TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility

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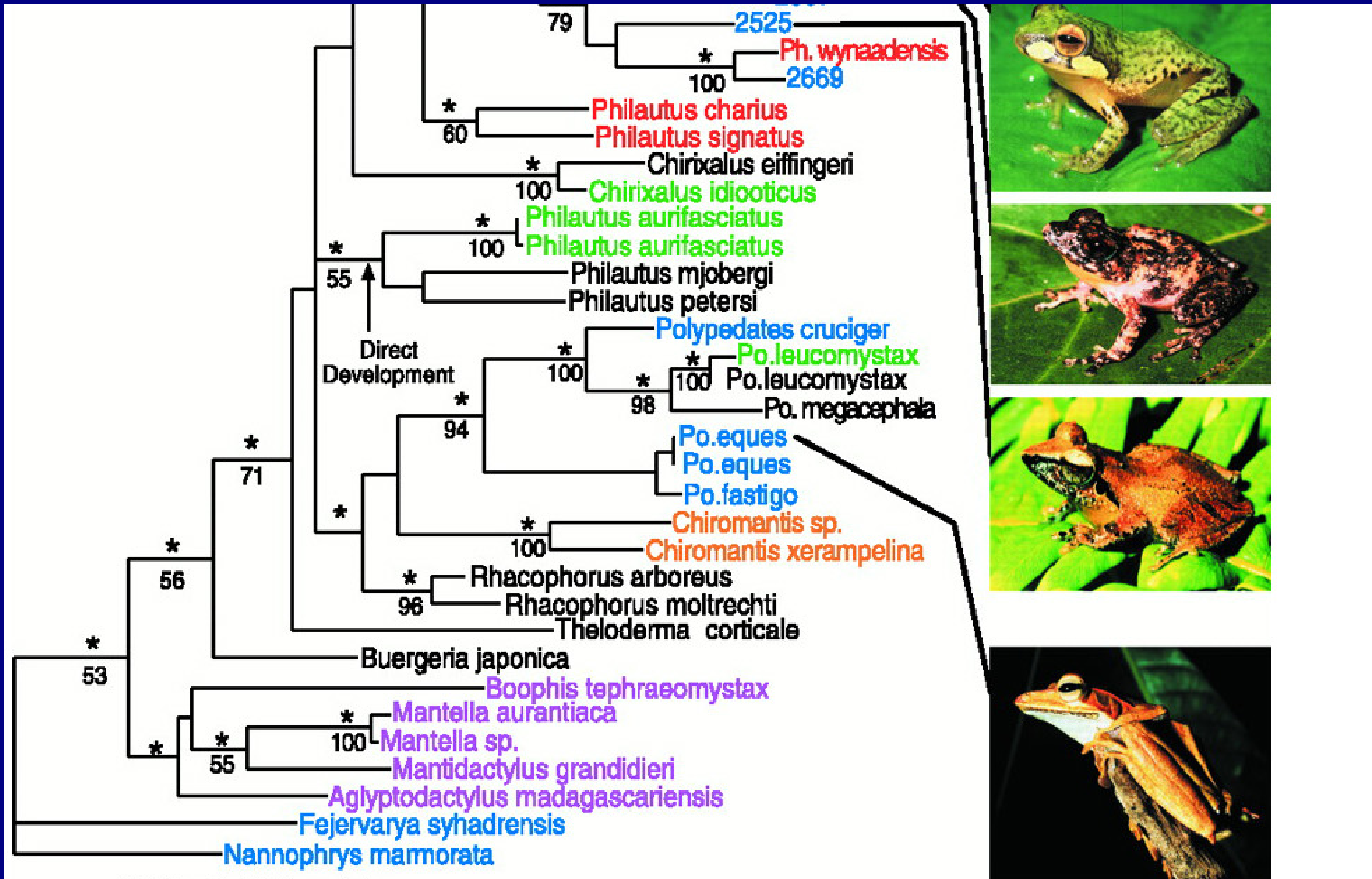
Tree comparison

- Active area: hierarchy visualization
  - previous work: browsing
  - comparison still open problem
- Bioinformatics application
  - phylogenetic trees reconstructed from DNA

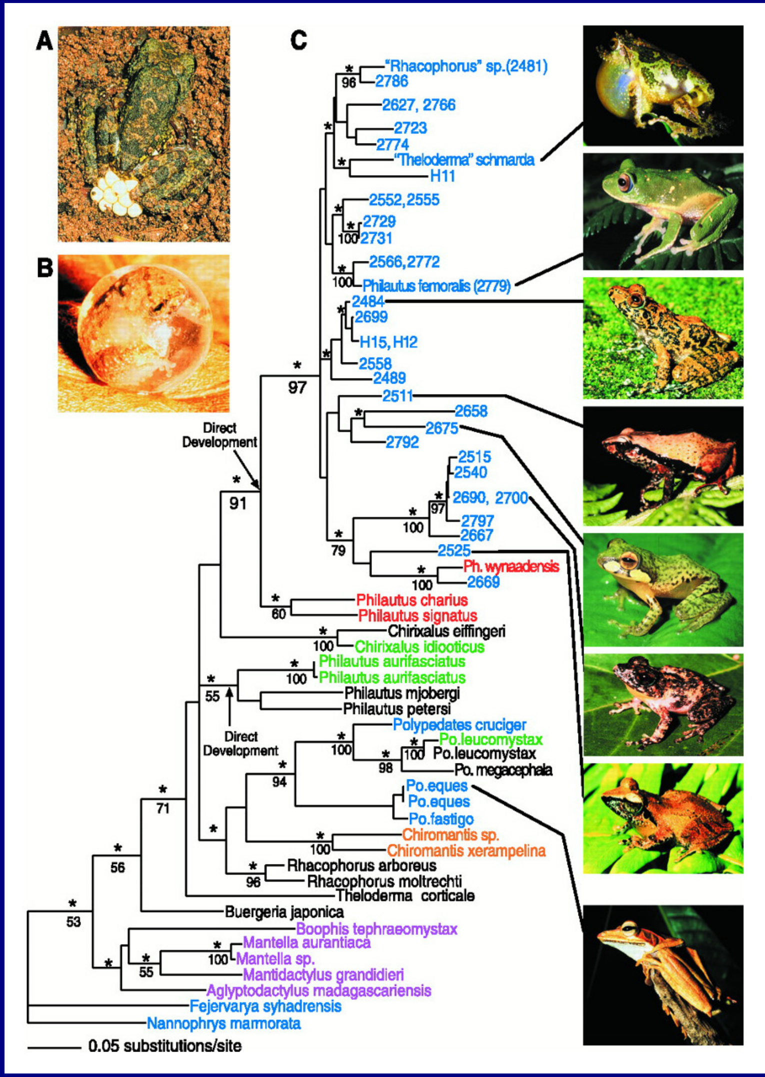
Inferring species relationships

Phylogenetic tree



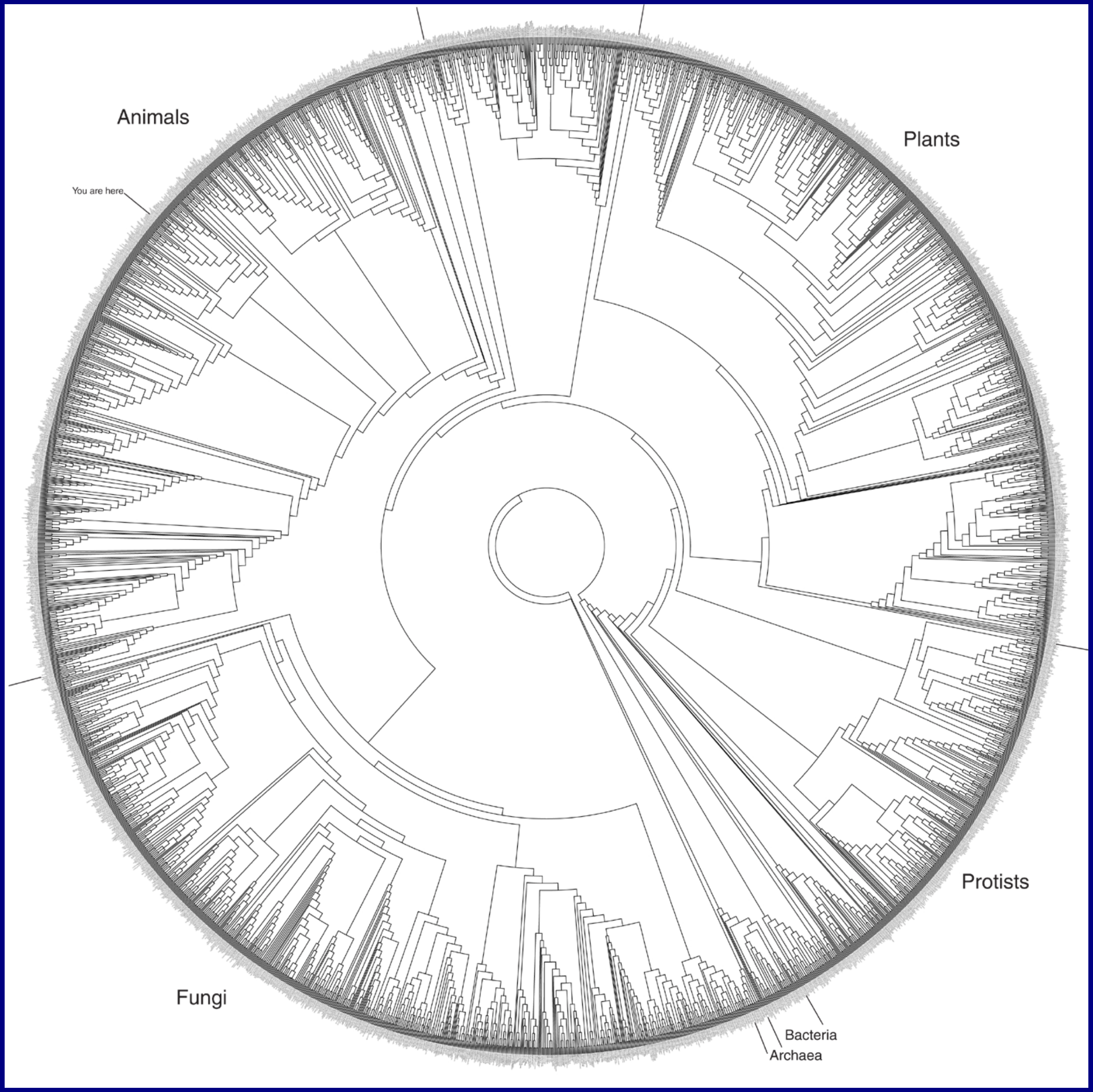
M Meegaskumbura et al., Science 298:379 (2002)

Phylogenetic tree



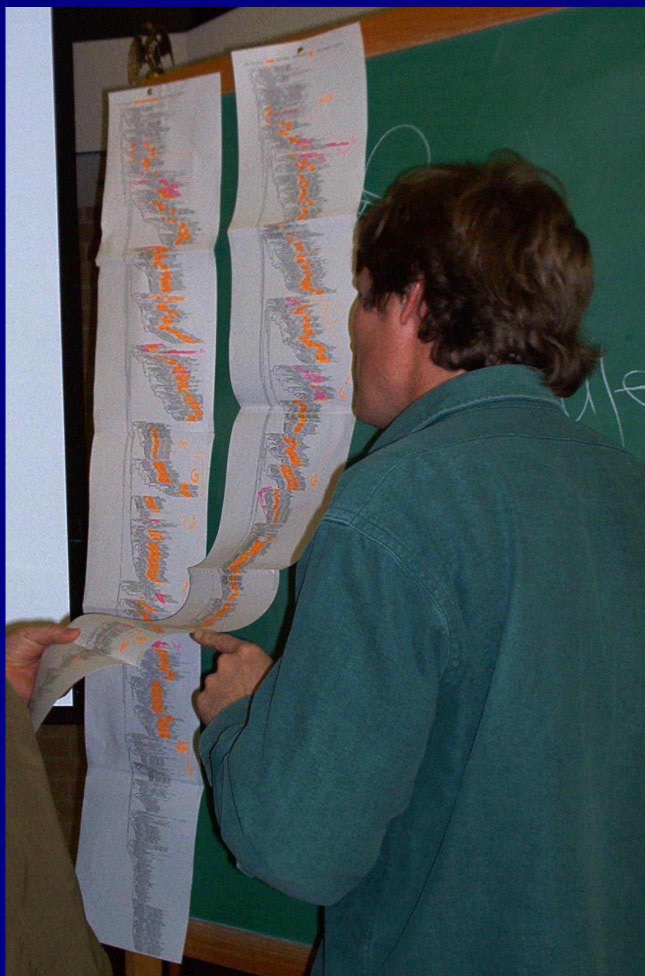
M Meegaskumbura et al., Science 298:379 (2002)

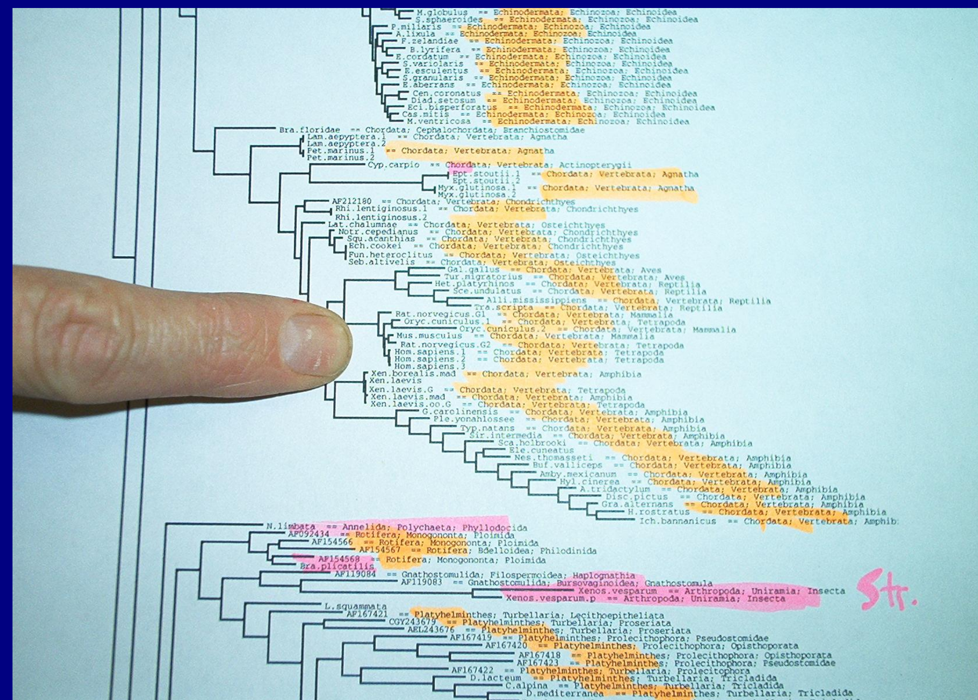
Tree of Life: 10M species



David Hillis, Science 300:1687 (2003)

Comparing trees: current practice





Will Fischer, postdoc with David Hillis at UT-Austin

Biologists' requirements

- Reliable detection of structural differences
  - rapid identification of interesting spots
- Analysis of differences in context
  - mostly side by side comparison
- Manipulation of increasingly larger trees

- Support for multiple platforms

TreeJuxtaposer contributions

- Interactive tree comparison system
  - automatic detection of structural differences
    - sub-quadratic preprocessing
  - efficient Focus+Context navigation and layout
    - merge overview and detail in single view
  - guaranteed visibility under extreme distortion

- Scalable
  - dataset size: handles 280K – 500K nodes
  - display size: handles 3800x2400 display

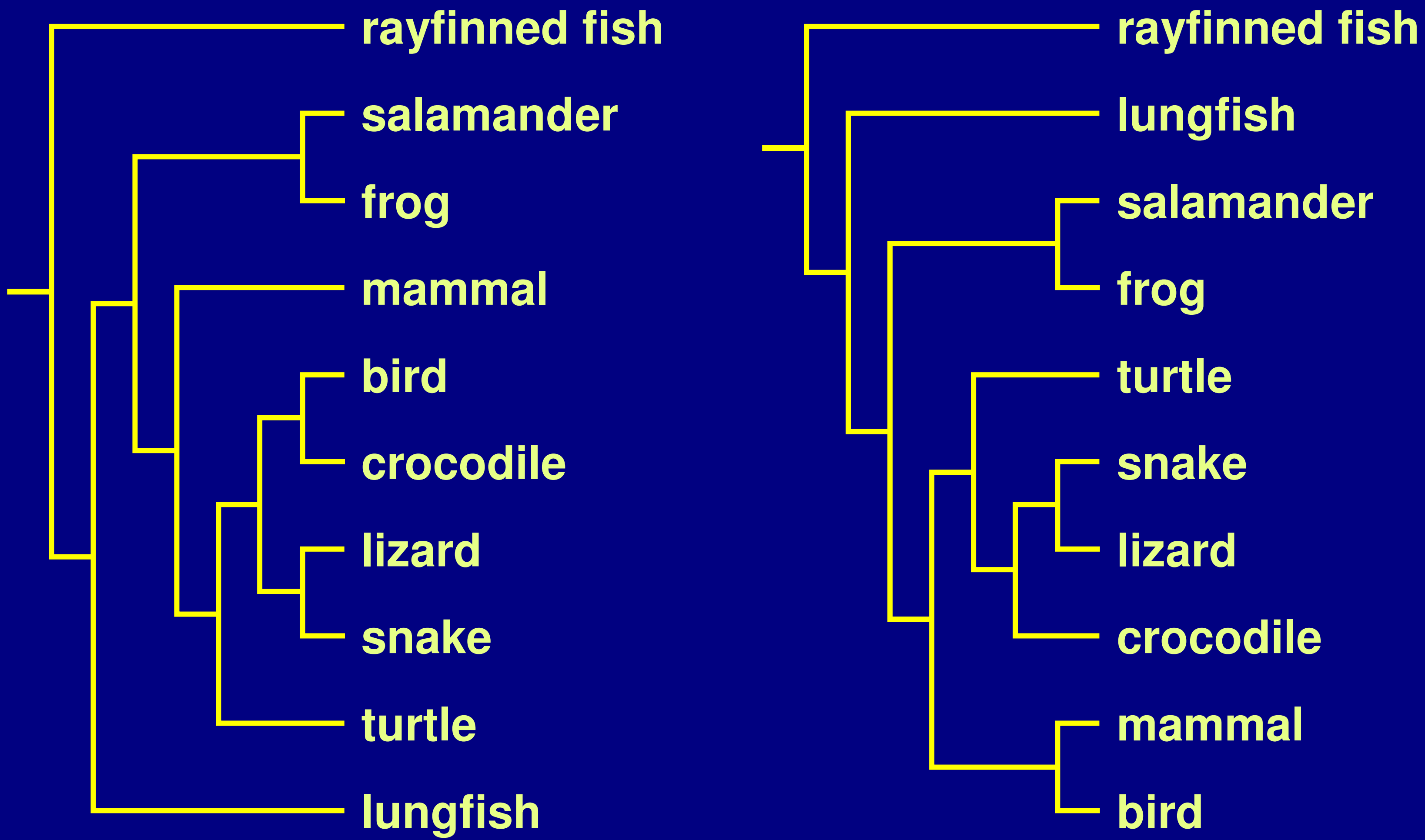
TreeJuxtaposer video

- Platforms shown
  - java 1.4, GL4Java 2.7 bindings for OpenGL
  - Windows
    - 2.4 GHz P3, nVidia Quadro4 700XGL
    - 1.1GB java heap
    - window sizes 1280x1024, 3800x2400
  - Linux
    - 3.1 GHz P4, nVidia GeForce FX 5800 Ultra
    - 1.7GB java heap
    - window size 800x600

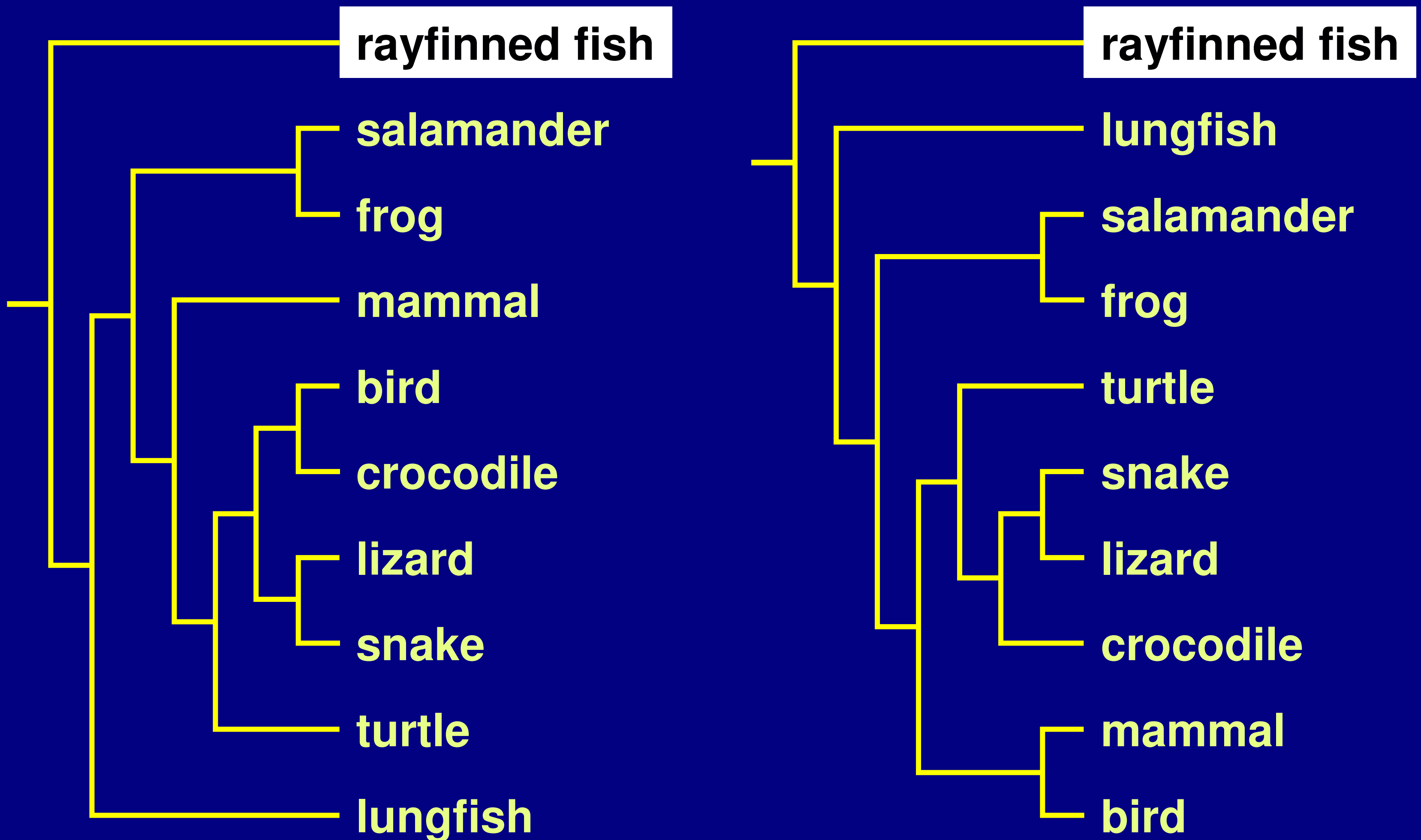
Outline

- Application domain: evolutionary trees
- Demonstration
- Computing structural differences
- Guaranteed visibility of marked areas
- Results and conclusions

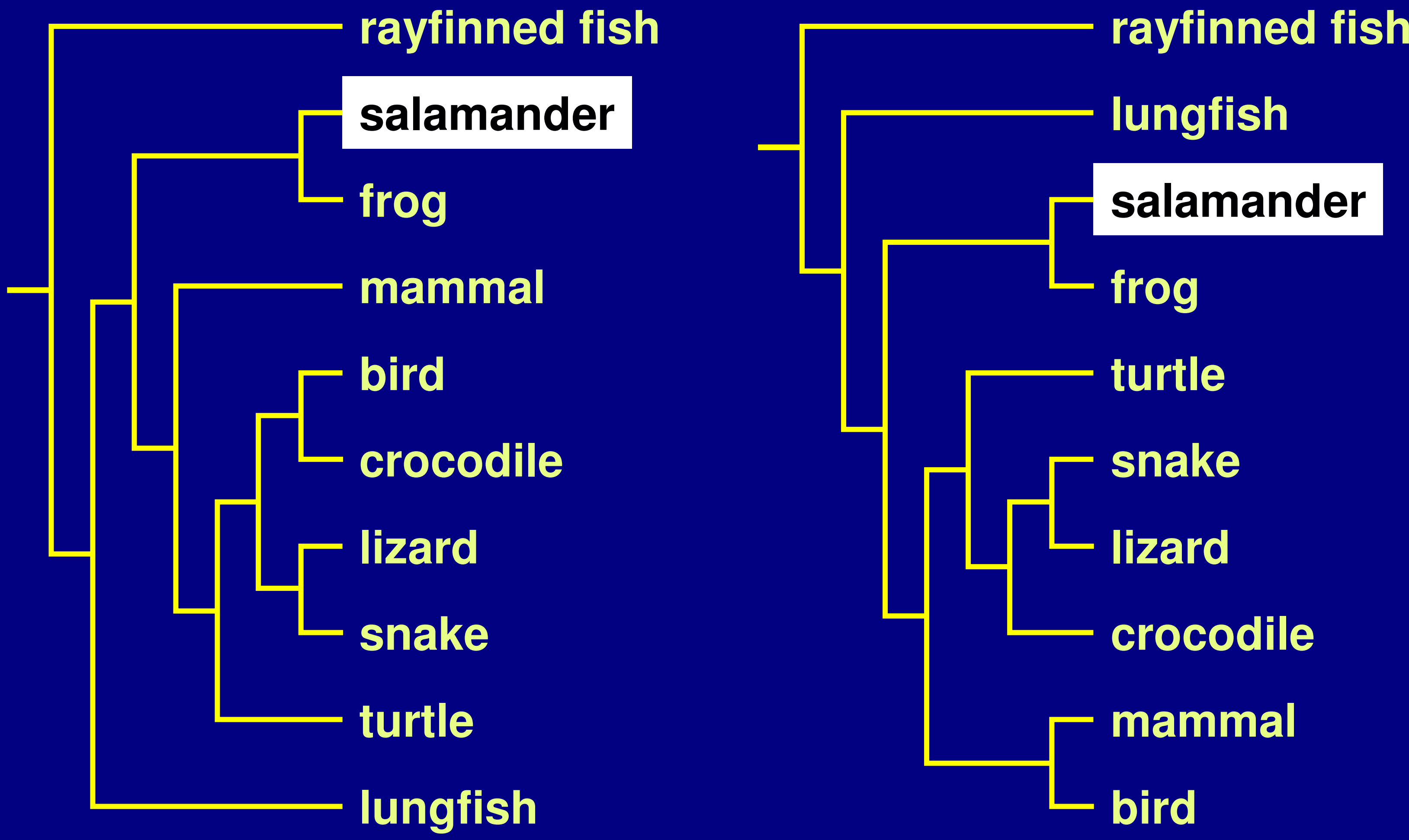
Comparing tree



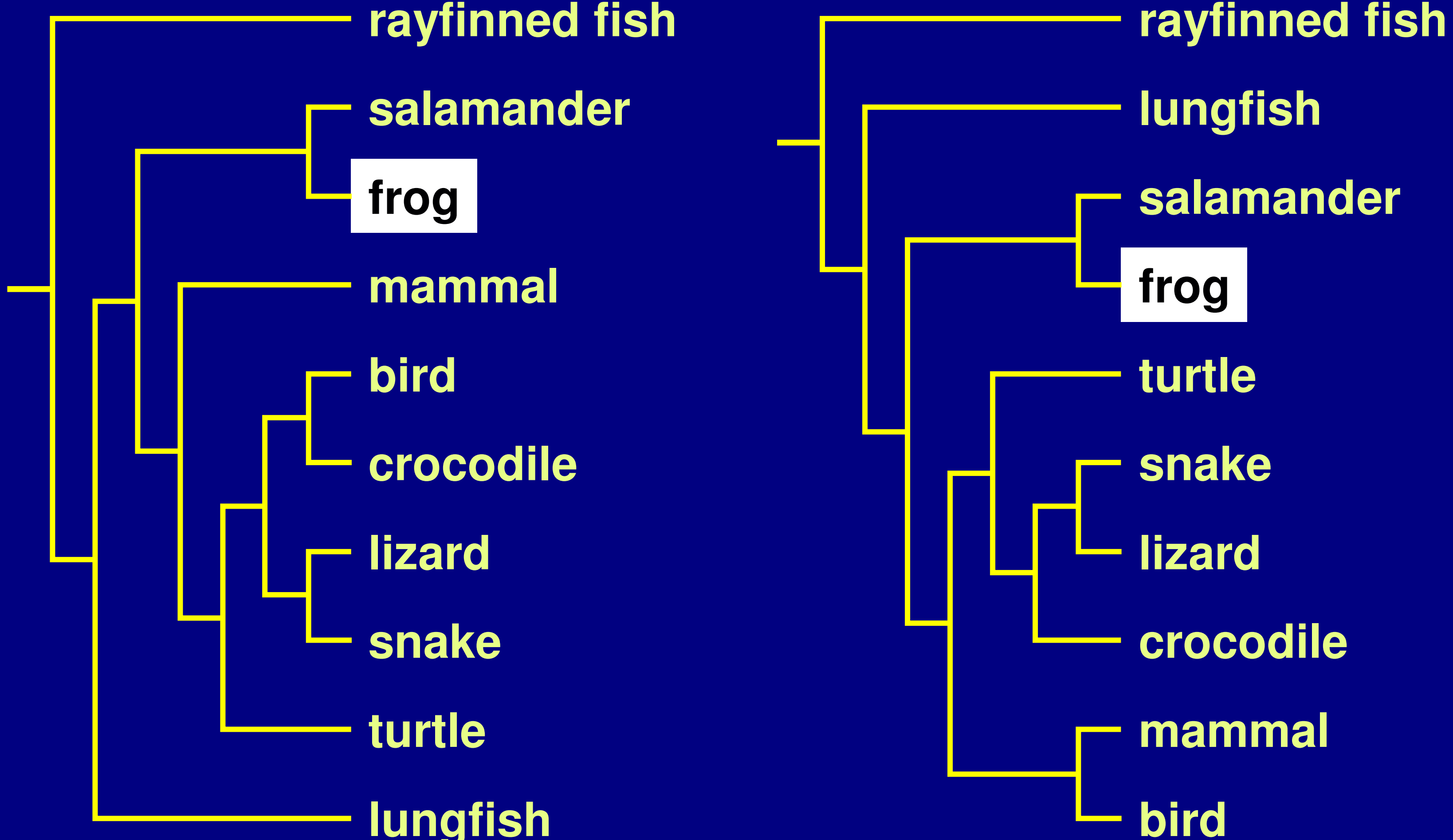
Matching leaf nodes



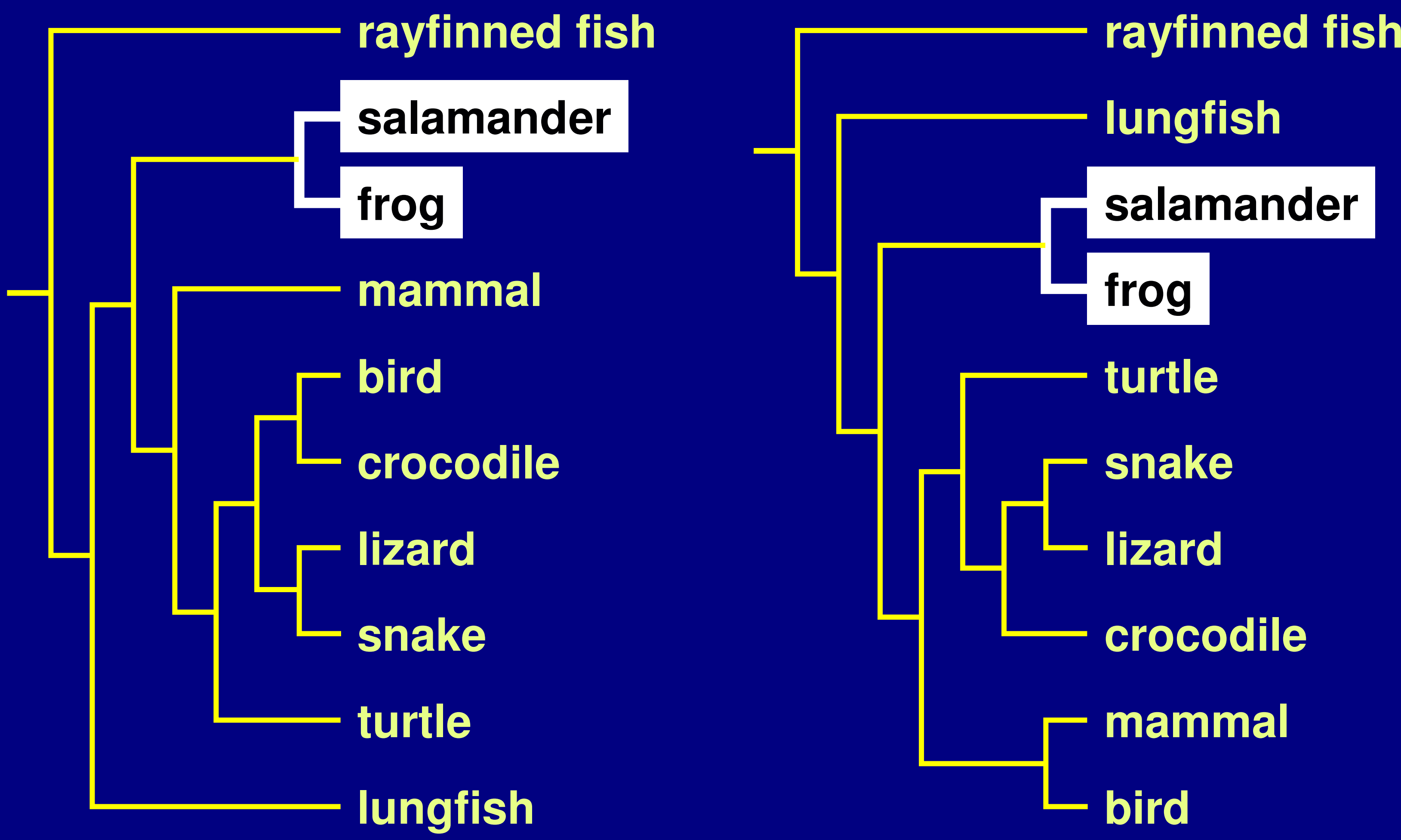
Matching leaf nodes



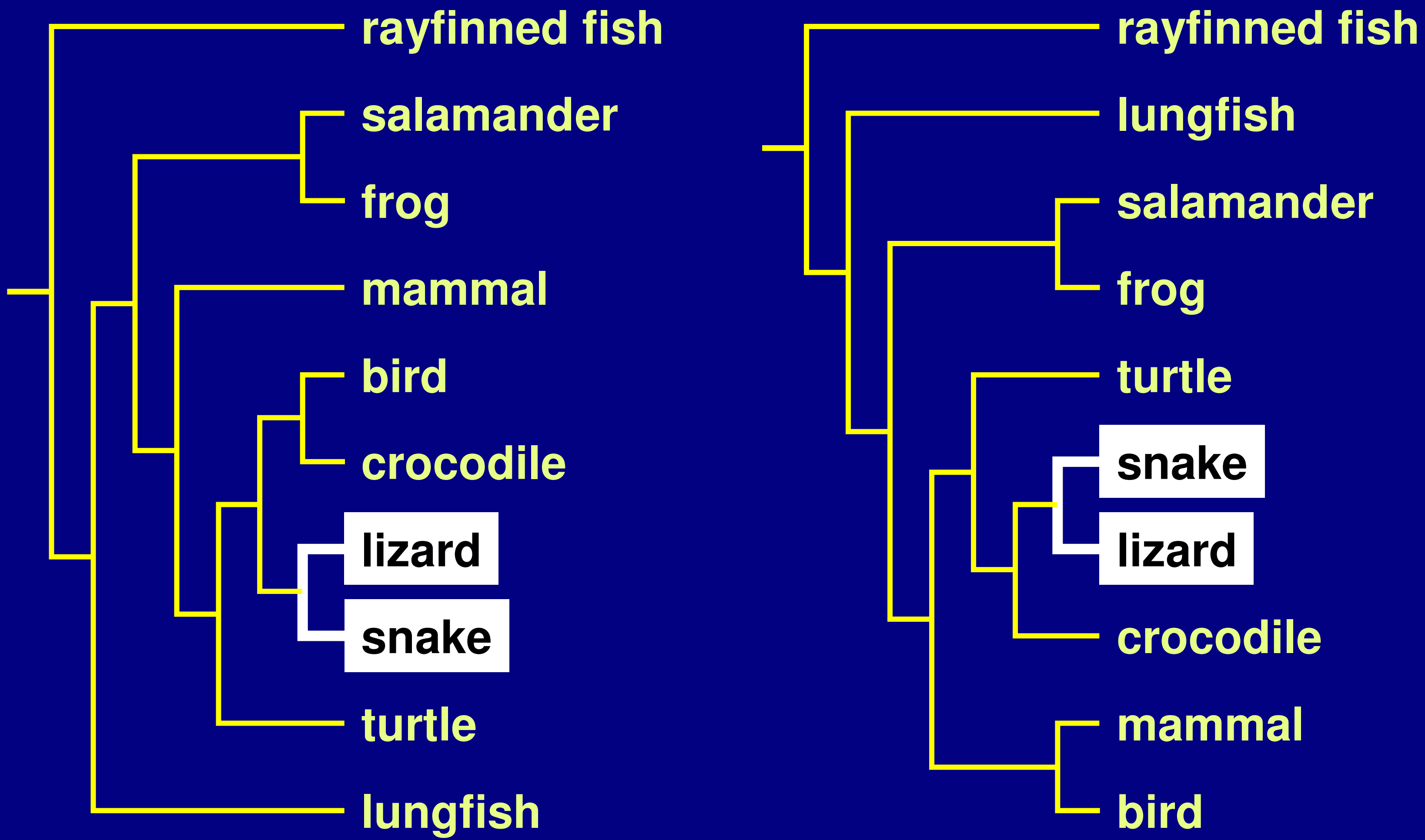
Matching leaf nodes



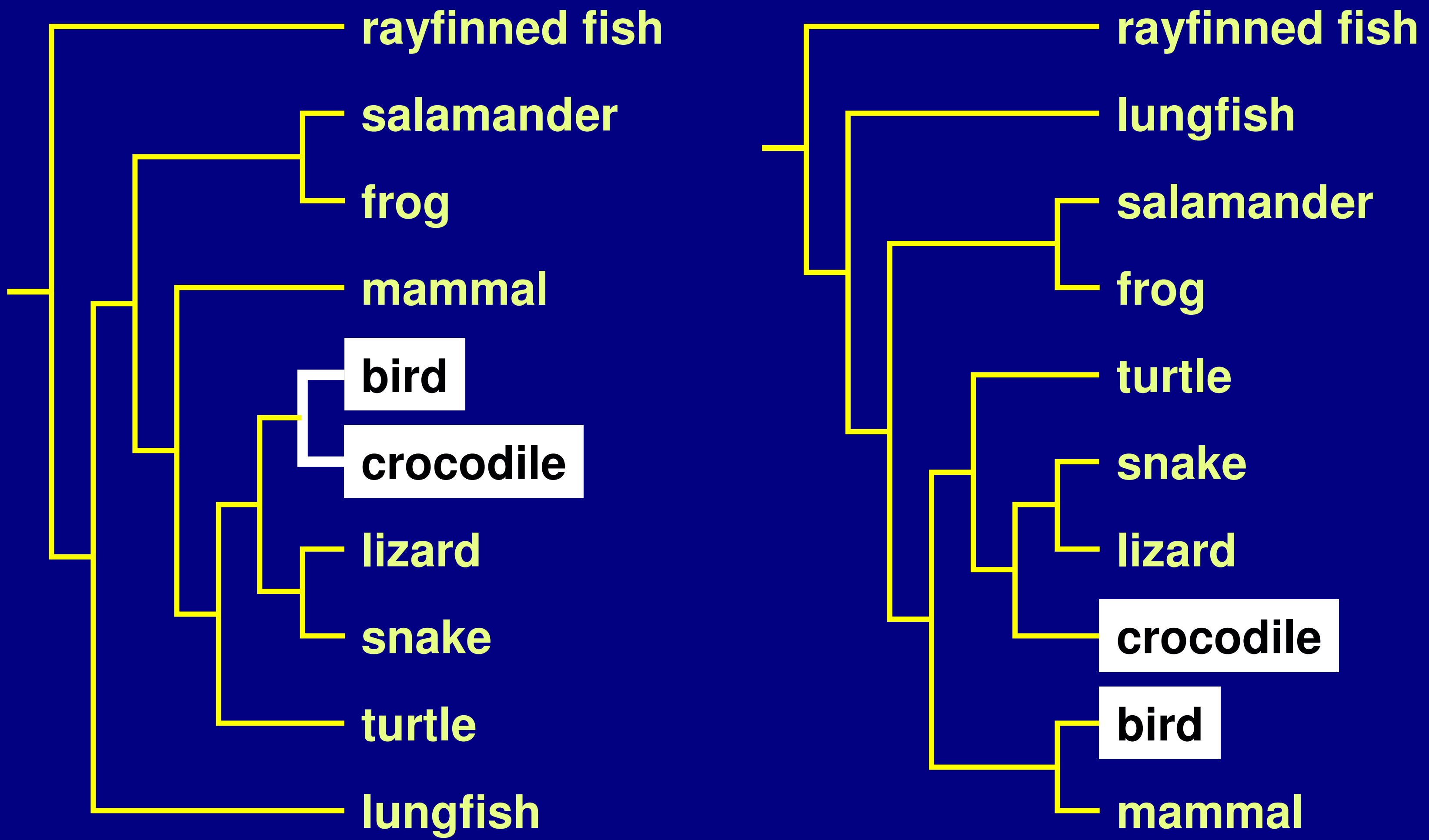
Matching interior nodes



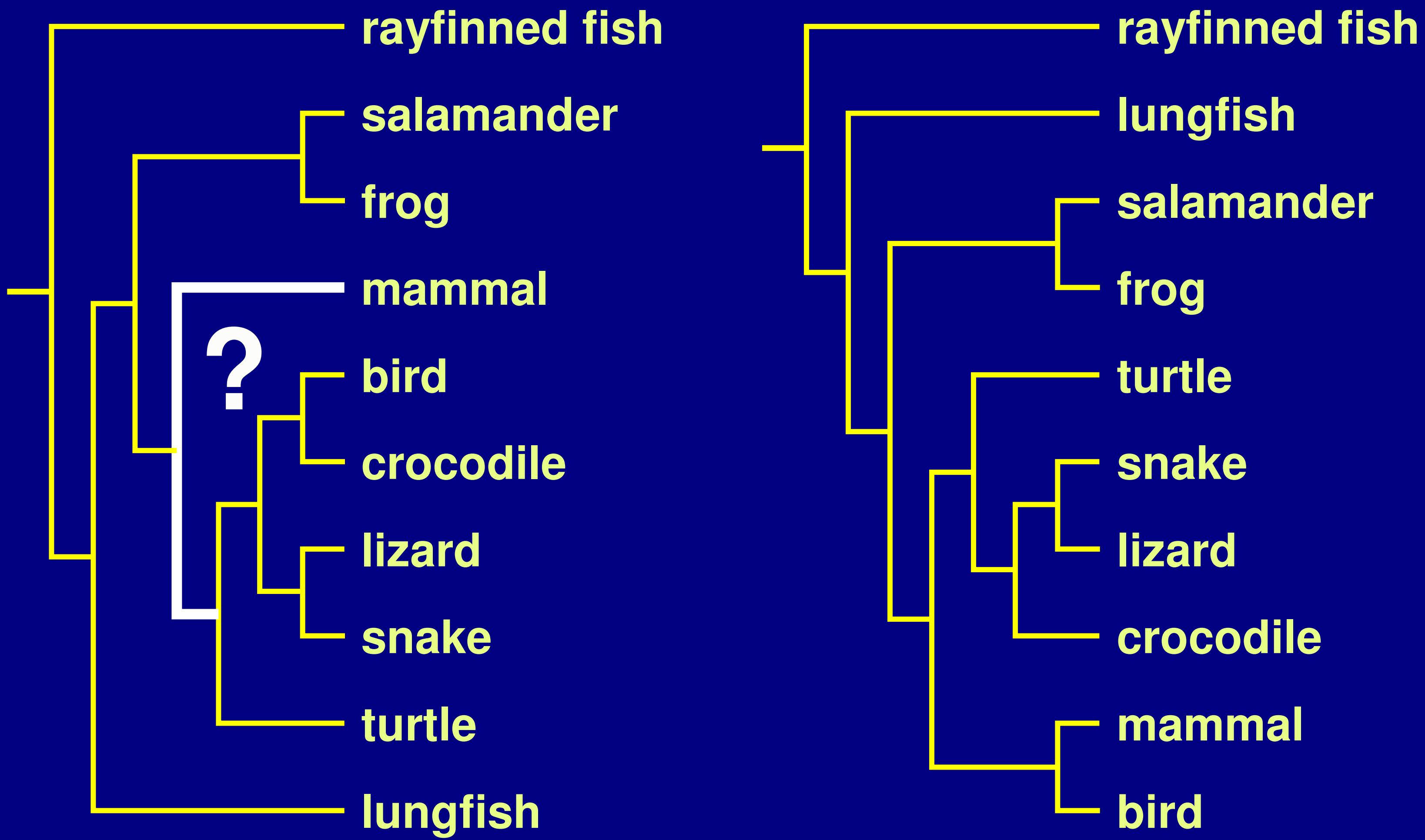
Matching interior nodes



Matching interior nodes



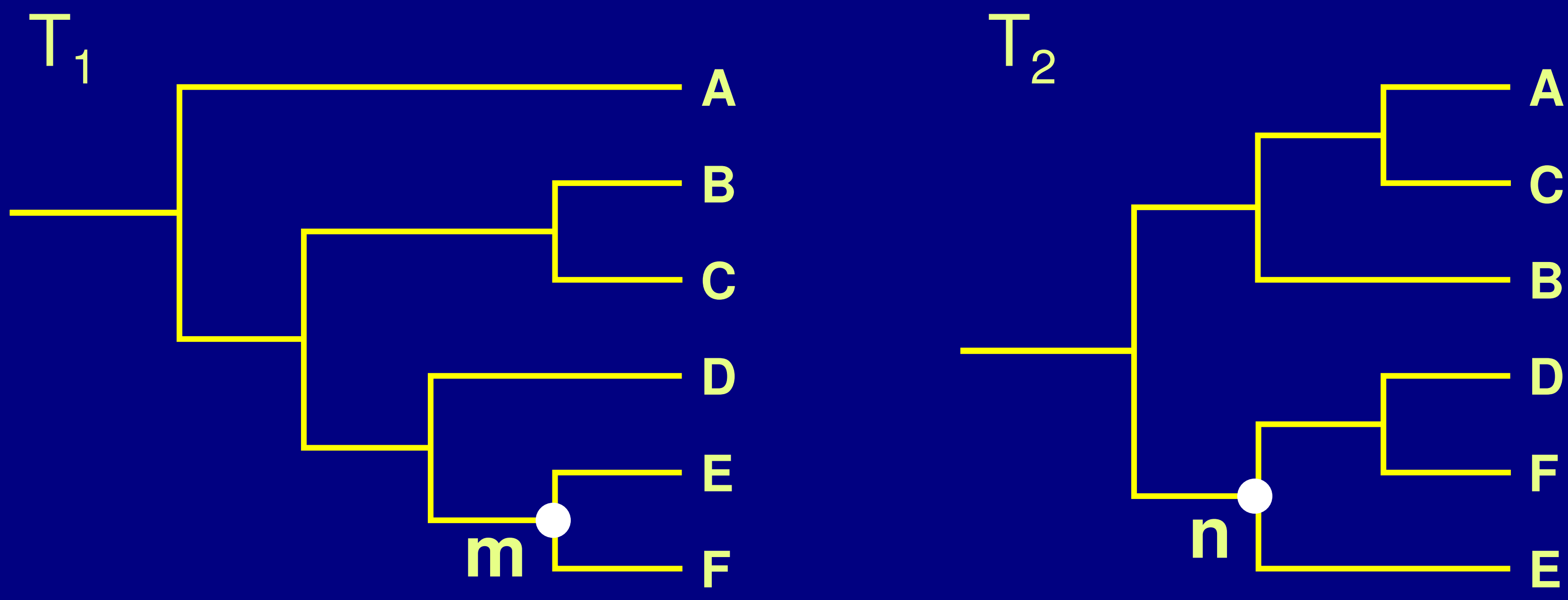
Matching interior nodes



Previous work

- Tree comparison
  - RF distance [Robinson and Foulds 81]
  - perfect node matching [Day 85]
  - creation/deletion [Chi and Card 99]
  - leaves only [Graham and Kennedy 01]

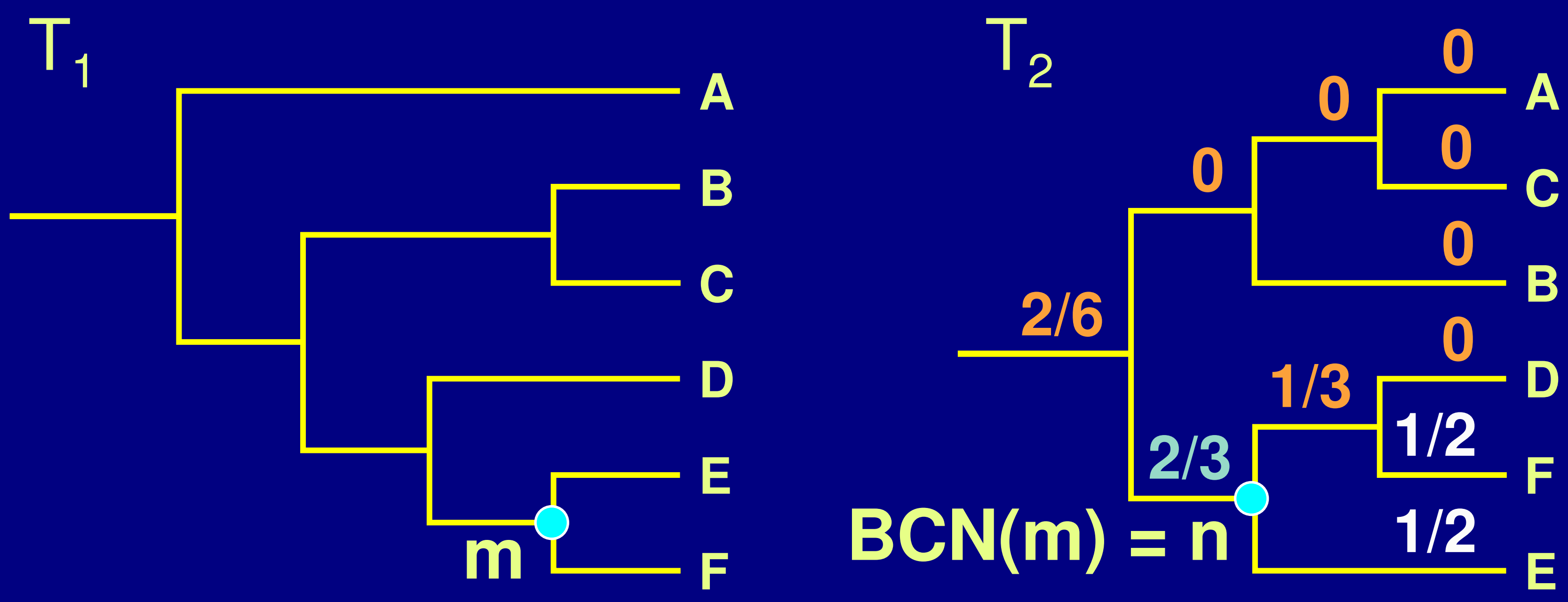
Similarity score: S(m,n)



$L(\mathrm{m}) = \{\mathrm{E,F}\}$ $\quad$ $L(\mathrm{n}) = \{\mathrm{D,E,F}\}$

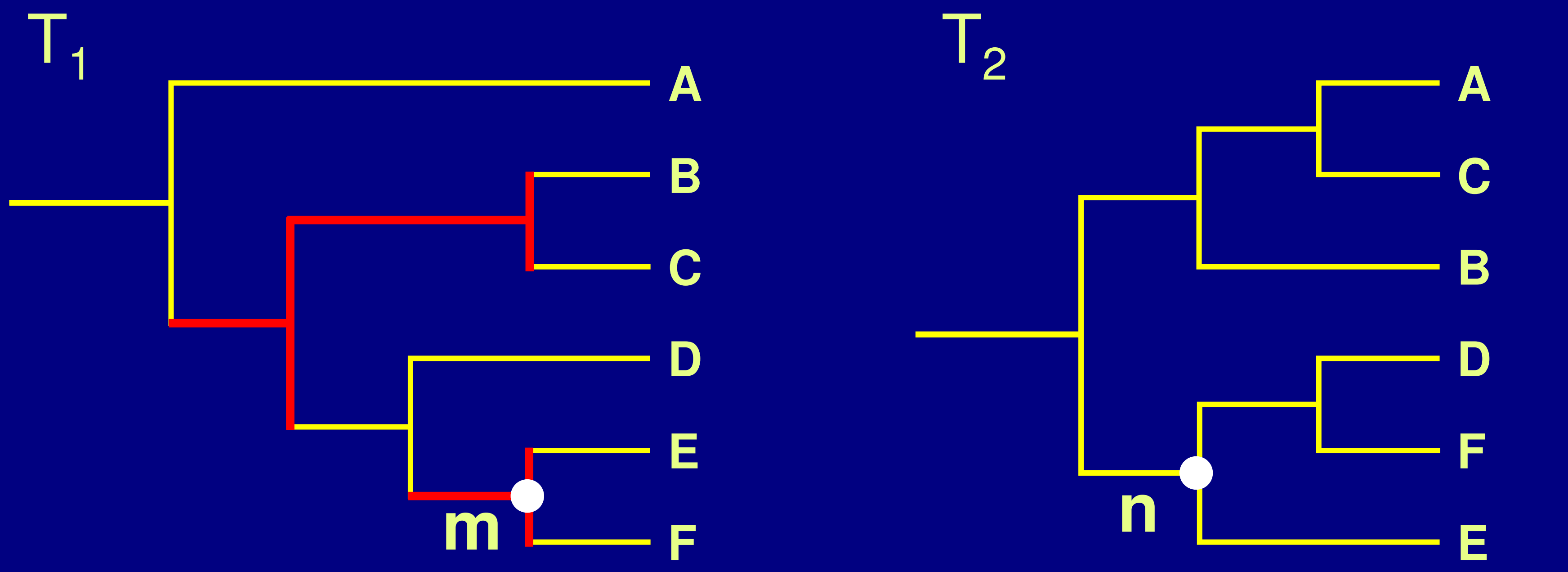
$$S(\mathrm{m,n}) = \frac{|L(\mathrm{m}) \cap L(\mathrm{n})|}{|L(\mathrm{m}) \cup L(\mathrm{n})|} = \frac{|\{\mathrm{E,F}\}|}{|\{\mathrm{D,E,F}\}|} = \frac{2}{3}$$

Best corresponding node



- $\text{BCN}(m) = \text{argmax}_{v \in T_2} (S(m, v))$
  - computable in $O(n \log^2 n)$
  - linked highlighting

Marking structural differences



- Nodes for which $S(v, \mathrm{BCN}(v)) \neq 1$
  - Matches intuition

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- Guaranteed visibility of marked areas
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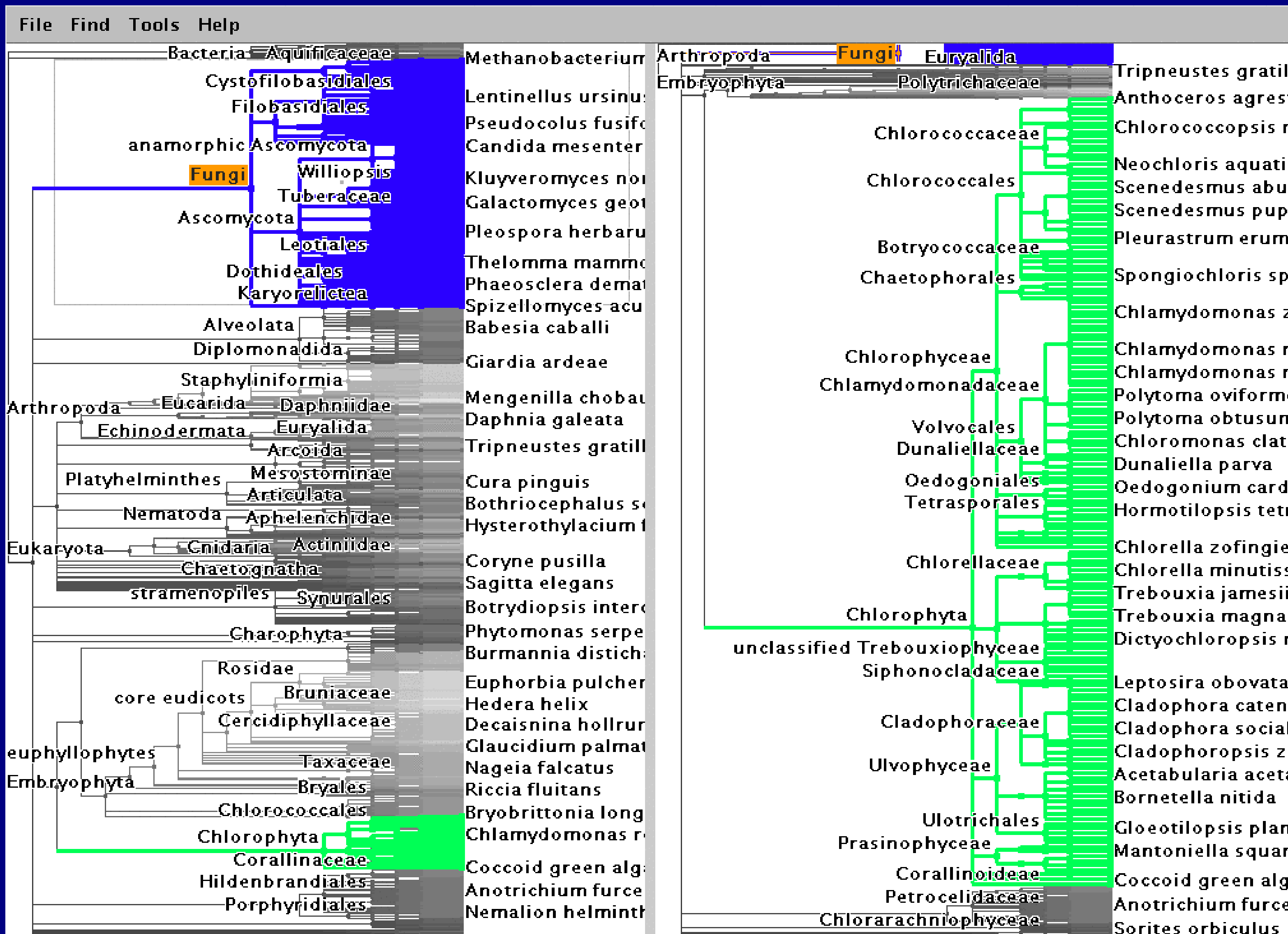
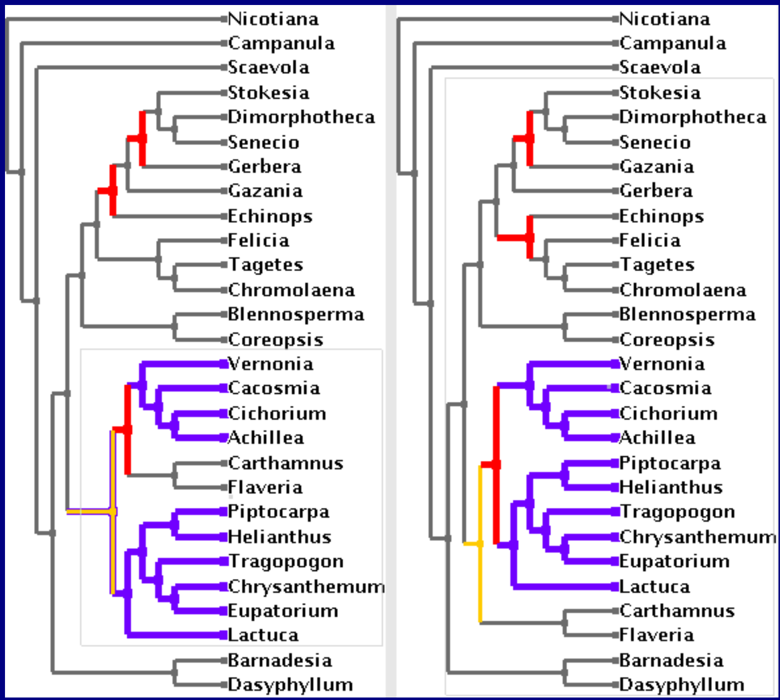
Guaranteed mark visibility



Marks

- Region of interest shown with color highlight
  - structural difference
  - search results
  - user-specified
- Purpose
  - guide navigation
  - provide landmarks
  - subtree contiguity check



Guaranteed visibility of marks

- How can a mark disappear?

Guaranteed visibility of marks

- How can a mark disappear?
  - moving outside the frustum

Guaranteed visibility of marks

- How can a mark disappear?
  - moving outside the frustum
- Solutions
  - choose global Focus+Context navigation
    - “tacked down” borders

Focus+Context previous work

- combine overview and detail into single view
- Focus+Context
  - large tree browsing
    - Cone Trees [Robertson et al 91]
    - Hyperbolic Trees [Lamping et al], H3 [Munzner 97]
    - SpaceTree [Plaisant et al 02]
    - DOI Trees [Card and Nation 02]
  - global
    - Document Lens [Robertson and Mackinlay 93]
    - Rubber Sheets [Sarkar et al 93]
- our contribution
  - scalability, guaranteed visibility

Guaranteed visibility of marks

- How can a mark disappear?
  - moving outside the frustum

- Solutions
  - choose global Focus+Context navigation
    - “tacked down” borders

Guaranteed visibility of marks

- How can a mark disappear?
  - moving outside the frustum
  - occlusion
- Solutions
  - choose global Focus+Context navigation
    - “tacked down” borders

Guaranteed visibility of marks

- How can a mark disappear?
  - moving outside the frustum
  - occlusion
- Solutions
  - choose global Focus+Context navigation
    - “tacked down” borders
  - choose 2D layout

Guaranteed visibility of marks

- How can a mark disappear?
  - moving outside the frustum
  - occlusion
  - culling at subpixel sizes
- Solutions
  - choose global Focus+Context navigation
    - “tacked down” borders
  - choose 2D layout

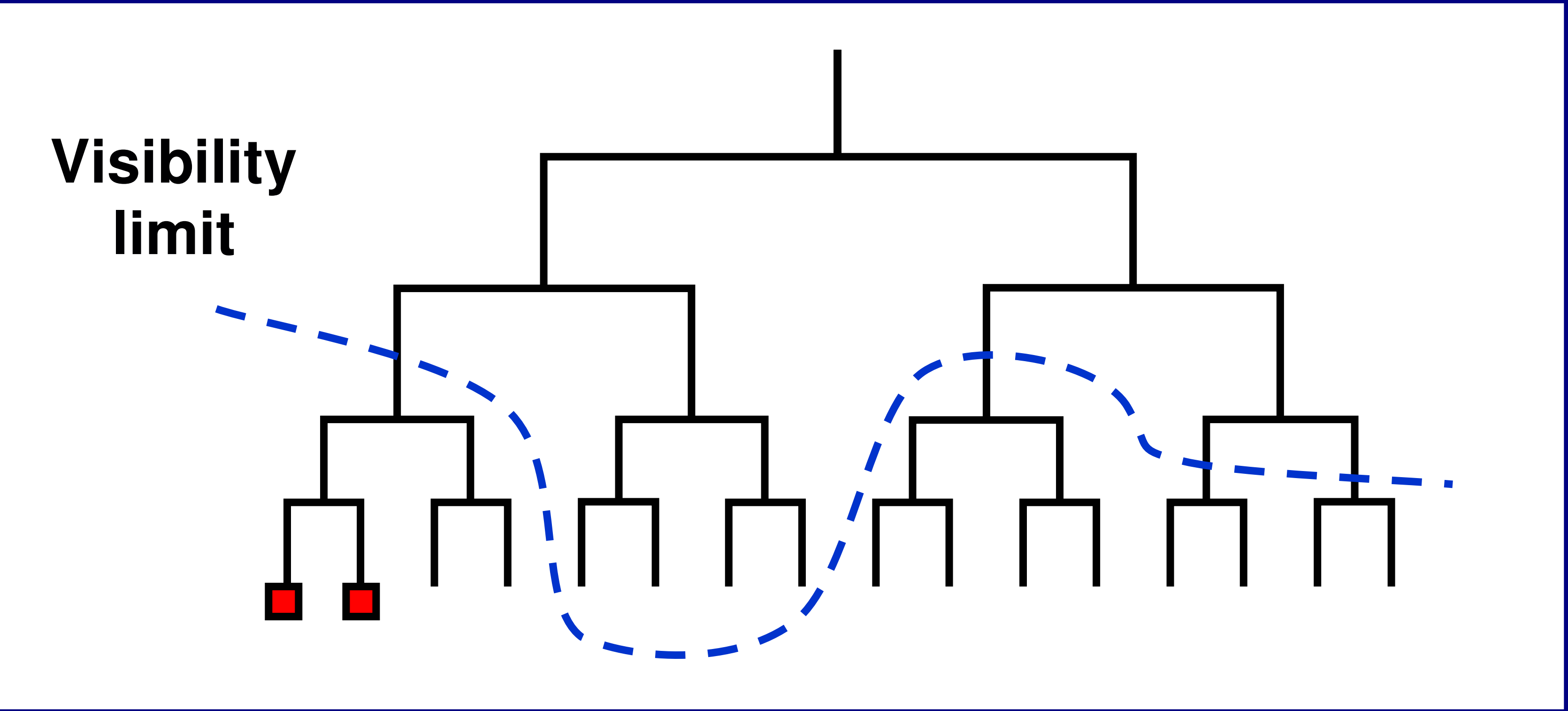
Guaranteed visibility of marks

- How can a mark disappear?
  – moving outside the frustum
  – occlusion
  – culling at subpixel sizes

- Solutions
  – choose global Focus+Context navigation
    - “tacked down” borders
  – choose 2D layout
  – develop efficient check for marks when culling

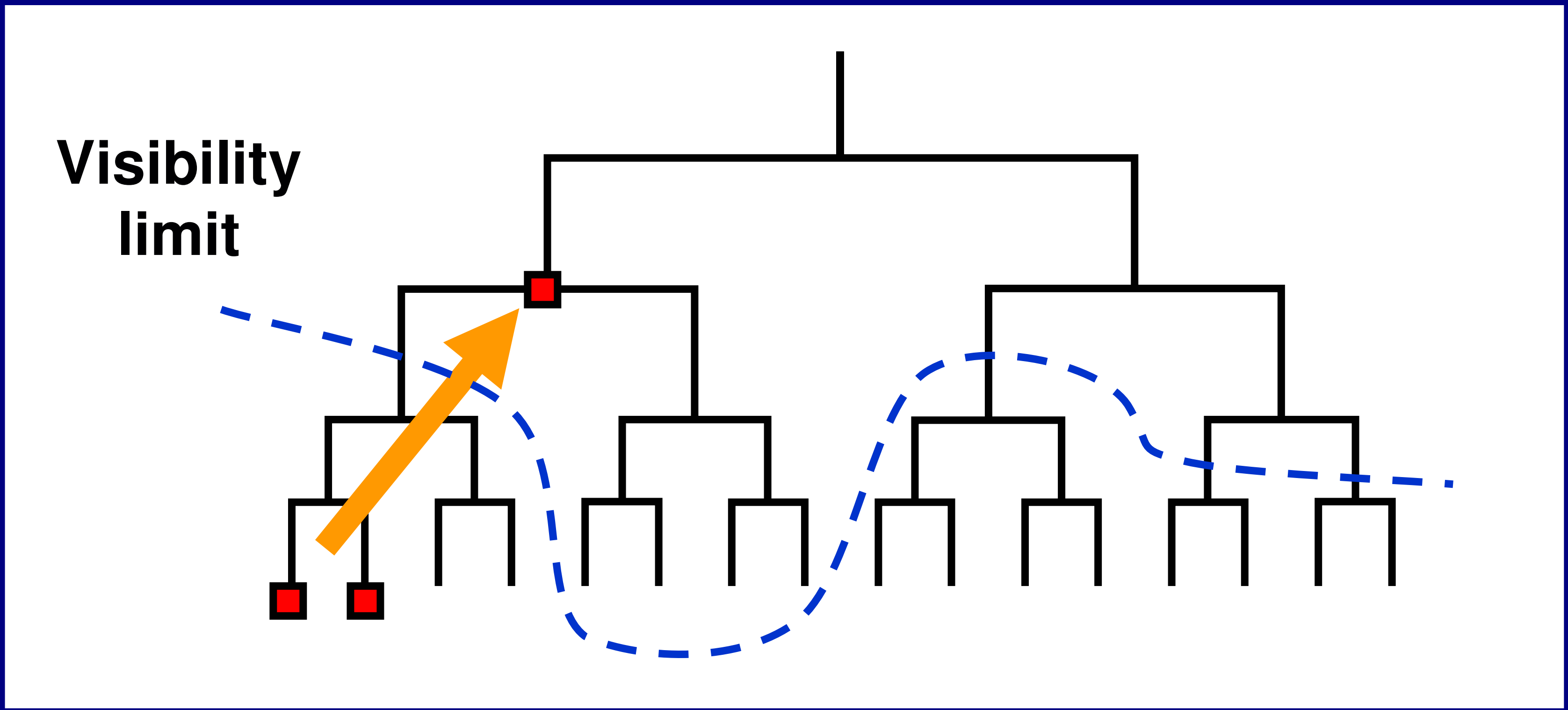
Preserving marks while culling

- Show mark at unculled node



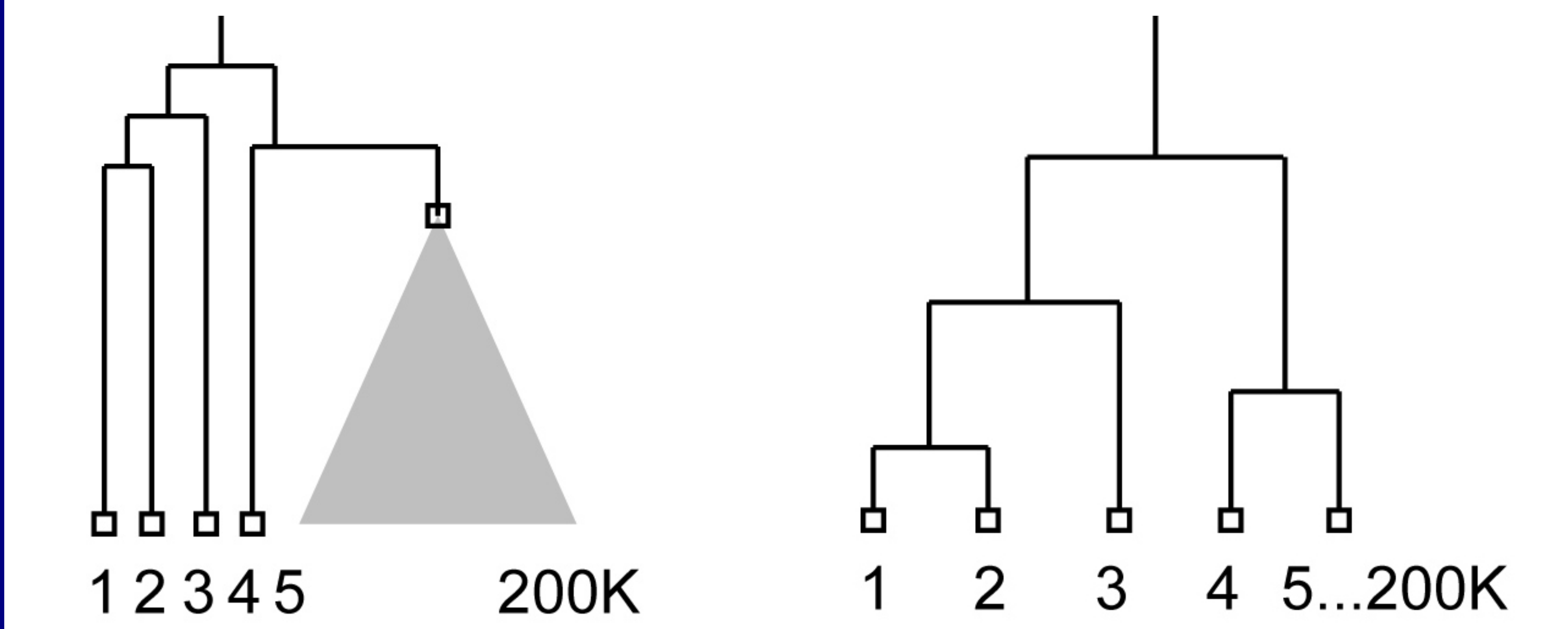
Preserving marks while culling

- Show mark at unculled node



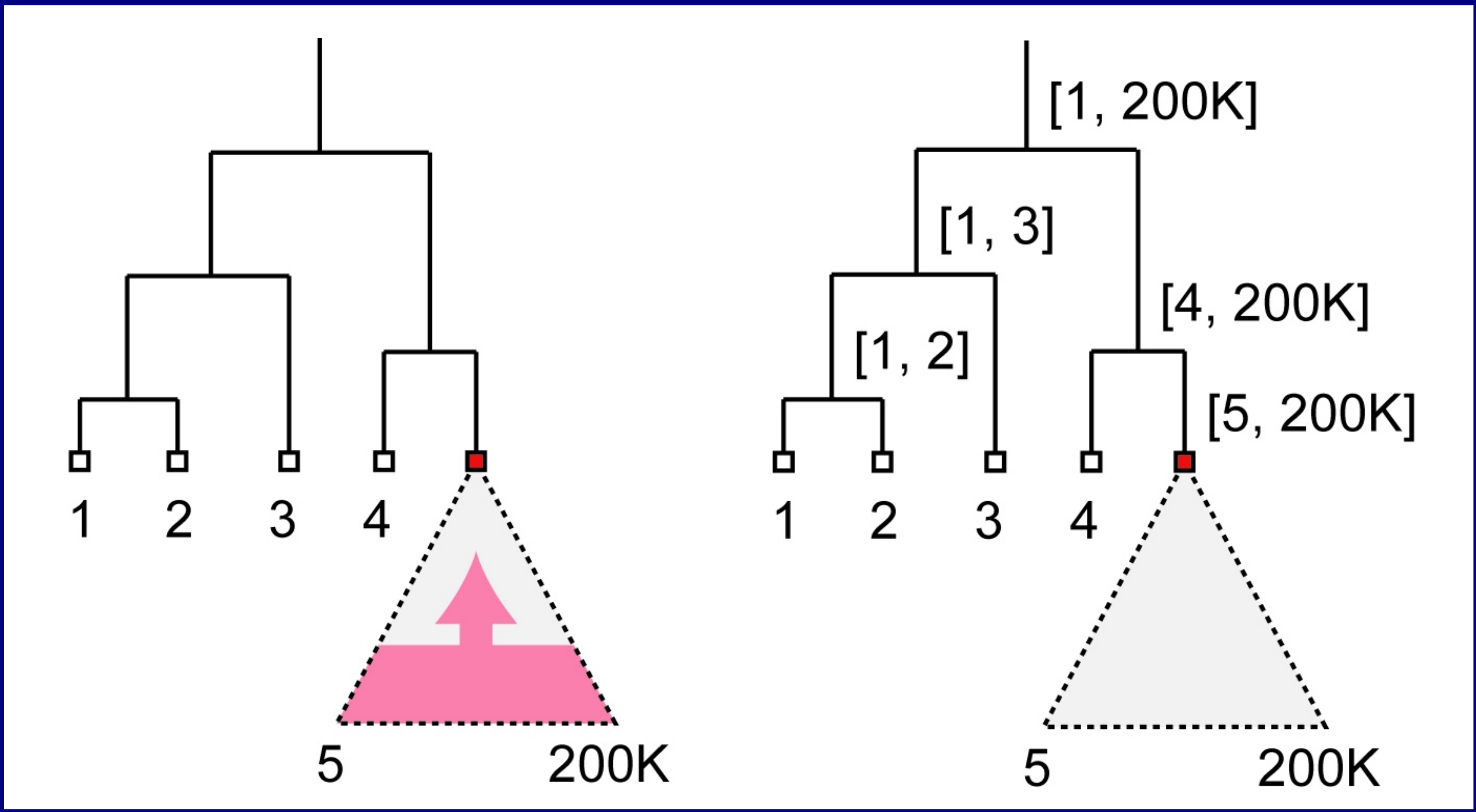
Mark preservation strategies

- Compress large subtree to small spatial area



User selects nodes [135,199995]

- Propagation : cost depends on total nodes
- Precomputation: cost depends visible nodes

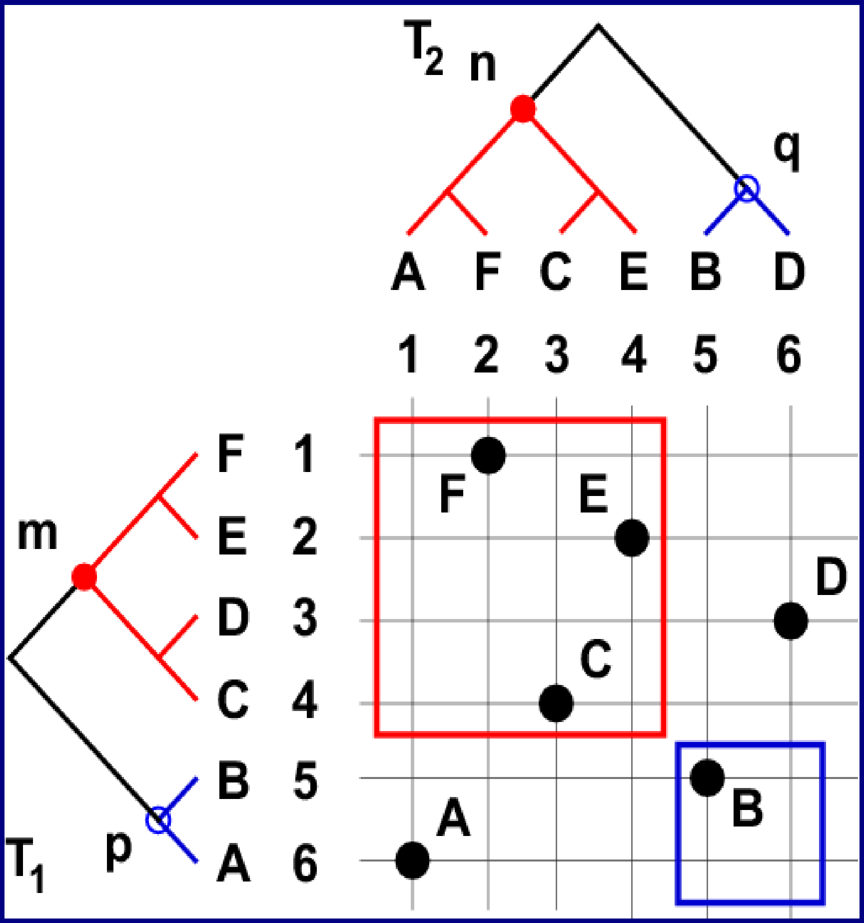


Marks and linked highlighting

- Also check for linked marks from other tree
  - check if best match for node is marked
    - up to O(n) to look up each node in range
  - intersect node ranges between trees
    - reduces to point in polygon test, $O(\log^2 n)$

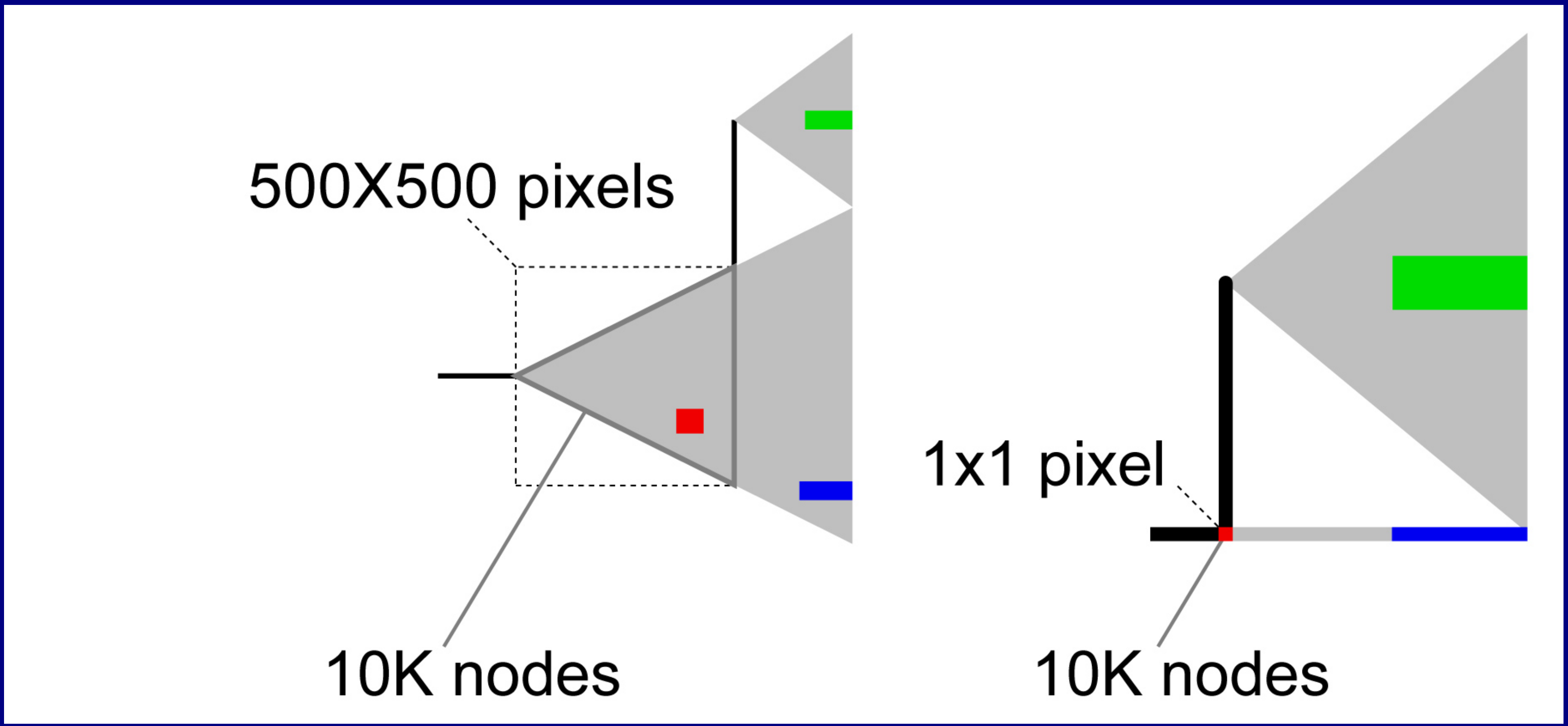
Efficient marking detection

- Intersecting ranges between trees
  - Query in $O(\log^2 n)$



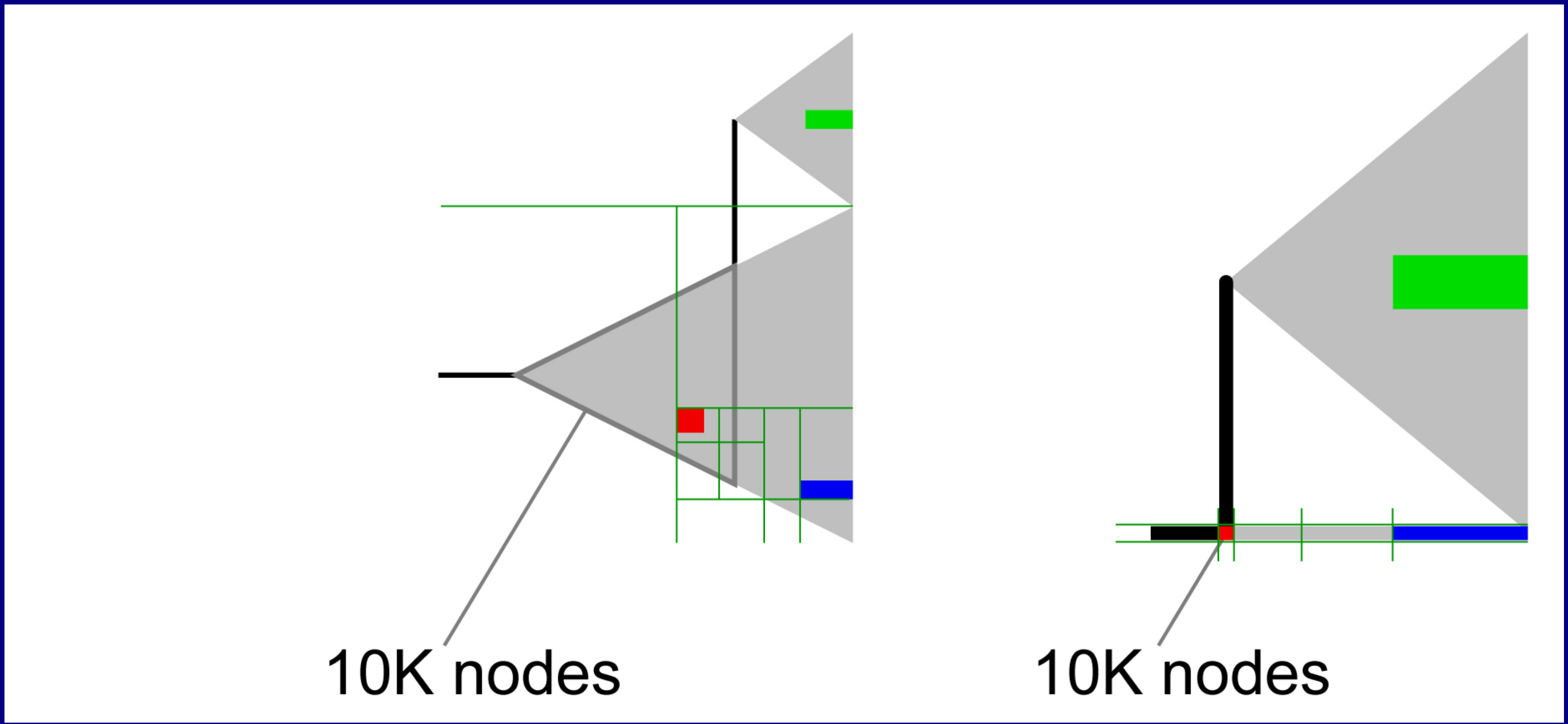
Storing topological ranges

- At each node, store range of subtree beneath
  - range stored doesn't match spatial range needed



Storing spatial ranges

- At each box, store range of objects inside



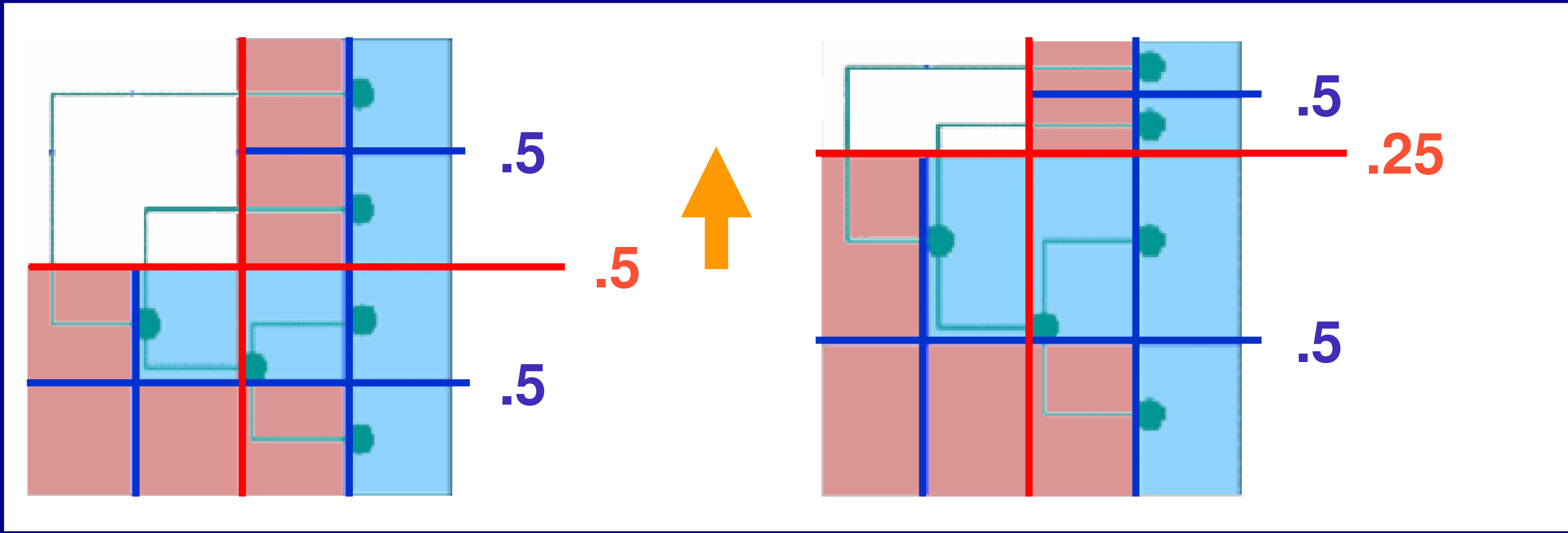
Spatial range solution

- Recursive spatial subdivision
  - quadtree
  - store range of objects enclosed for each cell
  - quick check: spatial range vs. selection range

- Extending quadtrees to Focus+Context
  - quadtree cells also “painted on rubber sheet”
  - efficient O(log n) update when stretch/shrink
    - details in paper

Rendering infrastructure

- Focus+Context QuadTree
  - Fixed mapping between nodes and quad cell
    - Sparse cell instantiation
  - Split boundary relative to the node parent
    - Hierarchical propagation of deformation



Guaranteed visibility previous work

- Visibility of abstract information
  - Effective view navigation [Furnas 97]
  - Critical zones [Jul and Furnas 98]

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Difference computation

- Powerful and totally automatic
  - leads users to important locations
  - efficient algorithms: 7s for 2x140K nodes
  - matches intuition
    - UT-Austin Biology Lab, several others
- Challenges
  - memory footprint
  - handling weighted edges

Guaranteed visibility

- Relief from exhaustive exploration
  - missed marks lead to false conclusions
  - hard to determine completion
  - tedious, error-prone
- Compelling reason for Focus+Context
  - controversy: does distortion help or hurt?
  - strong rationale for comparison

Guaranteed visibility challenges

- Integration with progressive rendering
  - might lose context during motion
  - need several seeds for rendering queue
    - focus point
    - marked items
  - up to empirical cutoff, no guarantees
- Constraint to fit everything in frustum
  - instead could show indirectly

Future Work

- Adoption
  - open-source release
  - tighter integration with biology tools
  - broad range of application domains
- Detectability vs. visibility
  - display resolution, surrounding colors
- Extend difference computation
  - weighted trees
  - graphs

Conclusion

- First interactive tree comparison system
  - automatic structural difference computation
  - guaranteed visibility of marked areas
- Scalable to large datasets
  - 250,000 to 500,000 total nodes
  - all preprocessing subquadratic
  - all realtime rendering sublinear
- Techniques broadly applicable
  - not limited to biological trees

Acknowledgments

- Biologists
  - David Hillis, Bob Jensen, Will Fischer, Derrick Zwickl
- Computer scientists
  - Nina Amenta, Katherine St. John
- Partial funding
  - NSF/DEB-0121682
- Talk preparation
  - Mary Czerwinski, Pat Hanrahan, George Robertson, Chris Stolte, Diane Tang, Gina Venolia