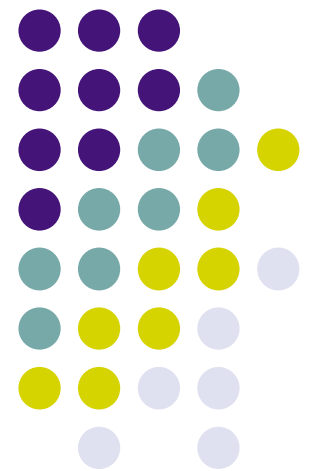


# Cytoscape

Efficient Rendering and Modeling of  
Large Biological Networks

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# What is Cytoscape?

- Cytoscape is a tool for visualizing networks in general (not necessarily biological).
- With Cytoscape, one is able to visualize attributes associated with nodes and edges.
- Cytoscape's open-source nature enables programmers to write custom code against a well-established API to do various computations on networks.
- Cytoscape is a huge collaboration between five labs.

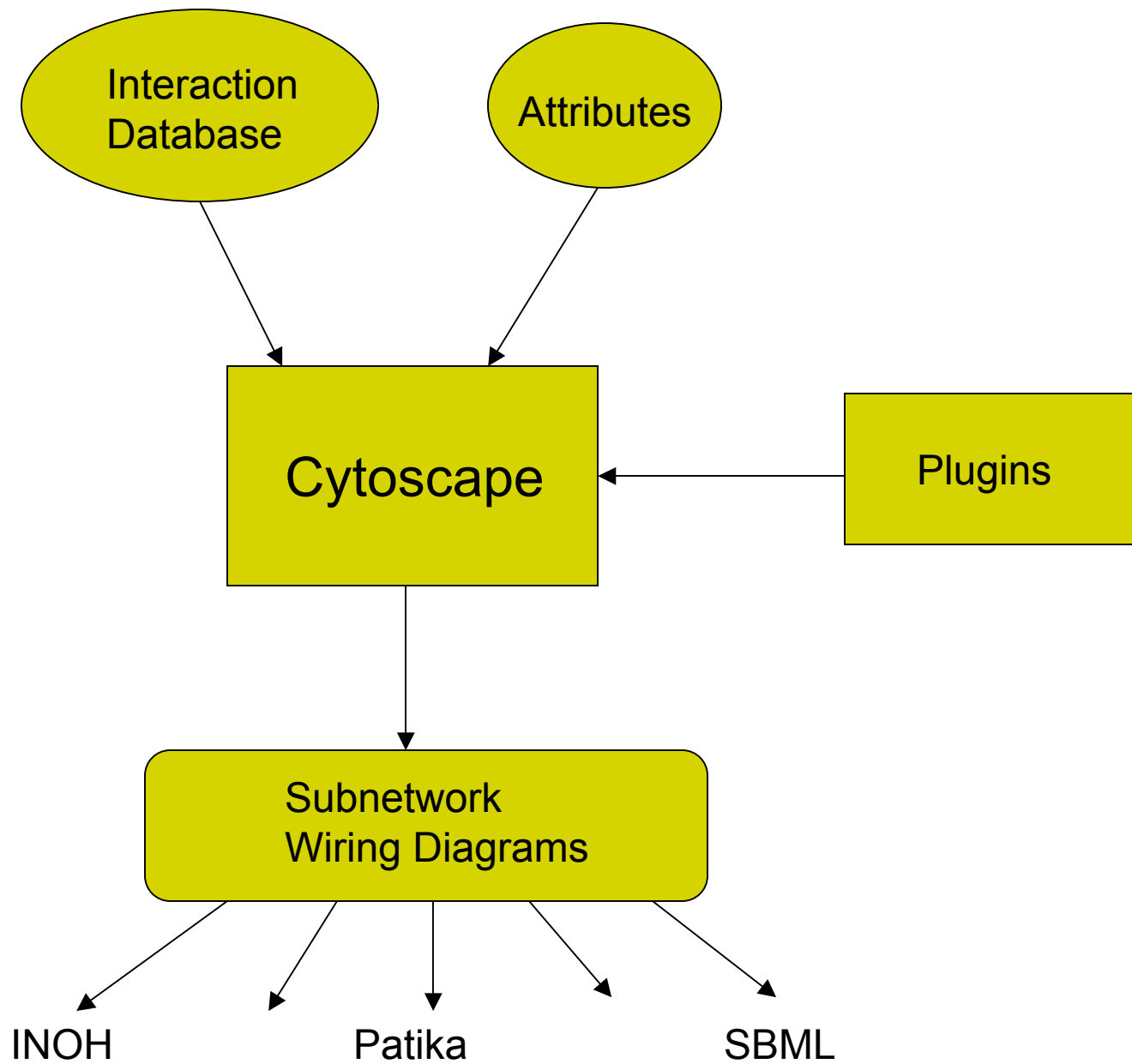
# Enabling biological semantics + representation in Cytoscape



We try to be agnostic with respect to semantics, but we try to support community standards.

What is Cytoscape's niche?

- Try to provide a tool to distill abstract biological models (protein wiring diagrams) out of large molecular interaction databases
- Cytoscape is not a general-purpose rendering tool
- Cytoscape's strength: rendering networks (networks in pure mathematical sense).





### Set Visual Style

Node Attributes | Edge Attributes | Global Defaults

Node Font | Node Label Color | Node Shape | Node Size | Node Label | Node Color | Node Border Color | Node Border Type

**Default**

Change Default

**Mapping**

foo

New Duplicate Rename Delete

Map Attribute: foo

Del 0

Below Add Point

Equal

Above

Apply to Network Close

### Cytoscape Desktop

File Edit Data Select Layout Visualization Plugins CytoPanels Help Filters

Nodes: 13 (1 selected) Edges: 20 (0 selected)

#### CytoPanel 2

##### Node Attribute Browser

Select Attributes Create New Attribute

ID	foo
YNL145W	0.0

Node Attribute Browser Edge Attribute Browser

Welcome to Cytoscape 2.2

# Currently Supported Visual Attributes for Nodes



- Node shape: rectangle, diamond, triangle, ellipse, rounded rectangle, hexagon, octagon, parallelogram
- Node paint
- Node size
- Node border thickness
- Node border paint
- Extensive text label support
- Some amount of custom node features (although it's a real hack at this point)

# Currently Supported Visual Attributes for Edges



- Arrowhead (both for target and source): none, delta, disc, tee, diamond
- Arrowhead size
- Arrowhead paint
- Edge thickness
- Edge paint
- Edge dash length
- Edge anchor points (to enable zig-zag or curvy edges)
- Extensive text label support



# Why reinvent the wheel?

Existing network rendering engines all seem to fall into at least one of the following categories:

1. Proprietary software, costs money, and/or not open source.
2. Low performance: architected heavily towards an object-oriented design (as opposed to procedural); therefore not suitable for some of the optimizations that are going into new engine.

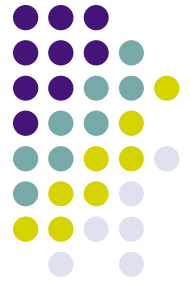




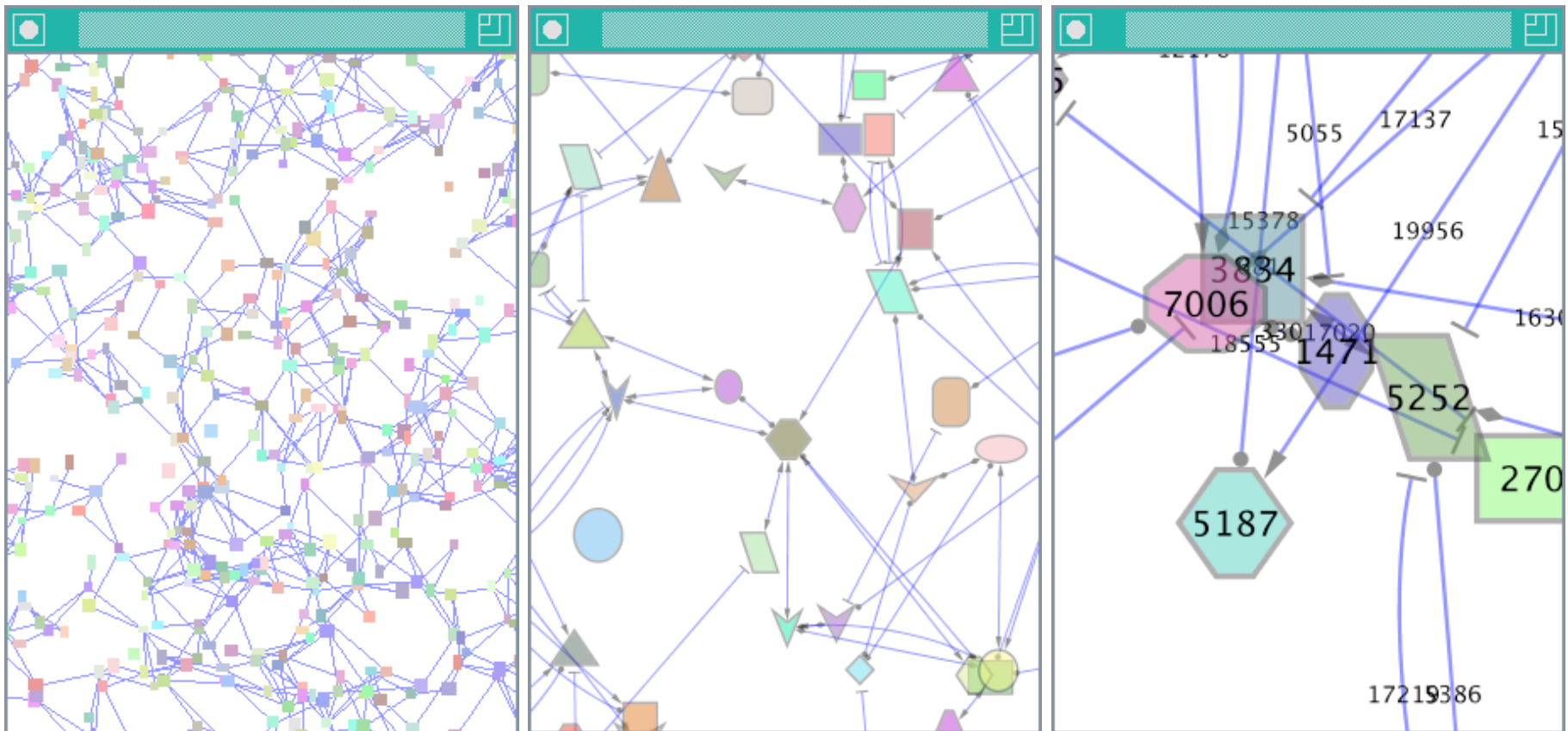
# Rendering Engine Goals:

- Most important: 100,000+ nodes and 200,000+ edges no problem
- Maybe even 2,000,000 nodes.
- Simplicity
- Keep semantics (biological or other) out of core
- Enough flexibility to support community standards

# Optimization #1: Level of Detail



The idea is to vary the level of detail based on how much is being rendered:



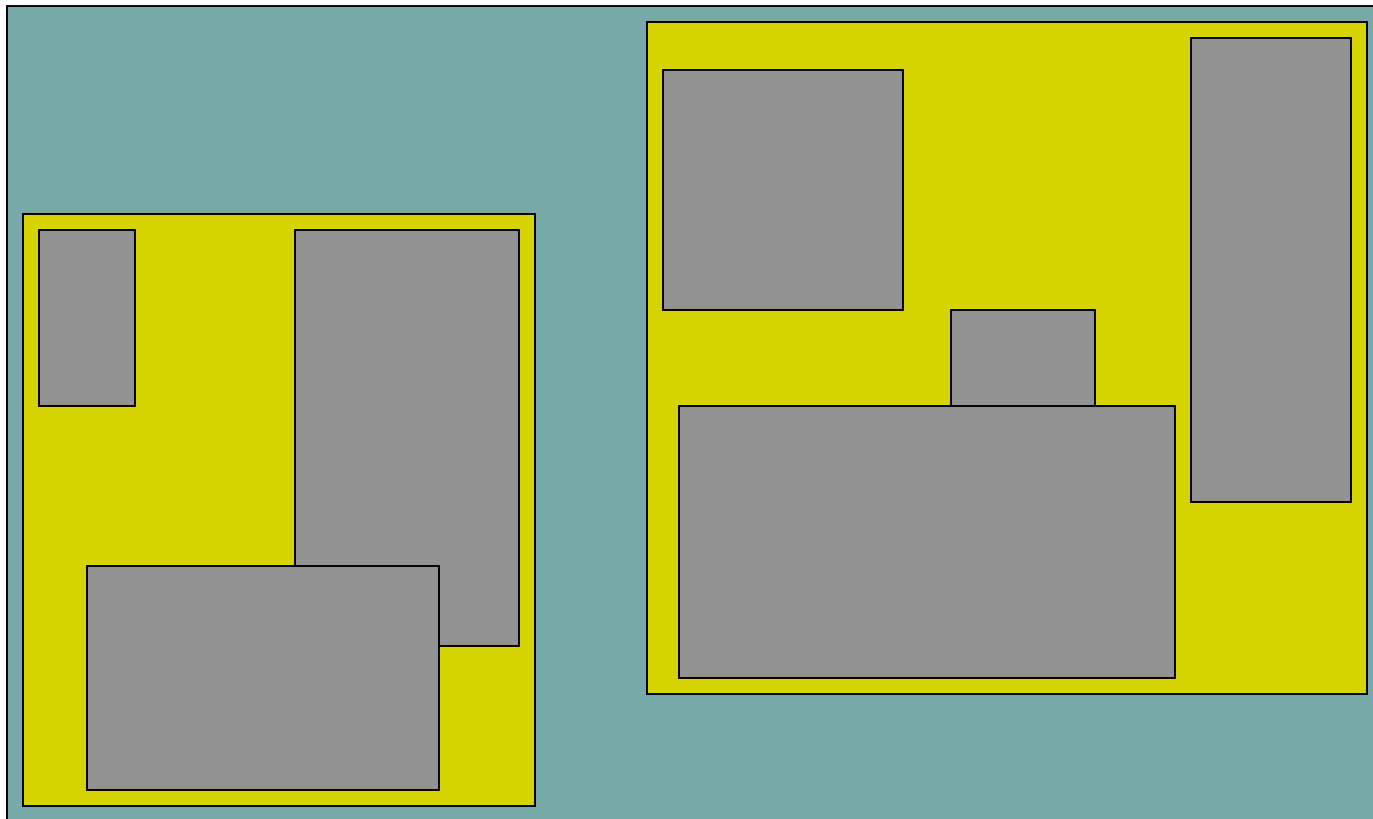
# Optimization #2: Spacial Indexing of Nodes



- Use spacial index for node positions
- “Give me the node lying directly under the mouse cursor.” Possibly  $O(\log(N))$  time for  $N$  nodes?
- “Give me the set of nodes intersecting the rectangular viewing area.” Between  $O(\log(N))$  and  $O(\sqrt{N})$  time possible?



# What is an R-tree?



# Optimization #2: R-tree (continued)

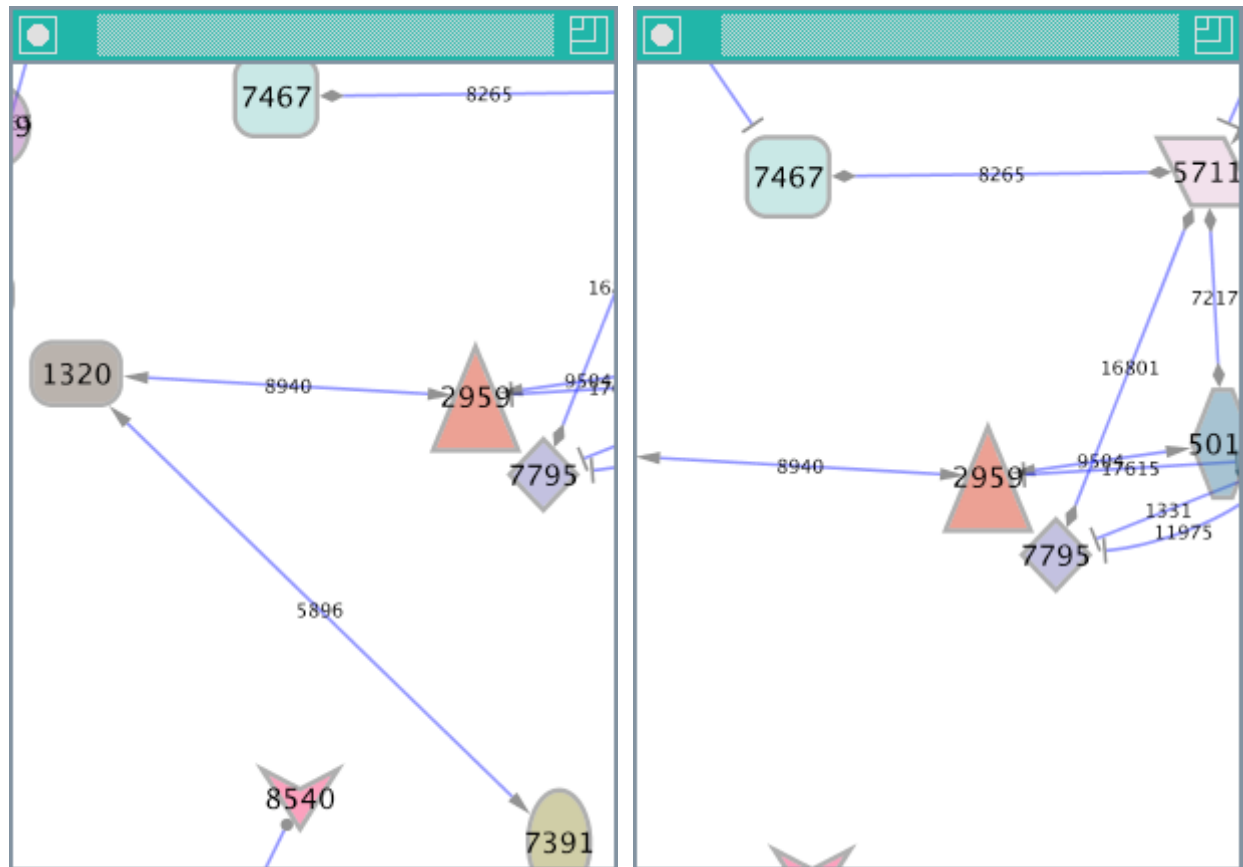


Which edges to render?

When viewing large networks, render an edge only if at least one of its endpoint nodes is visible.

Side effects:

- Edges which intersect viewing area may not necessarily be visible
- Edges may suddenly disappear during pan operations
- On the plus side: cobwebs of dense edges will not interfere with clarity of diagram

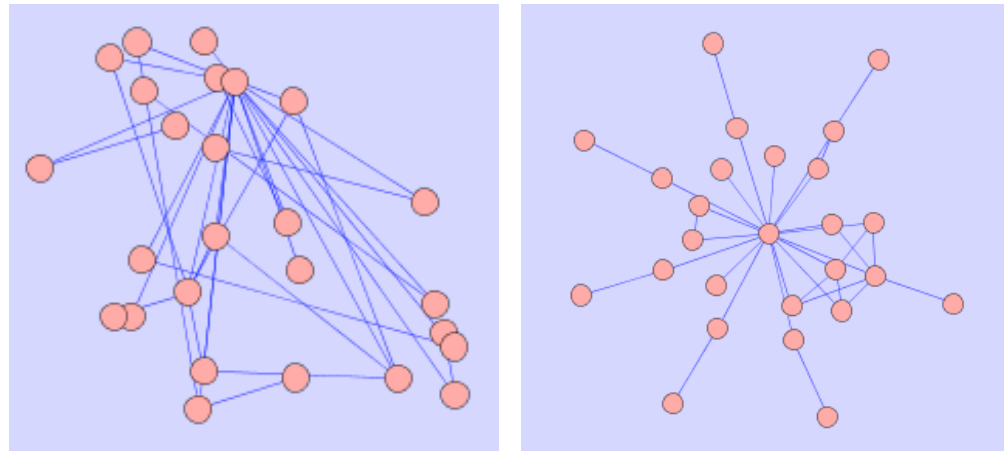
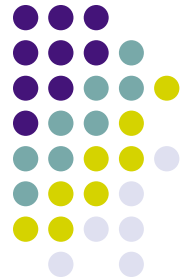


# Optimization #2: R-tree (continued)



- Viewing a network of 2,000,000 nodes.
- Being zoomed in so that 10 or so nodes are currently visible.
- Panning operation
- With R-tree, 30 frames per second (bottleneck is rendering itself)
- Without R-tree, 1 frame per second (bottleneck is iterating over 2,000,000 nodes on every frame being rendered)

# Optimization #2: R-tree (continued)



Layout algorithms:

Spacial index opens door for certain set of large network layout algorithms.

- Optimize topological queries (“give me all node neighbors”)
- Optimize spacial queries (“give me all nodes within two meters of this node”)
- Possible to implement layout algorithms suitable for large networks?
- Divide and conquer?
- $O(N \cdot \log(N))$  time?
- Plan to devote some amount of research in this area

## Optimization #2: R-tree (continued)



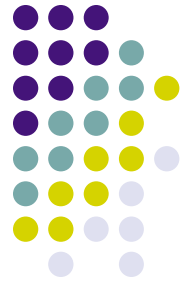
Drawbacks of using spacial indexing for storing node extents:

Insertions and deletions become more expensive. In particular, creating a network of  $N$  nodes takes approximately  $O(N \cdot \log(N))$  time instead of  $O(N)$  time.

Imagine an operation that modifies the position of every node, such as a global rotation. This operation may become sluggish with an R-tree.



# Optimization #3: Reduce Memory Footprint

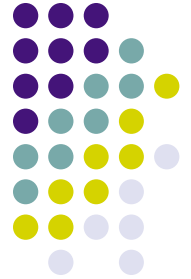


- Nodes and edges can have numerous visual attributes
- Node shape, color, edge type, etc.
- Do not store all of these attributes per-node and per-edge
- Only store visual information if it differs from a default value
- With large networks, avoid setting any visual attributes and simply use default values



# Summary

- Cytoscape's niche will be the ability to visualize and compute on large networks.
- Cytoscape will strive to support, in one way or another, standards that are decided upon in conferences such SBGN.
- The new rendering engine will have a well-defined API that will enable other applications (other than Cytoscape) to use it effectively.



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