearGradient id="linear1" x1="0%" y1="50%" x2="100%" y2="50%">
    <stop offset="0%" stop-color="#ff6600" />
    <stop offset="100%" stop-color="#ffff66" />
  </linearGradient>
        ...
</listOfGradientDefinitions>
```

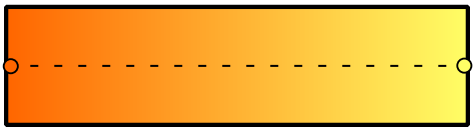

Figure 8: *Example of a* ***LinearGradient*** *along the horizontal line, starting from orange at 0%, going to yellow at 100%*

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3.7.5 The RadialGradient class

The **RadialGradient** object derives from the **GradientBase** class and thus inherits any attributes and elements that are present on this class. In addition, the **RadialGradient** object has seven attributes (each of type **RelAbsVector**) that are used to define the center, radius and focal point of the gradient.

The `cx`*,* `cy` *and* `cz` *attributes*

The attributes `cx`, `cy` and `cz` define the center of the gradient as a point in either two (`cz` undefined) or three dimensions.

The `r` *attribute*

The attribute `r` defines the radius of the gradient and must be positive. If the radius is given in relative values, the relation is to the width as well as the height. This means that if the width of the bounding box and the height of the bounding box are not equal, `cx`,`cy`,`cz` and `r` do not actually specify a circle, but an ellipse.

The `fx`*,* `fy` *and* `fz` *attributes*

The attributes `fx`, `fy` and `fz` define the focal point of the gradient as a point in either two (`fz` undefined) or three dimensions. The gradient is drawn such that this point is mapped to the 0% **GradientStop**. If one of these attributes is left undeclared it is considered to be equal to the corresponding coordinate of the center point. If the focal point lies outside the circle, the focal point is considered to be located on the intersection of the the line from the center point to the focal point and the sphere determined by the center point and the radius.

Note that these attributes are all considered optional. This is to preserve compatibility with the historical render specification that used default values (see Section 3.3.2 on page 12). The current recommendation is that the `x`, `y` and `r` values are considered required.

Example of specifying the RadialGradient shown in Figure 9:

```
<listOfGradientDefinitions>
  <radialGradient id="radial1" cx="50%" cy="50%" r="300" fx="50%" fy="50%">
    <stop offset="0%" stop-color="#FF0000" />
    <stop offset="50%" stop-color="#0000FF" />
    <stop offset="100%" stop-color="#FF0000" />
  </radialGradient>
      ...
</listOfGradientDefinitions>
```

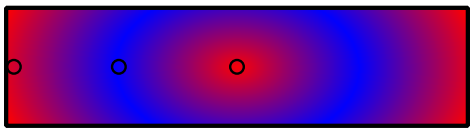

Figure 9: *Example of a **RadialGradient**, with red in the center, blue: radially around the middle of the gradient, and red again at the end.*

3.8 Transformation

In order to be able to display text that is not aligned horizontally or vertically or to effectively compose groups of objects from primitives, transformations like rotation, translation and scaling are needed. SVG, among other options, allows the user to specify a 3x3 matrix transformation matrix:

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$$\begin{bmatrix} a & c & e \\ b & d & f \\ 0 & 0 & 1 \end{bmatrix}$$

Since the last row of the matrix is always 0 0 1, the matrix is specified as a six value vector. In the render extension each group or graphical primitive is derived from the class **Transformation2D** and can have a `transform` attribute just as in SVG.

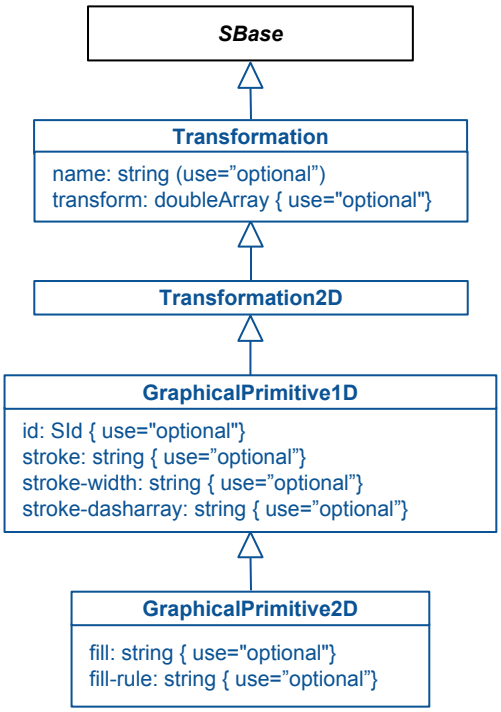

Figure 10: *A UML representation of the base graphical primitive classes for the Render package. See Section 1.4 for conventions related to this figure.*

3.8.1 The Transformation class

The **Transformation** class is a common base class for all elements that can be drawn. Currently there has been no requirement for 3D transformation and this class is only used as a base class for **Transformation2D**. We leave the complete specification of this class for a future version of this document.

The **Transformation** object derives from the ***SBase*** class and thus inherits any attributes and elements that are present on this class. In addition, the **Transformation** object has two optional attributes: `name` and `transform`.

The `name` *attribute*

A **Transformation** has an optional attribute `name` of type `string`. This `name` attribute can be used to give the object a user friendly identifier.

The `transform` *attribute*

A **Transformation** has an optional attribute `transform` of type **doubleArray**. This specifies an affine transformation matrix in three dimensions in which case the array must consist of exactly 12 values. However, we currently limit the Render package to the discussion of 2D transformations.

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3.8.2 The Transformation2D class

Since the current render information specification only defines two dimensional objects, we derive a second class called **Transformation2D** from **Transformation**. As illustrated in Figure 10 the class **Transformation2D** serves as the base class for all drawable 1D and 2D objects.

The `transform` *attribute*

The **Transformation2D** class restricts the transformation matrix to specify the six values of a 2D affine transformation. Thus the `transform` attribute consists of **doubleArray** with exactly 6 values of type `double`. Thus the allowed value for the attribute has the form: "`a, b, c, d, e, f`"

The values for `a`,`b`,`c`,`d`,`e` and `f` depend on the transformation operation components and the order in which those transformation components are executed.

There are four basic transformation operations that can be combined in a affine transformation matrix. Details of these are given in Appendix B on page 69 .

All objects that are derived from **Transformation2D** can have a transformation, this includes group elements. In contrast to other attributes on groups and children of groups, the transformation is not overwritten if it is specified in a child, but rather all transformations that are defined in an object hierarchy accumulate. Thus when a group specifies a transformation and a child of the group also sets a transformation, the transformation for the child has to be applied to the child only and the transformation that is set on the group has to be applied to the whole group, i.e., to all children of the group.

3.9 GraphicalPrimitives

The graphical primitives polygons, rectangles and ellipses are based on the corresponding elements from SVG. For lines, arcs and general path primitives, we introduce the **RenderCurve** element which differs slightly from the Layout package **Curve**. Whereas **Point** objects in the Layout package could only contain absolute values for their coordinates, **RenderPoint** objects in the Render package can contain relative coordinate values. Two primitive abstract classes are defined to specify the common properties of 1D and 2D shapes.

3.9.1 The GraphicalPrimitive1D class

The **GraphicalPrimitive1D** object derives from the **Transformation2D** class and thus inherits any attributes and elements that are present on this class (Figure 10). In addition, the **GraphicalPrimitive1D** object has the optional `id`, `stroke`, `stroke-width` and `stroke-dasharray` attributes.

The `id` *attribute*

A **GraphicalPrimitive1D** has an optional attribute `id` of type `SId` which can be used to uniquely identify the object.

The `stroke` *attribute*

A **GraphicalPrimitive1D** has an optional attribute `stroke` of type `string`. This is used to specify the color of the stroke that is used to draw the curve or the outline of geometric shapes. This `stroke` attribute can either hold a color value or it can hold the id of a predefined **ColorDefinition** object.

The `stroke-width` *attribute*

A **GraphicalPrimitive1D** has an optional attribute `stroke-width` of type `double` which specifies the width of the stroke to be used.

The `stroke-dasharray` *attribute*

A **GraphicalPrimitive1D** has an optional attribute `stroke-dasharray` consisting of an array of values of type `unsigned integer`. This list specifies the lengths of dashes and gaps that are used to draw the line. The individual

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numbers in the list are separated by commas. For example, `"5,10"` would mean to draw 5 points, make a 10 point gap, draw 5 points etc. If the pattern is to start with a gap, the first number has to be 0.

It should be noted that if a style defines a stroke dasharray and this style is applied to a **Curve** from the Layout package, one has to watch out for the fact that the layout curves may contain breaks (if the end point of segment n is not identical to the starting point of segment $n+1$). In this case each of the unbroken line stretches is considered a separate curve object and the line stippling is applied to each curve. That means the line stippling is not continuously applied through the gap, but it starts again after the gap.

3.9.2 The GraphicalPrimitive2D class

The **GraphicalPrimitive2D** object derives from the **GraphicalPrimitive1D** class and thus inherits any attributes and elements that are present on this class (Figure 10). In addition, the **GraphicalPrimitive2D** object has the optional `fill` and `fill-rule` attributes.

The `fill` *attribute*

A **GraphicalPrimitive2D** has an optional attribute `fill` of type `string` which specifies the fill style of the object. The fill style can either be a hexadecimal color value, the id of a **ColorDefinition** object or the id of a **GradientBase** object. Instead of a color or gradient id, "`none`" can be specified which means that the object is unfilled.

The `fill-rule` *attribute*

A **GraphicalPrimitive2D** has an optional attribute `fill-rule` of type **FillRule** that can be used to specify how the shape should be filled.

Currently the `fill-rule` attribute is only useful for polygons. No other shapes have alternating areas.

3.9.3 The RenderCurve class

Simple lines and complex curves are represented by a **RenderCurve** element.

The **RenderCurve** object derives from the **GraphicalPrimitive1D** class (see Figure 11) and thus inherits any attributes and elements that are present on this class. A **RenderCurve** contains at most one **ListOfElements** and at most one **ListOfCurveSegments** from the Layout package. In addition, the **RenderCurve** object has the optional attributes `startHead` and `endHead`.

The `startHead` *attribute*

A **RenderCurve** has an optional attribute `startHead` of type `SIdRef` and points to the **LineEnding** that should be applied to the start of the path.

The `endHead` *attribute*

A **RenderCurve** has an optional attribute `endHead` of type `SIdRef` and points to the **LineEnding** that should be applied to the end of the path.

The ListOfElements class

The **ListOfElements** object inherits the core attributes and subobjects from the **SBase** class. It contains one or more objects of type **RenderPoint** or of the derived type **RenderCubicBezier**. The only restriction is that the first element must be a **RenderPoint**.

The first point specifies the start point of the curve. If the next element is another **RenderPoint**, we have a straight line segment, going from the start point to the second point. Should the second point be a **RenderCubicBezier** a cubic bezier curve will be added from the start point with its values. Thus, the **ListOfElements** holds a concise definition of the curve specifying start and end points for all line segments.

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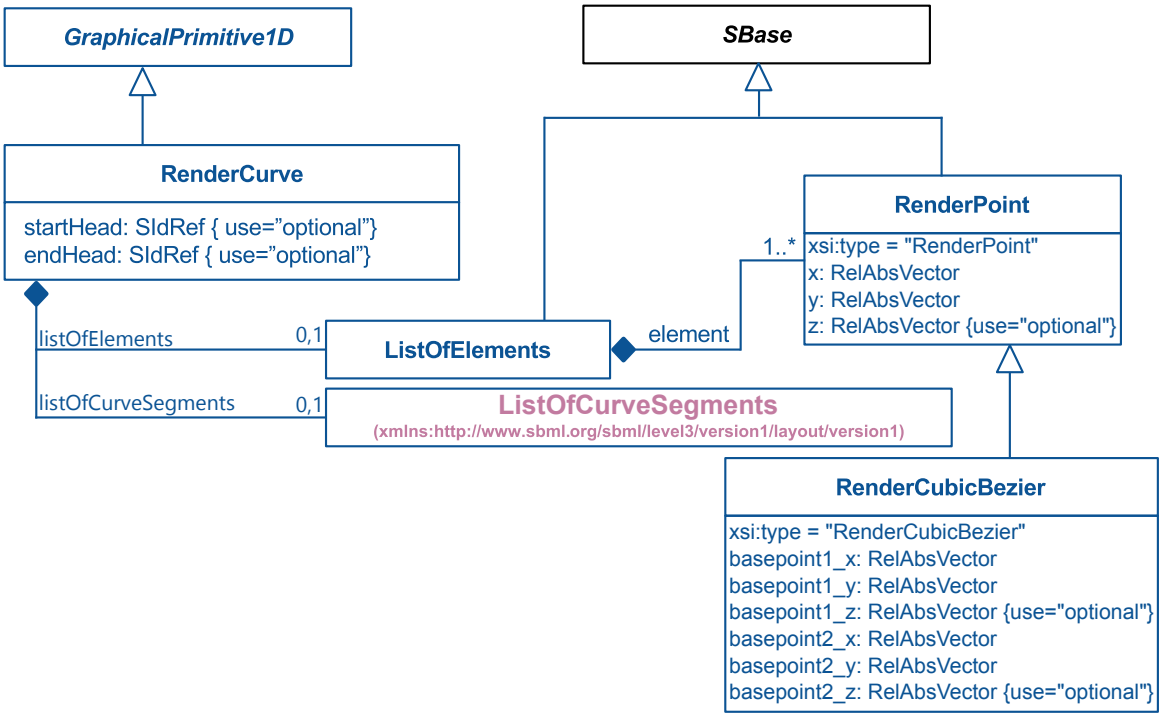

Figure 11: *A UML representation of the* ***RenderCurve*** *classes for the Render package. See Section 1.4 for conventions related to this figure.*

The ListOfCurveSegments

The Layout package defines a similar **Curve** that has identical specification except it is restricted to using absolute values. The classes involved have thus been redefined for the Render package which facilitates the use of relative values. However it is perfectly valid to use the **ListOfLineSegments** object from the Layout package either in place of the **ListOfElements** or In addition, to it.

The example in Section 3.9.5 on the next page illustrates both the **ListOfElements** and **ListOfCurveSegments** objects.

3.9.4 The RenderPoint class

RenderPoint objects are used to specify the individual curve segments.

The **RenderPoint** object derives from the ***SBase*** class and thus inherits any attributes and elements that are present on this class. In addition, the **RenderPoint** object has the required attributes `x` and `y` and the optional attribute `z`. It also has the required attribute `xsi:type`.

The `x`*,* `y` *and* `z` *attributes*

These three attributes are used to specify the coordinates of a **RenderPoint** in two (missing `z`) or three dimensions. They are of type **RelAbsVector** and can thus specify a coordinate as either an absolute or relative value. The coordinate values are always with respect to the bounding box of the layout object to which the render information applies.

The `xsi:type` *attribute*

This attribute is an `xsi:type`. For a **RenderPoint** object this attribute will always have the value "`RenderPoint`".

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3.9.5 The RenderCubicBezier class

The **RenderCubicBezier** object derives from the **RenderPoint** class and thus inherits any attributes and elements that are present on this class. In addition, the **RenderCubicBezier** object has the required attributes `basePoint1_x`, `basePoint1_y`, `basePoint2_x` and `basePoint2_y`. It also has the optional attributes `basePoint1_z` and `basePoint2_z`.

The `basePoint1_x`*,* `basePoint1_y` *and* `basePoint1_z` *attributes*

These three attributes are used to specify the coordinates of the first basepoint of a **RenderCubicBezier** in two (missing `basePoint1_z`) or three dimensions. They are of type **RelAbsVector** and can thus specify a coordinate as either an absolute or relative value. The coordinate values are always with respect to the bounding box of the layout object to which the render information applies.

The `basePoint2_x`*,* `basePoint2_y` *and* `basePoint2_z` *attributes*

These three attributes are used to specify the coordinates of the second basepoint of a **RenderCubicBezier** in two (missing `basePoint2_z`) or three dimensions. They are of type **RelAbsVector** and can thus specify a coordinate as either an absolute or relative value. The coordinate values are always with respect to the bounding box of the layout object to which the render information applies.

The `xsi:type` *attribute*

This attribute is an `xsi:type`. For a **RenderCubicBezier** object this attribute will always have the value "`RenderCubicBezier`".

The example snippet illustrates the definition of a **RenderCurve** with two line segments that are to be painted using a black stroke with width 2.0. The first line segment is a straight segment going from the objects left middle (0%, 50%) to the right middle(100%, 50%). The second segment represents a cubic bezier, that continues from the right middle(100%, 50%) back to the left middle(0%, 50%) with two control points at (50%, 90%). The equivalent curve defined using the **ListOfLineSegments** from the Layout package is also included (assuming a 100 × 100 square object).

```
<render:g ...>

  <!-- the curve is defined in the render namespace -->
  <render:curve render:stroke-width="2.0" render:stroke="#000000" >

    <!-- using the listOfElements from the render namespace -->
    <render:listOfElements>
      <!-- define the first point -->
      <render:element xsi:type="RenderPoint" render:x="0%" render:y="50%" />

      <!-- The next item starts at the previous point -->
      <!-- It is also a point so draw a straight line from the start point to here -->
      <render:element xsi:type="RenderPoint" render:x="100%" render:y="50%" />

      <!-- The next item starts at the previous point -->
      <!-- It is a cubic bezier so draw a curve using the basepoints from the start point to here -->
      <render:element xsi:type="RenderCubicBezier" render:x="0%" render:y="50%"
              render:basePoint1_x="50%" render:basePoint1_y="90%"
              render:basePoint2_x="50%" render:basePoint2_y="90%" />
    </render:listOfElements>

    <!-- using the listOfCurveSegments from the layout namespace -->
    <layout:listOfCurveSegments>

      <!-- the first segment is a line from start to end point -->
      <layout:curveSegment xsi:type="LineSegment">
        <layout:start layout:x="0" layout:y="50" />
        <layout:end layout:x="100" layout:y="50"/>
```


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```
      </layout:curveSegment>

      <!-- the second segment is a curve from start to end with given basepoints -->
      <layout:curveSegment xsi:type="CubicBezier">
        <layout:start layout:x="100" layout:y="50" />
        <layout:end layout:x="0" layout:y="50"/>
        <layout:basePoint1 layout:x="50" layout:y="90"/>
        <layout:basePoint2 layout:x="50" layout:y="90"/>
      </layout:curveSegment>
    </layout:listOfCurveSegments>

  </render:curve>
  ...
</render:g>
```


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3.10 Geometric Shapes

This section details the classes of geometric objects that can be defined using the transformations and graphical primitives described (see Figure 12).

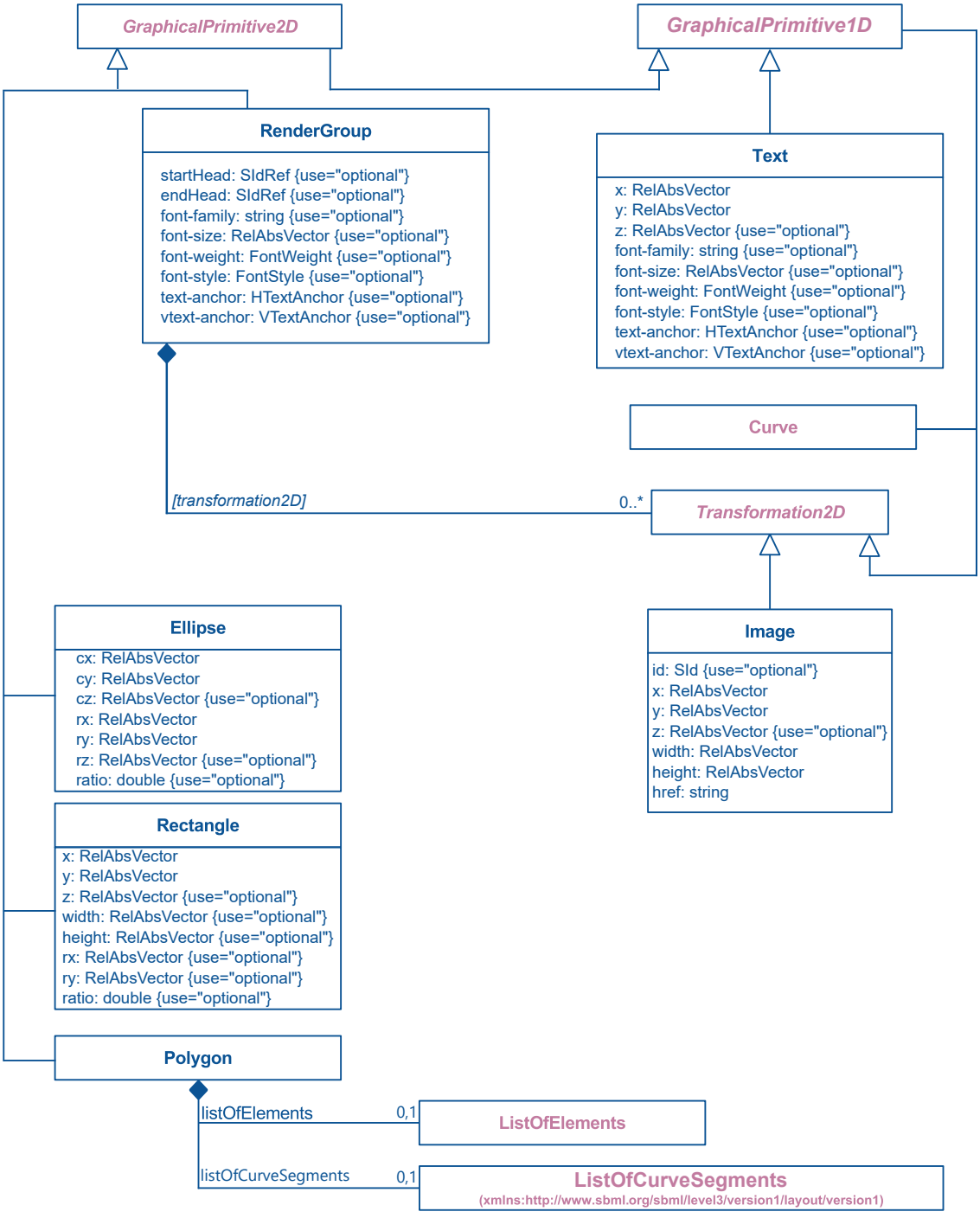

Figure 12: *A UML representation of the graphical primitive classes for the Render package. See Section 1.4 for conventions related to this figure.*

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3.10.1 The Polygon class

A **Polygon** object is made up of a `polygon` element which contains at most one **ListOfElements** and/or one **ListOfCurveSegments** used to define the edges of the polygon.

The major difference to the **RenderCurve** object is that the object is always closed. That is, the last point of the curve is connected to the first. Therefore, the polygon can have a fill style that determines how the inside of the polygon is to be rendered.

The example snippet shows the render specification of a **Polygon** and of an unclosed path. It uses a black pen with width 3, and a red fill brush. Figure 13 illustrates these shapes (without the red fill!).

```
<g ...>
   <!-- define a path with three points -->
   <curve stroke="#000000" stroke-width="3">
     <listOfElements>
       <element xsi:type="RenderPoint" x="0%" y="0%"/>
       <element xsi:type="RenderPoint" x="100%" y="0%"/>
       <element xsi:type="RenderPoint" x="0%" y="100%"/>
     </listOfElements>
   </curve>

   <!-- the same points defined as a polygon
         so the last point draws a line to the first point -->
   <polygon stroke="#000000" stroke-width="3" fill="#FF0000">
     <listOfElements>
       <element xsi:type="RenderPoint" x="0%" y="0%"/>
       <element xsi:type="RenderPoint" x="100%" y="0%"/>
       <element xsi:type="RenderPoint" x="0%" y="100%"/>
     </listOfElements>
   </polygon>
</g>
```

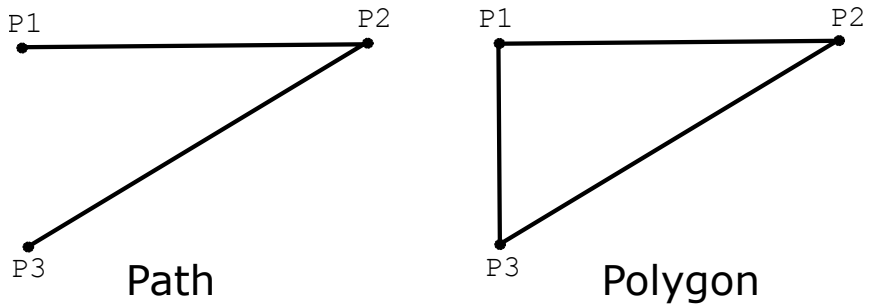

Figure 13: *Rendering of a Path vs. rendering of a Polygon with the same base points*

3.10.2 The Rectangle class

The **Rectangle** object was taken from the SVG specification and allows the definition of rectangles with or without rounded edges.

The **Rectangle** object derives from the **GraphicalPrimitive2D** class and thus inherits any attributes and elements that are present on this class. In addition, the **Rectangle** object has the required attributes `x`, `y`, `height`, and `width` as well as the optional attributes `z`, `rx`, `ry` and `ratio`.

The `x`*,* `y` *and* `z` *attributes*

These attributes are of type **RelAbsVector** and specify its position within the bounding box of the enclosing **Layout** object.

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The `width` *and* `height` *attributes*

These attributes are of type **RelAbsVector** and specify the width and height of the rectangle, either in absolute values or as a percentage of the width and height of the enclosing bounding box.

The `rx` *and* `ry` *attributes*

These attributes are of type **RelAbsVector** and specify the radius of the corner curvature. If only `rx` or `ry` is specified, the other is presumed to have the same value as the one given. If no values are supplied, this means that the edges are not rounded. The relative values in rx and ry are in relation to the width and the height of the rectangle respectively. So a value of 10% for rx means the radius of the corner is 10% of the width of the rectangle.

The `ratio` *attribute*

If the optional `ratio` attribute of `double` is set, the biggest rectangle with the desired ratio of width to height is to be drawn centered in the objects bounding box. Using this approach makes it possible to always encode a square (by specifying `ratio="1"`), even if used with relative radii and a rectangular bounding box.

3.10.3 The Ellipse class

The **Ellipse** object derives from the **GraphicalPrimitive2D** class and thus inherits any attributes and elements that are present on this class. In addition, the **Ellipse** object has the required attributes `cx`, `cy` and `rx` and the optional attributes `ry`, `cz` and `ratio`.

The `cx`*,* `cy` *and* `cz` *attributes*

These attributes are of type **RelAbsVector** and specify the center of the ellipse.

The `rx` *and* `ry` *attributes*

These attributes are of type **RelAbsVector** and specify the radius of the ellipse along the x-axis and y-axis, respectively. If only one value is specified, the other is assumed to have the same value.

Circles are a special case where the `rx` and `ry` attributes have the same value. However, a circle will only be encoded if either the radii are specified absolutely, or if the bounding box is square. To encode circles for arbitrary bounding boxes and relative positioning please see the `ratio` attribute below.

The `ratio` *attribute*

If the optional `ratio` attribute of `double` is set, the biggest ellipse with the desired ratio of width to height is to be drawn centered in the objects bounding box. Using this approach makes it possible to always encode a circle (by specifying `ratio="1"`), even if used with relative radii and a rectangular bounding box.

3.10.4 The Text class

In order to draw text, we use the `text` element from SVG with slight modifications. For reasons of simplicity, we limit the display of text to normal text. Outlined or filled-outlined text are not supported.

Since we have a right handed coordinate system, the positive y-axis normally faces downward on the screen if the positive z-axis goes into the screen. This means that text actually has to be rendered with the top towards lower y-values.

The **Text** object derives from the **GraphicalPrimitive1D** class and thus inherits any attributes and elements that are present on this class. In addition, the **Text** object has the required attributes `x` and `y` and the optional attributes `z`, `font-size`, `font-family`, `font-weight`, `font-style`, `text-anchor` and `vtext-anchor`.

The actual text to be rendered will be written as inline text characters of the **Text** element. Note that it is valid to have a **Text** element with empty characters.

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The `x` *attribute*

The `x` attribute is of type **RelAbsVector** and specifies the position of the horizontal text anchor.

The `y` *attribute*

The `y` attribute is of type **RelAbsVector** and specifies the position of the vertical text anchor.

The `z` *attribute*

The `z` attribute is of type **RelAbsVector** and directly specifies the depth value of the text element since there is no alignment attribute for text in the third dimension.

The `font-size` *attribute*

A **Text** has an optional attribute `font-size` of type **RelAbsVector** which must have a positive value. In the case of a relative value it specifies a percentage of the height of the corresponding object. Combinations of relative and absolute values are not allowed.

The `font-family` *attribute*

A **Text** has an optional attribute `font-family` of type `string` that allows to specify the font or font-family to be used for the text element. For maximum interoperability the font families specified in **FontFamily** have to be supported at a minimum. Those are the generic families "`serif`", "`sans-serif`" and "`monospace`".

The `font-weight` *attribute*

A **Text** has an optional attribute `font-weight` of type **FontWeight** and specifies if the text is to be "`normal`" or "`bold`".

The `font-style` *attribute*

A **Text** has an optional attribute `font-style` of type **FontStyle** which specifies whether the style for the text is to be "`italic`" or "`normal`".

The `text-anchor` *attribute*

A **Text** has an optional attribute `text-anchor` of type **HTextAnchor** which specifies the horizontal alignment of the text (see Appendix A on page 65).

The `vtext-anchor` *attribute*

A **Text** has an optional attribute `vtext-anchor` of type **VTextAnchor** which specifies the vertical alignment of the text (see Appendix A on page 65).

Note that since the way text is drawn is completely determined by the font specification, text elements should ignore the stroke-width attribute that they inherit from **GraphicalPrimitive1D**.

3.10.5 The Image class

To include bitmaps into a graphical representation we use the **Image** element from SVG. However, the use of the **Image** element to include complete SVG vector images has been excluded.

The **Image** object derives from the **Transformation2D** class and thus inherits any attributes and elements that are present on this class. In addition, the **Image** object has the optional attributes `id` and `z` and the attributes `x`, `y`, `width`, `height` and `href` that are required.

The `id` *attribute*

An **Image** has an optional attribute `id` of type `SId` that can be used to give the **Image** a unique identifier.

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The `x`*,* `y` *and* `z` *attributes*

These attributes are of type **RelAbsVector** and specify the position of the **Image** within its bounding box.

The `width` *and* `height` *attributes*

These attributes are of type **RelAbsVector** and specify the width and height to be used for the **Image**. These attributes are both required.

The `href` *attribute*

An **Image** has a required attribute `href` of type `string` which encodes a reference to an external JPEG or PNG file. The reference must be an absolute or relative path to a local file. Non-local image resources (e.g., from the net) are currently not supported.

Note that if the referenced image is larger then the given width and height, it has to be scaled to the given dimensions. If the referenced resource cannot be found, it is up to the application if nothing is drawn or some place holder is displayed. Preferably, the user would get some kind of notification about the missing resource.

The example shows the encoding for including the file Glucose.png.

```
 <g ...>
  <image x="10%" y="10%" width="80" height="100" href="Glucose.png" />
      ...
</g>
```

3.10.6 The RenderGroup class

Similar to the technique used by SVG, several graphical primitives can be grouped inside a `g` element to generate more complex render information.

The **RenderGroup** object derives from the **GraphicalPrimitive2D** class and thus inherits any attributes and elements that are present on this class. A **RenderGroup** contains one or more child elements that can be any class derived from the **Transformation2D** class. In addition, the **RenderGroup** object has the following attributes.

The `startHead` *and* `endHead` *attributes*

A **RenderGroup** has optional attributes `startHead` and `endHead` of type `SIdRef` which point to a **LineEnding** for the start and end of curves, respectively. These attributes only apply to the outermost **RenderCurve** objects in the outermost group of a style. Thus, they do not apply to polygons or more complex shapes.

The `font-size`*,* `font-family`*,* `font-weight` *,* `font-style`*,* `text-anchor` *and* `vtext-anchor` *attributes*

These attributes are of the same types as the identically named attributes specified on the **Text** object. If any of those attributes is specified for a **RenderGroup** object, it specifies the corresponding attribute for all graphical primitives and groups defined within this group. If a graphical primitive or a group redefines one or more of those attributes, the newly defined values take effect.

3.11 The LineEnding class

In many graphs the relations between nodes are depicted by lines and often the type of relation is encoded in the line ending. For this reason, the render extension provides ways to specify a set of arbitrary line endings and means to apply those to other objects. More information is provide in Appendix C.1.

The **LineEnding** object derives from the **GraphicalPrimitive2D** class and thus inherits any attributes and elements that are present on this class. A **LineEnding** contains exactly one **BoundingBox** element from the Layout package which allows the `position` and `dimensions` to be specified. It also contains a **RenderGroup** element which provides the necessary render information for the line ending.

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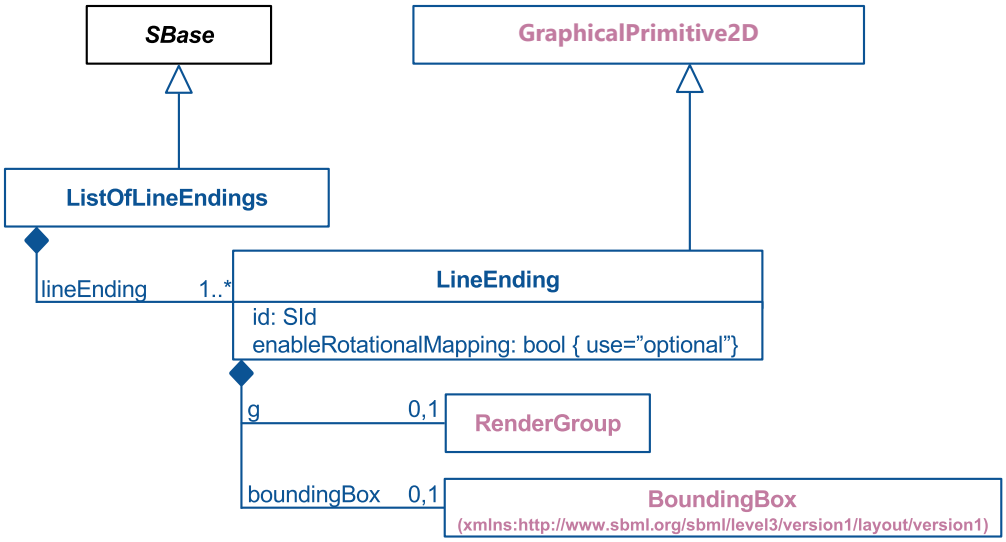

Figure 14: *A UML representation of the* ***LineEnding*** *class for the Render package. See Section 1.4 for conventions related to this figure.*

In addition, the **LineEnding** object has the a required `id` attribute and an optional `enableRotationalMapping` attribute.

The `id` *attribute*

A **LineEnding** has a required attribute `id` of type `SId` which allows a unique identifier to be provided for this **LineEnding** so that it may be referenced by other objects. The `startHead` and `endHead` attributes on a **RenderCurve** expect to point to the `id` of a **LineEnding**.

The `enableRotationalMapping` *attribute*

A **LineEnding** has an optional attribute `enableRotationalMapping` of type `boolean` which specifies whether a line ending will be rotated depending on the slope of the line it is applied to (if "`true`") or if it is drawn just the way it was specified (if "`false`").

It should be noted that the top level **RenderGroup** in a **LineEnding** differs from top level groups in normal graphical elements in one respect; that is, the top level **RenderGroup** of a **LineEnding** inherits all attributes from the line it is applied to except for the attributes for the line endings themselves. This way a style sheet can define one line ending which can be applied to lines of different colors and it inherits the color from the line. If the group also inherited the attributes for the line endings and it contained a `curve` element itself, we would have generated an endless loop.

The example snippet shows the definition of an arrow head.

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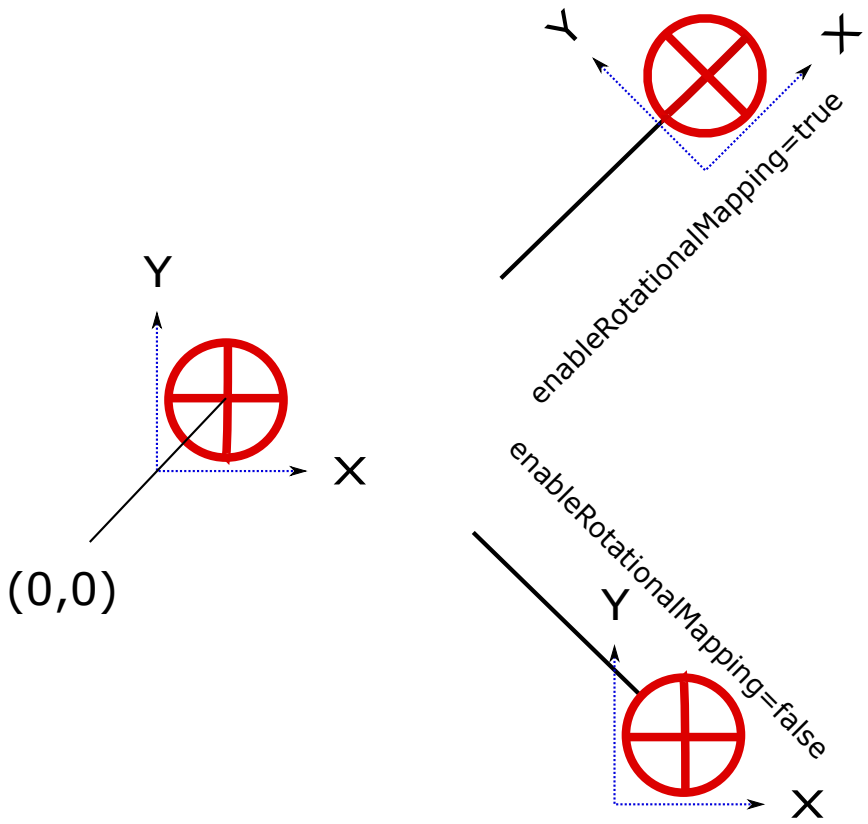

Figure 15: *example of a line ending with and without rotation mapping enabled*

```
<lineEnding id="SimpleArrowHead">
 <boundingBox>
   <position x="-10.0" y="-4.0" />
   <dimensions width="12.0" height="8.0"/>
 </boundingBox>
 <g>
   <polygon>
     <curve>
       <listOfCurveSegments>
         <curveSegment xsi:type="LineSegment">
           <start x="100%" y="50%" />
           <end x="0%" y="100%" />
         </curveSegment>
         <curveSegment xsi:type="LineSegment">
           <start x="0%" y="100%" />
           <end x="0%" y="0%" />
         </curveSegment>
       </listOfCurveSegments>
     </curve>
   </polygon>
 </g>
</lineEnding>
```


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4 Illustrative examples of the Render syntax

This is an example on how an SBGN document could be represented using the SBML layout and render extensions. The example represented once as an SBML Level 2 Version 1 document using annotations and once as an SBML Level 3 Version 1 document with the layout and render extension packages.

The example contains only one simple layout and three global as well as one local style. Although this example does not show all features of the render extension, it should give a good overview on how the layout and the render extension are used together.

The following four figures are generated from this example using the xslt style sheet implementation with xsltproc. The SVG images were then rendered with the Chrome Browser from Google. Additional implementations are available in COPASI (Hoops et al., 2006) as well as SBW (Bergmann and Sauro, 2006).

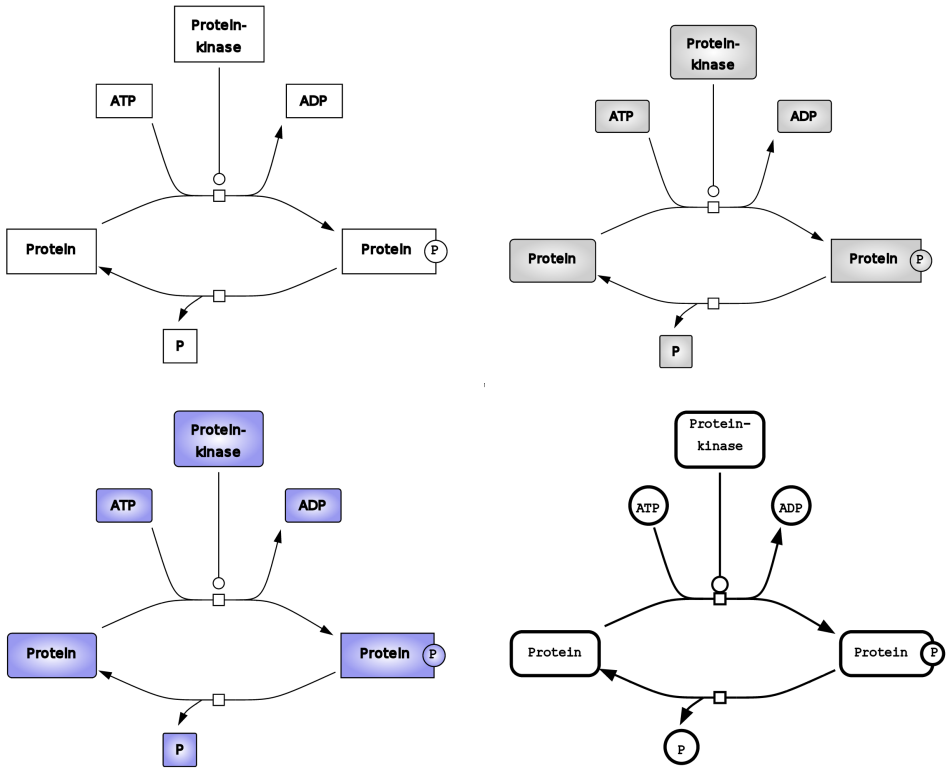

Figure 16: *example converted to SVG and rendered with Google Chrome browser*

SBML Level 3 Version 1

```
<?xml version="1.0" encoding="UTF-8"?>
<sbml xmlns="http://www.sbml.org/sbml/level3/version1/core"
  xmlns:layout="http://www.sbml.org/sbml/level3/version1/layout/version1"
  xmlns:render="http://www.sbml.org/sbml/level3/version1/render/version1"
  level="3" version="1">
  <model id="ProteinPhosphorylation" substanceUnits="substance"
    timeUnits="second" volumeUnits="volume" areaUnits="area" lengthUnits="metre"
    extentUnits="substance">
    <listOfUnitDefinitions>
```


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```
    <unitDefinition id="volume">
      <listOfUnits>
        <unit kind="litre" exponent="1" scale="0" multiplier="1" />
      </listOfUnits>
    </unitDefinition>
    <unitDefinition id="substance">
      <listOfUnits>
        <unit kind="mole" exponent="1" scale="0" multiplier="1" />
      </listOfUnits>
    </unitDefinition>
    <unitDefinition id="area">
      <listOfUnits>
        <unit kind="metre" exponent="2" scale="0" multiplier="1" />
      </listOfUnits>
    </unitDefinition>
  </listOfUnitDefinitions>
  <listOfCompartments>
    <compartment id="Cell" spatialDimensions="3" units="volume"
      constant="true" />
  </listOfCompartments>
  <listOfSpecies>
    <species id="Protein" name="Protein" compartment="Cell"
      substanceUnits="substance" hasOnlySubstanceUnits="false"
      boundaryCondition="false" constant="false" />
    <species id="ProteinP" name="Protein" compartment="Cell"
      substanceUnits="substance" hasOnlySubstanceUnits="false"
      boundaryCondition="false" constant="false" />
    <species id="ATP" name="ATP" compartment="Cell"
      substanceUnits="substance" hasOnlySubstanceUnits="false"
      boundaryCondition="false" constant="false" />
    <species id="ADP" name="ADP" compartment="Cell"
      substanceUnits="substance" hasOnlySubstanceUnits="false"
      boundaryCondition="false" constant="false" />
    <species id="P" name="P" compartment="Cell" substanceUnits="substance"
      hasOnlySubstanceUnits="false" boundaryCondition="false" constant="false" />
    <species id="ProteinKinase" name="Protein␣Kinase"
      compartment="Cell" substanceUnits="substance" hasOnlySubstanceUnits="false"
      boundaryCondition="false" constant="false" />
  </listOfSpecies>
  <listOfReactions>
    <reaction id="Phosphorylation" reversible="false" fast="false">
      <listOfReactants>
        <speciesReference id="SpeciesReference_Protein"
          species="Protein" stoichiometry="1" constant="true" />
        <speciesReference id="SpeciesReference_ATP"
          species="ATP" stoichiometry="1" constant="true" />
      </listOfReactants>
      <listOfProducts>
        <speciesReference id="SpeciesReference_ProteinP"
          species="ProteinP" stoichiometry="1" constant="true" />
        <speciesReference id="SpeciesReference_ADP"
          species="ADP" stoichiometry="1" constant="true" />
      </listOfProducts>
      <listOfModifiers>
        <modifierSpeciesReference id="ModifierSpeciesReference_ProteinKinase"
          species="ProteinKinase" />
      </listOfModifiers>
    </reaction>
    <reaction id="Dephosphorylation" reversible="false" fast="false">
      <listOfReactants>
        <speciesReference id="SpeciesReference_ProteinP_rev"
          species="ProteinP" stoichiometry="1" constant="true" />
      </listOfReactants>
      <listOfProducts>
        <speciesReference id="SpeciesReference_Protein_rev"
          species="Protein" stoichiometry="1" constant="true" />
```


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```
        <speciesReference id="SpeciesReference_P" species="P"
          stoichiometry="1" constant="true" />
      </listOfProducts>
    </reaction>
  </listOfReactions>
  <layout:listOfLayouts xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:layout="http://www.sbml.org/sbml/level3/version1/layout/version1">
    <layout:layout layout:id="Layout_1">
      <layout:dimensions layout:width="450"
        layout:height="400" />
      <layout:listOfSpeciesGlyphs>
        <layout:speciesGlyph layout:id="SpeciesGlyph_Protein"
          layout:species="Protein">
          <layout:boundingBox layout:id="bb1">
            <layout:position layout:x="30" layout:y="230" />
            <layout:dimensions layout:width="80"
              layout:height="40" />
          </layout:boundingBox>
        </layout:speciesGlyph>
        <layout:speciesGlyph layout:id="SpeciesGlyph_ProteinP"
          render:objectRole="phosphorylated" layout:species="ProteinP">
          <layout:boundingBox layout:id="bb2">
            <layout:position layout:x="330" layout:y="230" />
            <layout:dimensions layout:width="93"
              layout:height="40" />
          </layout:boundingBox>
        </layout:speciesGlyph>
        <layout:speciesGlyph layout:id="SpeciesGlyph_ATP"
          layout:species="ATP">
          <layout:boundingBox layout:id="bb3">
            <layout:position layout:x="110" layout:y="100" />
            <layout:dimensions layout:width="50"
              layout:height="30" />
          </layout:boundingBox>
        </layout:speciesGlyph>
        <layout:speciesGlyph layout:id="SpeciesGlyph_ADP"
          layout:species="ADP">
          <layout:boundingBox layout:id="bb4">
            <layout:position layout:x="280" layout:y="100" />
            <layout:dimensions layout:width="50"
              layout:height="30" />
          </layout:boundingBox>
        </layout:speciesGlyph>
        <layout:speciesGlyph layout:id="SpeciesGlyph_P"
          layout:species="P">
          <layout:boundingBox layout:id="bb5">
            <layout:position layout:x="170" layout:y="320" />
            <layout:dimensions layout:width="30"
              layout:height="30" />
          </layout:boundingBox>
        </layout:speciesGlyph>
        <layout:speciesGlyph layout:id="SpeciesGlyph_ProteinKinase"
          layout:species="ProteinKinase">
          <layout:boundingBox layout:id="bb6">
            <layout:position layout:x="180" layout:y="30" />
            <layout:dimensions layout:width="80"
              layout:height="50" />
          </layout:boundingBox>
        </layout:speciesGlyph>
      </layout:listOfSpeciesGlyphs>
      <layout:listOfReactionGlyphs>
        <layout:reactionGlyph layout:id="ReactionGlyph_Phosphorylation"
          layout:reaction="Phosphorylation">
          <layout:boundingBox layout:id="bb7">
            <layout:position layout:x="205" layout:y="195" />
            <layout:dimensions layout:width="30"
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```
        layout:height="10" />
    </layout:boundingBox>
    <layout:listOfSpeciesReferenceGlyphs>
      <layout:speciesReferenceGlyph
        layout:id="SpeciesReferenceGlyph_Protein" render:objectRole="substrate"
        layout:speciesReference="SpeciesReference_Protein"
        layout:speciesGlyph="SpeciesGlyph_Protein" layout:role="substrate">
        <layout:curve>
          <layout:listOfCurveSegments>
            <layout:curveSegment
              xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
              xsi:type="CubicBezier">
              <layout:start layout:x="115" layout:y="225" />
              <layout:end layout:x="205" layout:y="200" />
              <layout:basePoint1 layout:x="170" layout:y="200" />
              <layout:basePoint2 layout:x="170" layout:y="200" />
            </layout:curveSegment>
          </layout:listOfCurveSegments>
        </layout:curve>
      </layout:speciesReferenceGlyph>
      <layout:speciesReferenceGlyph
        layout:id="SpeciesReferenceGlyph_ATP" render:objectRole="sidesubstrate"
        layout:speciesReference="SpeciesReference_ATP"
        layout:speciesGlyph="SpeciesGlyph_ATP" layout:role="sidesubstrate">
        <layout:curve>
          <layout:listOfCurveSegments>
            <layout:curveSegment
              xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
              xsi:type="CubicBezier">
              <layout:start layout:x="160" layout:y="135" />
              <layout:end layout:x="205" layout:y="200" />
              <layout:basePoint1 layout:x="180" layout:y="200" />
              <layout:basePoint2 layout:x="180" layout:y="200" />
            </layout:curveSegment>
          </layout:listOfCurveSegments>
        </layout:curve>
      </layout:speciesReferenceGlyph>
      <layout:speciesReferenceGlyph
        layout:id="SpeciesReferenceGlyph_ProteinP" render:objectRole="product"
        layout:speciesReference="SpeciesReference_ProteinP"
        layout:speciesGlyph="SpeciesGlyph_ProteinP" layout:role="product">
        <layout:curve>
          <layout:listOfCurveSegments>
            <layout:curveSegment
              xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
              xsi:type="CubicBezier">
              <layout:start layout:x="235" layout:y="200" />
              <layout:end layout:x="320" layout:y="230" />
              <layout:basePoint1 layout:x="270" layout:y="200" />
              <layout:basePoint2 layout:x="270" layout:y="200" />
            </layout:curveSegment>
          </layout:listOfCurveSegments>
        </layout:curve>
      </layout:speciesReferenceGlyph>
      <layout:speciesReferenceGlyph
        layout:id="SpeciesReferenceGlyph_ADP" render:objectRole="sideproduct"
        layout:speciesReference="SpeciesReference_ADP"
        layout:speciesGlyph="SpeciesGlyph_ADP" layout:role="sideproduct">
        <layout:curve>
          <layout:listOfCurveSegments>
            <layout:curveSegment
              xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
              xsi:type="CubicBezier">
              <layout:start layout:x="235" layout:y="200" />
              <layout:end layout:x="275" layout:y="140" />
              <layout:basePoint1 layout:x="260" layout:y="200" />
```


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                    <layout:basePoint2 layout:x="260" layout:y="200" />
                  </layout:curveSegment>
                </layout:listOfCurveSegments>
              </layout:curve>
            </layout:speciesReferenceGlyph>
            <layout:speciesReferenceGlyph
              layout:id="SpeciesReferenceGlyph_ProteinKinase"
              render:objectRole="catalyst"
              layout:speciesReference="ModifierSpeciesReference_ProteinKinase"
              layout:speciesGlyph="SpeciesGlyph_ProteinKinase" layout:role="activator">
              <layout:curve>
                <layout:listOfCurveSegments>
                  <layout:curveSegment
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                    xsi:type="LineSegment">
                    <layout:start layout:x="220" layout:y="85" />
                    <layout:end layout:x="220" layout:y="180" />
                  </layout:curveSegment>
                </layout:listOfCurveSegments>
              </layout:curve>
            </layout:speciesReferenceGlyph>
          </layout:listOfSpeciesReferenceGlyphs>
        </layout:reactionGlyph>
        <layout:reactionGlyph layout:id="ReactionGlyph_Dephosphorylation"
          layout:reaction="Dephosphorylation">
          <layout:boundingBox layout:id="bb8">
            <layout:position layout:x="205" layout:y="285" />
            <layout:dimensions layout:width="30"
              layout:height="10" />
          </layout:boundingBox>
          <layout:listOfSpeciesReferenceGlyphs>
            <layout:speciesReferenceGlyph
              layout:id="SpeciesReferenceGlyph_ProteinP_rev"
              render:objectRole="substrate" layout:speciesReference="SpeciesReference_ProteinP_rev"
              layout:speciesGlyph="SpeciesGlyph_ProteinP" layout:role="substrate">
              <layout:curve>
                <layout:listOfCurveSegments>
                  <layout:curveSegment
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                    xsi:type="CubicBezier">
                    <layout:start layout:x="325" layout:y="265" />
                    <layout:end layout:x="235" layout:y="290" />
                    <layout:basePoint1 layout:x="270" layout:y="290" />
                    <layout:basePoint2 layout:x="270" layout:y="290" />
                  </layout:curveSegment>
                </layout:listOfCurveSegments>
              </layout:curve>
            </layout:speciesReferenceGlyph>
            <layout:speciesReferenceGlyph
              layout:id="SpeciesReferenceGlyph_Protein_rev" render:objectRole="product"
              layout:speciesReference="SpeciesReference_Protein_rev"
              layout:speciesGlyph="SpeciesGlyph_Protein" layout:role="product">
              <layout:curve>
                <layout:listOfCurveSegments>
                  <layout:curveSegment
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                    xsi:type="CubicBezier">
                    <layout:start layout:x="205" layout:y="290" />
                    <layout:end layout:x="115" layout:y="265" />
                    <layout:basePoint1 layout:x="170" layout:y="290" />
                    <layout:basePoint2 layout:x="170" layout:y="290" />
                  </layout:curveSegment>
                </layout:listOfCurveSegments>
              </layout:curve>
            </layout:speciesReferenceGlyph>
            <layout:speciesReferenceGlyph
```


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```
            layout:id="SpeciesReferenceGlyph_P" render:objectRole="sideproduct"
            layout:speciesReference="SpeciesReference_P"
            layout:speciesGlyph="SpeciesGlyph_P" layout:role="sideproduct">
            <layout:curve>
              <layout:listOfCurveSegments>
                <layout:curveSegment
                  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                  xsi:type="CubicBezier">
                  <layout:start layout:x="205" layout:y="290" />
                  <layout:end layout:x="185" layout:y="310" />
                  <layout:basePoint1 layout:x="190" layout:y="300" />
                  <layout:basePoint2 layout:x="190" layout:y="300" />
                </layout:curveSegment>
              </layout:listOfCurveSegments>
            </layout:curve>
          </layout:speciesReferenceGlyph>
        </layout:listOfSpeciesReferenceGlyphs>
      </layout:reactionGlyph>
    </layout:listOfReactionGlyphs>
    <layout:listOfTextGlyphs>
      <layout:textGlyph layout:id="TextGlyph_Protein"
        layout:originOfText="Protein" layout:graphicalObject="SpeciesGlyph_Protein">
        <layout:boundingBox layout:id="bb9">
          <layout:position layout:x="30" layout:y="220" />
          <layout:dimensions layout:width="80"
            layout:height="40" />
        </layout:boundingBox>
      </layout:textGlyph>
      <layout:textGlyph layout:id="TextGlyph_ProteinP"
        layout:originOfText="ProteinP" layout:graphicalObject="SpeciesGlyph_ProteinP">
        <layout:boundingBox layout:id="bb10">
          <layout:position layout:x="330" layout:y="220" />
          <layout:dimensions layout:width="80"
            layout:height="40" />
        </layout:boundingBox>
      </layout:textGlyph>
      <layout:textGlyph layout:id="TextGlyph_ATP"
        layout:originOfText="ATP" layout:graphicalObject="SpeciesGlyph_ATP">
        <layout:boundingBox layout:id="bb11">
          <layout:position layout:x="110" layout:y="95" />
          <layout:dimensions layout:width="50"
            layout:height="30" />
        </layout:boundingBox>
      </layout:textGlyph>
      <layout:textGlyph layout:id="TextGlyph_ADP"
        layout:originOfText="ADP" layout:graphicalObject="SpeciesGlyph_ADP">
        <layout:boundingBox layout:id="bb12">
          <layout:position layout:x="280" layout:y="95" />
          <layout:dimensions layout:width="50"
            layout:height="30" />
        </layout:boundingBox>
      </layout:textGlyph>
      <layout:textGlyph layout:id="TextGlyph_P"
        layout:originOfText="P" layout:graphicalObject="SpeciesGlyph_P">
        <layout:boundingBox layout:id="bb13">
          <layout:position layout:x="170" layout:y="315" />
          <layout:dimensions layout:width="30"
            layout:height="30" />
        </layout:boundingBox>
      </layout:textGlyph>
      <layout:textGlyph layout:id="TextGlyph_ProteinKinase1"
        layout:text="Protein-" layout:graphicalObject="SpeciesGlyph_ProteinKinase">
        <layout:boundingBox layout:id="bb14">
          <layout:position layout:x="180" layout:y="35" />
          <layout:dimensions layout:width="80"
            layout:height="20" />
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            </layout:boundingBox>
          </layout:textGlyph>
          <layout:textGlyph layout:id="TextGlyph_Proteinkinase2"
            layout:text="kinase" layout:graphicalObject="SpeciesGlyph_ProteinKinase">
            <layout:boundingBox layout:id="bb15">
              <layout:position layout:x="180" layout:y="55" />
              <layout:dimensions layout:width="80"
                layout:height="20" />
            </layout:boundingBox>
          </layout:textGlyph>
        </layout:listOfTextGlyphs>
        <render:listOfRenderInformation
          xmlns:render="http://www.sbml.org/sbml/level3/version1/render/version1"
          render:versionMajor="1" render:versionMinor="0">
          <render:renderInformation render:id="SBGN"
            render:programName="Ralph␣Gauges" render:programVersion="1.0"
            render:backgroundColor="#FFFFFFFF">
            <render:listOfColorDefinitions>
              <render:colorDefinition render:id="black"
                render:value="#000000" />
              <render:colorDefinition render:id="white"
                render:value="#ffffff" />
            </render:listOfColorDefinitions>
            <render:listOfLineEndings>
              <render:lineEnding
                xmlns:layout="http://www.sbml.org/sbml/level3/version1/layout/version1"
                render:id="productionHead">
                <layout:boundingBox>
                  <layout:position layout:x="-10" layout:y="-6" />
                  <layout:dimensions layout:width="14"
                    layout:height="10" />
                </layout:boundingBox>
                <render:g render:stroke="black" render:stroke-width="1"
                  render:fill="black">
                  <render:polygon render:stroke="black"
                    render:stroke-width="1" render:fill="black">
                    <render:listOfElements>
                      <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                        xsi:type="RenderPoint" render:x="0" render:y="0" />
                      <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                        xsi:type="RenderPoint" render:x="14" render:y="5" />
                      <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                        xsi:type="RenderPoint" render:x="14" render:y="5" />
                      <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                        xsi:type="RenderPoint" render:x="0" render:y="10" />
                    </render:listOfElements>
                  </render:polygon>
                </render:g>
              </render:lineEnding>
              <render:lineEnding
                xmlns:layout="http://www.sbml.org/sbml/level3/version1/layout/version1"
                render:id="catalysisHead">
                <layout:boundingBox>
                  <layout:position layout:x="0" layout:y="-7" />
                  <layout:dimensions layout:width="14"
                    layout:height="14" />
                </layout:boundingBox>
                <render:g render:stroke="black" render:stroke-width="2">
                  <render:ellipse render:cx="50%" render:cy="50%"
                    render:rx="50%" />
                </render:g>
              </render:lineEnding>
            </render:listOfLineEndings>
            <render:listOfStyles>
              <render:style render:id="proteinKinaseStyle"
                render:idList="SpeciesGlyph_ProteinKinase">
```


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    <render:g render:stroke="black" render:stroke-width="3"
      render:fill-rule="nonzero" render:font-size="12"
      render:font-family="monospace" render:font-style="normal"
      render:font-weight="normal" render:text-anchor="middle"
      render:vtext-anchor="top">
      <render:rectangle render:x="0" render:y="0"
        render:width="100%" render:height="100%" render:rx="10"
        render:ry="10" />
      <render:text render:x="0" render:y="0"
        render:text-anchor="middle"
        render:vtext-anchor="middle">Protein-&#10;kinase</render:text>
    </render:g>
  </render:style>
  <render:style render:id="proteinStyle"
    render:idList="SpeciesGlyph_Protein">
    <render:g render:stroke="black" render:stroke-width="3"
      render:fill-rule="nonzero" render:font-size="12"
      render:font-family="sans-serif" render:font-style="normal"
      render:font-weight="normal" render:text-anchor="middle"
      render:vtext-anchor="middle">
      <render:rectangle render:x="0" render:y="0"
        render:width="100%" render:height="100%" render:rx="10"
        render:ry="10" />
      <render:text render:x="0" render:y="0"
        render:font-family="monospace" render:text-anchor="middle"
        render:vtext-anchor="middle">Protein</render:text>
    </render:g>
  </render:style>
  <render:style render:id="proteinPStyle"
    render:idList="SpeciesGlyph_ProteinP">
    <render:g render:stroke="black" render:stroke-width="3"
      render:fill-rule="nonzero" render:font-size="12"
      render:font-family="sans-serif" render:font-style="normal"
      render:font-weight="normal" render:text-anchor="middle"
      render:vtext-anchor="middle">
      <render:rectangle render:x="0" render:y="0"
        render:width="90%" render:height="100%" render:rx="10"
        render:ry="10" />
      <render:ellipse render:fill="white" render:cx="90%"
        render:cy="50%" render:rx="10" />
      <render:text render:x="-10" render:y="0"
        render:font-family="monospace" render:text-anchor="middle"
        render:vtext-anchor="middle">Protein</render:text>
      <render:text render:x="-5%" render:y="0"
        render:font-family="monospace" render:text-anchor="end"
        render:vtext-anchor="middle">P</render:text>
    </render:g>
  </render:style>
  <render:style render:id="ATPStyle" render:idList="SpeciesGlyph_ATP">
    <render:g render:stroke="black" render:stroke-width="3"
      render:fill-rule="nonzero" render:font-size="12"
      render:font-family="sans-serif" render:font-style="normal"
      render:font-weight="normal" render:text-anchor="middle"
      render:vtext-anchor="middle">
      <render:ellipse render:cx="50%" render:cy="50%"
        render:rx="17" />
      <render:text render:x="0" render:y="0"
        render:font-family="monospace" render:text-anchor="middle"
        render:vtext-anchor="middle">ATP</render:text>
    </render:g>
  </render:style>
  <render:style render:id="ADPStyle" render:idList="SpeciesGlyph_ADP">
    <render:g render:stroke="black" render:stroke-width="3"
      render:fill-rule="nonzero" render:font-size="12"
      render:font-family="sans-serif" render:font-style="normal"
      render:font-weight="normal" render:text-anchor="middle"
```


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      render:vtext-anchor="middle">
      <render:ellipse render:cx="50%" render:cy="50%"
        render:rx="17" />
      <render:text render:x="0" render:y="0"
        render:font-family="monospace" render:text-anchor="middle"
        render:vtext-anchor="middle">ADP</render:text>
    </render:g>
  </render:style>
  <render:style render:id="PStyle" render:idList="SpeciesGlyph_P">
    <render:g render:stroke="black" render:stroke-width="3"
      render:fill-rule="nonzero" render:font-size="12"
      render:font-family="sans-serif" render:font-style="normal"
      render:font-weight="normal" render:text-anchor="middle"
      render:vtext-anchor="middle">
      <render:ellipse render:cx="50%" render:cy="50%"
        render:rx="15" />
      <render:text render:x="0" render:y="-5.6"
        render:font-family="monospace" render:text-anchor="middle"
        render:vtext-anchor="middle">P</render:text>
    </render:g>
  </render:style>
  <render:style render:id="reactionGlyphStyle"
    render:typeList="REACTIONGLYPH">
    <render:g render:stroke="black" render:stroke-width="2"
      render:fill-rule="nonzero" render:font-size="0"
      render:font-family="sans-serif" render:font-style="normal"
      render:font-weight="normal">
      <render:curve>
        <render:listOfElements>
          <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
            xsi:type="RenderPoint" render:x="0" render:y="5" />
          <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
            xsi:type="RenderPoint" render:x="10" render:y="5" />
        </render:listOfElements>
      </render:curve>
      <render:curve>
        <render:listOfElements>
          <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
            xsi:type="RenderPoint" render:x="20" render:y="5" />
          <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
            xsi:type="RenderPoint" render:x="30" render:y="5" />
        </render:listOfElements>
      </render:curve>
      <render:rectangle render:x="10" render:y="0"
        render:width="10" render:height="10" />
    </render:g>
  </render:style>
  <render:style render:id="textGlyphStyle"
    render:typeList="TEXTGLYPH">
    <render:g render:stroke-width="0" render:fill-rule="nonzero"
      render:font-size="0" render:font-family="sans-serif"
      render:font-style="normal" render:font-weight="normal" />
  </render:style>
  <render:style render:id="substrateSpeciesReferenceGlyphStyle"
    render:roleList="sidesubstrate␣substrate">
    <render:g render:stroke="#000000" render:stroke-width="2"
      render:fill-rule="nonzero" render:font-size="0"
      render:font-family="sans-serif" render:font-style="normal"
      render:font-weight="normal" />
  </render:style>
  <render:style render:id="productSpeciesReferenceGlyphStyle"
    render:roleList="product␣sideproduct">
    <render:g render:stroke="#000000" render:stroke-width="2"
      render:fill-rule="nonzero" render:font-size="0"
      render:font-family="sans-serif" render:font-style="normal"
      render:font-weight="normal" render:endHead="productionHead" />
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            </render:style>
            <render:style render:id="activatorSpeciesReferenceGlyphStyle"
              render:roleList="activator␣catalyst">
              <render:g render:stroke="black" render:stroke-width="2"
                render:fill-rule="nonzero" render:font-size="0"
                render:font-family="sans-serif" render:font-style="normal"
                render:font-weight="normal" render:endHead="catalysisHead" />
            </render:style>
          </render:listOfStyles>
        </render:renderInformation>
      </render:listOfRenderInformation>
    </layout:layout>
    <render:listOfGlobalRenderInformation
      xmlns:render="http://www.sbml.org/sbml/level3/version1/render/version1"
      render:versionMajor="1" render:versionMinor="0">
      <render:renderInformation render:id="wireFrame"
        render:programName="Ralph␣Gauges" render:programVersion="1.0"
        render:backgroundColor="#FFFFFFFF">
        <render:listOfColorDefinitions>
          <render:colorDefinition render:id="white"
            render:value="#ffffff" />
          <render:colorDefinition render:id="black"
            render:value="#000000" />
        </render:listOfColorDefinitions>
        <render:listOfLineEndings>
          <render:lineEnding
            xmlns:layout="http://www.sbml.org/sbml/level3/version1/layout/version1"
            render:id="simpleHead_black">
            <layout:boundingBox>
              <layout:position layout:x="-8" layout:y="-3" />
              <layout:dimensions layout:width="10"
                layout:height="6" />
            </layout:boundingBox>
            <render:g render:stroke="black" render:stroke-width="1"
              render:fill="black">
              <render:polygon render:stroke="black"
                render:stroke-width="1" render:fill="black">
                <render:listOfElements>
                  <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                    xsi:type="RenderPoint" render:x="0" render:y="0" />
                  <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                    xsi:type="RenderPoint" render:x="10" render:y="3" />
                  <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                    xsi:type="RenderPoint" render:x="10" render:y="3" />
                  <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                    xsi:type="RenderPoint" render:x="0" render:y="6" />
                </render:listOfElements>
              </render:polygon>
            </render:g>
          </render:lineEnding>
          <render:lineEnding
            xmlns:layout="http://www.sbml.org/sbml/level3/version1/layout/version1"
            render:id="catalysisHead_black">
            <layout:boundingBox>
              <layout:position layout:x="0" layout:y="-5" />
              <layout:dimensions layout:width="10"
                layout:height="10" />
            </layout:boundingBox>
            <render:g render:stroke="black" render:stroke-width="1">
              <render:ellipse render:stroke="black"
                render:stroke-width="1" render:cx="50%" render:cy="50%"
                render:rx="50%" />
            </render:g>
          </render:lineEnding>
        </render:listOfLineEndings>
        <render:listOfStyles>
```


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```
<render:style render:id="speciesGlyphStyle"
  render:typeList="SPECIESGLYPH">
  <render:g render:stroke="black" render:stroke-width="1"
    render:fill-rule="nonzero" render:font-size="0"
    render:font-family="sans-serif" render:font-style="normal"
    render:font-weight="normal">
    <render:rectangle render:x="0" render:y="0"
      render:width="100%" render:height="100%" />
  </render:g>
</render:style>
<render:style render:id="phosphorylatedSpeciesGlyphStyle"
  render:roleList="phosphorylated">
  <render:g render:stroke="black" render:stroke-width="1"
    render:fill-rule="nonzero" render:font-size="12"
    render:font-family="monospace" render:font-style="normal"
    render:font-weight="normal">
    <render:rectangle render:x="0" render:y="0"
      render:width="90%" render:height="100%" />
    <render:ellipse render:fill="white" render:cx="90%"
      render:cy="50%" render:rx="10" />
    <render:text render:x="85%" render:y="0"
      render:vtext-anchor="middle">P</render:text>
  </render:g>
</render:style>
<render:style render:id="speciesReferenceAndTextGlyphStyle"
  render:typeList="SPECIESREFERENCEGLYPH␣TEXTGLYPH">
  <render:g render:stroke="black" render:stroke-width="1"
    render:fill-rule="nonzero" render:font-size="12"
    render:font-family="sans" render:font-style="normal"
    render:font-weight="normal" render:text-anchor="middle"
    render:vtext-anchor="middle" />
</render:style>
<render:style render:id="productStyle"
  render:roleList="product␣sideproduct">
  <render:g render:stroke="black" render:stroke-width="1"
    render:fill-rule="nonzero" render:font-size="0"
    render:font-family="sans-serif" render:font-style="normal"
    render:font-weight="normal" render:endHead="simpleHead_black" />
</render:style>
<render:style render:id="activatorStyle"
  render:roleList="activator␣catalyst">
  <render:g render:stroke="black" render:stroke-width="1"
    render:fill-rule="nonzero" render:font-size="0"
    render:font-family="sans-serif" render:font-style="normal"
    render:font-weight="normal" render:endHead="catalysisHead_black" />
</render:style>
<render:style render:id="reactionGlyphStyle"
  render:typeList="REACTIONGLYPH">
  <render:g render:stroke="black" render:stroke-width="1"
    render:fill-rule="nonzero" render:font-size="0"
    render:font-family="sans-serif" render:font-style="normal"
    render:font-weight="normal">
    <render:curve>
      <render:listOfElements>
        <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xsi:type="RenderPoint" render:x="0" render:y="5" />
        <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xsi:type="RenderPoint" render:x="10" render:y="5" />
      </render:listOfElements>
    </render:curve>
    <render:curve>
      <render:listOfElements>
        <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xsi:type="RenderPoint" render:x="20" render:y="5" />
        <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xsi:type="RenderPoint" render:x="30" render:y="5" />
```


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```
            </render:listOfElements>
          </render:curve>
          <render:rectangle render:x="10" render:y="0"
            render:width="10" render:height="10" />
        </render:g>
      </render:style>
    </render:listOfStyles>
  </render:renderInformation>
  <render:renderInformation render:id="defaultGrayStyle"
    render:programName="Ralph␣Gauges" render:programVersion="1.0"
    render:backgroundColor="#FFFFFFFF">
    <render:listOfColorDefinitions>
      <render:colorDefinition render:id="lightGray"
        render:value="#cecece" />
      <render:colorDefinition render:id="white"
        render:value="#ffffff" />
      <render:colorDefinition render:id="black"
        render:value="#000000" />
      <render:colorDefinition render:id="lightGray2"
        render:value="#f0f0f0" />
      <render:colorDefinition render:id="gray"
        render:value="#0b0b0b" />
    </render:listOfColorDefinitions>
    <render:listOfGradientDefinitions>
      <render:radialGradient render:id="speciesGlyphGradient">
        <render:stop render:offset="0" render:stop-color="white" />
        <render:stop render:offset="100%" render:stop-color="lightGray" />
      </render:radialGradient>
    </render:listOfGradientDefinitions>
    <render:listOfLineEndings>
      <render:lineEnding
        xmlns:layout="http://www.sbml.org/sbml/level3/version1/layout/version1"
        render:id="simpleHead_black">
        <layout:boundingBox>
          <layout:position layout:x="-8" layout:y="-3" />
          <layout:dimensions layout:width="10"
            layout:height="6" />
        </layout:boundingBox>
        <render:g render:stroke="black" render:stroke-width="1"
          render:fill="black">
          <render:polygon render:stroke="black"
            render:stroke-width="1" render:fill="black">
            <render:listOfElements>
              <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                xsi:type="RenderPoint" render:x="0" render:y="0" />
              <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                xsi:type="RenderPoint" render:x="10" render:y="3" />
              <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                xsi:type="RenderPoint" render:x="10" render:y="3" />
              <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                xsi:type="RenderPoint" render:x="0" render:y="6" />
            </render:listOfElements>
          </render:polygon>
        </render:g>
      </render:lineEnding>
      <render:lineEnding
        xmlns:layout="http://www.sbml.org/sbml/level3/version1/layout/version1"
        render:id="catalysisHead_black">
        <layout:boundingBox>
          <layout:position layout:x="0" layout:y="-5" />
          <layout:dimensions layout:width="10"
            layout:height="10" />
        </layout:boundingBox>
        <render:g render:stroke="black" render:stroke-width="1">
          <render:ellipse render:cx="50%" render:cy="50%"
            render:rx="50%" />
```


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```
        </render:g>
      </render:lineEnding>
    </render:listOfLineEndings>
    <render:listOfStyles>
      <render:style render:id="speciesGlyphStyle"
        render:typeList="SPECIESGLYPH">
        <render:g render:stroke="black" render:stroke-width="1"
          render:fill-rule="nonzero" render:font-size="0"
          render:font-family="sans-serif" render:font-style="normal"
          render:font-weight="normal">
          <render:rectangle render:fill="speciesGlyphGradient"
            render:x="0" render:y="0" render:width="100%" render:height="100%"
            render:rx="5%" render:ry="5%" />
        </render:g>
      </render:style>
      <render:style render:id="phosphorylatedSpeciesGlyphStyle"
        render:roleList="phosphorylated">
        <render:g render:stroke="black" render:stroke-width="1"
          render:fill-rule="nonzero" render:font-size="12"
          render:font-family="monospace" render:font-style="normal"
          render:font-weight="normal">
          <render:rectangle render:fill="speciesGlyphGradient"
            render:x="0" render:y="0" render:width="90%" render:height="100%" />
          <render:ellipse render:fill="speciesGlyphGradient"
            render:cx="90%" render:cy="50%" render:rx="10" />
          <render:text render:x="85%" render:y="0"
            render:vtext-anchor="middle">P</render:text>
        </render:g>
      </render:style>
      <render:style render:id="speciesReferenceAndTextGlyphStyle"
        render:typeList="SPECIESREFERENCEGLYPH␣TEXTGLYPH">
        <render:g render:stroke="black" render:stroke-width="1"
          render:fill-rule="nonzero" render:font-size="12"
          render:font-family="sans" render:font-style="normal"
          render:font-weight="normal" render:text-anchor="middle"
          render:vtext-anchor="middle" />
      </render:style>
      <render:style render:id="speciesReferenceGlyphStyle"
        render:roleList="product␣sideproduct">
        <render:g render:stroke="#000000" render:stroke-width="1"
          render:fill-rule="nonzero" render:font-size="0"
          render:font-family="sans-serif" render:font-style="normal"
          render:font-weight="normal" render:endHead="simpleHead_black" />
      </render:style>
      <render:style render:id="activatorStyle"
        render:roleList="activator␣catalyst">
        <render:g render:stroke="black" render:stroke-width="1"
          render:fill-rule="nonzero" render:font-size="0"
          render:font-family="sans-serif" render:font-style="normal"
          render:font-weight="normal" render:endHead="catalysisHead_black" />
      </render:style>
      <render:style render:id="reactionGlyphStyle"
        render:typeList="REACTIONGLYPH">
        <render:g render:stroke="black" render:stroke-width="1"
          render:fill-rule="nonzero" render:font-size="0"
          render:font-family="sans-serif" render:font-style="normal"
          render:font-weight="normal">
          <render:curve>
            <render:listOfElements>
              <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                xsi:type="RenderPoint" render:x="0" render:y="5" />
              <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                xsi:type="RenderPoint" render:x="10" render:y="5" />
            </render:listOfElements>
          </render:curve>
          <render:curve>
```


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```
                <render:listOfElements>
                  <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                    xsi:type="RenderPoint" render:x="20" render:y="5" />
                  <render:element xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                    xsi:type="RenderPoint" render:x="30" render:y="5" />
                </render:listOfElements>
              </render:curve>
              <render:rectangle render:x="10" render:y="0"
                render:width="10" render:height="10" />
            </render:g>
          </render:style>
        </render:listOfStyles>
      </render:renderInformation>
      <render:renderInformation render:id="colorStyle"
        render:referenceRenderInformation="defaultGrayStyle"
        render:programName="Ralph␣Gauges" render:programVersion="1.0"
        render:backgroundColor="#FFFFFFFF">
        <render:listOfColorDefinitions>
          <render:colorDefinition render:id="lightGray"
            render:value="#9999f0" />
          <render:colorDefinition render:id="lightGray2"
            render:value="#9999f0" />
          <render:colorDefinition render:id="gray"
            render:value="#cecece" />
        </render:listOfColorDefinitions>
      </render:renderInformation>
    </render:listOfGlobalRenderInformation>
  </layout:listOfLayouts>
 </model>
</sbml>
```

SBML Level 2 Version 1

```
<?xml version="1.0" encoding="utf-8"?>
<!--Created on: 10/2/2017 2:42:41 PM -->
<sbml xmlns="http://www.sbml.org/sbml/level2/version4" level="2"
  version="4">
  <model id="ProteinPhosphorylation">
    <annotation>
      <layout:listOfLayouts xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xmlns:layout="http://projects.eml.org/bcb/sbml/level2">
        <annotation>
          <listOfGlobalRenderInformation
            xmlns="http://projects.eml.org/bcb/sbml/render/level2">
            <renderInformation id="wireFrame" programName="Ralph␣Gauges"
              programVersion="1.0">
              <listOfColorDefinitions>
                <colorDefinition id="white" value="#ffffff" />
                <colorDefinition id="black" value="#000000" />
              </listOfColorDefinitions>
              <listOfGradientDefinitions />
              <listOfLineEndings>
                <lineEnding id="simpleHead_black"
                  enableRotationalMapping="true">
                  <boundingBox>
                    <position x="-8" y="-3" />
                    <dimensions width="10" height="6" />
                  </boundingBox>
                  <g stroke="black" stroke-width="1" fill="black">
                    <polygon stroke="black" stroke-width="1" fill="black">
                      <listOfElements>
                        <element xsi:type="RenderPoint" x="0" y="0" z="0"
                          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                        <element xsi:type="RenderPoint" x="10" y="3" z="0"
```


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```
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                  <element xsi:type="RenderPoint" x="10" y="3" z="0"
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                  <element xsi:type="RenderPoint" x="0" y="6" z="0"
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                </listOfElements>
              </polygon>
            </g>
          </lineEnding>
          <lineEnding id="catalysisHead_black"
            enableRotationalMapping="true">
            <boundingBox>
              <position x="0" y="-5" />
              <dimensions width="10" height="10" />
            </boundingBox>
            <g stroke="black" stroke-width="1">
              <ellipse stroke="black" stroke-width="1" cx="50%" cy="50%"
                rx="50%" />
            </g>
          </lineEnding>
        </listOfLineEndings>
        <listOfStyles>
          <style id="speciesGlyphStyle" typeList="SPECIESGLYPH">
            <g stroke="black" stroke-width="1" font-family="sans-serif"
              font-size="0" font-style="normal" font-weight="normal">
              <rectangle x="0" y="0" width="100%" height="100%" />
            </g>
          </style>
          <style id="phosphorylatedSpeciesGlyphStyle" roleList="phosphorylated">
            <g stroke="black" stroke-width="1" font-family="monospace"
              font-size="12" font-style="normal" font-weight="normal">
              <rectangle x="0" y="0" width="90%" height="100%" />
              <ellipse fill="white" cx="90%" cy="50%" rx="10" />
              <text x="85%" y="0" vtext-anchor="middle">P</text>
            </g>
          </style>
          <style id="speciesReferenceAndTextGlyphStyle"
             typeList="SPECIESREFERENCEGLYPH␣TEXTGLYPH">
            <g stroke="black" stroke-width="1" font-family="sans"
              font-size="12" font-style="normal" font-weight="normal"
              text-anchor="middle" vtext-anchor="middle" />
          </style>
          <style id="productStyle" roleList="product␣sideproduct">
            <g stroke="black" stroke-width="1" font-family="sans-serif"
              font-size="0" font-style="normal" font-weight="normal"
              endHead="simpleHead_black" />
          </style>
          <style id="activatorStyle" roleList="activator␣catalyst">
            <g stroke="black" stroke-width="1" font-family="sans-serif"
              font-size="0" font-style="normal" font-weight="normal"
              endHead="catalysisHead_black" />
          </style>
          <style id="reactionGlyphStyle" typeList="REACTIONGLYPH">
            <g stroke="black" stroke-width="1" font-family="sans-serif"
              font-size="0" font-style="normal" font-weight="normal">
              <curve>
                <listOfElements>
                  <element xsi:type="RenderPoint" x="0" y="5" z="0"
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                  <element xsi:type="RenderPoint" x="10" y="5" z="0"
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                </listOfElements>
              </curve>
              <curve>
                <listOfElements>
                  <element xsi:type="RenderPoint" x="20" y="5" z="0"
```


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                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                  <element xsi:type="RenderPoint" x="30" y="5" z="0"
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                </listOfElements>
              </curve>
              <rectangle x="10" y="0" width="10" height="10" />
            </g>
          </style>
        </listOfStyles>
      </renderInformation>
      <renderInformation id="defaultGrayStyle"
        programName="Ralph␣Gauges" programVersion="1.0">
        <listOfColorDefinitions>
          <colorDefinition id="lightGray" value="#cecece" />
          <colorDefinition id="white" value="#ffffff" />
          <colorDefinition id="black" value="#000000" />
          <colorDefinition id="lightGray2" value="#f0f0f0" />
          <colorDefinition id="gray" value="#0b0b0b" />
        </listOfColorDefinitions>
        <listOfGradientDefinitions>
          <radialGradient id="speciesGlyphGradient" cx="50%"
            cy="50%" cz="50%" r="50%">
            <stop offset="0" stop-color="white" />
            <stop offset="100%" stop-color="lightGray" />
          </radialGradient>
        </listOfGradientDefinitions>
        <listOfLineEndings>
          <lineEnding id="simpleHead_black"
            enableRotationalMapping="true">
            <boundingBox>
              <position x="-8" y="-3" />
              <dimensions width="10" height="6" />
            </boundingBox>
            <g stroke="black" stroke-width="1" fill="black">
              <polygon stroke="black" stroke-width="1" fill="black">
                <listOfElements>
                  <element xsi:type="RenderPoint" x="0" y="0" z="0"
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                  <element xsi:type="RenderPoint" x="10" y="3" z="0"
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                  <element xsi:type="RenderPoint" x="10" y="3" z="0"
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                  <element xsi:type="RenderPoint" x="0" y="6" z="0"
                    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                </listOfElements>
              </polygon>
            </g>
          </lineEnding>
          <lineEnding id="catalysisHead_black"
            enableRotationalMapping="true">
            <boundingBox>
              <position x="0" y="-5" />
              <dimensions width="10" height="10" />
            </boundingBox>
            <g stroke="black" stroke-width="1">
              <ellipse cx="50%" cy="50%" rx="50%" />
            </g>
          </lineEnding>
        </listOfLineEndings>
        <listOfStyles>
          <style id="speciesGlyphStyle" typeList="SPECIESGLYPH">
            <g stroke="black" stroke-width="1" font-family="sans-serif"
              font-size="0" font-style="normal" font-weight="normal">
              <rectangle fill="speciesGlyphGradient" x="0" y="0"
                width="100%" height="100%" rx="5%" ry="5%" />
            </g>
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```
            </style>
            <style id="phosphorylatedSpeciesGlyphStyle" roleList="phosphorylated">
              <g stroke="black" stroke-width="1" font-family="monospace"
                font-size="12" font-style="normal" font-weight="normal">
                <rectangle fill="speciesGlyphGradient" x="0" y="0"
                  width="90%" height="100%" />
                <ellipse fill="speciesGlyphGradient" cx="90%" cy="50%"
                  rx="10" />
                <text x="85%" y="0" vtext-anchor="middle">P</text>
              </g>
            </style>
            <style id="speciesReferenceAndTextGlyphStyle"
              typeList="SPECIESREFERENCEGLYPH␣TEXTGLYPH">
              <g stroke="black" stroke-width="1" font-family="sans"
                font-size="12" font-style="normal" font-weight="normal"
                text-anchor="middle" vtext-anchor="middle" />
            </style>
            <style id="speciesReferenceGlyphStyle" roleList="product␣sideproduct">
              <g stroke="#000000" stroke-width="1" font-family="sans-serif"
                font-size="0" font-style="normal" font-weight="normal"
                endHead="simpleHead_black" />
            </style>
            <style id="activatorStyle" roleList="activator␣catalyst">
              <g stroke="black" stroke-width="1" font-family="sans-serif"
                font-size="0" font-style="normal" font-weight="normal"
                endHead="catalysisHead_black" />
            </style>
            <style id="reactionGlyphStyle" typeList="REACTIONGLYPH">
              <g stroke="black" stroke-width="1" font-family="sans-serif"
                font-size="0" font-style="normal" font-weight="normal">
                <curve>
                  <listOfElements>
                    <element xsi:type="RenderPoint" x="0" y="5" z="0"
                      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                    <element xsi:type="RenderPoint" x="10" y="5" z="0"
                      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                  </listOfElements>
                </curve>
                <curve>
                  <listOfElements>
                    <element xsi:type="RenderPoint" x="20" y="5" z="0"
                      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                    <element xsi:type="RenderPoint" x="30" y="5" z="0"
                      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                  </listOfElements>
                </curve>
                <rectangle x="10" y="0" width="10" height="10" />
              </g>
            </style>
          </listOfStyles>
        </renderInformation>
        <renderInformation id="colorStyle" programName="Ralph␣Gauges"
          programVersion="1.0" referenceRenderInformation="defaultGrayStyle">
          <listOfColorDefinitions>
            <colorDefinition id="lightGray" value="#9999f0" />
            <colorDefinition id="lightGray2" value="#9999f0" />
            <colorDefinition id="gray" value="#cecece" />
          </listOfColorDefinitions>
          <listOfGradientDefinitions />
          <listOfLineEndings />
          <listOfStyles />
        </renderInformation>
      </listOfGlobalRenderInformation>
    </annotation>
    <layout id="Layout_1" name="Layout_1"
      xmlns="http://projects.eml.org/bcb/sbml/level2">
```


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```
<!--Created by SBW SBML LayoutViewer/Manipulator -->
<annotation>
  <listOfRenderInformation
    xmlns="http://projects.eml.org/bcb/sbml/render/level2">
    <renderInformation id="SBGN" programName="Ralph␣Gauges"
      programVersion="1.0">
      <listOfColorDefinitions>
        <colorDefinition id="black" value="#000000" />
        <colorDefinition id="white" value="#ffffff" />
      </listOfColorDefinitions>
      <listOfGradientDefinitions />
      <listOfLineEndings>
        <lineEnding id="productionHead"
          enableRotationalMapping="true">
          <boundingBox>
            <position x="-10" y="-6" />
            <dimensions width="14" height="10" />
          </boundingBox>
          <g stroke="black" stroke-width="1" fill="black">
            <polygon stroke="black" stroke-width="1" fill="black">
              <listOfElements>
                <element xsi:type="RenderPoint" x="0" y="0" z="0"
                  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                <element xsi:type="RenderPoint" x="14" y="5" z="0"
                  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                <element xsi:type="RenderPoint" x="14" y="5" z="0"
                  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
                <element xsi:type="RenderPoint" x="0" y="10" z="0"
                  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
              </listOfElements>
            </polygon>
          </g>
        </lineEnding>
        <lineEnding id="catalysisHead"
          enableRotationalMapping="true">
          <boundingBox>
            <position x="0" y="-7" />
            <dimensions width="14" height="14" />
          </boundingBox>
          <g stroke="black" stroke-width="2">
            <ellipse cx="50%" cy="50%" rx="50%" ry="50%" />
          </g>
        </lineEnding>
      </listOfLineEndings>
      <listOfStyles>
        <style id="proteinKinaseStyle" idList="SpeciesGlyph_ProteinKinase">
          <g stroke="black" stroke-width="3" font-family="monospace"
            font-size="12" font-style="normal" font-weight="normal"
            text-anchor="middle" vtext-anchor="top">
            <rectangle x="0" y="0" width="100%" height="100%"
              rx="10" ry="10" />
            <text x="0" y="0" text-anchor="middle"
            vtext-anchor="middle">Protein-&#10;kinase</text>
          </g>
        </style>
        <style id="proteinStyle" idList="SpeciesGlyph_Protein">
          <g stroke="black" stroke-width="3" font-family="sans-serif"
            font-size="12" font-style="normal" font-weight="normal"
            text-anchor="middle" vtext-anchor="middle">
            <rectangle x="0" y="0" width="100%" height="100%"
              rx="10" ry="10" />
            <text x="0" y="0" font-family="monospace" text-anchor="middle"
              vtext-anchor="middle">Protein</text>
          </g>
        </style>
        <style id="proteinPStyle" idList="SpeciesGlyph_ProteinP">
```


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```
      <g stroke="black" stroke-width="3" font-family="sans-serif"
        font-size="12" font-style="normal" font-weight="normal"
        text-anchor="middle" vtext-anchor="middle">
        <rectangle x="0" y="0" width="90%" height="100%"
          rx="10" ry="10" />
        <ellipse fill="white" cx="90%" cy="50%" rx="10" ry="10" />
        <text x="-10" y="0" font-family="monospace" text-anchor="middle"
          vtext-anchor="middle">Protein</text>
        <text x="-5%" y="0" font-family="monospace" text-anchor="end"
          vtext-anchor="middle">P</text>
      </g>
    </style>
    <style id="ATPStyle" idList="SpeciesGlyph_ATP">
      <g stroke="black" stroke-width="3" font-family="sans-serif"
        font-size="12" font-style="normal" font-weight="normal"
        text-anchor="middle" vtext-anchor="middle">
        <ellipse cx="50%" cy="50%" rx="17" ry="17" />
        <text x="0" y="0" font-family="monospace" text-anchor="middle"
          vtext-anchor="middle">ATP</text>
      </g>
    </style>
    <style id="ADPStyle" idList="SpeciesGlyph_ADP">
      <g stroke="black" stroke-width="3" font-family="sans-serif"
        font-size="12" font-style="normal" font-weight="normal"
        text-anchor="middle" vtext-anchor="middle">
        <ellipse cx="50%" cy="50%" rx="17" ry="17" />
        <text x="0" y="0" font-family="monospace" text-anchor="middle"
          vtext-anchor="middle">ADP</text>
      </g>
    </style>
    <style id="PStyle" idList="SpeciesGlyph_P">
      <g stroke="black" stroke-width="3" font-family="sans-serif"
        font-size="12" font-style="normal" font-weight="normal"
        text-anchor="middle" vtext-anchor="middle">
        <ellipse cx="50%" cy="50%" rx="15" ry="15" />
        <text x="0" y="-5.6" font-family="monospace"
          text-anchor="middle" vtext-anchor="middle">P</text>
      </g>
    </style>
    <style id="reactionGlyphStyle" typeList="REACTIONGLYPH">
      <g stroke="black" stroke-width="2" font-family="sans-serif"
        font-size="0" font-style="normal" font-weight="normal">
        <curve>
          <listOfElements>
            <element xsi:type="RenderPoint" x="0" y="5" z="0"
              xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
            <element xsi:type="RenderPoint" x="10" y="5" z="0"
              xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
          </listOfElements>
        </curve>
        <curve>
          <listOfElements>
            <element xsi:type="RenderPoint" x="20" y="5" z="0"
              xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
            <element xsi:type="RenderPoint" x="30" y="5" z="0"
              xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" />
          </listOfElements>
        </curve>
        <rectangle x="10" y="0" width="10" height="10" />
      </g>
    </style>
    <style id="textGlyphStyle" typeList="TEXTGLYPH">
      <g stroke-width="0" font-family="sans-serif" font-size="0"
        font-style="normal" font-weight="normal" />
    </style>
    <style id="substrateSpeciesReferenceGlyphStyle" roleList="sidesubstrate␣substrate">
```


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```
                <g stroke="#000000" stroke-width="2" font-family="sans-serif"
                  font-size="0" font-style="normal" font-weight="normal" />
              </style>
              <style id="productSpeciesReferenceGlyphStyle" roleList="product␣sideproduct">
                <g stroke="#000000" stroke-width="2" font-family="sans-serif"
                  font-size="0" font-style="normal" font-weight="normal"
                  endHead="productionHead" />
              </style>
              <style id="activatorSpeciesReferenceGlyphStyle" roleList="activator␣catalyst">
                <g stroke="black" stroke-width="2" font-family="sans-serif"
                  font-size="0" font-style="normal" font-weight="normal"
                  endHead="catalysisHead" />
              </style>
            </listOfStyles>
          </renderInformation>
        </listOfRenderInformation>
      </annotation>
      <dimensions width="453" height="380" />
      <listOfSpeciesGlyphs>
        <speciesGlyph id="SpeciesGlyph_Protein" species="Protein">
          <boundingBox id="bb1">
            <position x="30" y="230" />
            <dimensions width="80" height="40" />
          </boundingBox>
        </speciesGlyph>
        <speciesGlyph id="SpeciesGlyph_ProteinP"
          render:objectRole="phosphorylated" species="ProteinP"
          xmlns:render="http://projects.eml.org/bcb/sbml/render/level2">
          <boundingBox id="bb2">
            <position x="330" y="230" />
            <dimensions width="93" height="40" />
          </boundingBox>
        </speciesGlyph>
        <speciesGlyph id="SpeciesGlyph_ATP" species="ATP">
          <boundingBox id="bb3">
            <position x="110" y="100" />
            <dimensions width="50" height="30" />
          </boundingBox>
        </speciesGlyph>
        <speciesGlyph id="SpeciesGlyph_ADP" species="ADP">
          <boundingBox id="bb4">
            <position x="280" y="100" />
            <dimensions width="50" height="30" />
          </boundingBox>
        </speciesGlyph>
        <speciesGlyph id="SpeciesGlyph_P" species="P">
          <boundingBox id="bb5">
            <position x="170" y="320" />
            <dimensions width="30" height="30" />
          </boundingBox>
        </speciesGlyph>
        <speciesGlyph id="SpeciesGlyph_ProteinKinase"
          species="ProteinKinase">
          <boundingBox id="bb6">
            <position x="180" y="30" />
            <dimensions width="80" height="50" />
          </boundingBox>
        </speciesGlyph>
      </listOfSpeciesGlyphs>
      <listOfReactionGlyphs>
        <reactionGlyph id="ReactionGlyph_Phosphorylation"
          reaction="Phosphorylation">
          <boundingBox id="bb7">
            <position x="205" y="195" />
            <dimensions width="30" height="10" />
          </boundingBox>
```


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```
<listOfSpeciesReferenceGlyphs>
  <speciesReferenceGlyph id="SpeciesReferenceGlyph_Protein"
    render:objectRole="substrate" speciesReference="SpeciesReference_Protein"
    speciesGlyph="SpeciesGlyph_Protein" role="substrate"
    xmlns:render="http://projects.eml.org/bcb/sbml/render/level2">
    <boundingBox>
      <position x="0" y="0" />
      <dimensions width="0" height="0" />
    </boundingBox>
    <curve>
      <listOfCurveSegments>
        <curveSegment xsi:type="CubicBezier"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
          <start x="115" y="225" />
          <end x="205" y="200" />
          <basePoint1 x="170" y="200" />
          <basePoint2 x="170" y="200" />
        </curveSegment>
      </listOfCurveSegments>
    </curve>
  </speciesReferenceGlyph>
  <speciesReferenceGlyph id="SpeciesReferenceGlyph_ATP"
    render:objectRole="sidesubstrate" speciesReference="SpeciesReference_ATP"
    speciesGlyph="SpeciesGlyph_ATP" role="sidesubstrate"
    xmlns:render="http://projects.eml.org/bcb/sbml/render/level2">
    <boundingBox>
      <position x="0" y="0" />
      <dimensions width="0" height="0" />
    </boundingBox>
    <curve>
      <listOfCurveSegments>
        <curveSegment xsi:type="CubicBezier"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
          <start x="160" y="135" />
          <end x="205" y="200" />
          <basePoint1 x="180" y="200" />
          <basePoint2 x="180" y="200" />
        </curveSegment>
      </listOfCurveSegments>
    </curve>
  </speciesReferenceGlyph>
  <speciesReferenceGlyph id="SpeciesReferenceGlyph_ProteinP"
    render:objectRole="product" speciesReference="SpeciesReference_ProteinP"
    speciesGlyph="SpeciesGlyph_ProteinP" role="product"
    xmlns:render="http://projects.eml.org/bcb/sbml/render/level2">
    <boundingBox>
      <position x="0" y="0" />
      <dimensions width="0" height="0" />
    </boundingBox>
    <curve>
      <listOfCurveSegments>
        <curveSegment xsi:type="CubicBezier"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
          <start x="235" y="200" />
          <end x="320" y="230" />
          <basePoint1 x="270" y="200" />
          <basePoint2 x="270" y="200" />
        </curveSegment>
      </listOfCurveSegments>
    </curve>
  </speciesReferenceGlyph>
  <speciesReferenceGlyph id="SpeciesReferenceGlyph_ADP"
    render:objectRole="sideproduct" speciesReference="SpeciesReference_ADP"
    speciesGlyph="SpeciesGlyph_ADP" role="sideproduct"
    xmlns:render="http://projects.eml.org/bcb/sbml/render/level2">
    <boundingBox>
```


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```
                    <position x="0" y="0" />
                    <dimensions width="0" height="0" />
                  </boundingBox>
                  <curve>
                    <listOfCurveSegments>
                      <curveSegment xsi:type="CubicBezier"
                        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
                        <start x="235" y="200" />
                        <end x="275" y="140" />
                        <basePoint1 x="260" y="200" />
                        <basePoint2 x="260" y="200" />
                      </curveSegment>
                    </listOfCurveSegments>
                  </curve>
                </speciesReferenceGlyph>
                <speciesReferenceGlyph id="SpeciesReferenceGlyph_ProteinKinase"
                  render:objectRole="catalyst"
                  speciesReference="ModifierSpeciesReference_ProteinKinase"
                  speciesGlyph="SpeciesGlyph_ProteinKinase" role="activator"
                  xmlns:render="http://projects.eml.org/bcb/sbml/render/level2">
                  <boundingBox>
                    <position x="0" y="0" />
                    <dimensions width="0" height="0" />
                  </boundingBox>
                  <curve>
                    <listOfCurveSegments>
                      <curveSegment xsi:type="LineSegment"
                        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
                        <start x="220" y="85" />
                        <end x="220" y="180" />
                      </curveSegment>
                    </listOfCurveSegments>
                  </curve>
                </speciesReferenceGlyph>
              </listOfSpeciesReferenceGlyphs>
            </reactionGlyph>
            <reactionGlyph id="ReactionGlyph_Dephosphorylation"
              reaction="Dephosphorylation">
              <boundingBox id="bb8">
                <position x="205" y="285" />
                <dimensions width="30" height="10" />
              </boundingBox>
              <listOfSpeciesReferenceGlyphs>
                <speciesReferenceGlyph id="SpeciesReferenceGlyph_ProteinP_rev"
                  render:objectRole="substrate" speciesReference="SpeciesReference_ProteinP_rev"
                  speciesGlyph="SpeciesGlyph_ProteinP" role="substrate"
                  xmlns:render="http://projects.eml.org/bcb/sbml/render/level2">
                  <boundingBox>
                    <position x="0" y="0" />
                    <dimensions width="0" height="0" />
                  </boundingBox>
                  <curve>
                    <listOfCurveSegments>
                      <curveSegment xsi:type="CubicBezier"
                        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
                        <start x="325" y="265" />
                        <end x="235" y="290" />
                        <basePoint1 x="270" y="290" />
                        <basePoint2 x="270" y="290" />
                      </curveSegment>
                    </listOfCurveSegments>
                  </curve>
                </speciesReferenceGlyph>
                <speciesReferenceGlyph id="SpeciesReferenceGlyph_Protein_rev"
                  render:objectRole="product" speciesReference="SpeciesReference_Protein_rev"
                  speciesGlyph="SpeciesGlyph_Protein" role="product"
```


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```
                xmlns:render="http://projects.eml.org/bcb/sbml/render/level2">
                <boundingBox>
                  <position x="0" y="0" />
                  <dimensions width="0" height="0" />
                </boundingBox>
                <curve>
                  <listOfCurveSegments>
                    <curveSegment xsi:type="CubicBezier"
                      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
                      <start x="205" y="290" />
                      <end x="115" y="265" />
                      <basePoint1 x="170" y="290" />
                      <basePoint2 x="170" y="290" />
                    </curveSegment>
                  </listOfCurveSegments>
                </curve>
              </speciesReferenceGlyph>
              <speciesReferenceGlyph id="SpeciesReferenceGlyph_P"
                render:objectRole="sideproduct" speciesReference="SpeciesReference_P"
                speciesGlyph="SpeciesGlyph_P" role="sideproduct"
                xmlns:render="http://projects.eml.org/bcb/sbml/render/level2">
                <boundingBox>
                  <position x="0" y="0" />
                  <dimensions width="0" height="0" />
                </boundingBox>
                <curve>
                  <listOfCurveSegments>
                    <curveSegment xsi:type="CubicBezier"
                      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
                      <start x="205" y="290" />
                      <end x="185" y="310" />
                      <basePoint1 x="190" y="300" />
                      <basePoint2 x="190" y="300" />
                    </curveSegment>
                  </listOfCurveSegments>
                </curve>
              </speciesReferenceGlyph>
            </listOfSpeciesReferenceGlyphs>
          </reactionGlyph>
        </listOfReactionGlyphs>
        <listOfTextGlyphs>
          <textGlyph id="TextGlyph_Protein" graphicalObject="SpeciesGlyph_Protein"
            originOfText="Protein">
            <boundingBox id="bb9">
              <position x="30" y="220" />
              <dimensions width="80" height="40" />
            </boundingBox>
          </textGlyph>
          <textGlyph id="TextGlyph_ProteinP" graphicalObject="SpeciesGlyph_ProteinP"
            originOfText="ProteinP">
            <boundingBox id="bb10">
              <position x="330" y="220" />
              <dimensions width="80" height="40" />
            </boundingBox>
          </textGlyph>
          <textGlyph id="TextGlyph_ATP" graphicalObject="SpeciesGlyph_ATP"
            originOfText="ATP">
            <boundingBox id="bb11">
              <position x="110" y="95" />
              <dimensions width="50" height="30" />
            </boundingBox>
          </textGlyph>
          <textGlyph id="TextGlyph_ADP" graphicalObject="SpeciesGlyph_ADP"
            originOfText="ADP">
            <boundingBox id="bb12">
              <position x="280" y="95" />
```


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```
            <dimensions width="50" height="30" />
          </boundingBox>
        </textGlyph>
        <textGlyph id="TextGlyph_P" graphicalObject="SpeciesGlyph_P"
          originOfText="P">
          <boundingBox id="bb13">
            <position x="170" y="315" />
            <dimensions width="30" height="30" />
          </boundingBox>
        </textGlyph>
        <textGlyph id="TextGlyph_ProteinKinase1"
          graphicalObject="SpeciesGlyph_ProteinKinase" text="Protein-">
          <boundingBox id="bb14">
            <position x="180" y="35" />
            <dimensions width="80" height="20" />
          </boundingBox>
        </textGlyph>
        <textGlyph id="TextGlyph_Proteinkinase2"
          graphicalObject="SpeciesGlyph_ProteinKinase" text="kinase">
          <boundingBox id="bb15">
            <position x="180" y="55" />
            <dimensions width="80" height="20" />
          </boundingBox>
        </textGlyph>
      </listOfTextGlyphs>
    </layout>
  </layout:listOfLayouts>
</annotation>
<listOfUnitDefinitions>
  <unitDefinition id="volume">
    <listOfUnits>
      <unit kind="litre" />
    </listOfUnits>
  </unitDefinition>
  <unitDefinition id="substance">
    <listOfUnits>
      <unit kind="mole" />
    </listOfUnits>
  </unitDefinition>
  <unitDefinition id="area">
    <listOfUnits>
      <unit kind="metre" exponent="2" />
    </listOfUnits>
  </unitDefinition>
  <unitDefinition id="length">
    <listOfUnits>
      <unit kind="metre" />
    </listOfUnits>
  </unitDefinition>
  <unitDefinition id="time">
    <listOfUnits>
      <unit kind="second" />
    </listOfUnits>
  </unitDefinition>
</listOfUnitDefinitions>
<listOfCompartments>
  <compartment id="Cell" units="volume" />
</listOfCompartments>
<listOfSpecies>
  <species id="Protein" name="Protein" compartment="Cell"
    substanceUnits="substance" />
  <species id="ProteinP" name="Protein" compartment="Cell"
    substanceUnits="substance" />
  <species id="ATP" name="ATP" compartment="Cell"
    substanceUnits="substance" />
  <species id="ADP" name="ADP" compartment="Cell"
```


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```
        substanceUnits="substance" />
      <species id="P" name="P" compartment="Cell" substanceUnits="substance" />
      <species id="ProteinKinase" name="Protein Kinase"
        compartment="Cell" substanceUnits="substance" />
    </listOfSpecies>
    <listOfReactions>
      <reaction id="Phosphorylation" reversible="false">
        <listOfReactants>
          <speciesReference id="SpeciesReference_Protein"
            species="Protein" />
          <speciesReference id="SpeciesReference_ATP"
            species="ATP" />
        </listOfReactants>
        <listOfProducts>
          <speciesReference id="SpeciesReference_ProteinP"
            species="ProteinP" />
          <speciesReference id="SpeciesReference_ADP"
            species="ADP" />
        </listOfProducts>
        <listOfModifiers>
          <modifierSpeciesReference id="ModifierSpeciesReference_ProteinKinase"
            species="ProteinKinase" />
        </listOfModifiers>
      </reaction>
      <reaction id="Dephosphorylation" reversible="false">
        <listOfReactants>
          <speciesReference id="SpeciesReference_ProteinP_rev"
            species="ProteinP" />
        </listOfReactants>
        <listOfProducts>
          <speciesReference id="SpeciesReference_Protein_rev"
            species="Protein" />
          <speciesReference id="SpeciesReference_P" species="P" />
        </listOfProducts>
      </reaction>
    </listOfReactions>
  </model>
</sbml>
```


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5 Best practices

In this section, we recommend a number of practices for using and interpreting various constructs in the Render package. These recommendations are non-normative, but we advocate them strongly; ignoring them will not render a model invalid, but may reduce interoperability between software and models.

5.1 Text

A **Text** has an optional attribute `font-family` of type `string` that allows to specify the font or font-family to be used for the text element. For maximum interoperability the font families specified in **FontFamily** have to be supported at a minimum. Those are the generic families "`serif`", "`sans-serif`" and "`monospace`". Is is recommended good practice to use only these fonts to allow for greater exchangeability.

5.2 Image

If the referenced resource can not be found, it is up to the application if nothing is drawn or some place holder is displayed. Preferably the user would get some kind of notification about the missing resource.

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6 Future development

In this section we highlight some open issues not addressed in this version of the Render specification.

6.1 Values for StyleType

Concerning the valid keywords for the `roleList` attribute we had thought about taking those from some kind of controlled vocabulary. Preferably, this would be some kind of ontology like SBO. The specifics of this will have to be discussed with other interested parties

6.2 3D drawings

Both the transformations and graphical primitives considered here have been limited to the 2D situation.

6.3 Text

Outlined or filled-outlined text are currently not covered by this specification.

6.4 Image

To include bitmaps into a graphical representation we use the **Image** element from SVG. The **Image** element in SVG can also be used to include complete SVG vector images which we explicitly exclude in this version of the proposal since we think it would be too complex. If the need for the inclusion of SVG drawings arises, it is only a matter of rephrasing this specification.

Non-local image resources (e.g., from the web) are currently not supported.

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A Text Anchor Examples

A.1 Vertical Text Anchor Examples

The following figures illustrate the use of the different **VTextAnchor** values.

A.1.1 Top

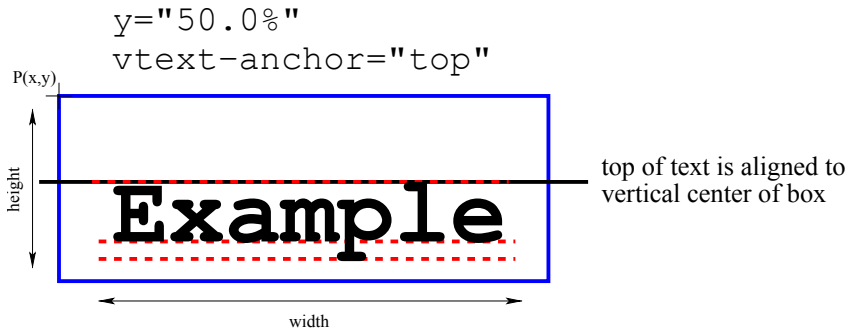

Figure 17: *vertical text alignment* `top`

A.1.2 Bottom

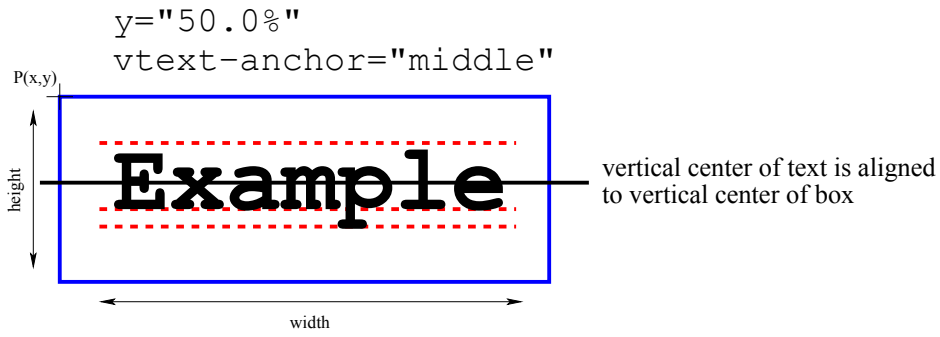

Figure 18: *vertical text alignment* `bottom`

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A.1.3 Middle

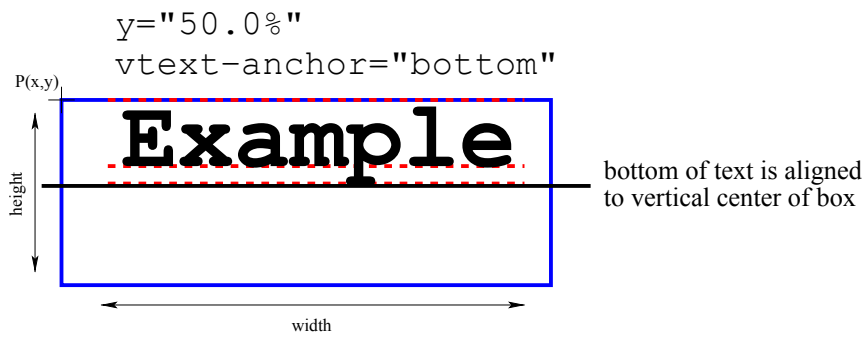

Figure 19: *vertical text alignment* `middle`

A.1.4 Baseline

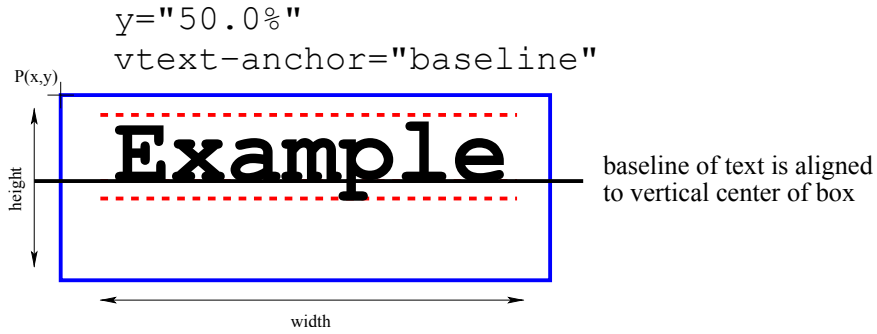

Figure 20: *vertical text alignment* `baseline`

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A.2 Horizontal Text Anchor Examples

The following figures illustrate the use of different **HTextAnchor** values.

A.2.1 Start

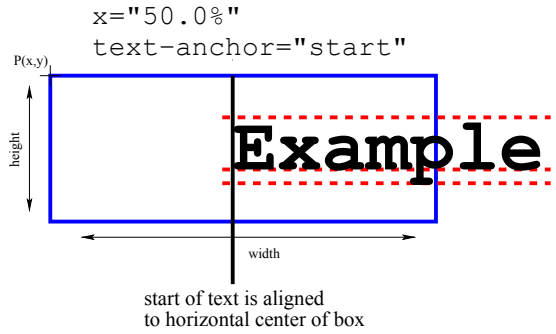

Figure 21: *horizontal text alignment* `start`

A.2.2 Middle

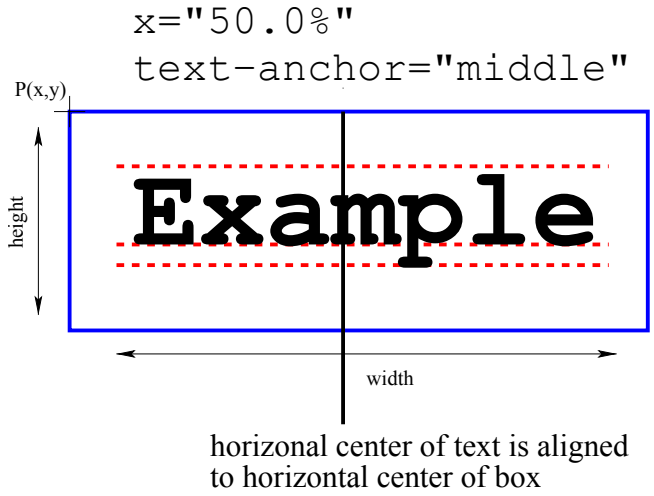

Figure 22: *horizontal text alignment* `middle`

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A.2.3 End

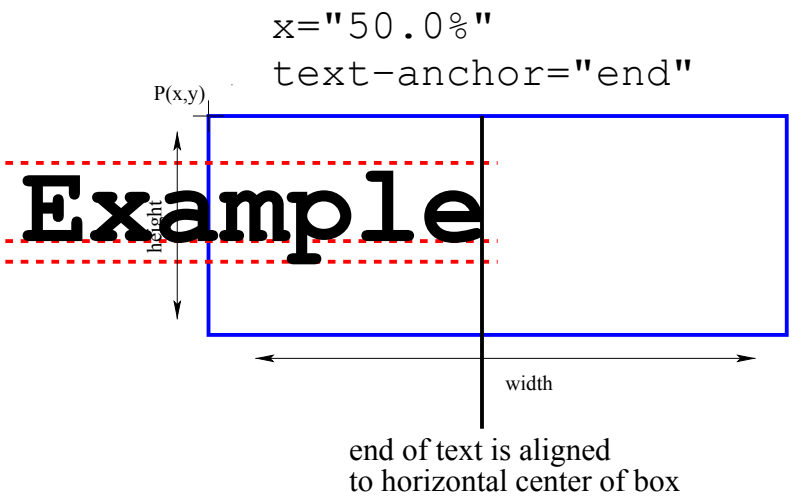

Figure 23: *horizontal text alignment* end

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B Transformations

There are four basic transformation operations that can be combined in a affine transformation matrix.

B.1 Translation

Translating something means moving it some distance along one or more of the axes. The corresponding 2D transformation matrix is

$$\begin{bmatrix} 1 & 0 & tx \\ 0 & 1 & ty \\ 0 & 0 & 1 \end{bmatrix}$$

where tx and ty are the distance along the x and y axes by which the object shall be moved.

B.2 Scaling

Scaling means to multiply all coordinate components of an object by a certain value. The corresponding 2D transformation matrix is

$$\begin{bmatrix} sx & 0 & 0 \\ 0 & sy & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

where sx and sy are the scaling factors along the x and y axis respectively.

B.3 Rotation

With a rotation, an object can be rotated around the origin of the coordinate system. The corresponding 2D transformation matrix is

$$\begin{bmatrix} cos(\alpha) & -sin(\alpha) & 0 \\ sin(\alpha) & cos(\alpha) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

where α is the angle of rotation around the origin.

B.4 Skewing

Skewing is the least used operation and we have to distinguish between skewing along the x- or the y-axis. The corresponding 2D transformation matrices are

$$\begin{bmatrix} 1 & tan(\alpha) & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

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$$\begin{bmatrix} 1 & 0 & 0 \\ tab(\beta) & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

where α is the skewing angle of skewing along the x-axis and β is the angle for skewing along the y-axis.

Combining several of the operations above means multiplying the transformation matrices that belong to the individual operations. Depending on the matrices that are multiplied, the order of the operations matter, e.g., it makes a difference if an object is translated before it is rotated or if it is rotated first.

If an object specifies a transformation, this transformation is to be applied to the object prior to any other coordinate properties of the object. For instance, if a rectangle specifies a position of $x = 10$ and $y = 20$ and it also specifies a rotation by 45 degrees, the rotation is applied before the object is placed at $P(10,20)$. The transformation for an object is always in relation to the objects view port. For most render objects, this would be the bounding box of the corresponding layout object. For layout curves, e.g., in reaction glyphs or species reference glyphs, the viewport is the complete diagram. For objects defined in line endings, the viewport is the bounding box of the line ending before it is applied to the line.

example:

```
 <g ...>
   <text x="50%" y="50%" text-anchor="middle" stroke="#FF0000"
        font-family="serif" font-size="20.0"
        transform="1.0,␣3.0,␣2.5,␣1.4,␣4.0,␣5.0">This is a Text</text>
      ...
</g>
```


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C Resolving render information

C.1 Mapping line endings to curves

In order to apply a line ending which is defined using only 2D coordinates onto a line which has been defined using 3D coordinates, we need to define a mapping. The first definition we make is that the origin of the line ending viewport is mapped to the end of the line to which the line ending is applied. If the `enableRotationalMapping` attribute is set to "`false`", the line endings coordinate system is the same as the global coordinate system used to draw the layout, only the origin is moved to that end of the line the line ending is applied to. If the `enableRotationalMapping` attribute is set to "`true`", which is the default, we define that the x,y-plane of the line endings viewport is mapped to the plane that results from taking the unit vector of the slope of the line and the unit vector that results from ortho-normalizing the slope vector and a second vector that has no component along the z-axis. If the slope of the line has a positive component along the x-axis, the ortho-normalized vector also has to have a positive component along the y-axis. In order to retain the right handed coordinate system, the z-axis of the line endings coordinate system is perpendicular to the plane created by the other two vectors and has a positive component along the global coordinate systems z-axis. Likewise if the slope has a negative component along the global coordinate systems x-axis, the y-component of the ortho-normalized second vector has a negative component along the y-axis of the global coordinate system and to retain the right handed coordinate system, the third vector which is perpendicular to the plane made by the slope and its ortho-normalized vector, has a positive component along the global coordinate systems z-axis.

If the slope of the line points directly along the positive z-axis of the global coordinate system, the line endings coordinate system is mapped to the line ending by a -90 rotation around the y-axis of the line endings coordinate system and a translation of the origin of the line endings coordinate system to the end of the line. If the slope points directly down the negative z-axis, the line endings coordinate system has to be rotated by +90 around its y-axis before translation to the position of the curves end.

This may all sound very complicated, but in the end, the calculations to be done are not difficult and straightforward.

The mapping of arrowheads to line endings involves some transformations which we would like to illustrate with two examples. The first example as depicted in Figure 24 defines a straight line and a line ending which is to be applied to the end of the line. The line ending specifies a bounding box with a size of 4×4 and a position of $P(-2,-2)$. The origin of the line ending is at $o(0.0,0.0,0.0)$ and the bounding box extends along the positive x- and y-axes. The position of the bounding box is the offset by which the origin of the bounding box has to be translated from the endpoint of the curve.

Since the arrow head in the first example explicitly disables rotation mapping by specifying **enableRotationalMapping=false** in the definition of the line ending, the process of mapping the arrow head to the line is simply a matter of moving the origin of the line endings coordinate system to the end point of the line $E(ex,ey)$ plus the offset that is specified as the position $P(px,py,pz)$ of the line endings bounding box $F = E + P = (ex+px, ey+py, ez+pz)$. In our example the origin of the line endings coordinate system has to be moved 2 units up and two to the left of the and of the curve that the line ending is applied to.

The result of this operation is depicted in Figure 25.

The second example is very similar to the first example, only now, the rotational mapping for the arrow head is enabled. This means that we now have to execute two steps in order to map the arrow head to the line ending.

First we need to rotate the arrow head so that the x-axis of the arrow heads coordinate system is aligned with the slope $s = \frac{dy}{dx}$ of the curve.

The rotation of the arrow head involves the following steps:

1. Calculate the normalized direction vector of the slope:
   We first need to find the two points that determine the slope at the end of the line. One point is always the

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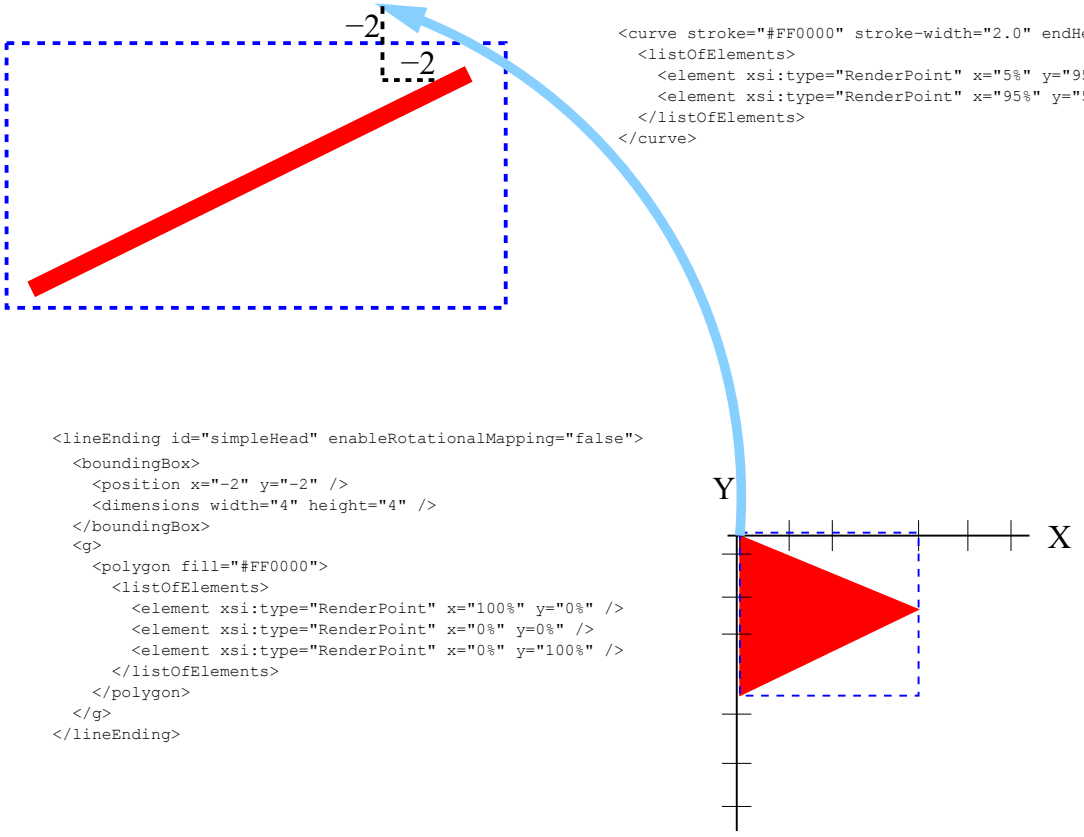


```
<curve stroke="#FF0000" stroke-width="2.0" endHead="simpleHead">
  <listOfElements>
    <element xsi:type="RenderPoint" x="5%" y="95%" />
    <element xsi:type="RenderPoint" x="95%" y="5%" />
  </listOfElements>
</curve>
```

```
<lineEnding id="simpleHead" enableRotationalMapping="false">
  <boundingBox>
    <position x="-2" y="-2" />
    <dimensions width="4" height="4" />
  </boundingBox>
  <g>
    <polygon fill="#FF0000">
      <listOfElements>
        <element xsi:type="RenderPoint" x="100%" y="0%" />
        <element xsi:type="RenderPoint" x="0%" y="0%" />
        <element xsi:type="RenderPoint" x="0%" y="100%" />
      </listOfElements>
    </polygon>
  </g>
</lineEnding>
```

Figure 24: *Curve with arrow head and no rotational mapping*

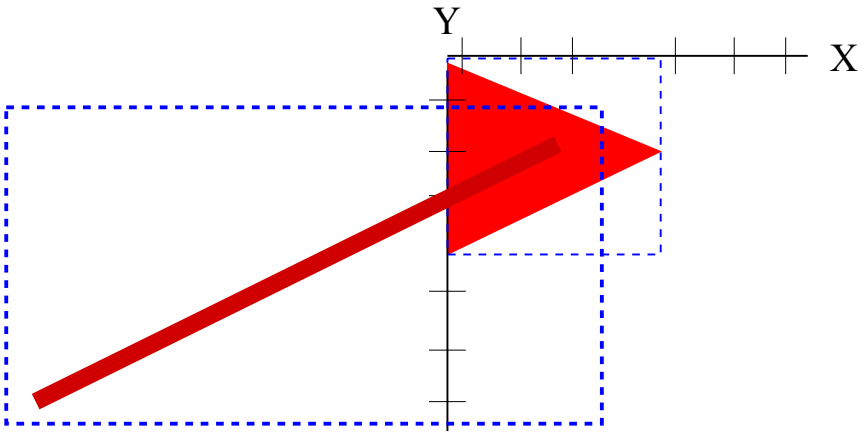

Figure 25: *Curve with mapped arrow head and no rotational mapping*

endpoint of the line ($E(ex, ey, ez)$). The second point depends on whether the last element of the line is a straight line or if it is a BÃľzier element. If it is a BÃľzier element, the second point is the second base point of the BÃľzier element, if it is a straight line, it is either the preceding point or the endpoint of the preceding BÃľzier element. We call this second point $S(sy, dy, sz)$.

The direction vector can be calculated as $v(vx, vy, vz) = (ex - sy.ey - sy, ez - sz)$. To normalize the vector we have to calculate the length $l = \sqrt{vx^2 + vy^2 + vz^2}$ of the direction vector and divide all elements of v by this length: $v_n(v_n x, v_n y, v_n z) = (vx/l, vy/l, vz/l)$.

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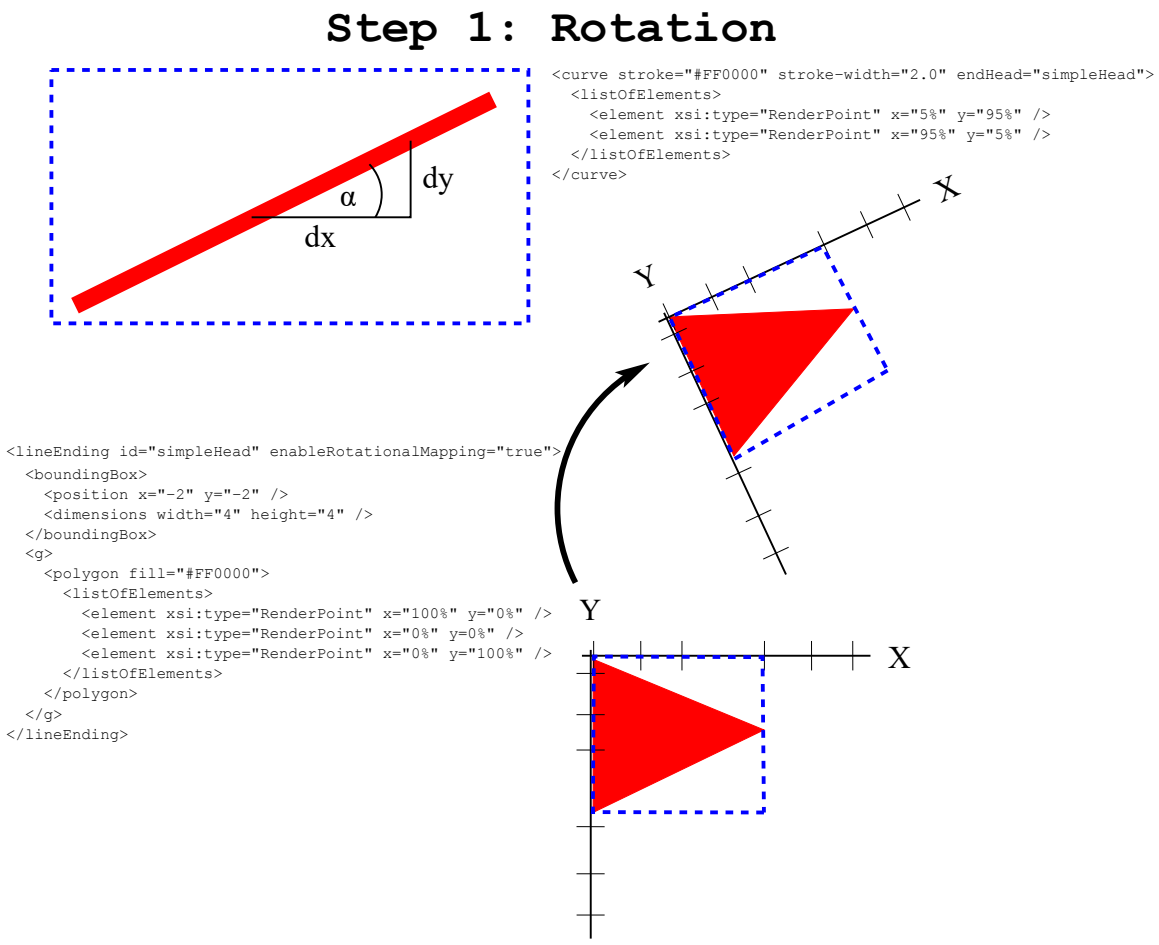

Figure 26: *Step 1: Rotation*

2. Calculate the normalized vector that is

   (a) orthogonal to the direction vector of the line

   (b) located in the plane x- and y-axis

   If the direction vector is parallel to the y-axis ($vx = 0.0$), the orthogonal vector w is parallel to the x-axis ($w(vy, 0, 0)$). For all other cases w is $w(wx, wy, wz) = (-vny * vnx, 1 - vny^2, -vny * vnz)$.
   Again, we have to normalize this vector by dividing through its length $n = \sqrt{wx^2 + wy^2 + wz^2}$, which results in the normalized vector $wn(wnx, wny, wnz) = (wx/n, wy/n, wz/n)$.

3. Create the transformation matrix that converts the original coordinate system into the coordinate system that is made up of the two calculated vectors. The transformation matrix that results from the two normalized vector that we calculated in the steps above is

$$m = \begin{pmatrix} vnx & wnx & 0.0 & 0.0 \\ vny & wny & 0.0 & 0.0 \\ vnz & wnz & 0.0 & 1.0 \end{pmatrix}$$

The second step moves the origin of the arrow heads coordinate system to the endpoint of the line, which is exactly the same as we did in the first example.

Mapping of an arrow head to the beginning of a curve is exactly the same as for the end of a curve, only the direction of the line has to be reversed and in case of a cubic bezier, one has to use the first base point rather than the second

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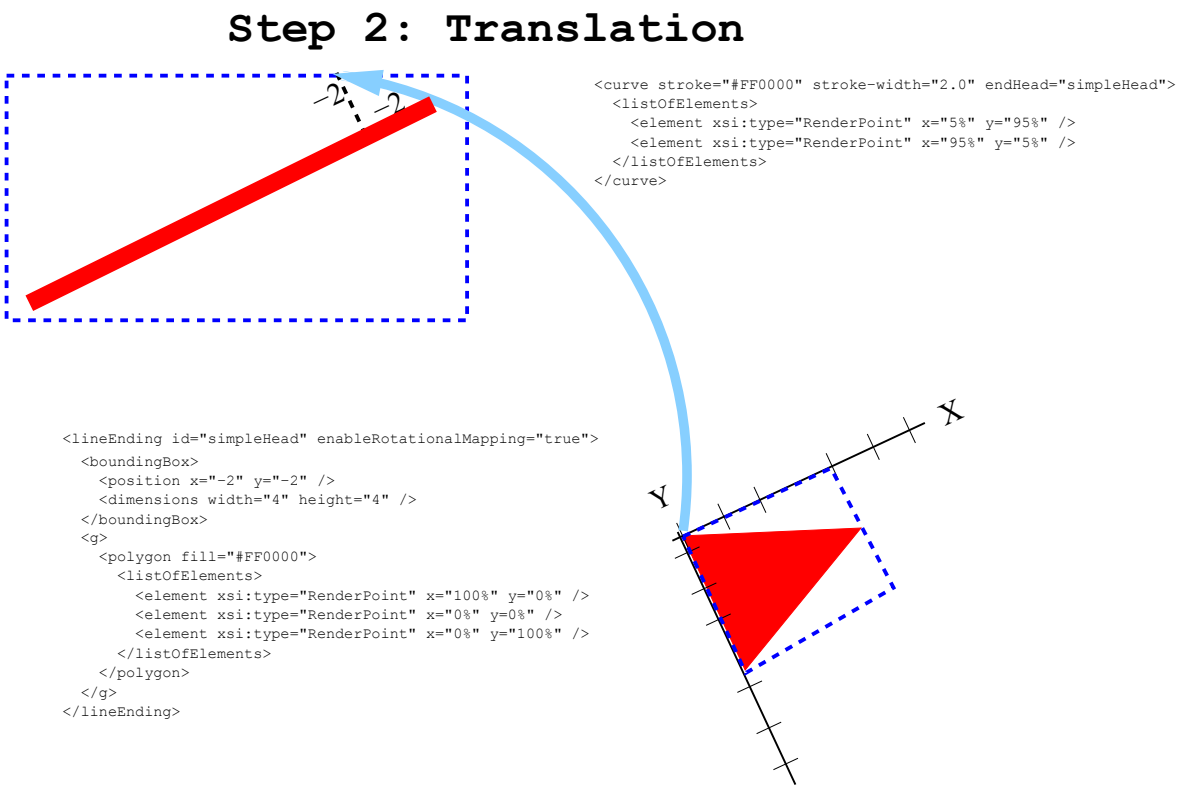

Figure 27: *Step 2: Translation*

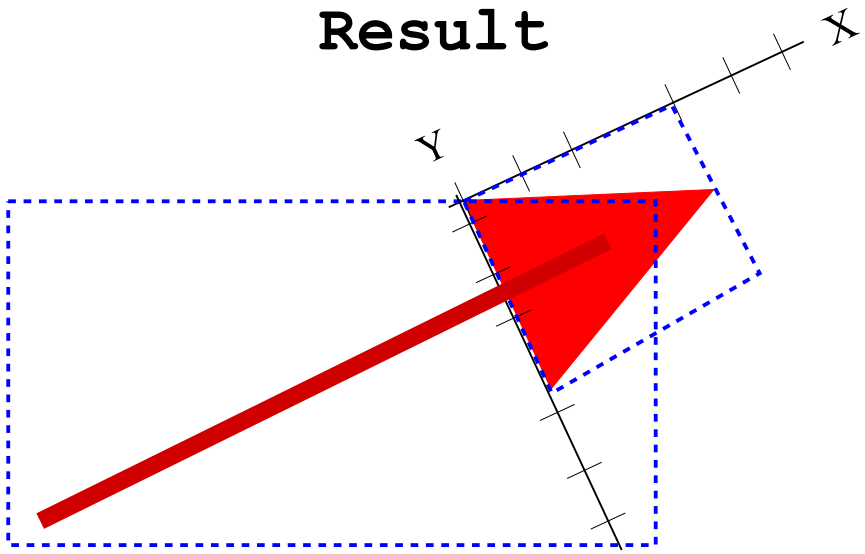

Figure 28: *Curve with mapped arrow head and rotational mapping*

base point.

C.2 Style resolution

To resolve which style applies to a certain object, one should follow the rule that more specific style definitions take precedence over less specific ones and that if there are several styles with the same specificity, the first one

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encountered in the file is to be used. In essence, this means that a program first has to search the local render information for a style that references the id of the object. If none is found, it searches for a style that mentions the role of the object. If it has one, see next section. If it does not find one, it searches for a style for the type of the object.

If a render information references another render information object via its `referenceRenderInformation` attribute, the program has to go through that one as well to see if a more specific render information is present there. If the chain of referenced **RenderInformation** objects has been searched and no style has been found that fits, it is up to the program how the object is rendered.

If several type-based styles are found that would fit, a style that applies to only one type takes precedence over a style that applies to several types.

If a program explicitly wants to define render information that states that some objects are not to be rendered at all, it has to define a style that does nothing, i.e., has no render information but applies to the objects that should not be rendered.

C.3 Role resolution

This render extension explicitly provides means to write render information that renders layout objects based on certain roles those render objects or their corresponding model objects have. So far SBML models or layouts do not contain such role information or only for a limited number of objects if one would consider the role attribute of **SpeciesReferenceGlyph** objects to fall into this category. Although there is currently no means to specify these roles, there are already initiatives underway that try to complement SBML files with more biological information based on ontologies.

For the time being, we define an additional attribute called `objectRole` for all layout objects derived from **GraphicalObject** including **GraphicalObject** itself. The attribute specifies a user defined role string. Render information including the same role string in its `roleList` attribute applies to the object. This is only true if no more specific render information takes precedence (see "Style resolution").

A specific style can reference one or more roles to which it applies. When a program tries to determine which style applies to a specific object it might have to determine the role of the object layout first. If the layout object itself has a role, this will be taken, otherwise if the layout object is associated with an object in the model, the program should get the role from the associated object. If none of them has a role, no role based style can be applied to the object.

C.4 Style information for reaction glyphs and species reference glyphs

When defining a style for a **ReactionGlyph** or **SpeciesReferenceGlyph** object, one has to distinguish between layout objects that only specify a bounding box for the object and those that specify a curve. In the case of a bounding box, it is necessary to define complete render information, whereas in the case of a curve, only certain attributes that determine certain aspects of how the curve should be drawn, e.g., its color. To resolve this conflict, the style for such an object has to define render information for both cases. The render information for the case of a bounding box is specified just like render information for any other object within a group. Render information for the case of a curve is defined by the appropriate attributes that are in effect in the outermost **RenderGroup** object itself. Those attributes include `stroke`, `stroke-width` and `stroke-dasharray`. Additionally, `startHead` and `endHead` can be specified to define line endings for layout curve objects. If the group does not define one or more of these attributes, the default value is used (see also Section 3.3.2 on page 12).

C.5 Style information for text glyphs

Just as in the case of curves in **ReactionGlyph**s and **SpeciesReferenceGlyph**s, **TextGlyph**s can be considered render information which is located in the layout. A **TextGlyph** specifies the text to be rendered, it therefore does not need additional render information in the form of a `text` element. On the other hand, it needs render information in

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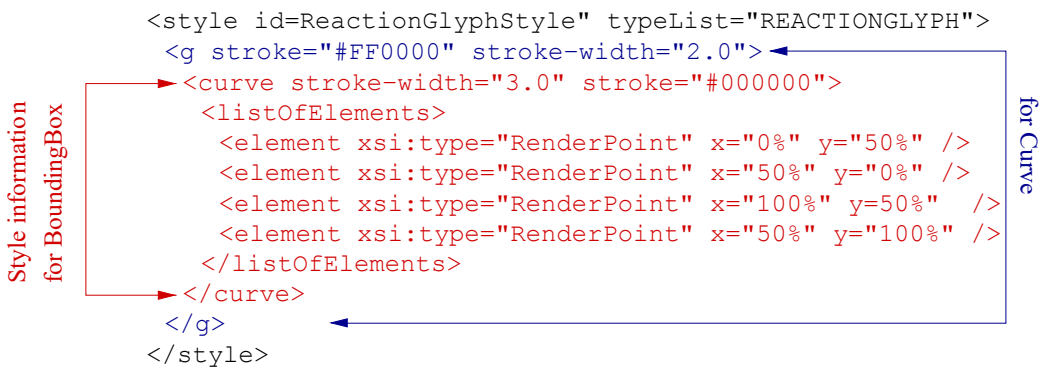

Figure 29: *style with render information for objects with curve or bounding box*

the form of font properties. Just as for the **RenderCurve** object for **ReactionGlyph**s and **SpeciesReferenceGlyph**s, this render information is taken from the font related attributes of the outermost group element of the style that is used to render a **TextGlyph**. Any additional information within the group is ignored. If the group does not specify any of the `font-family`, `font-size`, `font-weight`, `font-style`, `text-anchor` or `vtext-anchor` attributes, the default values are to be used.

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D Validation of SBML documents

D.1 Validation and consistency rules

This section summarizes all the conditions that must (or in some cases, at least *should*) be true of an SBML Level 3 Version 1 model that uses the Render package. We use the same conventions as are used in the SBML Level 3 Version 1 Core specification document. In particular, there are different degrees of rule strictness. Formally, the differences are expressed in the statement of a rule: either a rule states that a condition *must* be true, or a rule states that it *should* be true. Rules of the former kind are strict SBML validation rules—a model encoded in SBML must conform to all of them in order to be considered valid. Rules of the latter kind are consistency rules. To help highlight these differences, we use the following three symbols next to the rule numbers:

☑ A checked box indicates a *requirement* for SBML conformance. If a model does not follow this rule, it does not conform to the Render package specification. (Mnemonic intention behind the choice of symbol: "This must be checked.")

▲ A triangle indicates a *recommendation* for model consistency. If a model does not follow this rule, it is not considered strictly invalid as far as the Render package specification is concerned; however, it indicates that the model contains a physical or conceptual inconsistency. (Mnemonic intention behind the choice of symbol: "This is a cause for warning.")

★ A star indicates a strong recommendation for good modeling practice. This rule is not strictly a matter of SBML encoding, but the recommendation comes from logical reasoning. As in the previous case, if a model does not follow this rule, it is not strictly considered an invalid SBML encoding. (Mnemonic intention behind the choice of symbol: "You're a star if you heed this.")

The validation rules listed in the following subsections are all stated or implied in the rest of this specification document. They are enumerated here for convenience. Unless explicitly stated, all validation rules concern objects and attributes specifically defined in the Render package package.

☞ For convenience and brevity, we use the shorthand "`render:x`" to stand for an attribute or element name `x` in the namespace for the Render package package, using the namespace prefix `render`. In reality, the prefix string may be different from the literal "`render`" used here (and indeed, it can be any valid XML namespace prefix that the modeler or software chooses). We use "`render:x`" because it is shorter than to write a full explanation everywhere we refer to an attribute or element in the Render package namespace.

General rules about this package

render-10101 ☑ To conform to the Render package specification for SBML Level 3 Version 1, an SBML document must declare "`http://www.sbml.org/sbml/level3/version1/render/version1`" as the XMLNamespace to use for elements of this package. (Reference: SBML Level 3 Specification for Render, Version 1 Section 3.1 on page 7.)

render-10102 ☑ Wherever they appear in an SBML document, elements and attributes from the Render package must use the "`http://www.sbml.org/sbml/level3/version1/render/version1`" namespace, declaring so either explicitly or implicitly. (Reference: SBML Level 3 Specification for Render, Version 1 Section 3.1 on page 7.)

General rules about identifiers

render-10301 ☑ (Extends validation rule #10301 in the SBML Level 3 Version 1 Core specification.) Within a **Model** the values of the `render:id` attributes of a **GlobalRenderInformation** object and a **LocalRenderInformation** object should not clash with any other attribute `id` values from the global model scope Within the Render package the attribute `render:id` need only be unique for **LineEndings**. (Reference: SBML Level 3 Version 1 Core, Section 3.1.7.)

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render-10302 ☑ The value of a `render:id` must conform to the syntax of the **SBML** data type `SId` (Reference: SBML Level 3 Version 1 Core, Section 3.1.7.)

Rules for the extended SBML class

render-20101 ☑ In all SBML documents using the Render package, the **SBML** object must have the `render:required` attribute. (Reference: SBML Level 3 Version 1 Core, Section 4.1.2.)

render-20102 ☑ The value of attribute `render:required` on the **SBML** object must be of data type `boolean`. (Reference: SBML Level 3 Version 1 Core, Section 4.1.2.)

render-20103 ☑ The value of attribute `render:required` on the **SBML** object must be set to "`false`". (Reference: SBML Level 3 Specification for Render, Version 1 Section 3.1 on page 7.)

Rules for extended GraphicalObject object

render-20201 ☑ A **GraphicalObject** object may have the optional attribute `render:objectRole`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **GraphicalObject** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.1 on page 14.)

render-20202 ☑ The attribute `render:objectRole` on a **GraphicalObject** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.1 on page 14.)

Rules for extended Layout object

render-20301 ☑ A **Layout** object may contain one and only one instance of the **ListOfLocalRenderInformation** element. No other elements from the SBML Level 3 Render namespaces are permitted on a **Layout** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.3 on page 15.)

render-20302 ☑ The **ListOfLocalRenderInformation** subobject on a **Layout** object is optional, but if present, this container object must not be empty. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.3 on page 15.)

render-20303 ☑ Apart from the general notes and annotations subobjects permitted on all SBML objects, a **ListOfLocalRenderInformation** container object may only contain **LocalRenderInformation** objects. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.3 on page 15.)

render-20304 ☑ A **ListOfLocalRenderInformation** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **ListOfLocalRenderInformation** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.3 on page 15.)

render-20305 ☑ A **ListOfLocalRenderInformation** object may have the optional attributes `render:versionMajor`, `render:versionMinor` and `render:defaultValues`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **ListOfLocalRenderInformation** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.3 on page 15.)

render-20306 ☑ The attribute `render:versionMajor` on a **Layout** must have a value of data type `integer`, and must be non negative. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.3 on page 15.)

render-20307 ☑ The attribute `render:versionMinor` on a **Layout** must have a value of data type `integer`, and must be non negative. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.3 on page 15.)

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Rules for extended ListOfLayouts object

render-20401 ☑ A **ListOfLayouts** object may contain one and only one instance of the **ListOfGlobalRenderInformation** element. No other elements from the SBML Level 3 Render namespaces are permitted on a **ListOfLayouts** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.2 on page 14.)

render-20402 ☑ The **ListOfGlobalRenderInformation** subobject on a **ListOfLayouts** object is optional, but if present, this container object must not be empty. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.2 on page 14.)

render-20403 ☑ Apart from the general notes and annotations subobjects permitted on all SBML objects, a **ListOfGlobalRenderInformation** container object may only contain **GlobalRenderInformation** objects. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.2 on page 14.)

render-20404 ☑ A **ListOfGlobalRenderInformation** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **ListOfGlobalRenderInformation** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.2 on page 14.)

render-20405 ☑ A **ListOfGlobalRenderInformation** object may have the optional attributes `render:versionMajor`, `render:versionMinor` and `render:defaultValues`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **ListOfGlobalRenderInformation** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.2 on page 14.)

render-20406 ☑ The attribute `render:versionMajor` on a **ListOfLayouts** must have a value of data type `integer`, and must be non negative. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.2 on page 14.)

render-20407 ☑ The attribute `render:versionMinor` on a **ListOfLayouts** must have a value of data type `integer`, and must be non negative. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.4.2 on page 14.)

Rules for ColorDefinition object

render-20501 ☑ A **ColorDefinition** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **ColorDefinition**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-20502 ☑ A **ColorDefinition** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **ColorDefinition**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-20503 ☑ A **ColorDefinition** object must have the required attributes `render:id` and `render:value`, and may have the optional attribute `render:name`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **ColorDefinition** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.1 on page 20.)

render-20504 ☑ The attribute `render:value` on a **ColorDefinition** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.1 on page 20.)

render-20505 ☑ The attribute `render:name` on a **ColorDefinition** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.1 on page 20.)

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Rules for Ellipse object

render-20601 ☑ An **Ellipse** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on an **Ellipse**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-20602 ☑ An **Ellipse** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on an **Ellipse**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-20603 ☑ An **Ellipse** object must have the required attributes `render:cx`, `render:cy` and `render:rx`, and may have the optional attributes `render:ratio`, `render:cz` and `render:ry`. No other attributes from the SBML Level 3 Render namespaces are permitted on an **Ellipse** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.3 on page 33.)

render-20604 ☑ The value of the attribute `render:cx` of an **Ellipse** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.3 on page 33.)

render-20605 ☑ The value of the attribute `render:cy` of an **Ellipse** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.3 on page 33.)

render-20606 ☑ The value of the attribute `render:rx` of an **Ellipse** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.3 on page 33.)

render-20607 ☑ The attribute `render:ratio` on an **Ellipse** must have a value of data type `double`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.3 on page 33.)

render-20608 ☑ The value of the attribute `render:cz` of an **Ellipse** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.3 on page 33.)

render-20609 ☑ The value of the attribute `render:ry` of an **Ellipse** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.3 on page 33.)

Rules for GlobalRenderInformation object

render-20701 ☑ A **GlobalRenderInformation** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **GlobalRenderInformation**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-20702 ☑ A **GlobalRenderInformation** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **GlobalRenderInformation**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

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render-20703 ☑ A **GlobalRenderInformation** object may contain one and only one instance of the **ListOfGlobalStyles** element. No other elements from the SBML Level 3 Render namespaces are permitted on a **GlobalRenderInformation** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.3 on page 17.)

render-20704 ☑ The **ListOfGlobalStyles** subobject on a **GlobalRenderInformation** object is optional, but if present, this container object must not be empty. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.3 on page 17.)

render-20705 ☑ Apart from the general notes and annotations subobjects permitted on all SBML objects, a **ListOfGlobalStyles** container object may only contain **GlobalStyle** objects. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.3 on page 17.)

render-20706 ☑ A **ListOfGlobalStyles** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **ListOfGlobalStyles** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.3 on page 17.)

Rules for GlobalStyle object

render-20801 ☑ A **GlobalStyle** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **GlobalStyle**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-20802 ☑ A **GlobalStyle** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **GlobalStyle**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

Rules for GradientBase object

render-20901 ☑ A **GradientBase** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **GradientBase**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-20902 ☑ A **GradientBase** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **GradientBase**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-20903 ☑ A **GradientBase** object must have the required attribute `render:id`, and may have the optional attributes `render:name` and `render:spreadMethod`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **GradientBase** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.2 on page 21.)

render-20904 ☑ A **GradientBase** object must contain at least one instance of the **GradientStop** element. No other elements from the SBML Level 3 Render namespaces are permitted on a **GradientBase** object. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.7.2 on page 21.)

render-20905 ☑ The attribute `render:name` on a **GradientBase** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.2 on page 21.)

render-20906 ☑ The value of the attribute `render:spreadMethod` of a **GradientBase** object must conform to the syntax of SBML data type `GradientSpreadMethod` and may only take on the allowed values of `GradientSpreadMethod` defined in SBML; that is, the value must be one of the following: "`pad`", "`reflect`" or "`repeat`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.2 on page 21.)

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Rules for GradientStop object

render-21001 ☑ A **GradientStop** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **GradientStop**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21002 ☑ A **GradientStop** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **GradientStop**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21003 ☑ A **GradientStop** object must have the required attributes `render:stop-color` and `render:offset`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **GradientStop** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.3 on page 21.)

render-21004 ☑ The attribute `render:stop-color` on a **GradientStop** must have a value of data type `string` where that string is restricted to either a 6 or 8 digit hex number; the `id` of an existing **ColorDefinition** or the value "`none`". (Reference: SBML Level 3 Specification for Render Version 1, Section 3.7.3 on page 21.)

render-21005 ☑ The value of the attribute `render:offset` of a **GradientStop** object must conform to the syntax of SBML data type **RelAbsVector** but in this case can only encode a relative value i.e. a string encoding a number followed by a % sign. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.7.3 on page 21.)

render-21006 ▲ The value of the attribute `render:offset` of a **GradientStop** object should be between "`0%`" and "`100%`". (Reference: SBML Level 3 Specification for Render Version 1, Section 3.7.3 on page 21.)

render-21007 ▲ The value of the attribute `render:offset` of a **GradientStop** object should be greater than or equal to the value of the `offset` attribute on the previous **GradientStop**. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.7.3 on page 21.)

Rules for RenderGroup object

render-21101 ☑ A **RenderGroup** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **RenderGroup**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21102 ☑ A **RenderGroup** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **RenderGroup**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21103 ☑ A **RenderGroup** object may have the optional attributes `render:startHead`, `render:endHead`, `render:font-family`, `render:font-weight`, `render:font-style`, `render:text-anchor`, `render:vtext-anchor` and `render:font-size`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **RenderGroup** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.6 on page 35.)

render-21104 ☑ The value of the attribute `render:startHead` of a **RenderGroup** object must be the identifier of an existing **LineEnding** object defined in the enclosing **Model** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.6 on page 35.)

render-21105 ☑ The value of the attribute `render:endHead` of a **RenderGroup** object must be the identifier of an existing **LineEnding** object defined in the enclosing **Model** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.6 on page 35.)

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render-21106 ☑ The attribute `render:font-family` on a **RenderGroup** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.6 on page 35.)

render-21107 ☑ The value of the attribute `render:font-weight` of a **RenderGroup** object must conform to the syntax of SBML data type `FontWeight` and may only take on the allowed values of `FontWeight` defined in SBML; that is, the value must be one of the following: "`bold`" or "`normal`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.6 on page 35.)

render-21108 ☑ The value of the attribute `render:font-style` of a **RenderGroup** object must conform to the syntax of SBML data type `FontStyle` and may only take on the allowed values of `FontStyle` defined in SBML; that is, the value must be one of the following: "`italic`" or "`normal`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.6 on page 35.)

render-21109 ☑ The value of the attribute `render:text-anchor` of a **RenderGroup** object must conform to the syntax of SBML data type `HTextAnchor` and may only take on the allowed values of `HTextAnchor` defined in SBML; that is, the value must be one of the following: "`start`", "`middle`" or "`end`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.6 on page 35.)

render-21110 ☑ The value of the attribute `render:vtext-anchor` of a **RenderGroup** object must conform to the syntax of SBML data type `VTextAnchor` and may only take on the allowed values of `VTextAnchor` defined in SBML; that is, the value must be one of the following: "`top`", "`middle`", "`bottom`" or "`baseline`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.6 on page 35.)

render-21111 ☑ The value of the attribute `render:font-size` of a **RenderGroup** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.6 on page 35.)

Rules for Image object

render-21201 ☑ An **Image** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on an **Image**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21202 ☑ An **Image** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on an **Image**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21203 ☑ An **Image** object must have the required attributes `render:href`, `render:x`, `render:y`, `render:width` and `render:height`, and may have the optional attributes `render:id` and `render:z`. No other attributes from the SBML Level 3 Render namespaces are permitted on an **Image** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.5 on page 34.)

render-21204 ☑ The attribute `render:href` on an **Image** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.5 on page 34.)

render-21205 ☑ The value of the attribute `render:x` of an **Image** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.5 on page 34.)

render-21206 ☑ The value of the attribute `render:y` of an **Image** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by

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an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.5 on page 34.)

render-21207 ☑ The value of the attribute `render:width` of an **Image** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.5 on page 34.)

render-21208 ☑ The value of the attribute `render:height` of an **Image** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.5 on page 34.)

render-21209 ☑ The attribute `render:href` on an **Image** must point to a local file of type "`jpeg`" or "`png`". (Reference: SBML Level 3 Specification for Render Version 1, Section 3.10.5 on page 34.)

render-21210 ☑ The value of the attribute `render:z` of an **Image** object must conform to the syntax of SBML data type **RelAbsVector** i.e. a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.10.5 on page 34.)

Rules for LineEnding object

render-21301 ☑ A **LineEnding** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **LineEnding**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21302 ☑ A **LineEnding** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **LineEnding**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21303 ☑ A **LineEnding** object must have the required attribute `render:id`, and may have the optional attribute `render:enableRotationalMapping`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **LineEnding** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.11 on page 35.)

render-21304 ☑ A **LineEnding** object may contain one and only one instance of each of the RenderGroup and BoundingBox elements. No other elements from the SBML Level 3 Render namespaces are permitted on a **LineEnding** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.11 on page 35.)

render-21305 ☑ The attribute `render:enableRotationalMapping` on a **LineEnding** must have a value of data type `boolean`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.11 on page 35.)

Rules for LinearGradient object

render-21401 ☑ A **LinearGradient** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **LinearGradient**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21402 ☑ A **LinearGradient** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **LinearGradient**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

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render-21403 ☑ A **LinearGradient** object may have the optional attributes `render:x1`, `render:y1`, `render:z1`, `render:x2`, `render:y2` and `render:z2`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **LinearGradient** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.4 on page 23.)

render-21404 ☑ The value of the attribute `render:x1` of a **LinearGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.4 on page 23.)

render-21405 ☑ The value of the attribute `render:y1` of a **LinearGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.4 on page 23.)

render-21406 ☑ The value of the attribute `render:z1` of a **LinearGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.4 on page 23.)

render-21407 ☑ The value of the attribute `render:x2` of a **LinearGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.4 on page 23.)

render-21408 ☑ The value of the attribute `render:y2` of a **LinearGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.4 on page 23.)

render-21409 ☑ The value of the attribute `render:z2` of a **LinearGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.4 on page 23.)

Rules for LocalRenderInformation object

render-21501 ☑ A **LocalRenderInformation** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **LocalRenderInformation**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21502 ☑ A **LocalRenderInformation** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **LocalRenderInformation**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21503 ☑ A **LocalRenderInformation** object may contain one and only one instance of the **ListOfLocalStyles** element. No other elements from the SBML Level 3 Render namespaces are permitted on a **LocalRenderInformation** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.2 on page 16.)

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render-21504 ☑ The **ListOfLocalStyles** subobject on a **LocalRenderInformation** object is optional, but if present, this container object must not be empty. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.2 on page 16.)

render-21505 ☑ Apart from the general notes and annotations subobjects permitted on all SBML objects, a **ListOfLocalStyles** container object may only contain **LocalStyle** objects. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.2 on page 17.)

render-21506 ☑ A **ListOfLocalStyles** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **ListOfLocalStyles** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.2 on page 17.)

Rules for LocalStyle object

render-21601 ☑ A **LocalStyle** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **LocalStyle**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21602 ☑ A **LocalStyle** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **LocalStyle**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21603 ☑ A **LocalStyle** object may have the optional attribute `render:idList`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **LocalStyle** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.6.3 on page 20.)

render-21604 ☑ The attribute `render:idList` on a **LocalStyle** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.6.3 on page 20.)

Rules for Polygon object

render-21701 ☑ A **Polygon** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **Polygon**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21702 ☑ A **Polygon** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **Polygon**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21703 ☑ A **Polygon** object may contain one and only one instance of the **ListOfElements** element. No other elements from the SBML Level 3 Render namespaces are permitted on a **Polygon** object. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.10.1 on page 32.)

render-21704 ☑ A **Polygon** object may contain one and only one instance of the **ListOfCurveSegments** element from the Layout package. No other elements from the SBML Level 3 Layout namespaces are permitted on a **Polygon** object. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.10.1 on page 32.)

Rules for RadialGradient object

render-21801 ☑ A **RadialGradient** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **RadialGradient**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21802 ☑ A **RadialGradient** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **RadialGradient**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

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render-21803 ☑ A **RadialGradient** object may have the optional attributes `render:cx`, `render:cy`, `render:cz`, `render:r`, `render:fx`, `render:fy` and `render:fz`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **RadialGradient** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.5 on page 24.)

render-21804 ☑ The value of the attribute `render:cx` of a **RadialGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.5 on page 24.)

render-21805 ☑ The value of the attribute `render:cy` of a **RadialGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.5 on page 24.)

render-21806 ☑ The value of the attribute `render:cz` of a **RadialGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.5 on page 24.)

render-21807 ☑ The value of the attribute `render:r` of a **RadialGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.5 on page 24.)

render-21808 ☑ The value of the attribute `render:fx` of a **RadialGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.5 on page 24.)

render-21809 ☑ The value of the attribute `render:fy` of a **RadialGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.5 on page 24.)

render-21810 ☑ The value of the attribute `render:fz` of a **RadialGradient** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.7.5 on page 24.)

Rules for Rectangle object

render-21901 ☑ A **Rectangle** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **Rectangle**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-21902 ☑ A **Rectangle** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **Rectangle**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

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render-21903 ☑ A **Rectangle** object must have the required attributes `render:x`, `render:y`, `render:width` and `render:height`, and may have the optional attributes `render:ratio`, `render:z`, `render:rX` and `render:rY`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **Rectangle** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.2 on page 32.)

render-21904 ☑ The value of the attribute `render:x` of a **Rectangle** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.2 on page 32.)

render-21905 ☑ The value of the attribute `render:y` of a **Rectangle** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.2 on page 32.)

render-21906 ☑ The value of the attribute `render:width` of a **Rectangle** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.2 on page 32.)

render-21907 ☑ The value of the attribute `render:height` of a **Rectangle** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.2 on page 32.)

render-21908 ☑ The attribute `render:ratio` on a **Rectangle** must have a value of data type `double`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.2 on page 32.)

render-21909 ☑ The value of the attribute `render:z` of a **Rectangle** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.2 on page 32.)

render-21910 ☑ The value of the attribute `render:rX` of a **Rectangle** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.2 on page 32.)

render-21911 ☑ The value of the attribute `render:rY` of a **Rectangle** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.2 on page 32.)

Rules for RenderCubicBezier object

render-22001 ☑ A **RenderCubicBezier** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **RenderCubicBezier**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

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render-22002 ☑ A **RenderCubicBezier** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **RenderCubicBezier**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22003 ☑ A **RenderCubicBezier** object must have the required attributes `render:basePoint1_x`, `render:basePoint1_y`, `render:basePoint2_x` and `render:basePoint2_y`, and may have the optional attributes `render:basePoint1_z` and `render:basePoint2_z`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **RenderCubicBezier** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.5 on page 29.)

render-22004 ☑ The value of the attribute `render:basePoint1_x` of a **RenderCubicBezier** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.5 on page 29.)

render-22005 ☑ The value of the attribute `render:basePoint1_y` of a **RenderCubicBezier** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.5 on page 29.)

render-22006 ☑ The value of the attribute `render:basePoint2_x` of a **RenderCubicBezier** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.5 on page 29.)

render-22007 ☑ The value of the attribute `render:basePoint2_y` of a **RenderCubicBezier** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.5 on page 29.)

render-22008 ☑ The value of the attribute `render:basePoint1_z` of a **RenderCubicBezier** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.5 on page 29.)

render-22009 ☑ The value of the attribute `render:basePoint2_z` of a **RenderCubicBezier** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.5 on page 29.)

Rules for RenderCurve object

render-22101 ☑ A **RenderCurve** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **RenderCurve**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22102 ☑ A **RenderCurve** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **RenderCurve**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

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render-22103 ☑ A **RenderCurve** object may have the optional attributes `render:startHead` and `render:endHead`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **RenderCurve** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.3 on page 27.)

render-22104 ☑ A **RenderCurve** object may contain one and only one instance of the **ListOfElements** element. No other elements from the SBML Level 3 Render namespaces are permitted on a **RenderCurve** object. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.9.3 on page 27.)

render-22104 ☑ A **RenderCurve** object may contain one and only one instance of the **ListOfCurveSegments** element from the Layout package. No other elements from the SBML Level 3 Layout namespaces are permitted on a **RenderCurve** object. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.9.3 on page 27.)

render-22105 ☑ The value of the attribute `render:startHead` of a **RenderCurve** object must be the identifier of an existing **LineEnding** object defined in the enclosing **Model** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.3 on page 27.)

render-22106 ☑ The value of the attribute `render:endHead` of a **RenderCurve** object must be the identifier of an existing **LineEnding** object defined in the enclosing **Model** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.3 on page 27.)

Rules for RenderPoint object

render-22201 ☑ A **RenderPoint** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **RenderPoint**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22202 ☑ A **RenderPoint** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **RenderPoint**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22203 ☑ A **RenderPoint** object must have the required attributes `render:x` and `render:y`, and may have the optional attribute `render:z`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **RenderPoint** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.4 on page 28.)

render-22204 ☑ The value of the attribute `render:x` of a **RenderPoint** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.4 on page 28.)

render-22205 ☑ The value of the attribute `render:y` of a **RenderPoint** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.4 on page 28.)

render-22206 ☑ The value of the attribute `render:z` of a **RenderPoint** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.4 on page 28.)

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Rules for Text object

render-22301 ☑ A **Text** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **Text**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22302 ☑ A **Text** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **Text**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22303 ☑ A **Text** object must have the required attributes `render:x` and `render:y`, and may have the optional attributes `render:font-family`, `render:font-weight`, `render:font-style`, `render:text-anchor`, `render:vtext-anchor`, `render:z` and `render:font-size`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **Text** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.4 on page 33.)

render-22304 ☑ The value of the attribute `render:x` of a **Text** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.4 on page 33.)

render-22305 ☑ The value of the attribute `render:y` of a **Text** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.4 on page 33.)

render-22306 ☑ The attribute `render:font-family` on a **Text** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.4 on page 33.)

render-22307 ☑ The value of the attribute `render:font-weight` of a **Text** object must conform to the syntax of SBML data type `FontWeight` and may only take on the allowed values of `FontWeight` defined in SBML; that is, the value must be one of the following: "`bold`" or "`normal`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.4 on page 33.)

render-22308 ☑ The value of the attribute `render:font-style` of a **Text** object must conform to the syntax of SBML data type `FontStyle` and may only take on the allowed values of `FontStyle` defined in SBML; that is, the value must be one of the following: "`italic`" or "`normal`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.4 on page 33.)

render-22309 ☑ The value of the attribute `render:text-anchor` of a **Text** object must conform to the syntax of SBML data type `HTextAnchor` and may only take on the allowed values of `HTextAnchor` defined in SBML; that is, the value must be one of the following: "`start`", "`middle`" or "`end`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.4 on page 33.)

render-22310 ☑ The value of the attribute `render:vtext-anchor` of a **Text** object must conform to the syntax of SBML data type `VTextAnchor` and may only take on the allowed values of `VTextAnchor` defined in SBML; that is, the value must be one of the following: "`top`", "`middle`", "`bottom`" or "`baseline`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.4 on page 33.)

render-22311 ☑ The value of the attribute `render:z` of a **Text** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.4 on page 33.)

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render-22312 ☑ The value of the attribute `render:font-size` of a **Text** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.10.4 on page 33.)

Rules for Transformation2D object

render-22401 ☑ A **Transformation2D** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **Transformation2D**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22402 ☑ A **Transformation2D** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **Transformation2D**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

Rules for Transformation object

render-22501 ☑ A **Transformation** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **Transformation**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22502 ☑ A **Transformation** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **Transformation**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22503 ☑ A **Transformation** object must have the required attribute `render:transform`, and may have the optional attribute `render:name`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **Transformation** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.8.1 on page 25.)

render-22504 ☑ The value of the attribute `render:transform` of a **Transformation** object must be an array of values of type `double`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.8.1 on page 25.)

render-22505 ☑ The attribute `render:name` on a **Transformation** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.8.1 on page 25.)

Rules for GraphicalPrimitive1D object

render-22601 ☑ A **GraphicalPrimitive1D** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **GraphicalPrimitive1D**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22602 ☑ A **GraphicalPrimitive1D** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **GraphicalPrimitive1D**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22603 ☑ A **GraphicalPrimitive1D** object may have the optional attributes `render:id`, `render:stroke`, `render:stroke-width` and `render:stroke-dasharray`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **GraphicalPrimitive1D** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.1 on page 26.)

render-22604 ☑ The attribute `render:stroke` on a **GraphicalPrimitive1D** must have a value of data type `string` where that string is restricted to either a 6 or 8 digit hex number or the `id` of an existing **ColorDefinition**. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.1 on page 26.)

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render-22605 ☑ The attribute `render:stroke-width` on a **GraphicalPrimitive1D** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.1 on page 26.)

render-22606 ☑ The attribute `render:stroke-dasharray` on a **GraphicalPrimitive1D** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.1 on page 26.)

Rules for GraphicalPrimitive2D object

render-22701 ☑ A **GraphicalPrimitive2D** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **GraphicalPrimitive2D**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22702 ☑ A **GraphicalPrimitive2D** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **GraphicalPrimitive2D**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22703 ☑ A **GraphicalPrimitive2D** object may have the optional attributes `render:fill` and `render:fill-rule`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **GraphicalPrimitive2D** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.2 on page 27.)

render-22704 ☑ The attribute `render:fill` on a **GraphicalPrimitive2D** must have a value of data type `string` where that string is restricted to either a 6 or 8 digit hex number; the `id` of an existing **ColorDefinition** or the value "`none`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.2 on page 27.)

render-22705 ☑ The value of the attribute `render:fill-rule` of a **GraphicalPrimitive2D** object must conform to the syntax of SBML data type `FillRule` and may only take on the allowed values of `FillRule` defined in SBML; that is, the value must be one of the following: "`nonzero`" or "`evenodd`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.9.2 on page 27.)

Rules for Style object

render-22801 ☑ A **Style** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **Style**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22802 ☑ A **Style** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **Style**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22803 ☑ A **Style** object may have the optional attributes `render:id`, `render:name`, `render:roleList` and `render:typeList`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **Style** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.6.1 on page 17.)

render-22804 ☑ A **Style** object may contain one and only one instance of the RenderGroup element. No other elements from the SBML Level 3 Render namespaces are permitted on a **Style** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.6.1 on page 17.)

render-22805 ☑ The attribute `render:name` on a **Style** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.6.1 on page 17.)

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render-22806 ☑ The attribute `render:roleList` on a **Style** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.6.1 on page 17.)

render-22807 ☑ The attribute `render:typeList` on a **Style** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.6.1 on page 17.)

Rules for RenderInformationBase object

render-22901 ☑ A **RenderInformationBase** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **RenderInformationBase**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22902 ☑ A **RenderInformationBase** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **RenderInformationBase**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-22903 ☑ A **RenderInformationBase** object must have the required attribute `render:id`, and may have the optional attributes `render:name`, `render:programName`, `render:programVersion`, `render:referenceRenderInformation` and `render:backgroundColor`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **RenderInformationBase** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.1 on page 15.)

render-22904 ☑ A **RenderInformationBase** object may contain one and only one instance of each of the **ListOfColorDefinitions**, **ListOfGradientDefinitions** and **ListOfLineEndings** elements. No other elements from the SBML Level 3 Render namespaces are permitted on a **RenderInformationBase** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.1 on page 15.)

render-22905 ☑ The attribute `render:name` on a **RenderInformationBase** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.1 on page 15.)

render-22906 ☑ The attribute `render:programName` on a **RenderInformationBase** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.1 on page 15.)

render-22907 ☑ The attribute `render:programVersion` on a **RenderInformationBase** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.1 on page 15.)

render-22908 ☑ The value of the attribute `render:referenceRenderInformation` of a **RenderInformationBase** object must be the identifier of an existing **RenderInformation** object defined in the enclosing **Model** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.1 on page 15.)

render-22909 ☑ The attribute `render:backgroundColor` on a **RenderInformationBase** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.1 on page 15.)

render-22910 ☑ The **ListOfColorDefinitions**, **ListOfGradientDefinitions** and **ListOfLineEndings** subobjects on a **RenderInformationBase** object are optional, but if present, these container objects must not be empty. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.5.1 on page 15.)

render-22911 ☑ Apart from the general notes and annotations subobjects permitted on all SBML objects, a **ListOfColorDefinitions** container object may only contain **ColorDefinition** objects. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.1 on page 15.)

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render-22912 ☑ Apart from the general notes and annotations subobjects permitted on all SBML objects, a **ListOfGradientDefinitions** container object may only contain **GradientBase** objects. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.1 on page 15.)

render-22913 ☑ Apart from the general notes and annotations subobjects permitted on all SBML objects, a **ListOfLineEndings** container object may only contain **LineEnding** objects. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.5.1 on page 15.)

render-22914 ☑ A **ListOfColorDefinitions** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **ListOfColorDefinitions** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.5.1 on page 15.)

render-22915 ☑ A **ListOfGradientDefinitions** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **ListOfGradientDefinitions** object. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.5.1 on page 15.)

render-22916 ☑ A **ListOfLineEndings** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **ListOfLineEndings** object. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.5.1 on page 15.)

Rules for DefaultValues object

render-23001 ☑ A **DefaultValues** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **DefaultValues**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-23002 ☑ A **DefaultValues** object may have the optional SBML Level 3 Core subobjects for notes and annotations. No other elements from the SBML Level 3 Core namespaces are permitted on a **DefaultValues**. (Reference: SBML Level 3 Version 1 Core, Section 3.2.)

render-23003 ☑ A **DefaultValues** object may have the optional attributes `render:backgroundColor`, `render:spreadMethod`, `render:fill`, `render:fill-rule`, `render:stroke`, `render:stroke-width`, `render:font-family`, `render:font-weight`, `render:font-style`, `render:text-anchor`, `render:vtext-anchor`, `render:startHead`, `render:endHead`, `render:enableRotationalMapping`, `render:linearGradient_x1`, `render:linearGradient_y1`, `render:linearGradient_z1`, `render:linearGradient_x2`, `render:linearGradient_y2`, `render:linearGradient_z2`, `render:radialGradient_cx`, `render:radialGradient_cy`, `render:radialGradient_cz`, `render:radialGradient_r`, `render:radialGradient_fx`, `render:radialGradient_fy`, `render:radialGradient_fz`, `render:default_z` and `render:font-size`. No other attributes from the SBML Level 3 Render namespaces are permitted on a **DefaultValues** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23004 ☑ The attribute `render:backgroundColor` on a **DefaultValues** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23005 ☑ The value of the attribute `render:spreadMethod` of a **DefaultValues** object must conform to the syntax of SBML data type `GradientSpreadMethod` and may only take on the allowed values of `GradientSpreadMethod` defined in SBML; that is, the value must be one of the following: "`pad`", "`reflect`" or "`repeat`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23006 ☑ The attribute `render:fill` on a **DefaultValues** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

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render-23007 ☑ The value of the attribute `render:fill-rule` of a **DefaultValues** object must conform to the syntax of SBML data type `FillRule` and may only take on the allowed values of `FillRule` defined in SBML; that is, the value must be one of the following: "`nonzero`" or "`evenodd`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23008 ☑ The attribute `render:stroke` on a **DefaultValues** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23009 ☑ The attribute `render:stroke-width` on a **DefaultValues** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23010 ☑ The attribute `render:font-family` on a **DefaultValues** must have a value of data type `string`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23011 ☑ The value of the attribute `render:font-weight` of a **DefaultValues** object must conform to the syntax of SBML data type `FontWeight` and may only take on the allowed values of `FontWeight` defined in SBML; that is, the value must be one of the following: "`bold`" or "`normal`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23012 ☑ The value of the attribute `render:font-style` of a **DefaultValues** object must conform to the syntax of SBML data type `FontStyle` and may only take on the allowed values of `FontStyle` defined in SBML; that is, the value must be one of the following: "`italic`" or "`normal`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23013 ☑ The value of the attribute `render:text-anchor` of a **DefaultValues** object must conform to the syntax of SBML data type `HTextAnchor` and may only take on the allowed values of `HTextAnchor` defined in SBML; that is, the value must be one of the following: "`start`", "`middle`" or "`end`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23014 ☑ The value of the attribute `render:vtext-anchor` of a **DefaultValues** object must conform to the syntax of SBML data type `VTextAnchor` and may only take on the allowed values of `VTextAnchor` defined in SBML; that is, the value must be one of the following: "`top`", "`middle`", "`bottom`" or "`baseline`". (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23015 ☑ The value of the attribute `render:startHead` of a **DefaultValues** object must be the identifier of an existing **LineEnding** object defined in the enclosing **Model** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23016 ☑ The value of the attribute `render:endHead` of a **DefaultValues** object must be the identifier of an existing **LineEnding** object defined in the enclosing **Model** object. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23017 ☑ The attribute `render:enableRotationalMapping` on a **DefaultValues** must have a value of data type `boolean`. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23018 ☑ The value of the attribute `render:linearGradient_x1` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23019 ☑ The value of the attribute `render:linearGradient_y1` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces

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between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23020 ☑ The value of the attribute `render:linearGradient_z1` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23021 ☑ The value of the attribute `render:linearGradient_x2` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23022 ☑ The value of the attribute `render:linearGradient_y2` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23023 ☑ The value of the attribute `render:linearGradient_z2` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23024 ☑ The value of the attribute `render:radialGradient_cx` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23025 ☑ The value of the attribute `render:radialGradient_cy` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23026 ☑ The value of the attribute `render:radialGradient_cz` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23027 ☑ The value of the attribute `render:radialGradient_r` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23028 ☑ The value of the attribute `render:radialGradient_fx` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

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render-23029 ☑ The value of the attribute `render:radialGradient_fy` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23030 ☑ The value of the attribute `render:radialGradient_fz` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23031 ☑ The value of the attribute `render:default_z` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

render-23032 ☑ The value of the attribute `render:font-size` of a **DefaultValues** object must conform to the syntax of SBML data type **RelAbsVector**, i.e., a string encoding optionally an absolute number followed by an optional relative number followed by a % sign. Adding spaces between the coordinates is encouraged, but not required. (Reference: SBML Level 3 Specification for Render, Version 1, Section 3.3.2 on page 12.)

Rules for ListOfElements object

render-23040 ☑ The **ListOfElements** subobject on a **RenderCurve** or a **Polygon** object is optional, but if present, this container object must not be empty. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.9.3 on page 27.)

render-23041 ☑ Apart from the general notes and annotations subobjects permitted on all SBML objects, a **ListOfElements** container object may only contain **RenderPoint** or the derived **RenderCubicBezier** objects. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.9.3 on page 27.)

render-23042 ☑ A **ListOfElements** object may have the optional SBML Level 3 Core attributes `metaid` and `sboTerm`. No other attributes from the SBML Level 3 Core namespaces are permitted on a **ListOfElements** object. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.9.3 on page 27.)

render-23043 ☑ The first element within a **ListOfElements** container object must be of type **RenderPoint**. (Reference: SBML Level 3 Specification for Render Version 1, Section 3.9.3 on page 27.)

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Acknowledgments

We would like to thank all the people who contributed in various ways to the development of both the original proposal and this specification.

For financial/travel/technical and moral support we thank especially (in alphabetical order): Michael Hucka (CalTech, USA), Ursula Kummer (Heidelberg University, Germany) and Herbert Sauro (University of Washington, USA).

We also would like to thank the members of the Render Package Working Group and all others who contributed to discussions on various occasions.

A thanks also to the SBML editors for providing detailed feedback, especially Andreas Dräger, Lucian P. Smith and Fengkai Zhang.

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