Algorithms for Visualizing Phylogenetic Networks

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and

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PHYLOGENETIC TREE:

A model to represent evolution (of some species, or genes).

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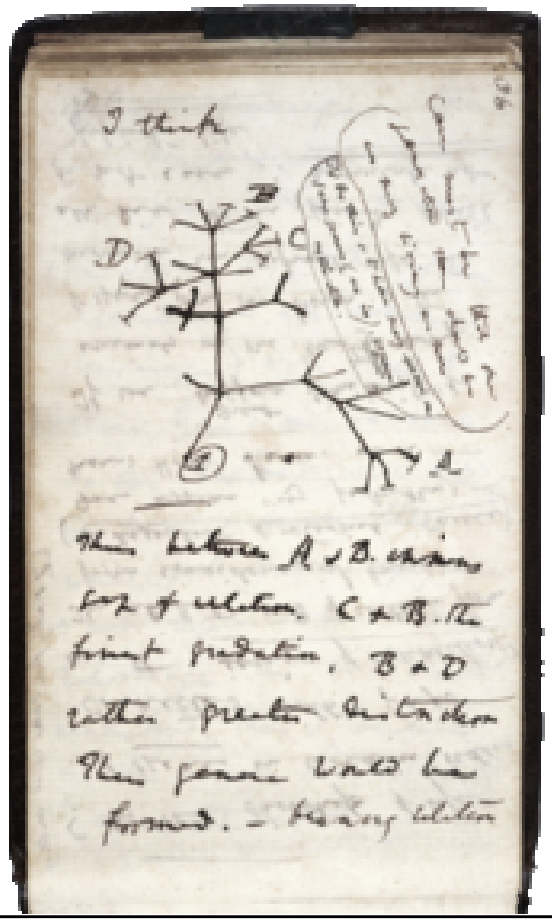

Darwin's first sketch of an evolutionary tree (1837)

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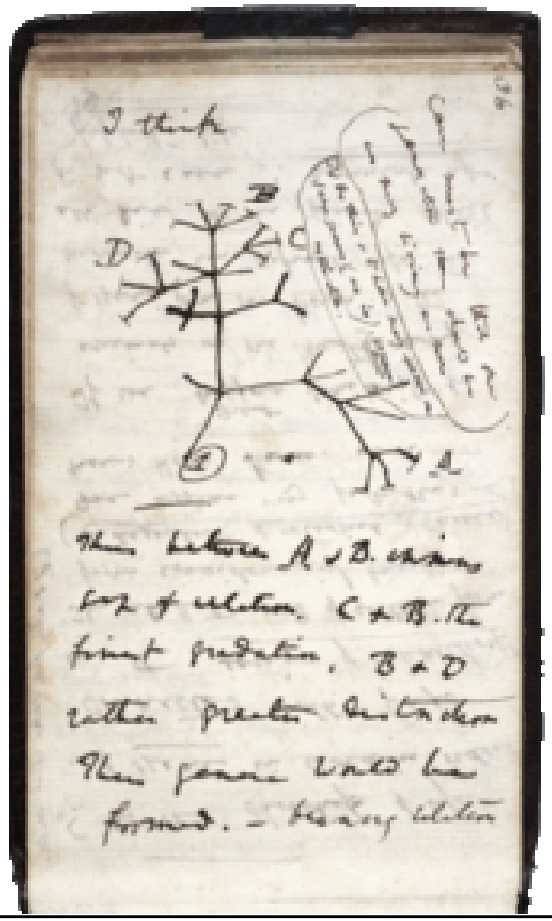

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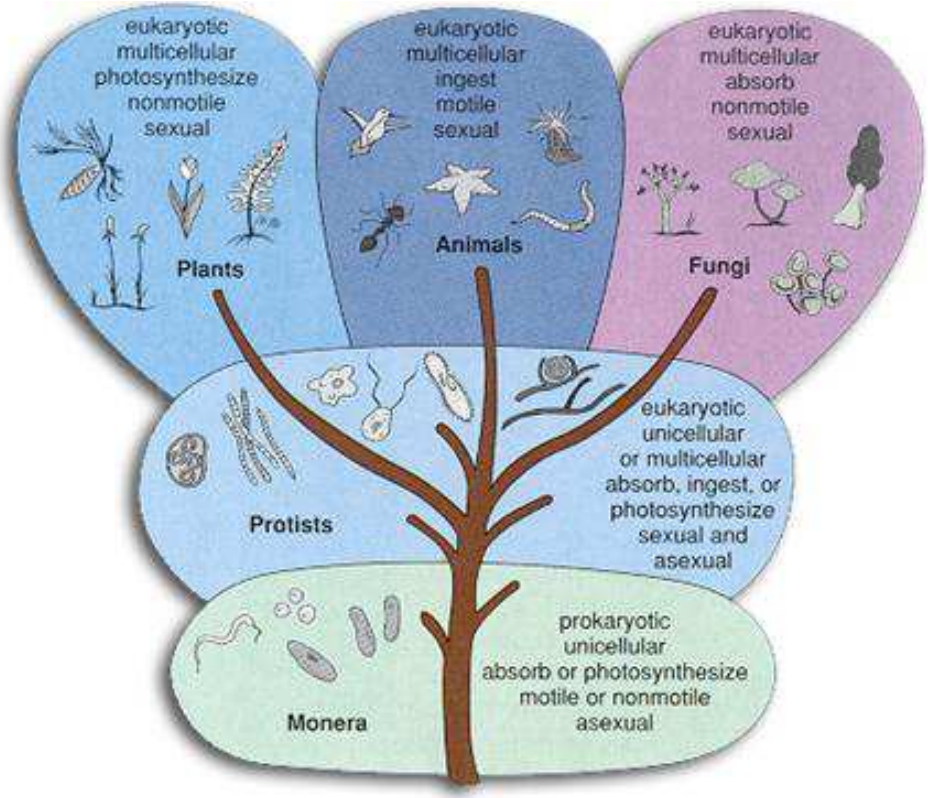

Five Kingdom Classification (by R.H Whittaker,1969)

Evolution cannot be properly represented as a tree.

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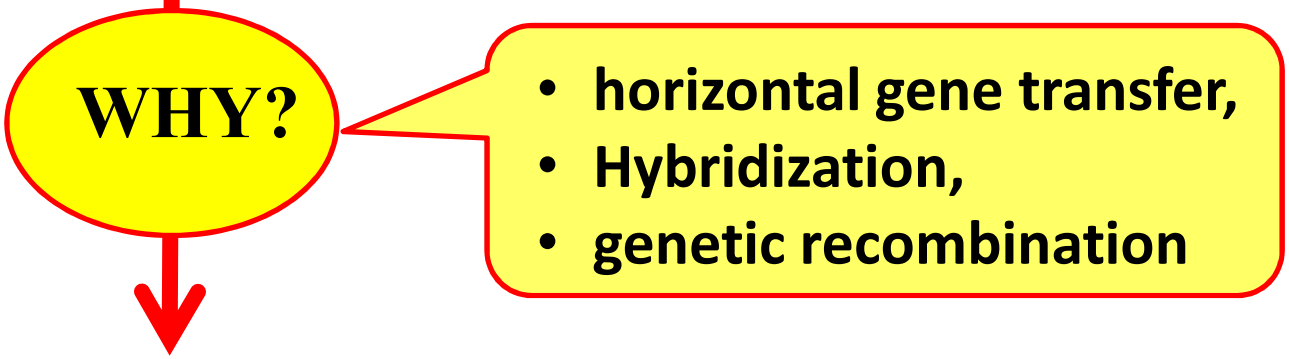
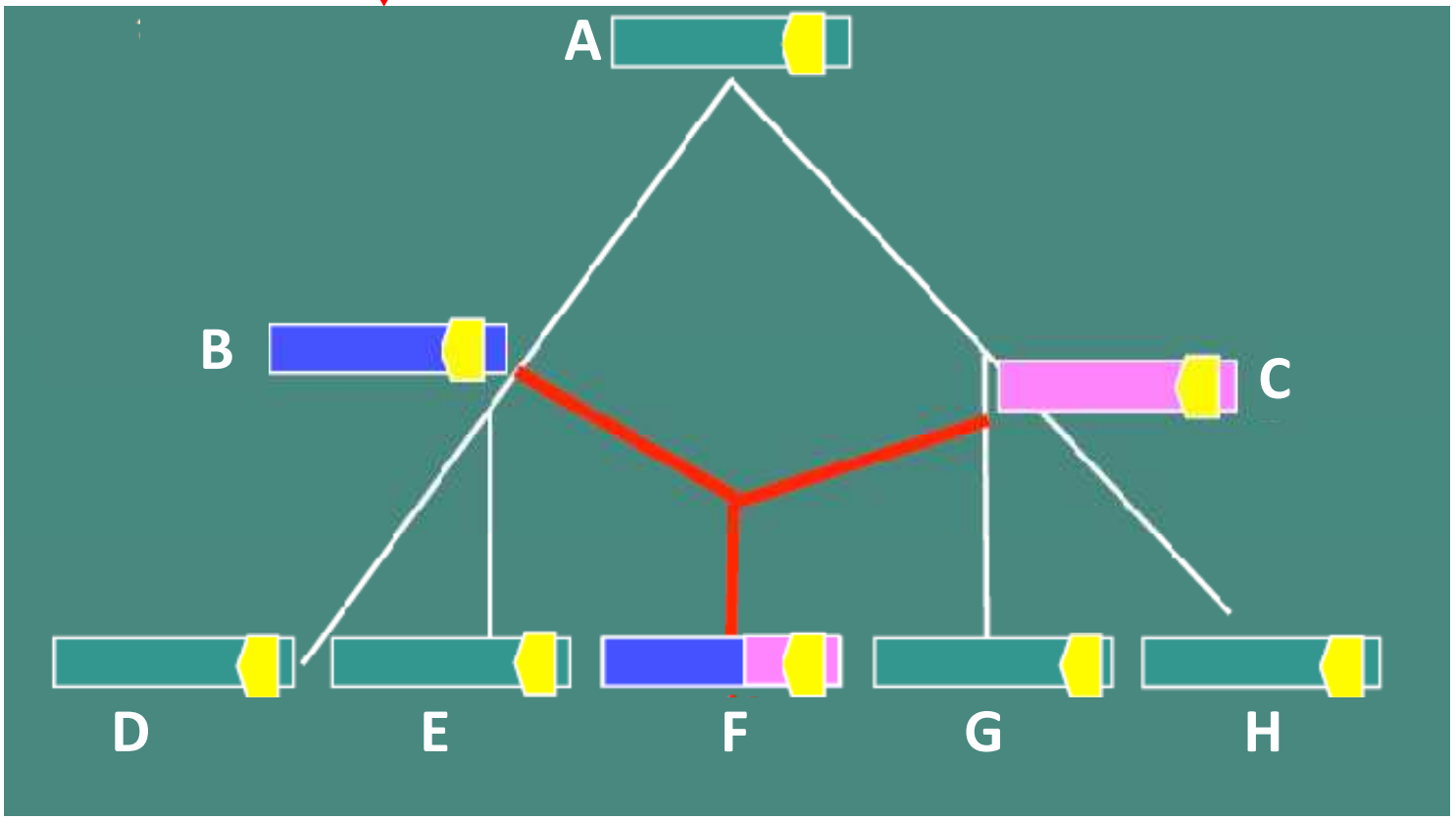


Evolution cannot be properly represented as a tree.

WHY?

- **horizontal gene transfer,**
- **Hybridization,**
- **genetic recombination**



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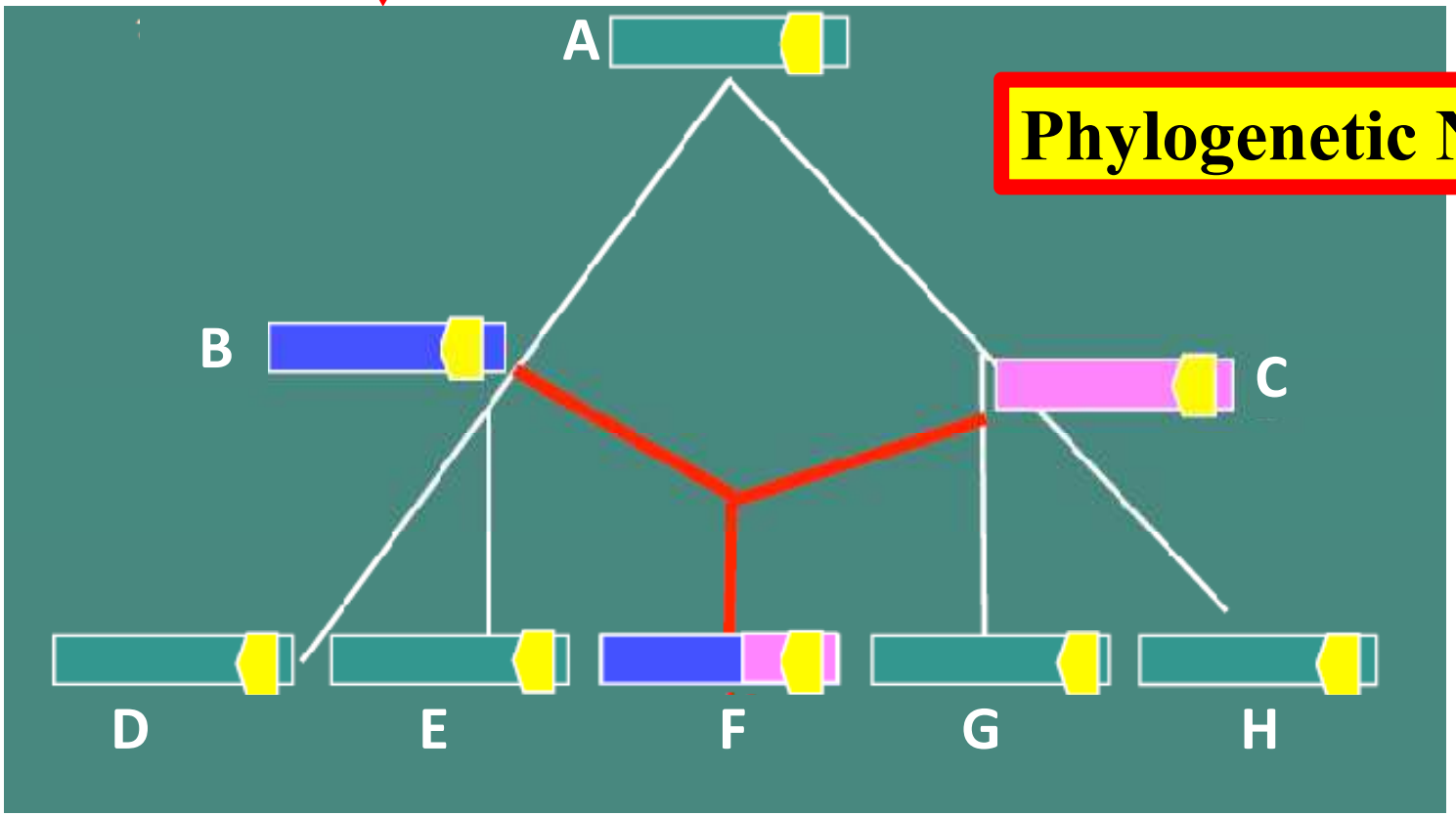

Phylogenetic Networks

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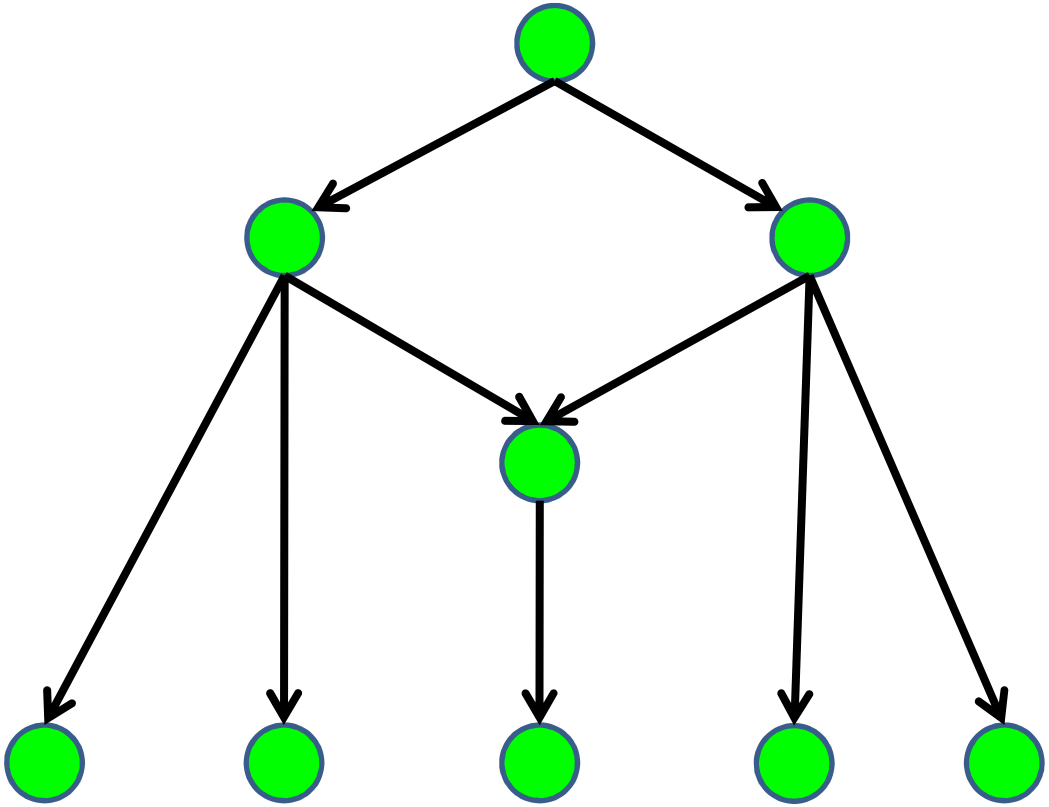

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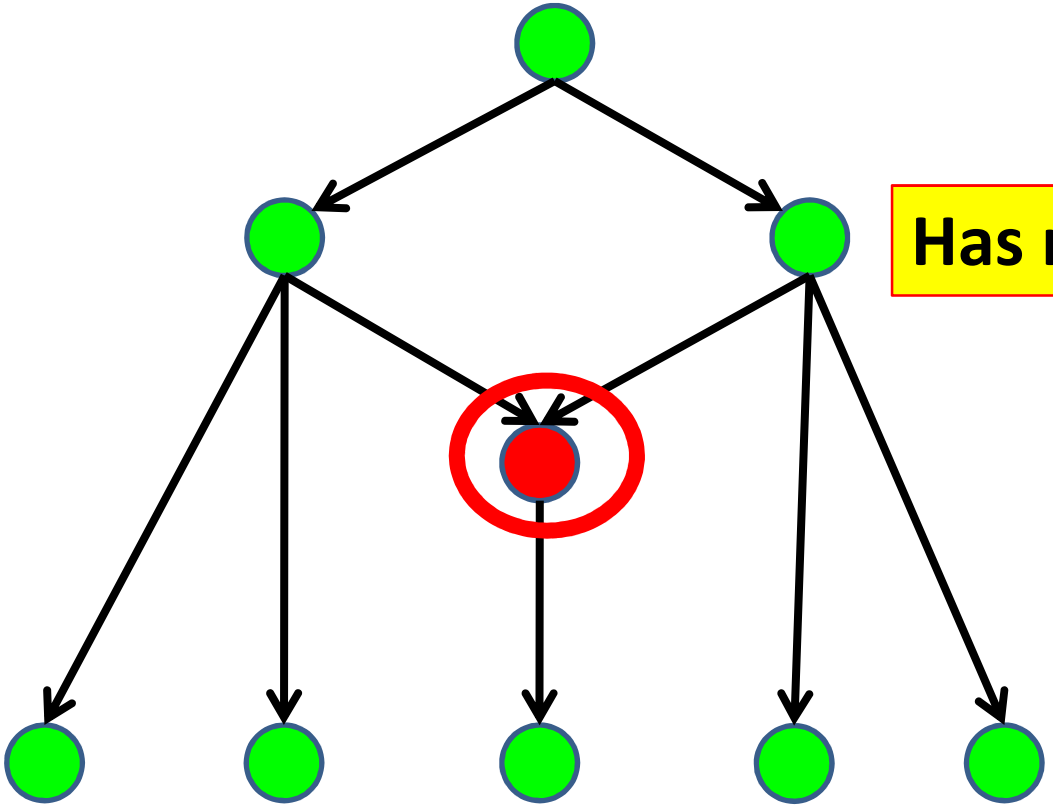
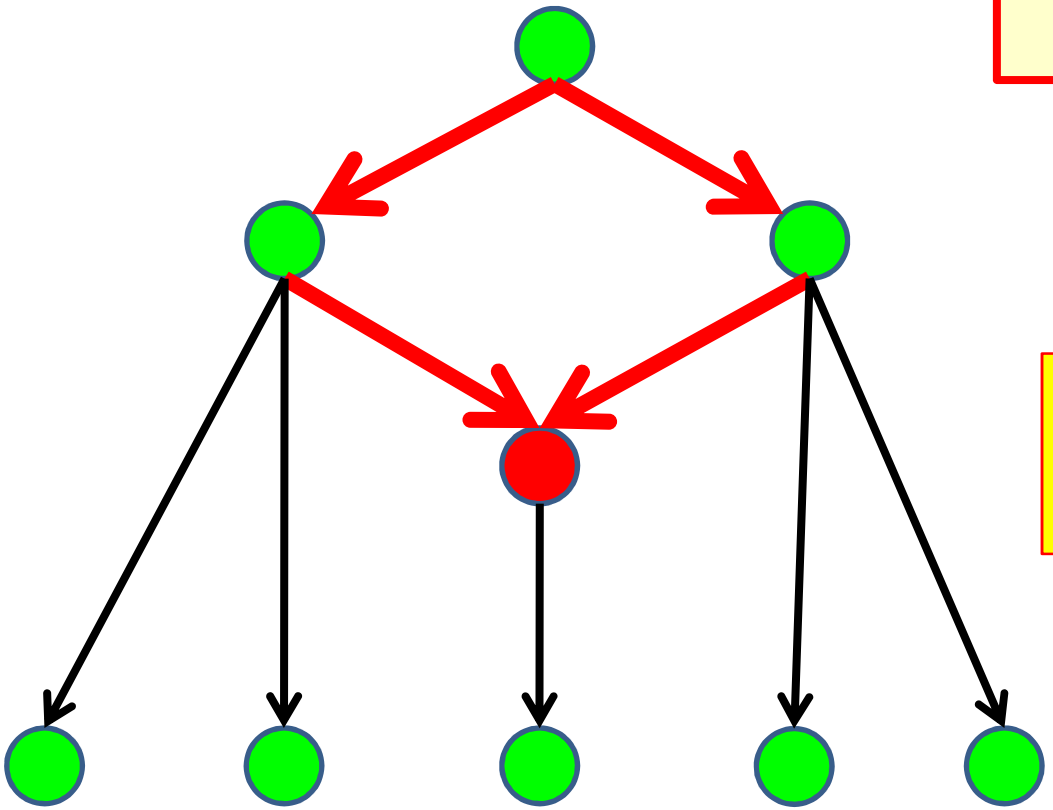


Reticulation node

Has more than one ancestors.

Phylogenetic Networks



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Reticulation cycle

Every reticulation node belongs to a cycle.

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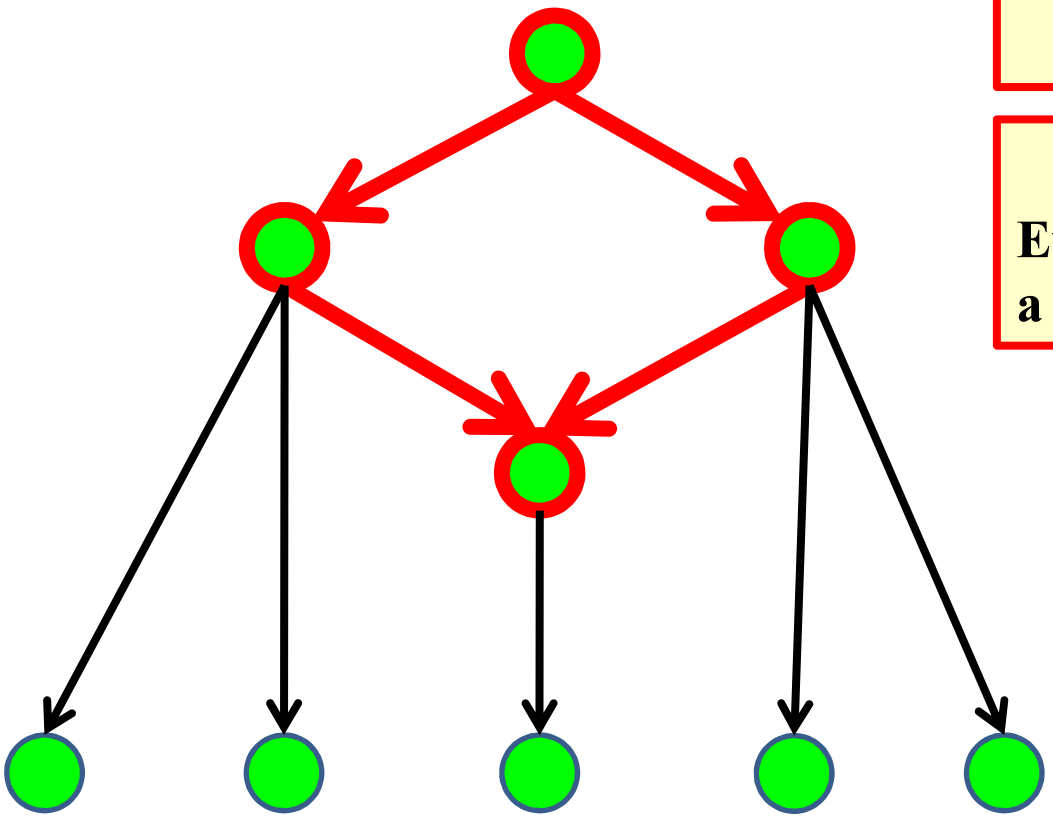

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A single (isolated) reticulation cycle

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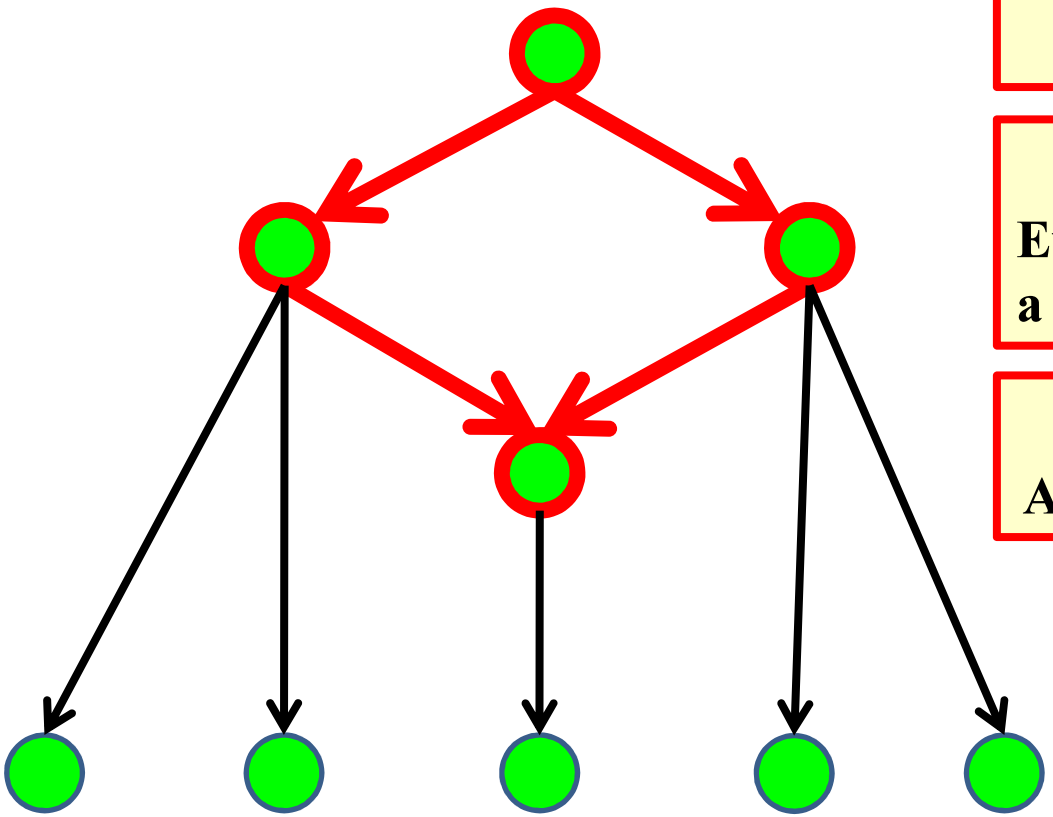

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Galled tree

A network in which the galls do not share edges or nodes

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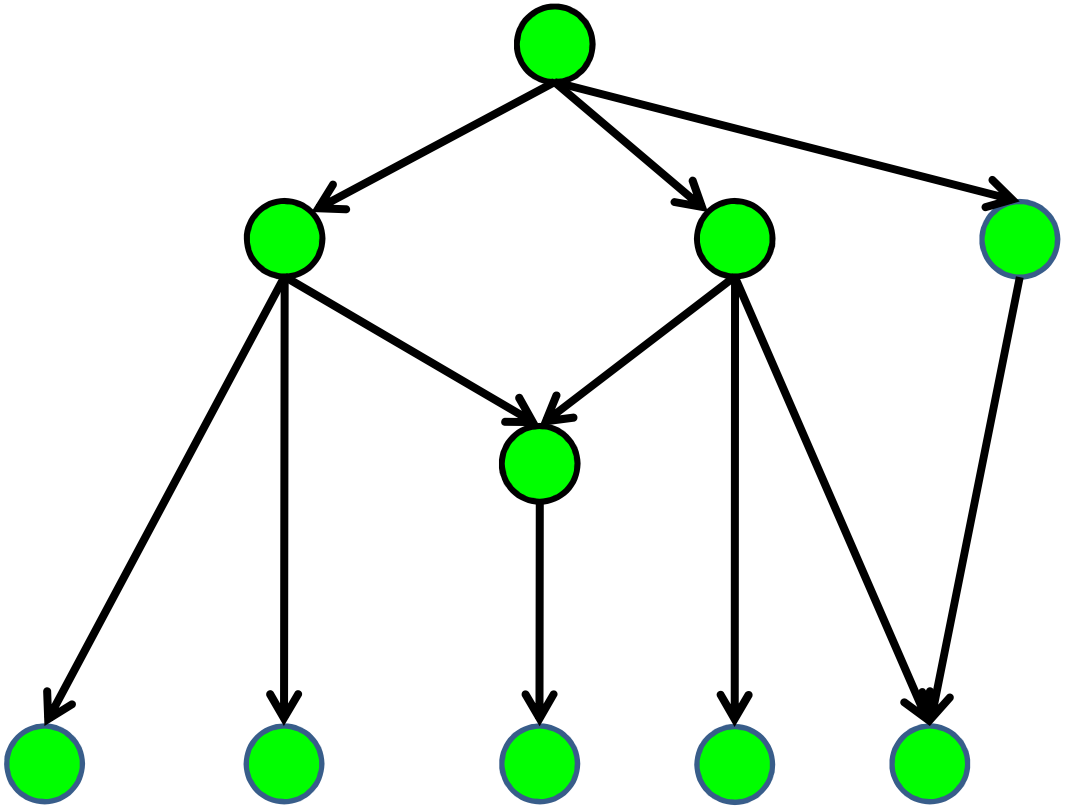

Galled network

A network in which the galls can share edges but not reticulation nodes

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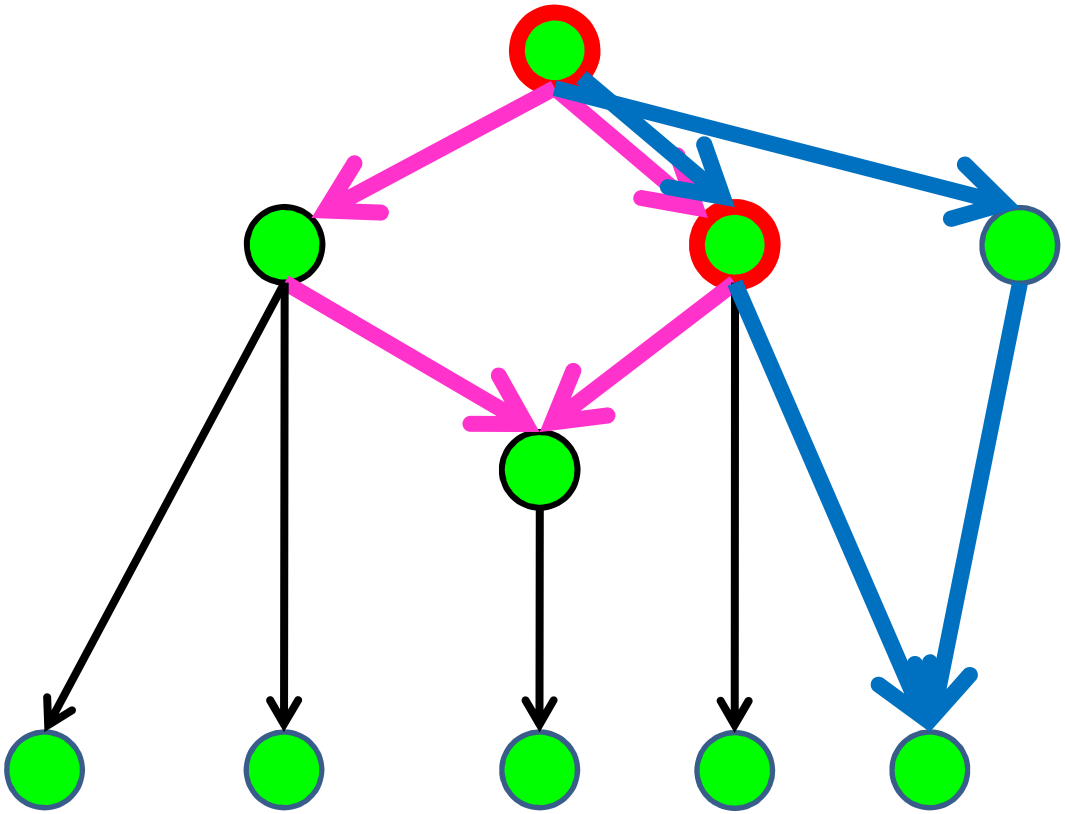

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Visualization of Phylogenetic Trees and Networks

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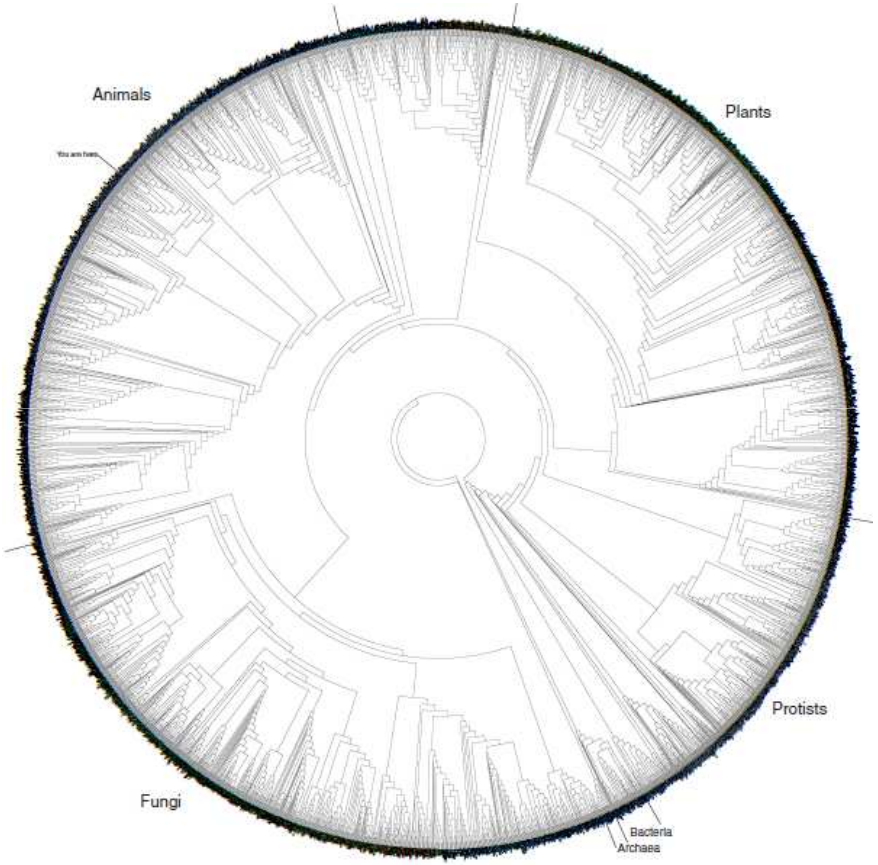

Tree of life for 3,000 of the 1.8 million known species based on RNA sequences.

node-link representation

- Huge graphs.
- Visual clutter.

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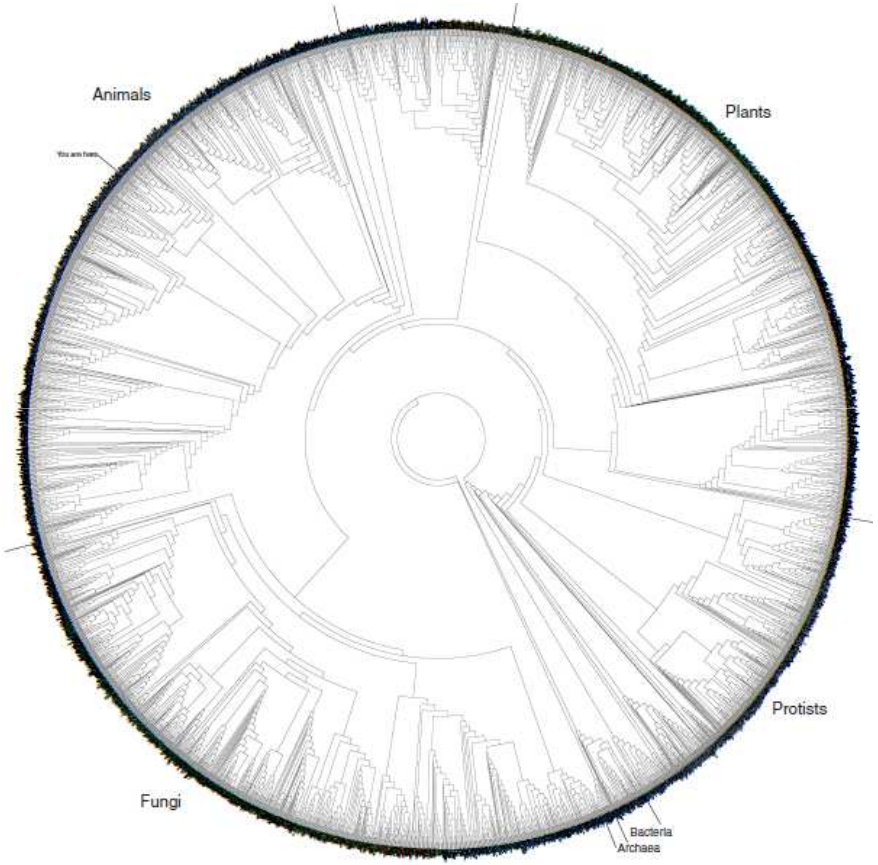

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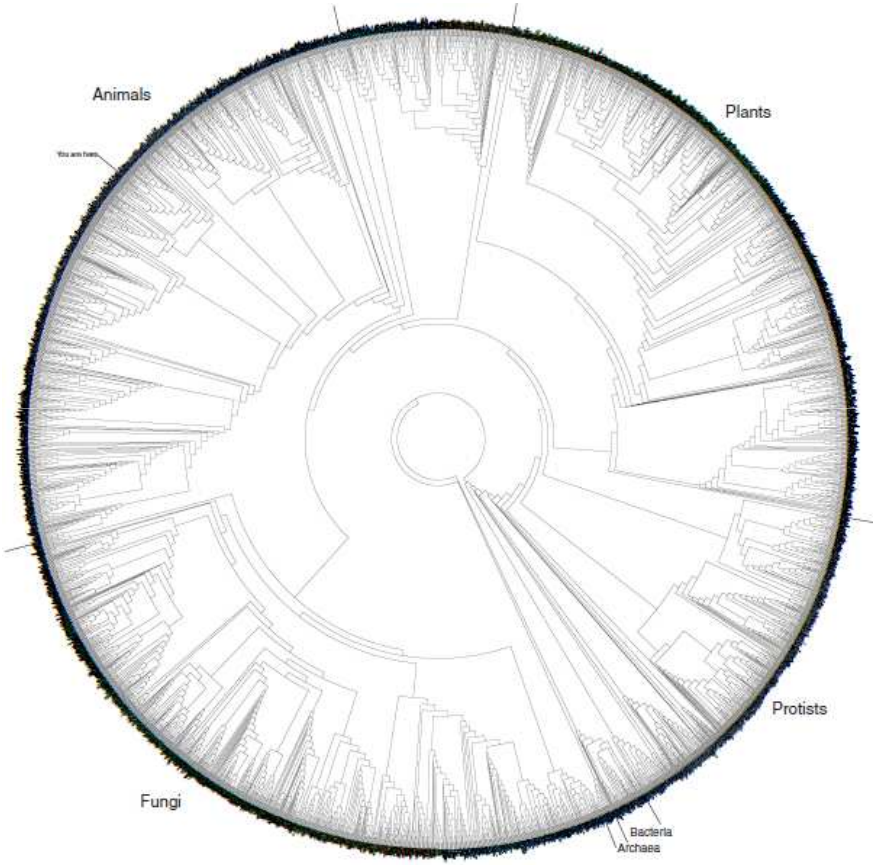

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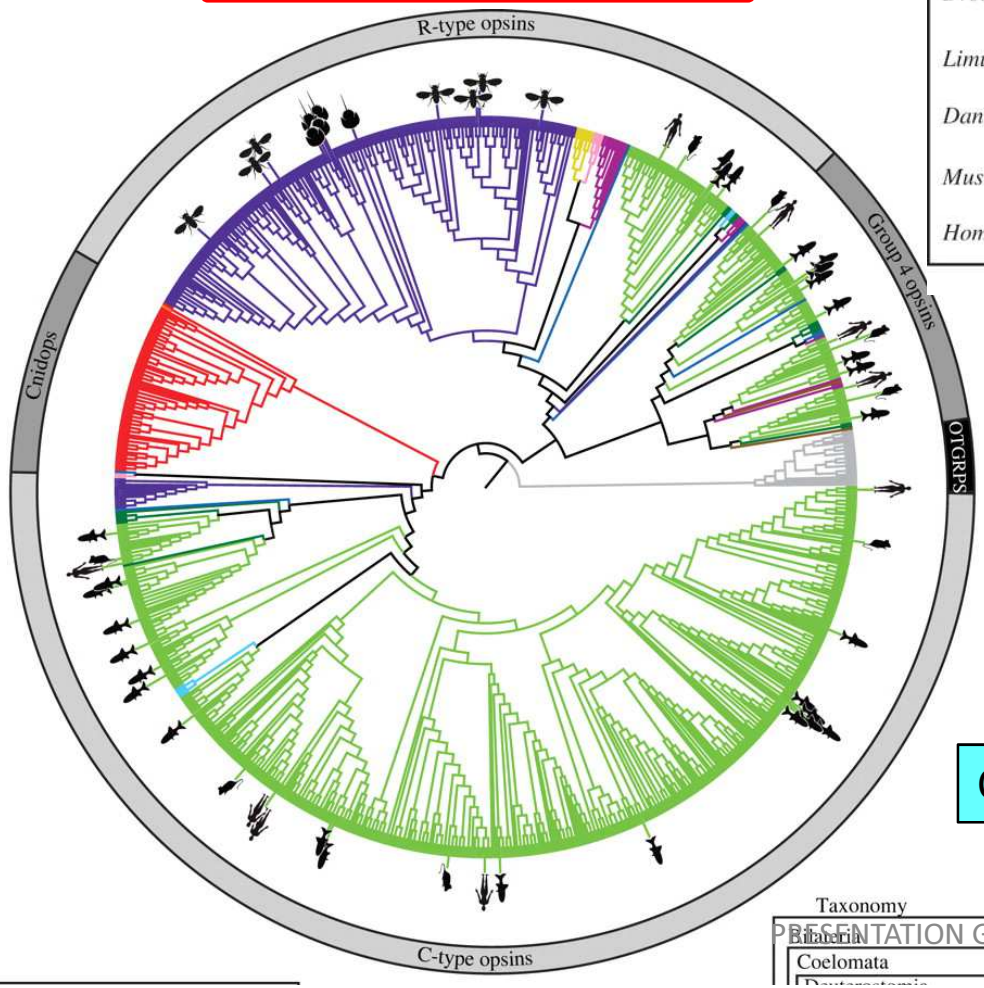
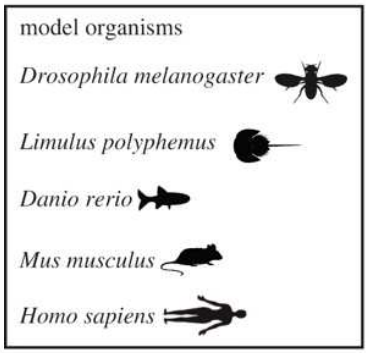
- **Space filling techniques**
  - ✓**Treemaps**
  - ✓**DAGmaps**

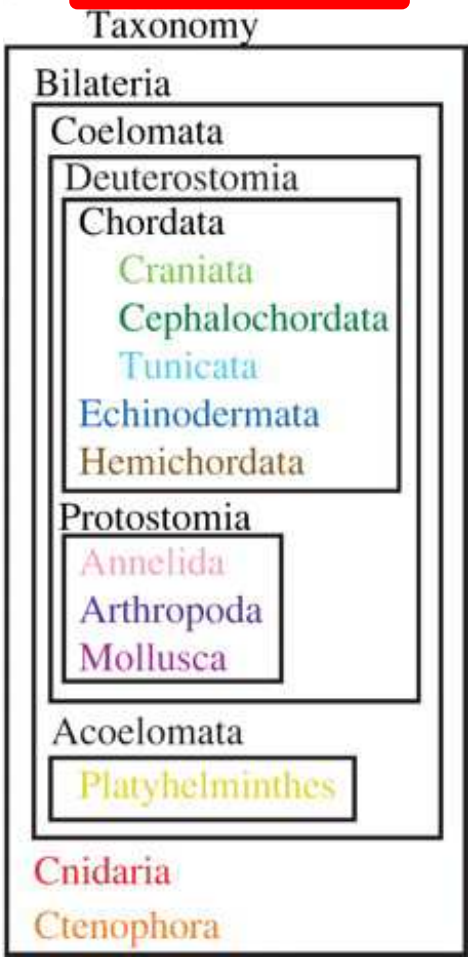
Visualization of Phylogenetic Trees and Networks

node-link



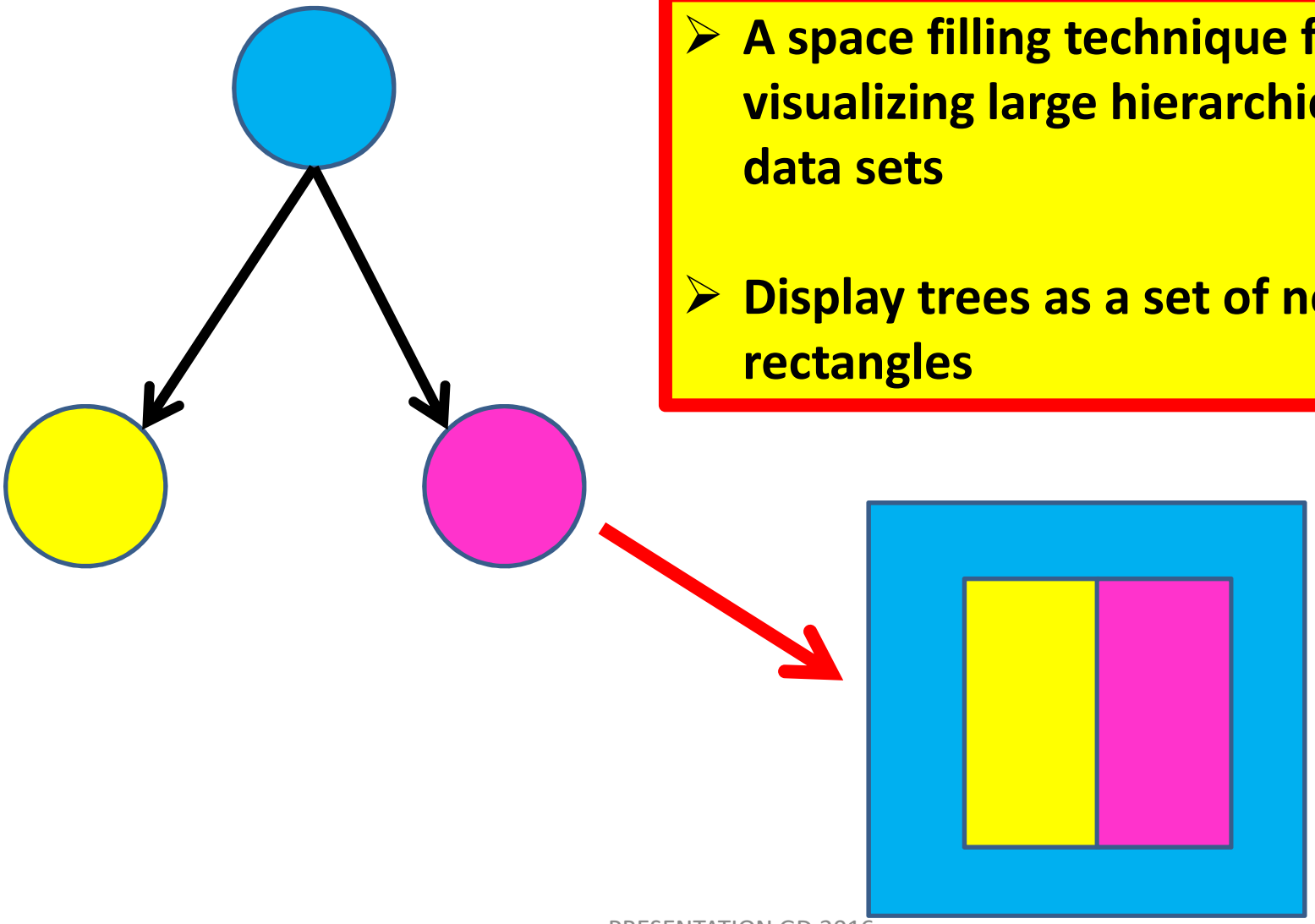


Treemap



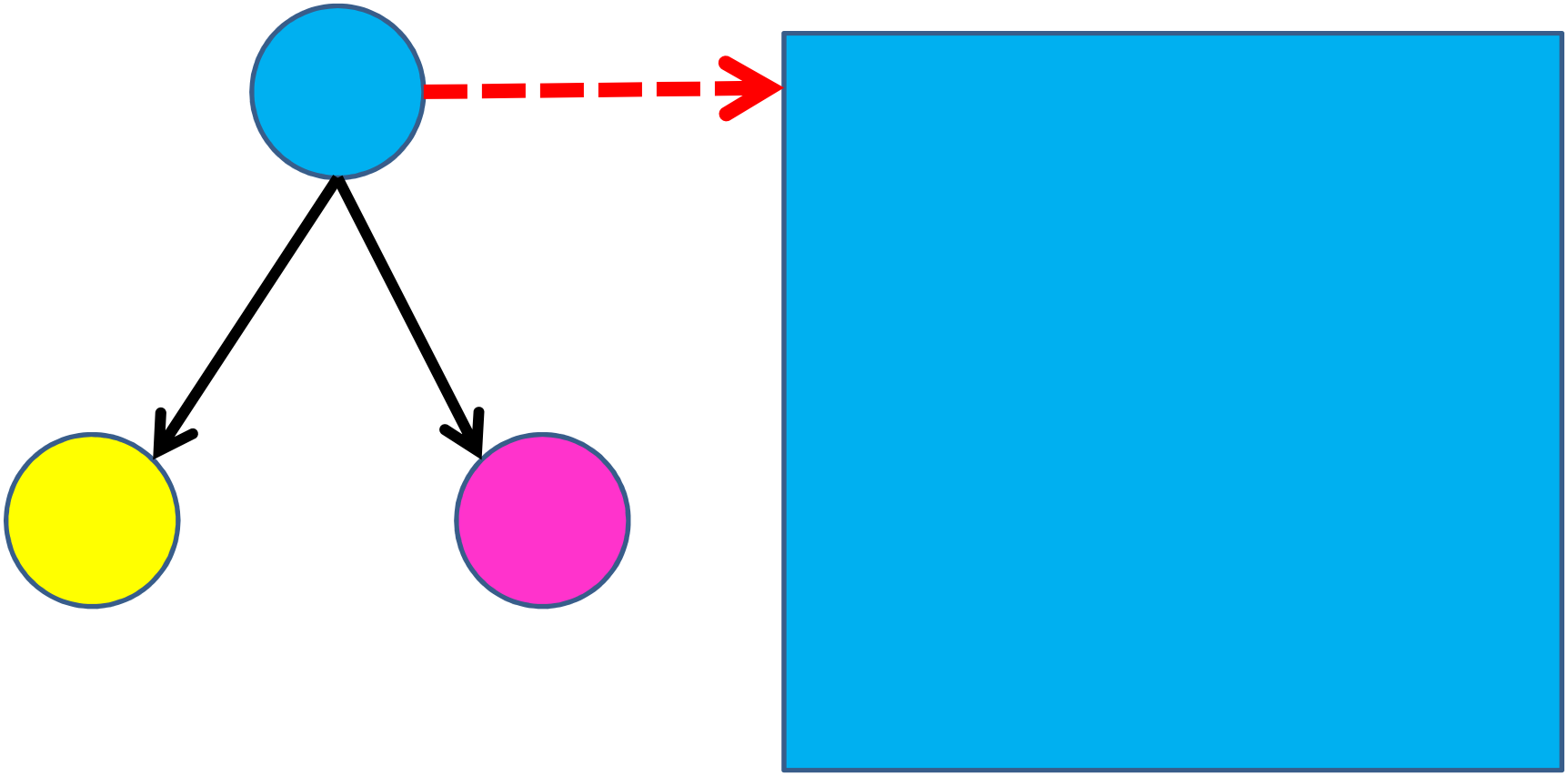
C-type opsins

TREEMAP DRAWINGS (Johnson and Shneiderman, 1990)



- A space filling technique for visualizing large hierarchical data sets
- Display trees as a set of nested rectangles

TREEMAP DRAWINGS



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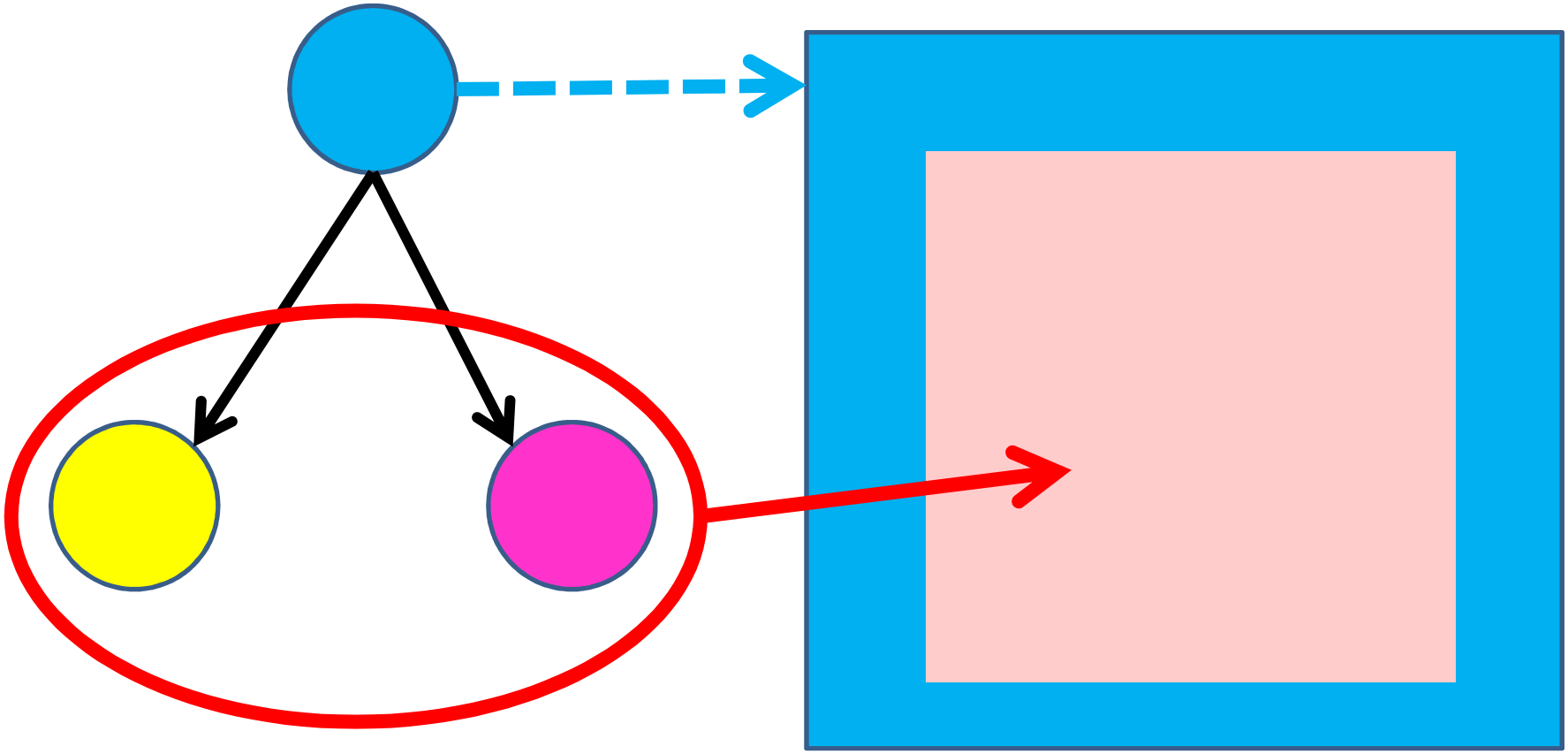

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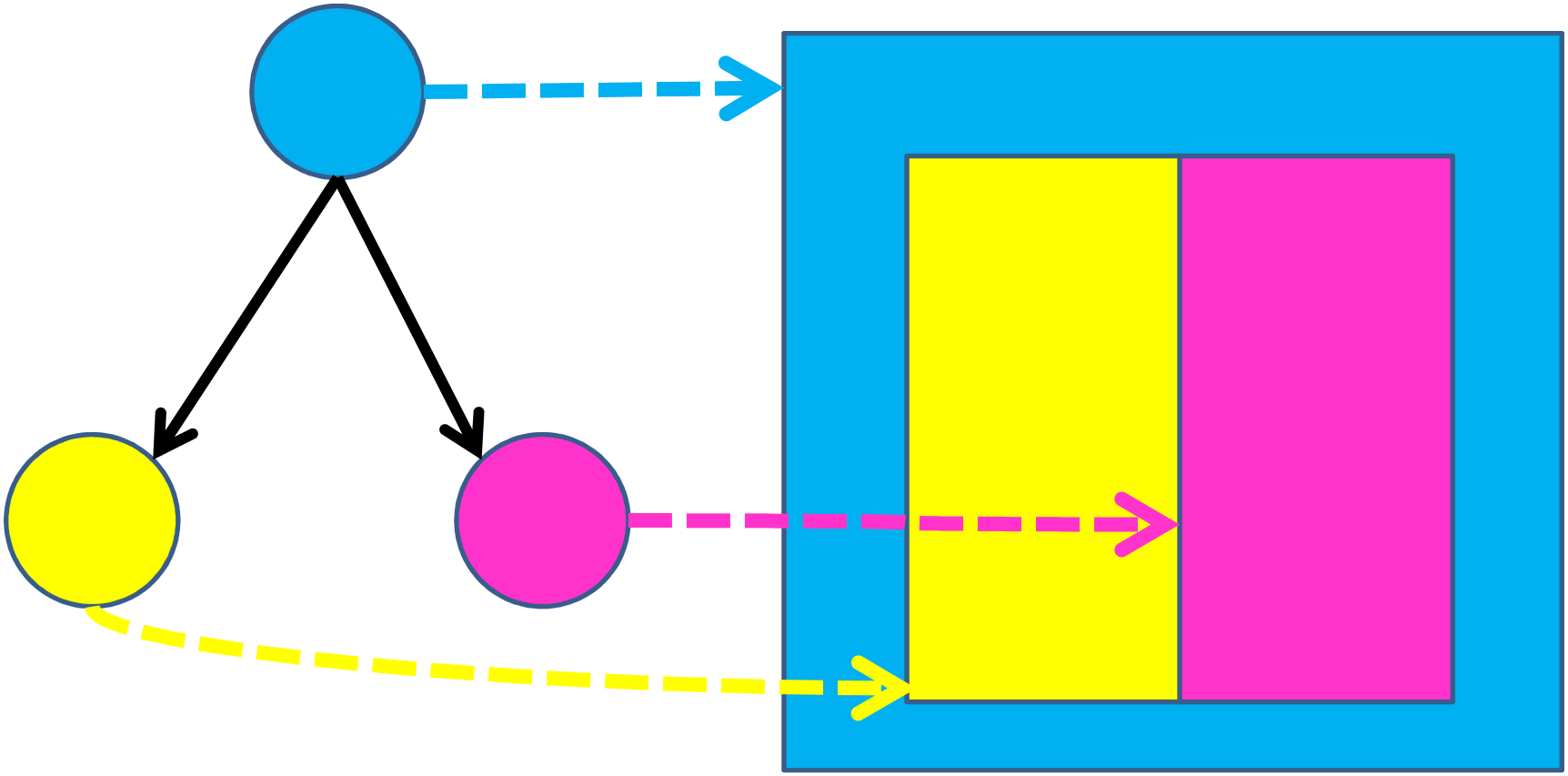
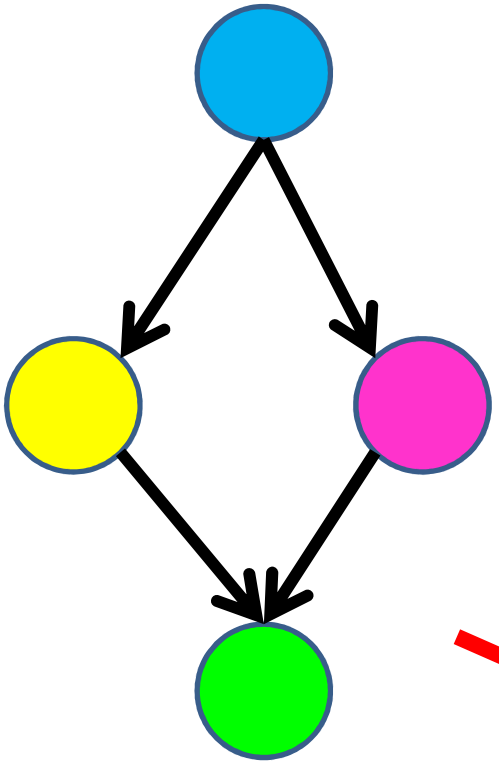
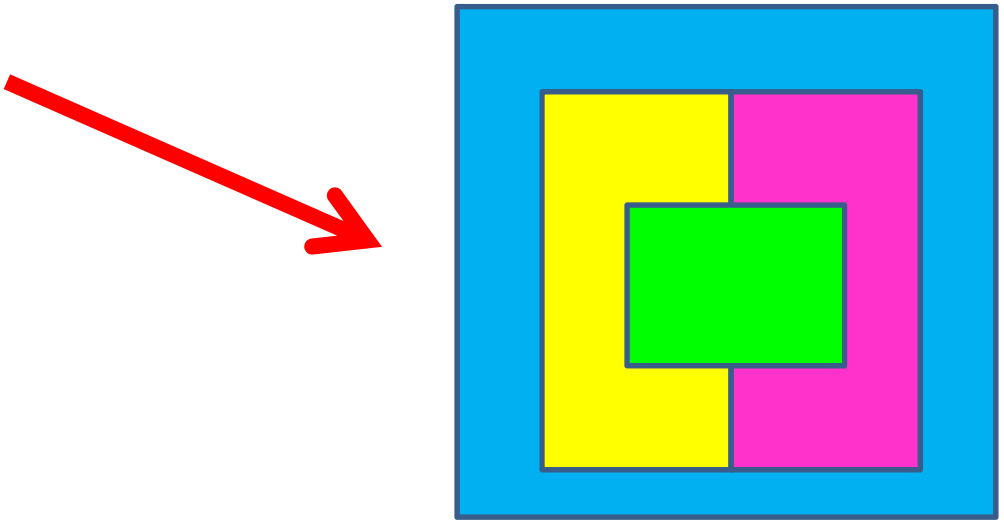


DAGMAP DRAWINGS (Tsiaras, Triantafilou, and Tollis, 2007)



- **An extension of treemaps for visualizing Directed Acyclic Graphs (DAGs).**
- **It is not always possible to visualize a DAG with a DAGmap without having node duplications.**



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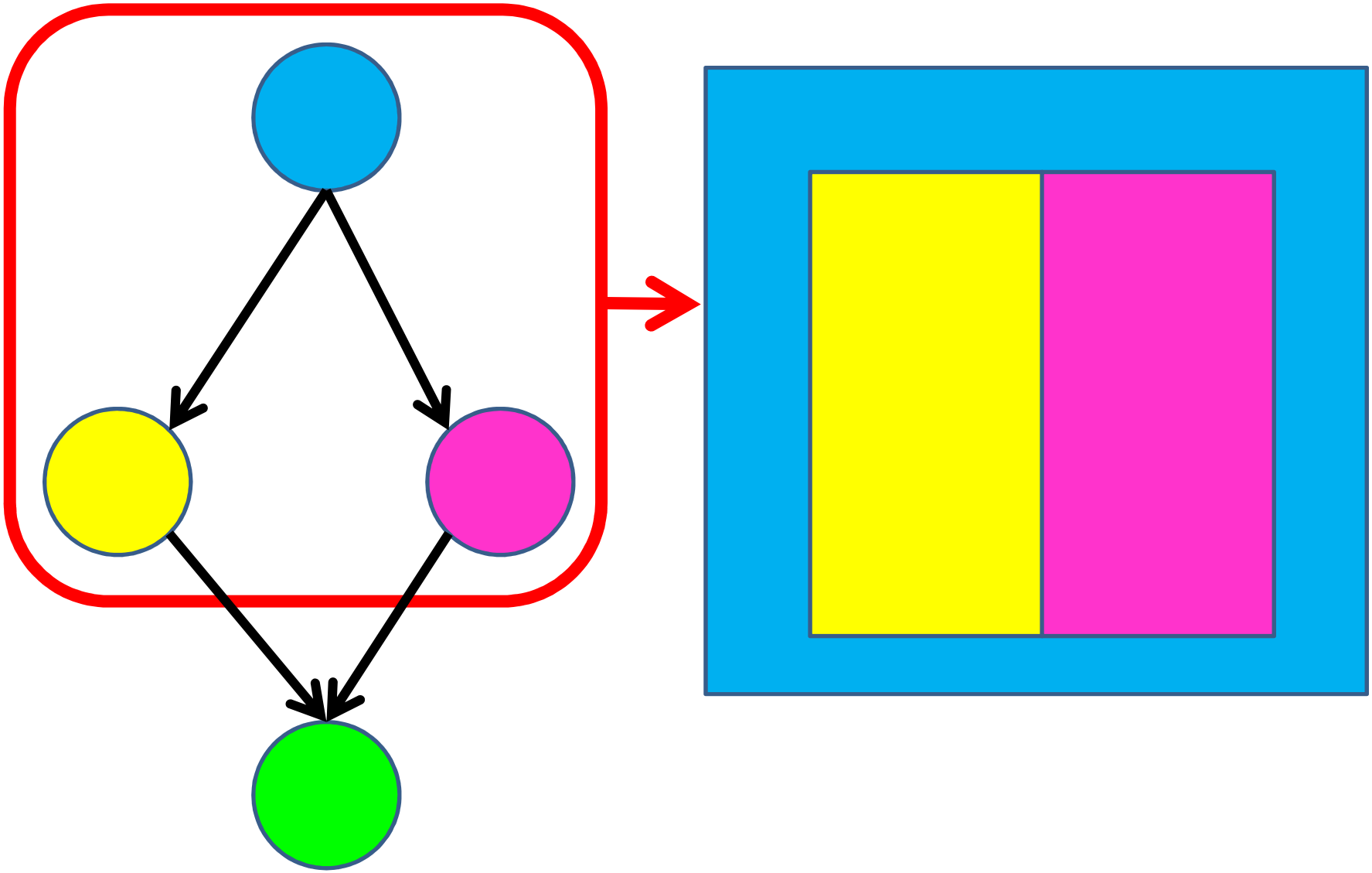

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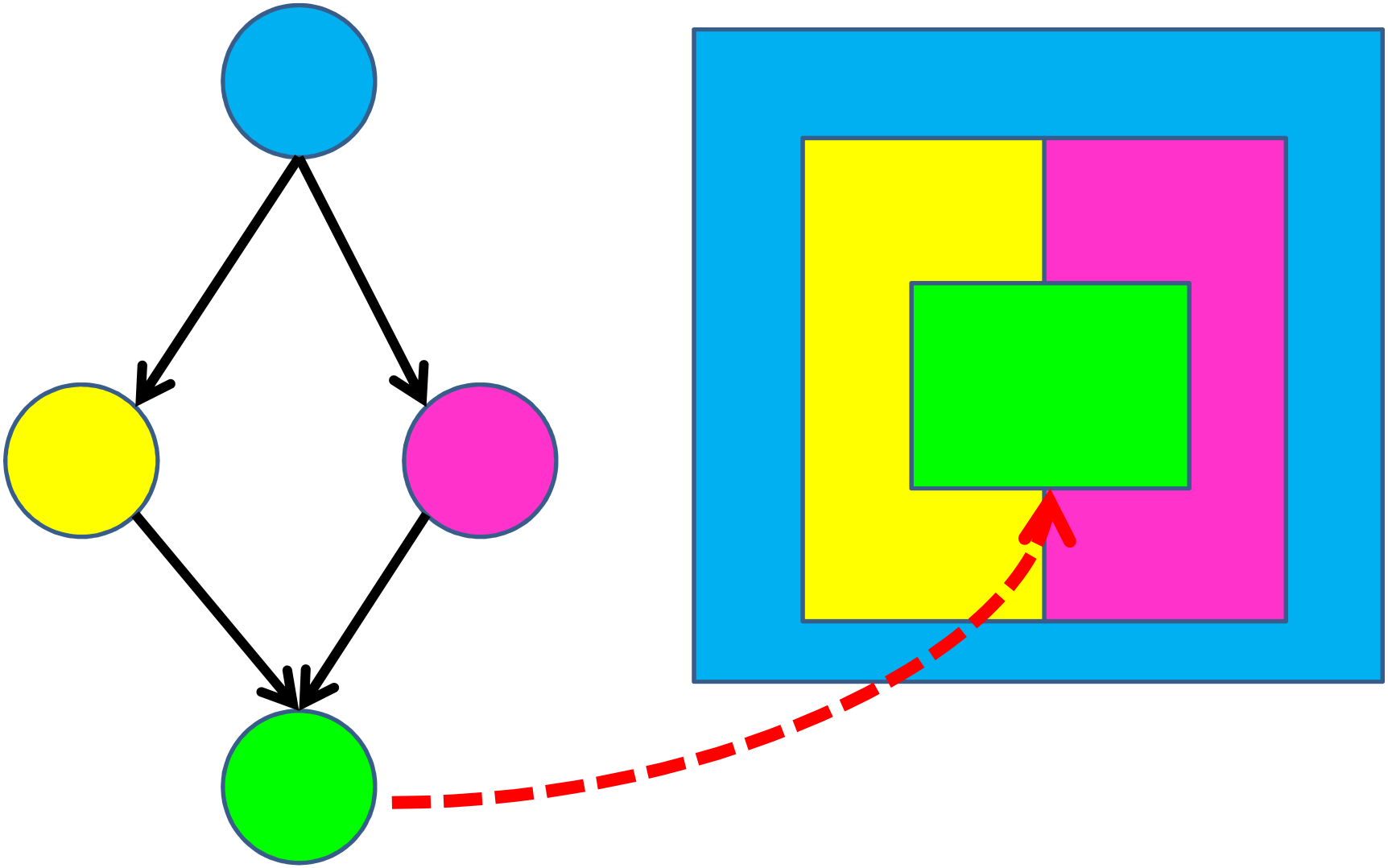
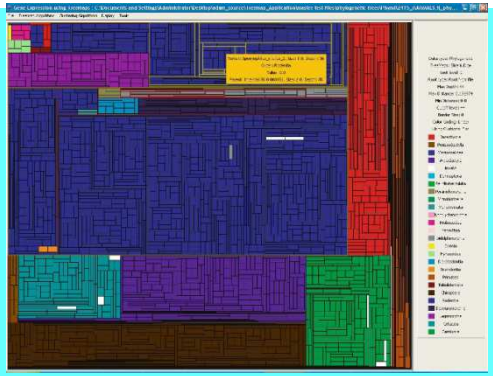
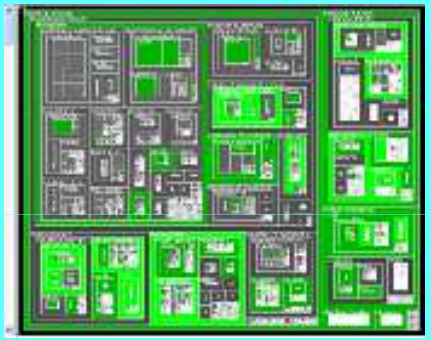


Treemaps have been used in bioinformatics to visualize:

1. Phylogenetic trees



2. Gene expression data



3. Gene ontologies

4. Encyclopedia of Life

Main Results

Drawing Galled Networks as DAGmaps, without node duplications, is NP-Complete.

<u>Linear time algorithms for:</u>

1. **Drawing Galled Trees as DAGmaps**
2. **Drawing Planar Galled Networks as DAGmaps**

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Linear time algorithms for:

1. **Drawing Galled Trees as DAGmaps**
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NOTE

- **Galled trees and galled networks have received much attention in recent years.**
- **They are important types of phylogenetic networks.**
- **A galled tree or network may suffice to accurately describe an evolutionary process when the number of recombination events is limited and most of them have occurred recently (Guseld, Eddhu, and Langley, 2004).**

DRAWINGS GALLED TREES AS DAGMAPS

Algorithm

Input: A galled tree G.
Output: A DAGmap drawing of G.

1. **Transform the galled tree G into a tree T, by unifying the two chains of each gall.**
2. **Draw the treemap of T.**
3. **Split the rectangles, corresponding to the nodes of the unified chains of the galls, to obtain the initial parallel chains.**

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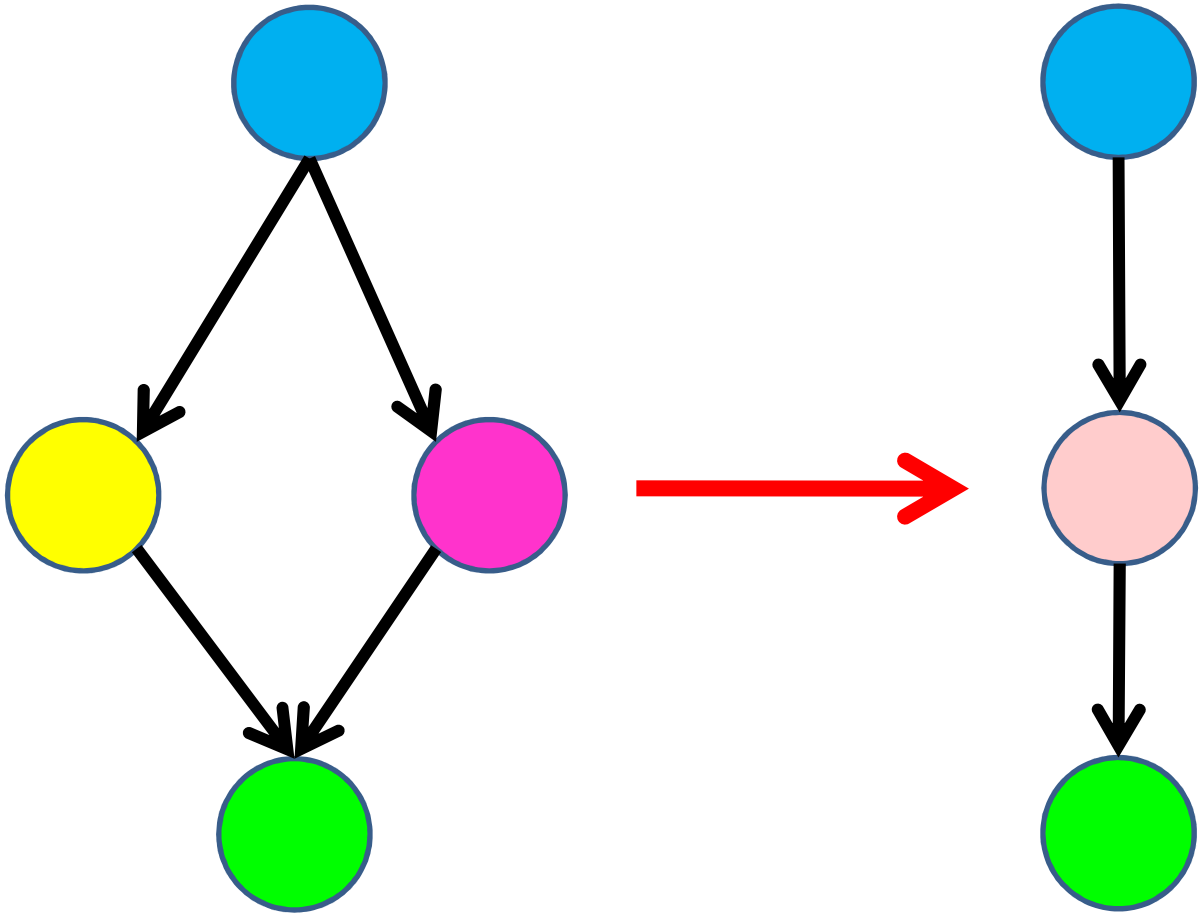
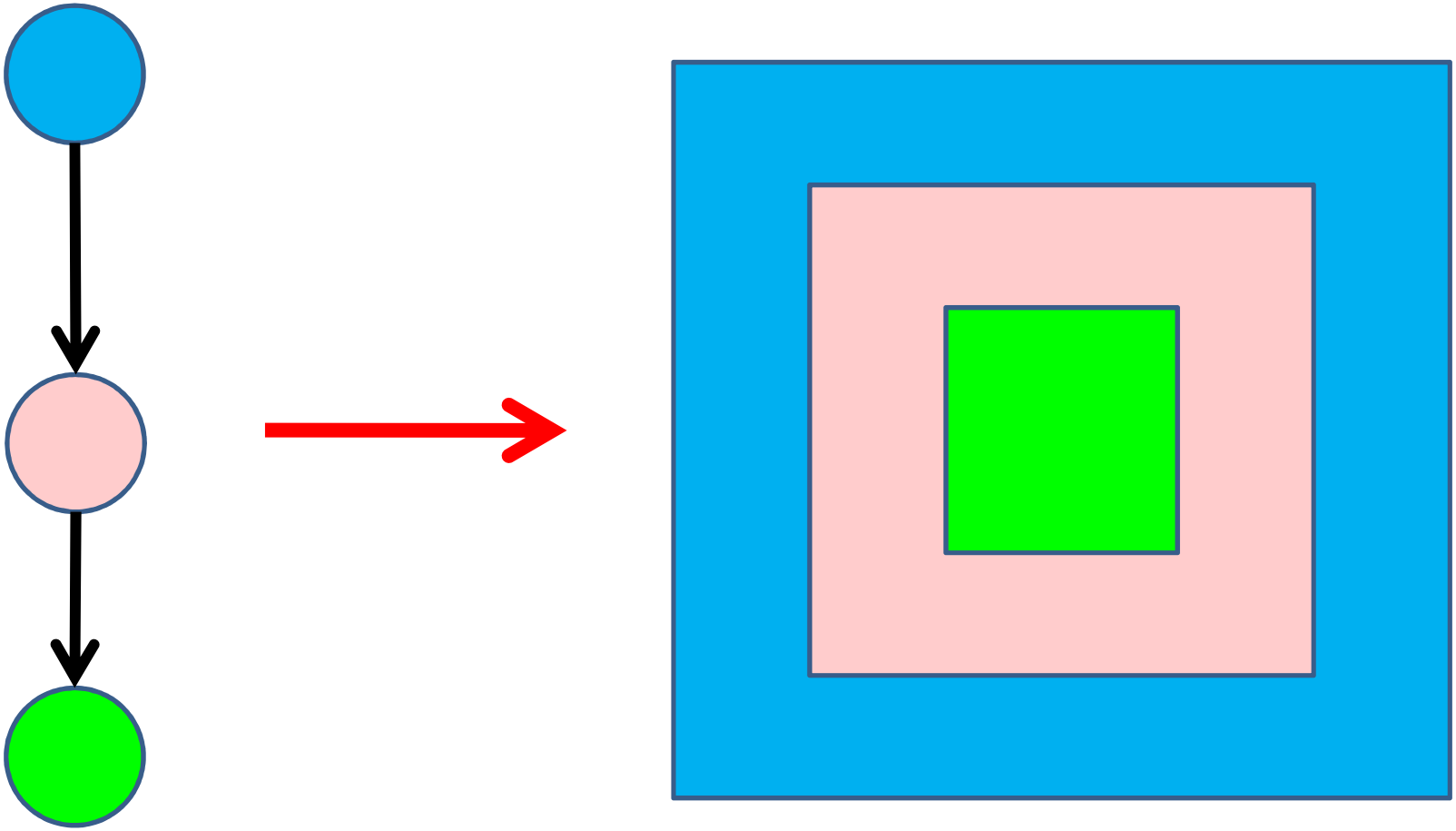


DRAWINGS GALLED TREES AS DAGMAPS

STEP 2: Draw the treemap of T.



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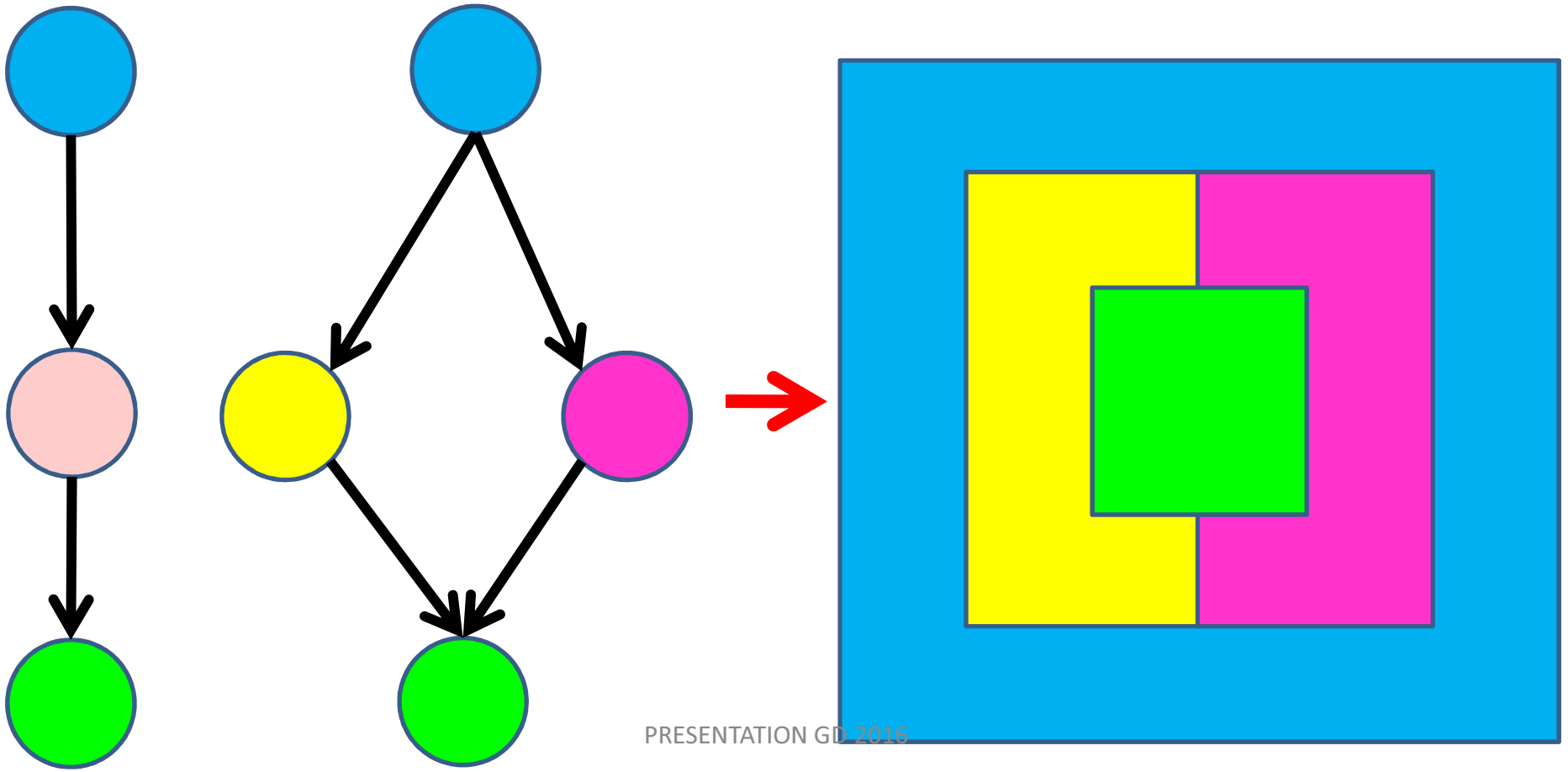
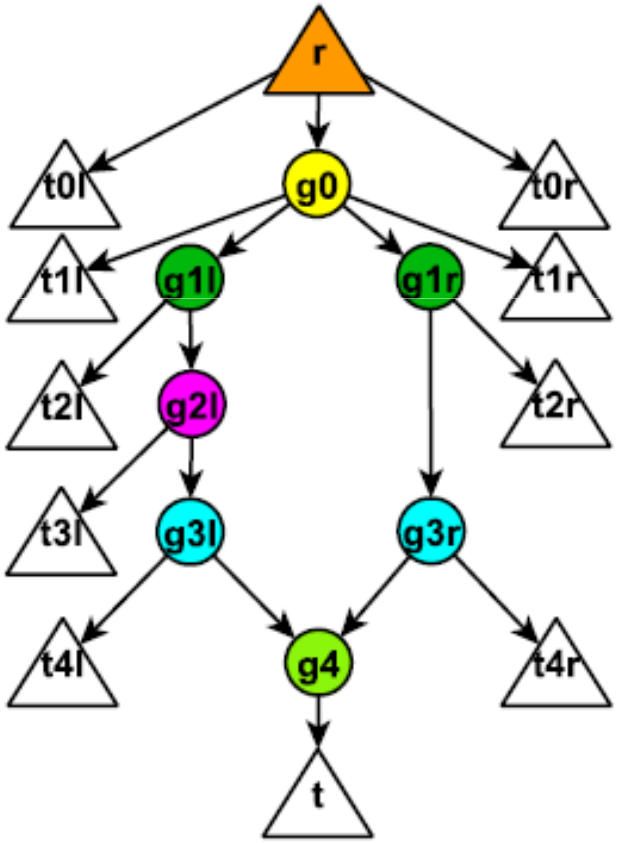
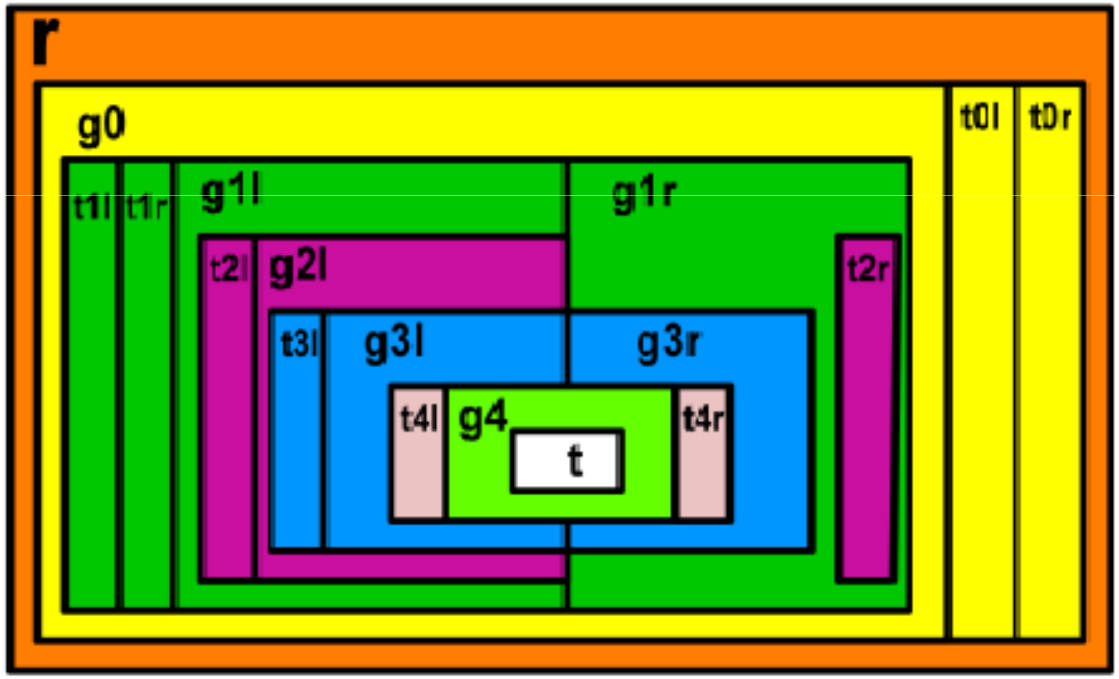


DRAWINGS GALLED TREES AS DAGMAPS

Example 2





DRAWINGS PLANAR GALLED NETWORKS AS DAGMAPS

Algorithm

Input: A planar galled network G.

Output: A DAGmap drawing of G.

1. **Transform the galled network G into a galled tree GT.**

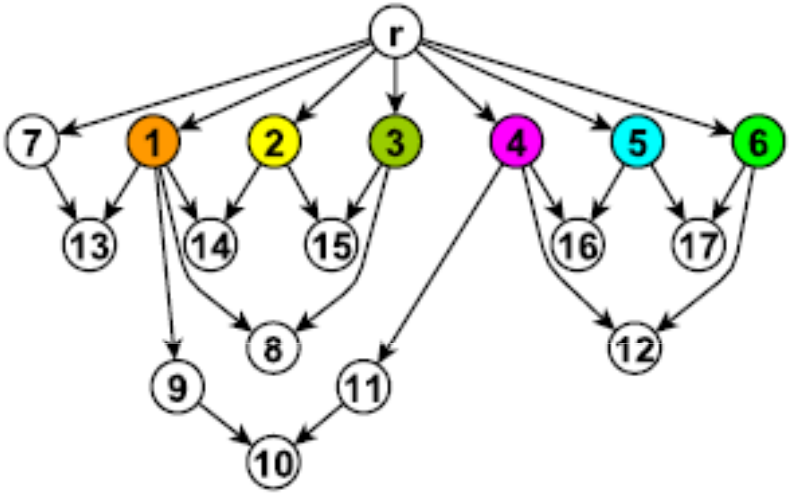
2. **Construct a planar embedding of GT.**

3. **Draw the DAGmaps of the galls of GT.**

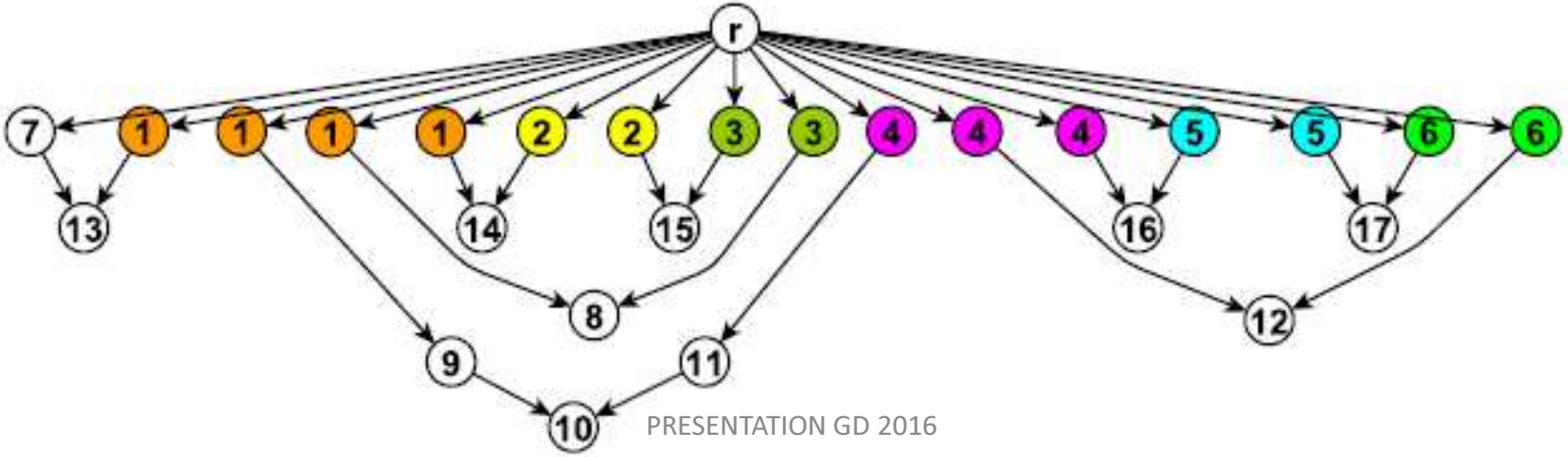
4. **Unify the split nodes and remove unused space.**

DRAWINGS PLANAR GALLED NETWORKS AS DAGMAPS

STEP1: Transform the galled network G into a galled tree GT.

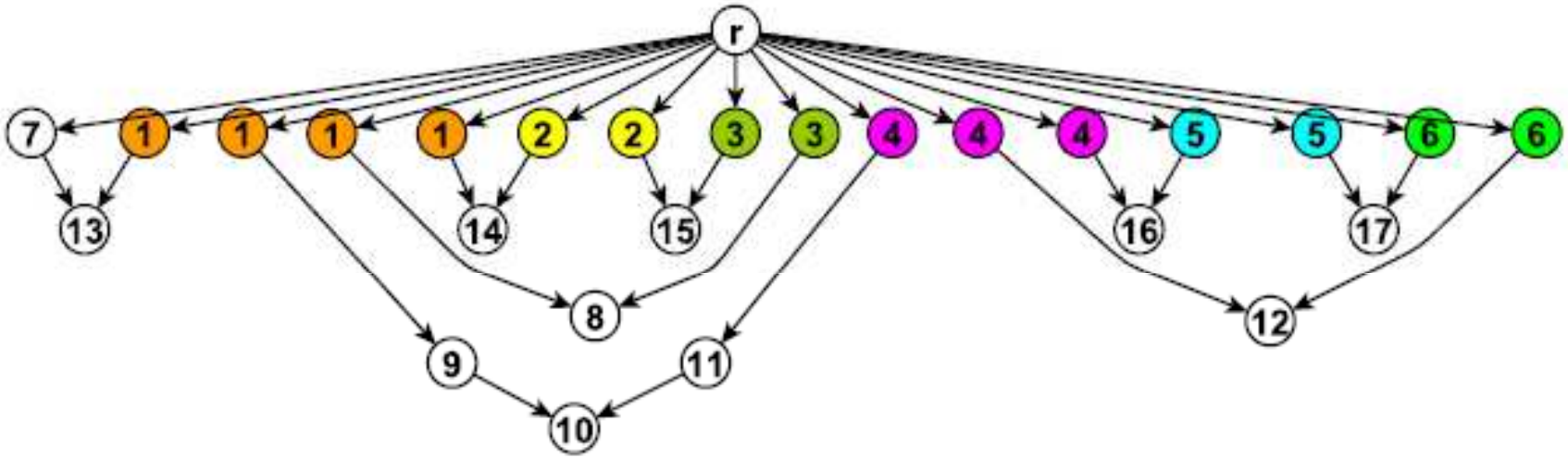


Split the nodes that belong to more than one galls.



DRAWINGS PLANAR GALLED NETWORKS AS DAGMAPS

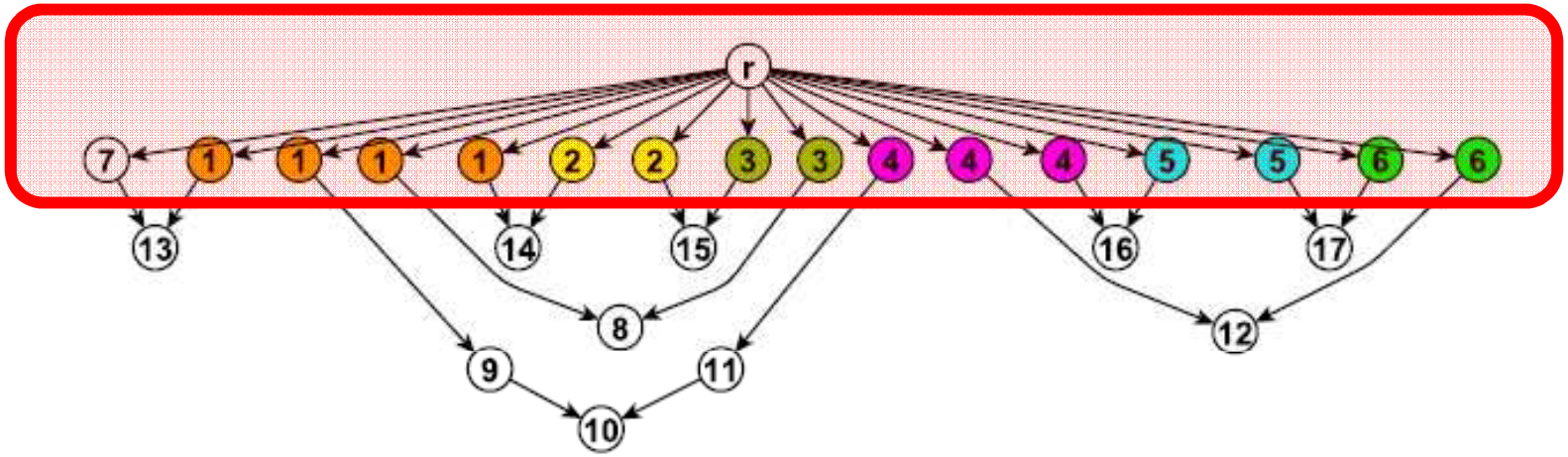
STEP 2: Construct a planar embedding of GT.



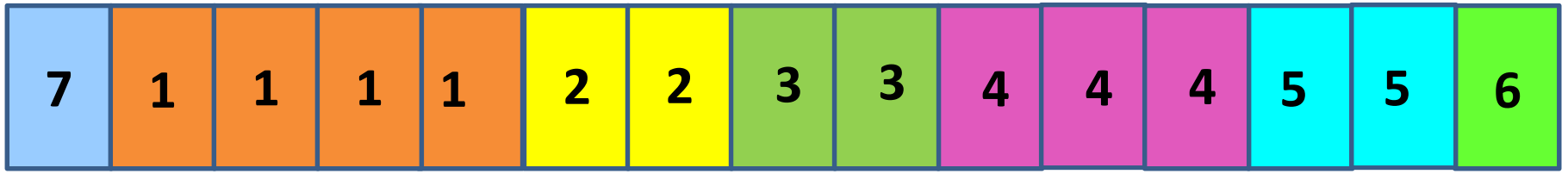
- **Each planar galled network is a single source upward planar DAG.**
- **Bertolazzi et al. (1998) have shown that a drawing of a single source upward planar DAG can be constructed in O(n) time.**
- **Thus, we can construct an upward planar drawing of a planar galled network in linear time.**

DRAWINGS PLANAR GALLED NETWORKS AS DAGMAPS

STEP 3: Draw the DAGmaps of the galls of GT.



DRAW AS TREEMAP



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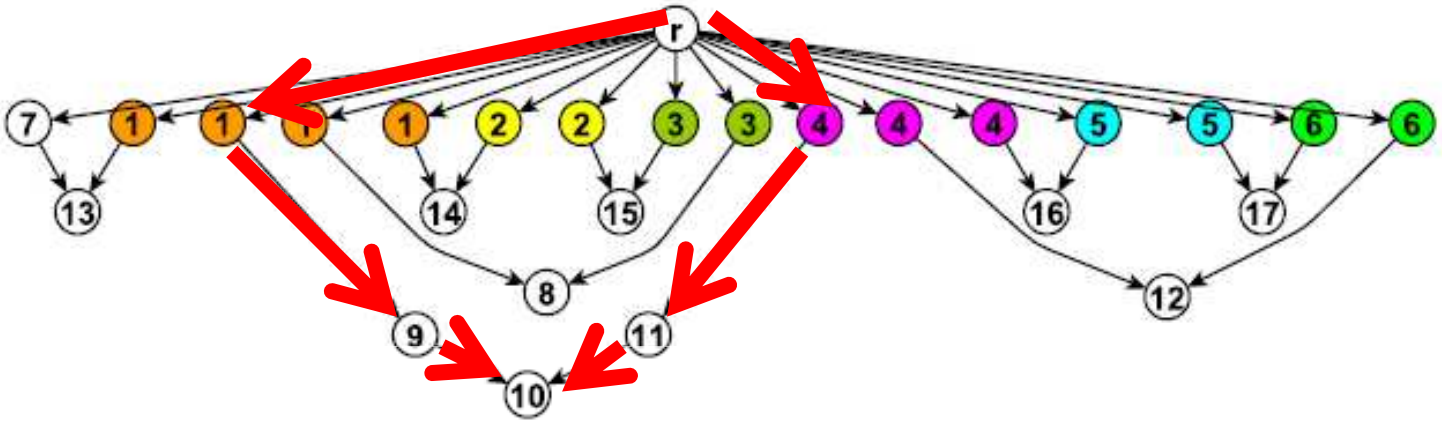

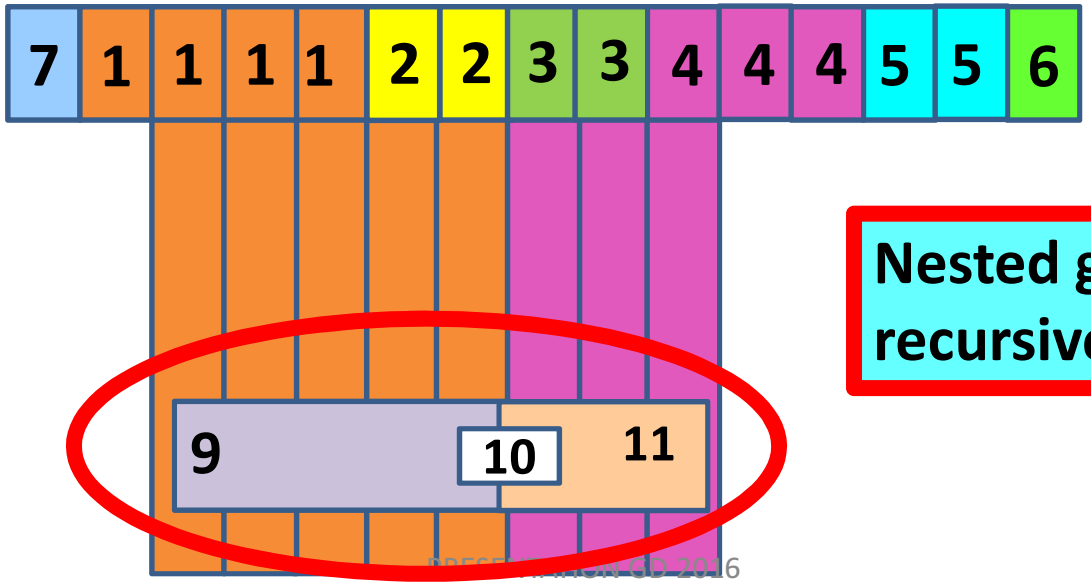

Nested galls are drawn recursively.

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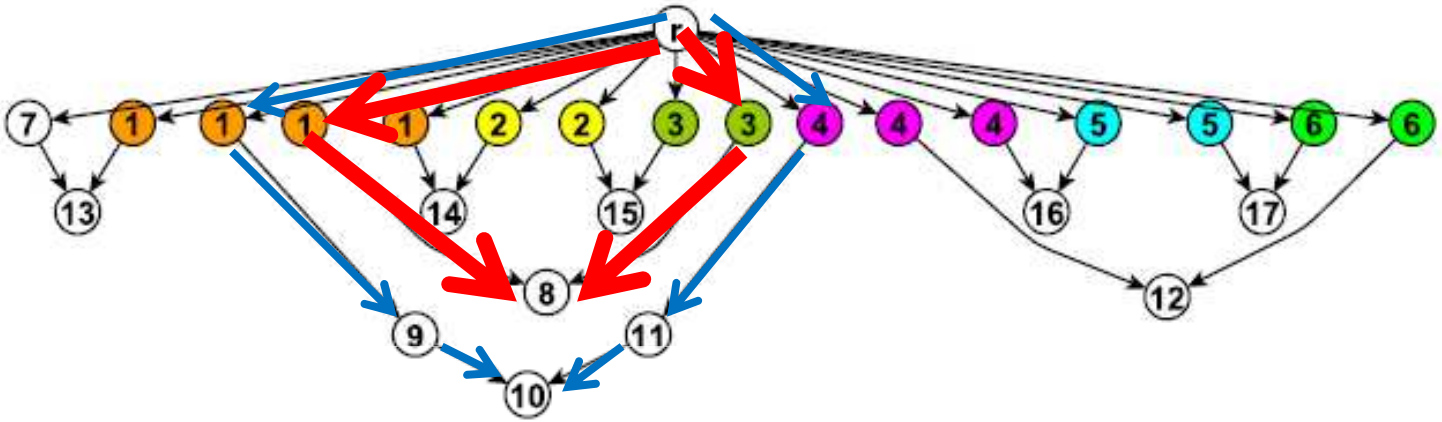

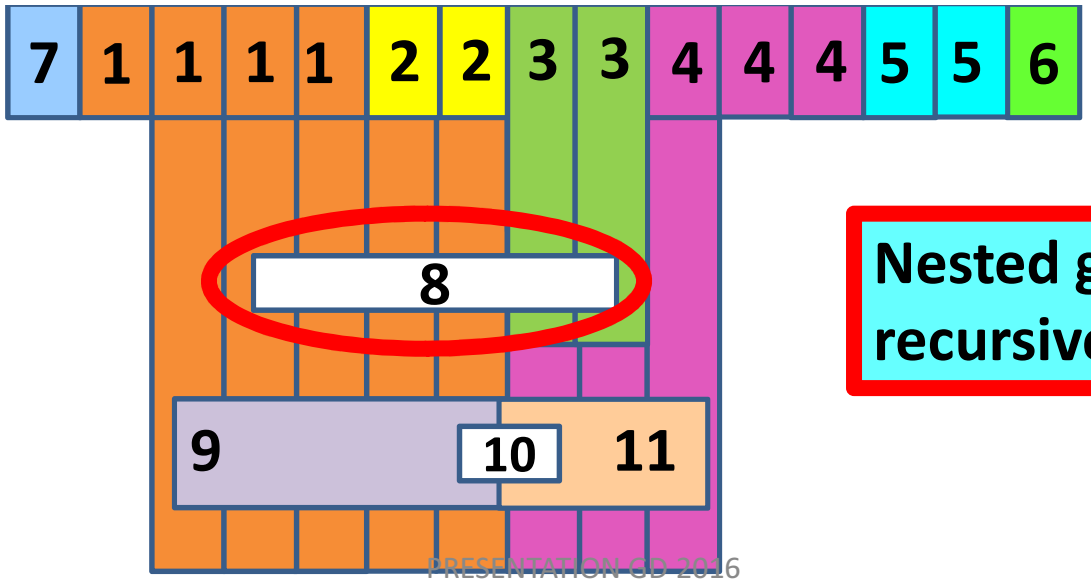

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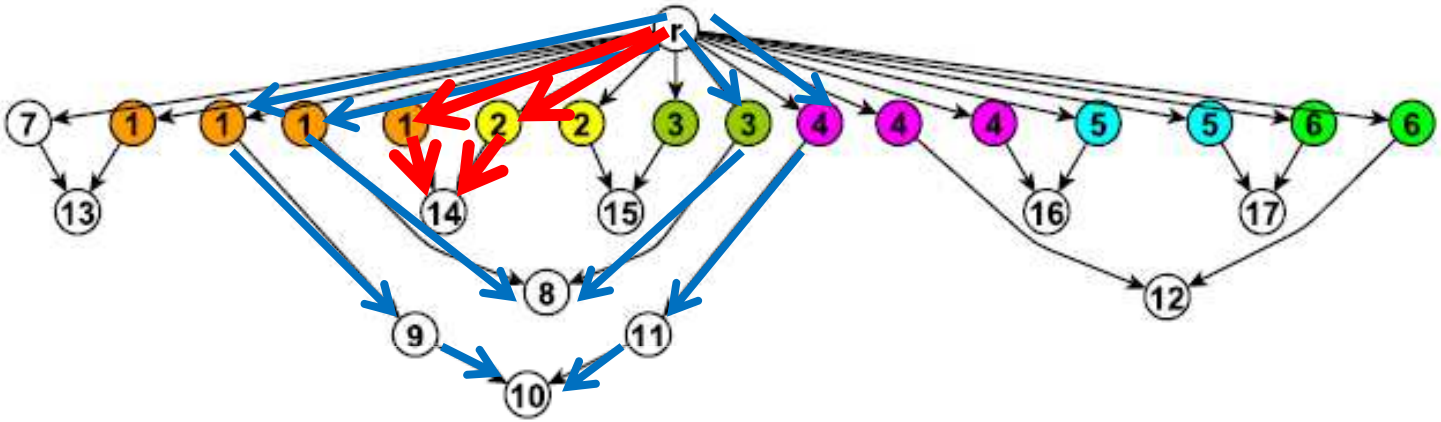

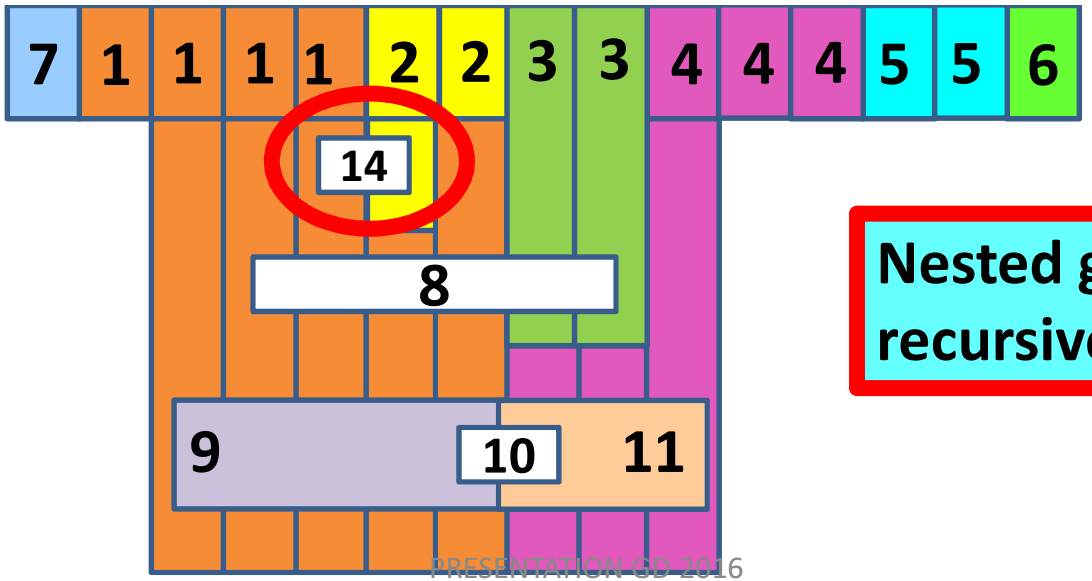

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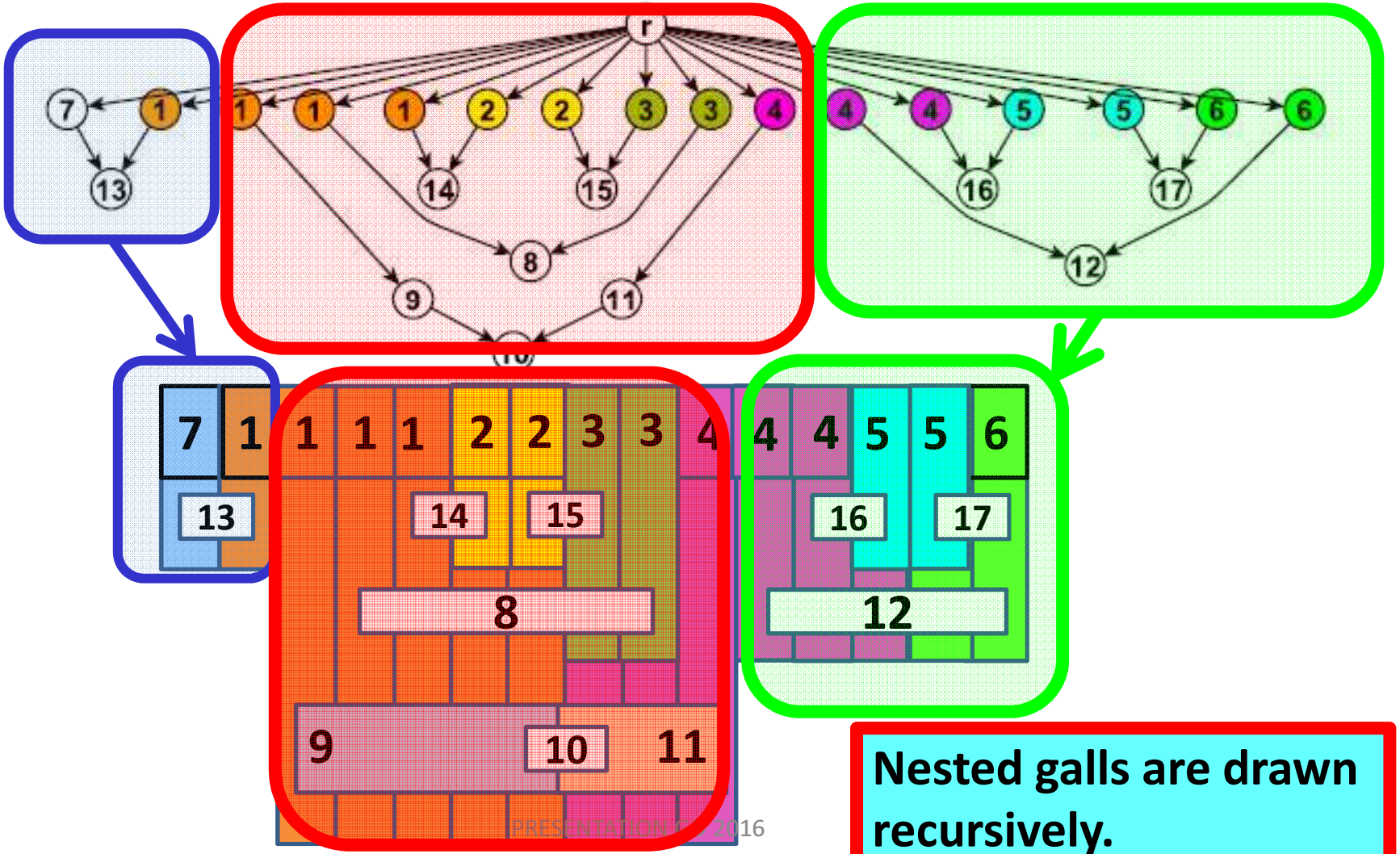

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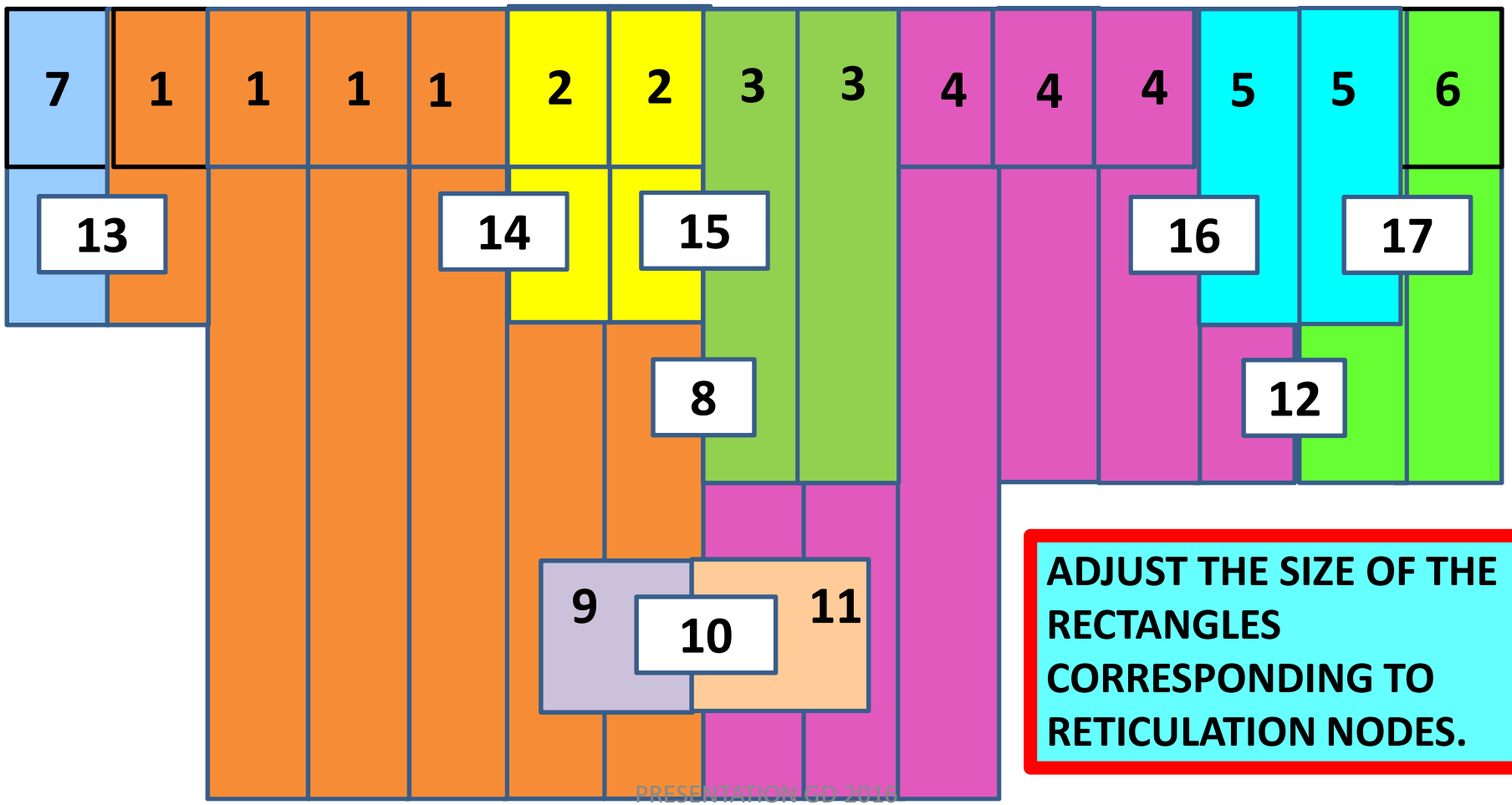
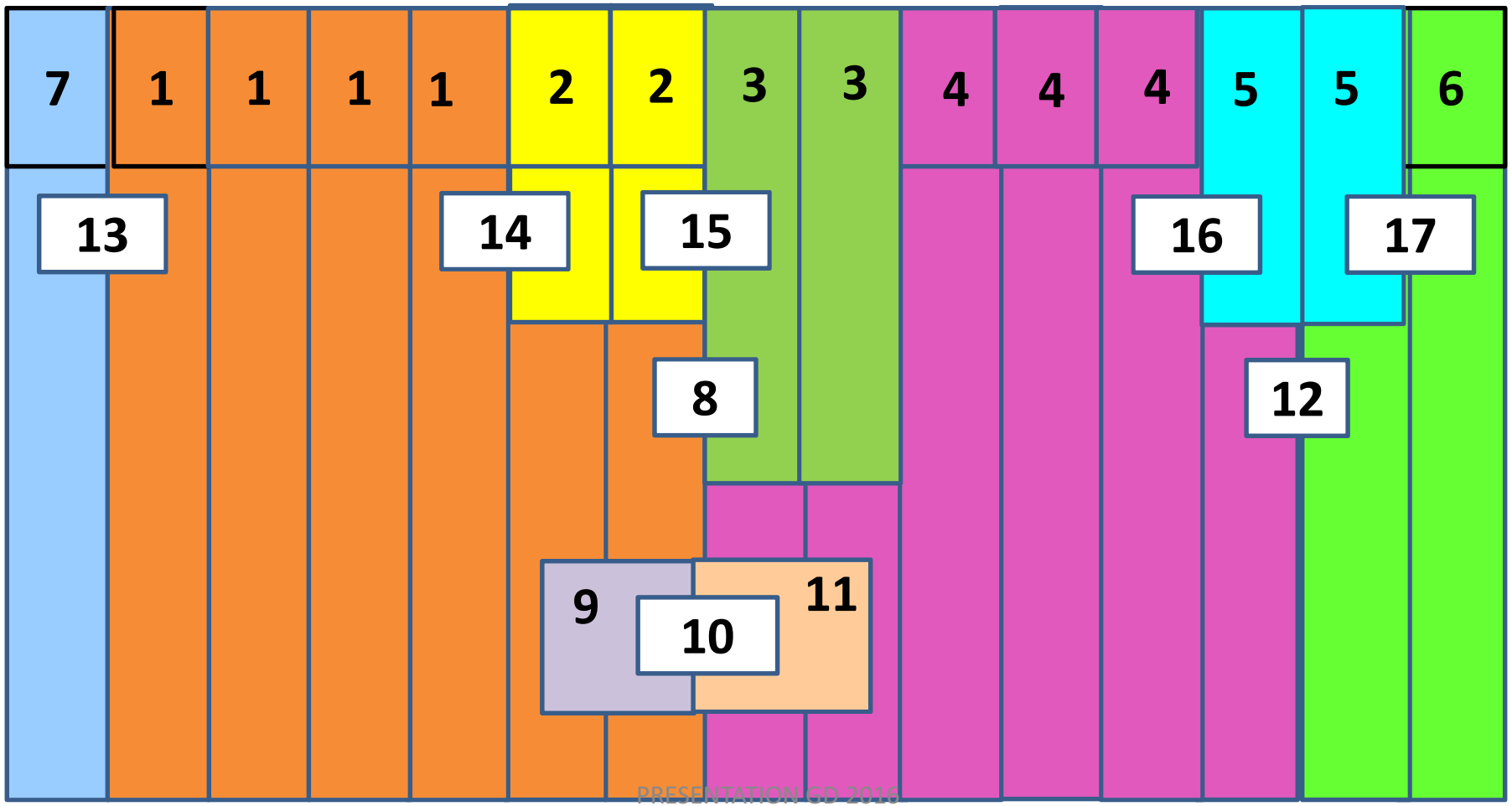


ADJUST THE SIZE OF THE RECTANGLES CORRESPONDING TO RETICULATION NODES.

DRAWINGS PLANAR GALLED NETWORKS AS DAGMAPS

STEP 3: Draw the DAGmaps of the galls of GT.



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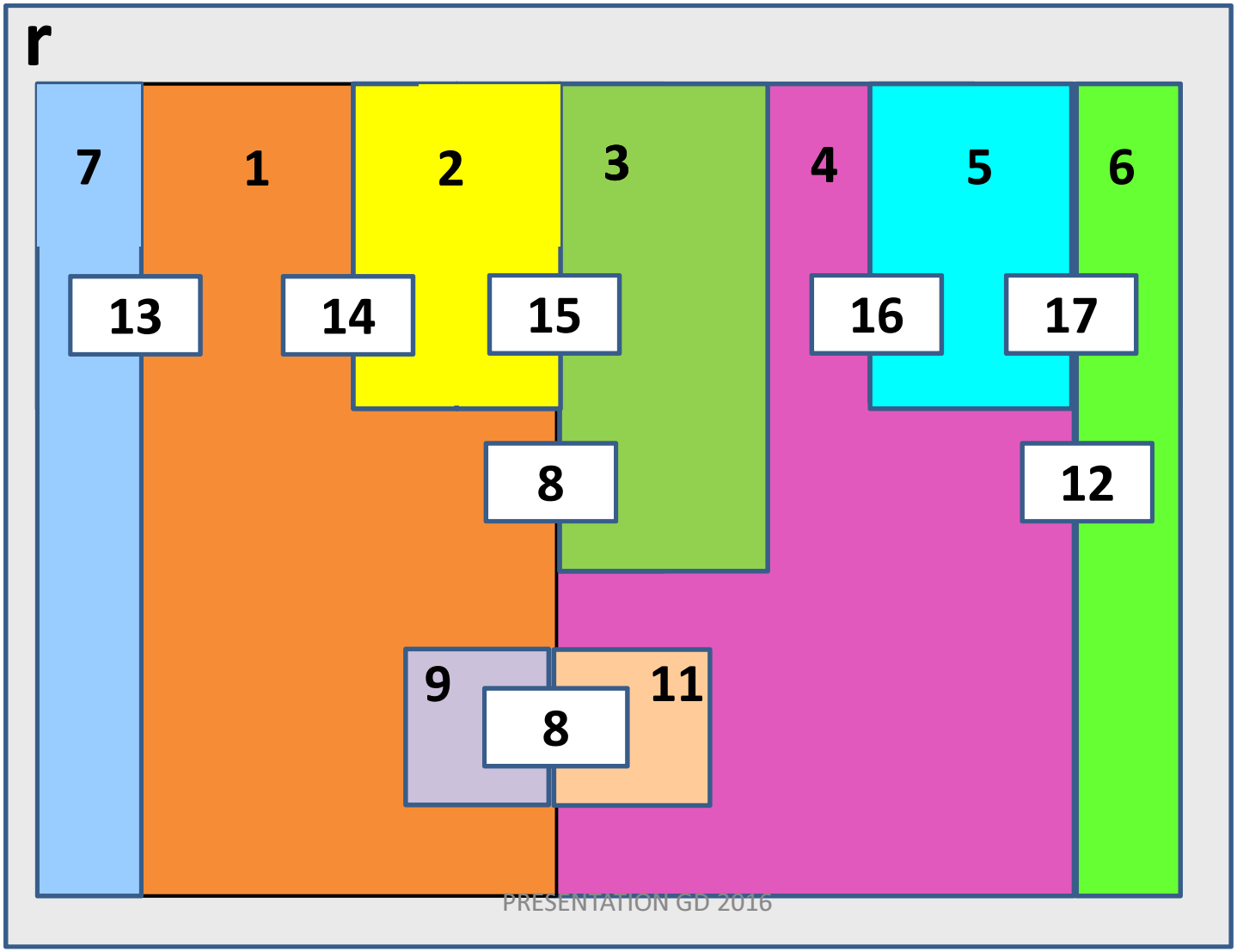
STEP 4: Unify the split nodes and remove unused space.



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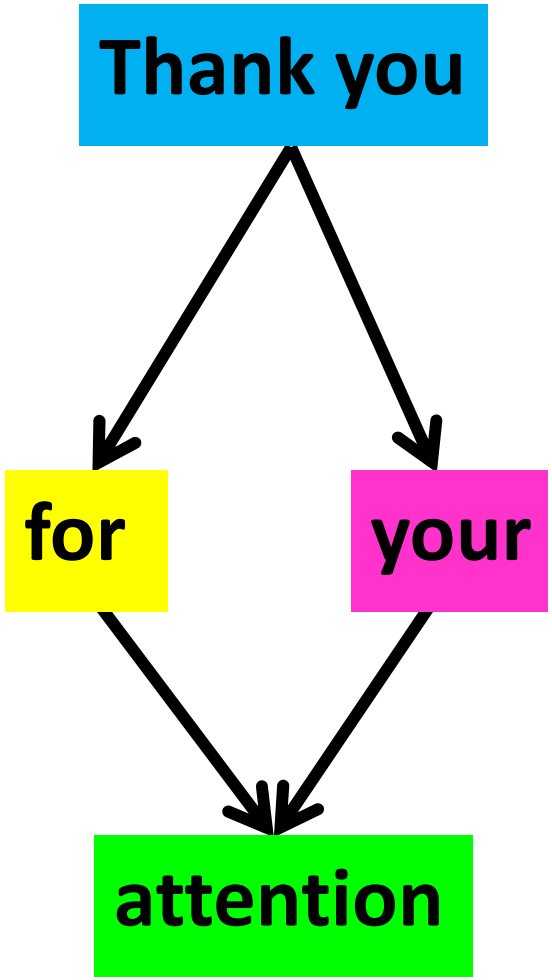
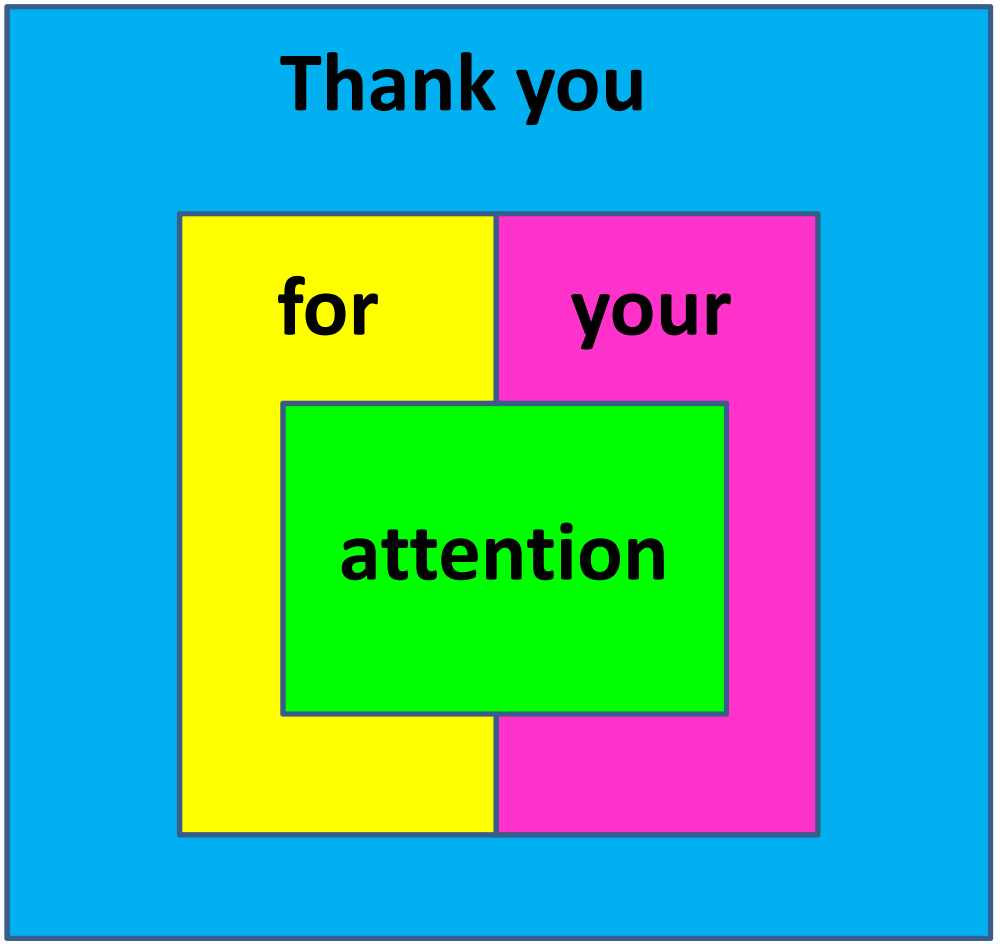
Open Problems

- **Heuristics for reducing the number of node duplications for drawing non planar galled networks as DAGmaps.**


Thank you
for
your
attention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