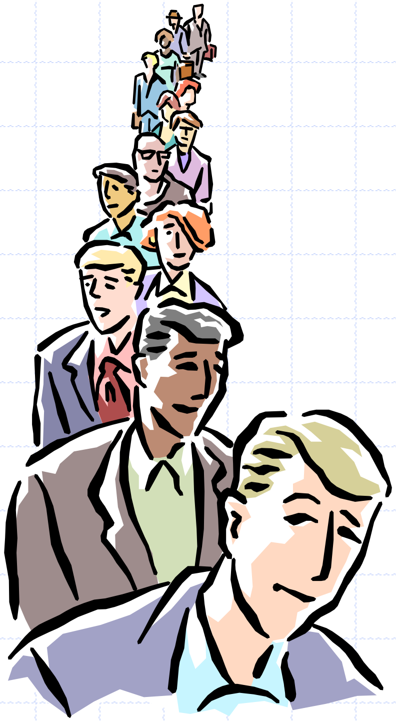
Iterators and Sequences

Sections 6.2.5 – 6.4

with an introduction to trees



STL Containers

- The STL container classes are
  - vector
  - deque
  - list
  - stack
  - queue
  - priority queue
  - set (and multiset)
  - map (and multimap)

- Each container type C supports iterators:
  - C::iterator – read/write iterator type
  - C::const_iterator – read-only iterator type
  - C.begin(), C.end() – return start/end iterators

STL Iterators

- Operators defined for iterators:
  - *p: access current element
  - ++p, --p: advance to next/previous element
- Common STL vector operations using iterators:
  - assign(p, q): replace the vector's contents with contents referenced by the iterator range [p, q) (from p up to, but not including, q)
  - insert(p, e): insert e prior to position p
  - erase(p): remove element at position p
  - erase(p, q): remove elements in the iterator range [p, q)

Using STL Iterators

- A common use case of iterators is to iterate through all of the elements of a collection (for instance, a vector).

```
int vectorSum2(vector<int> V) {
    typedef vector<int>::iterator Iterator;
    int sum = 0;
    for (Iterator p = V.begin(); p != V.end(); ++p)
        sum += *p;
    return sum;
}
```

STL Container Algorithms

- STL provides algorithms that operate on general containers. To use them, you must

```
#include <algorithm>
```

- In the following, p and q are iterators over a base type, and e is an object of this base type.
  - sort(p, q)
  - random_shuffle(p, q)
  - reverse(p, q)
  - find(p, q, e)
  - min_element(p, q)
  - max_element(p, q)
  - for_each(p, q, f)

Sequence ADT

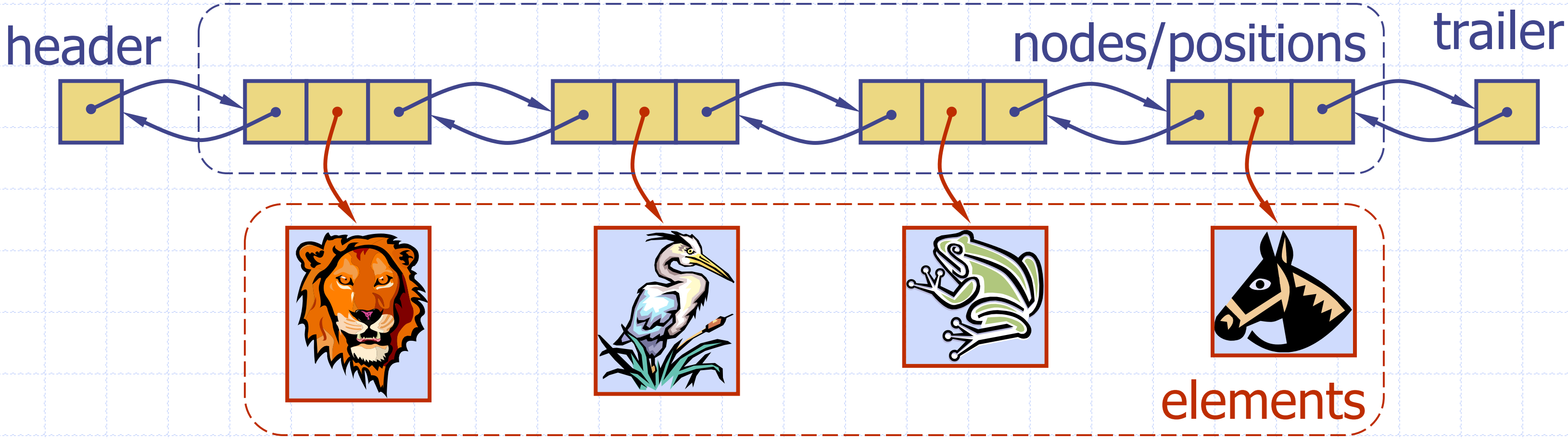
- The Sequence ADT is the union of the Vector and List ADTs
- Elements accessed by
  - Index, or
  - Position
- Generic methods:
  - size(), empty()
- Vector-based methods:
  - at(i), set(i, o), insert(i, o), erase(i)
- List-based methods:
  - begin(), end()
  - insertFront(o), insertBack(o)
  - eraseFront(), eraseBack()
  - insert (p, o), erase(p)
- Bridge methods:
  - atIndex(i), indexOf(p)

Applications of Sequences

- The Sequence ADT is a basic, general-purpose data structure for storing an ordered collection of elements
- Direct applications:
  - Generic replacement for stack, queue, vector, or list
  - small database (e.g., address book)
- Indirect applications:
  - Building block of more complex data structures

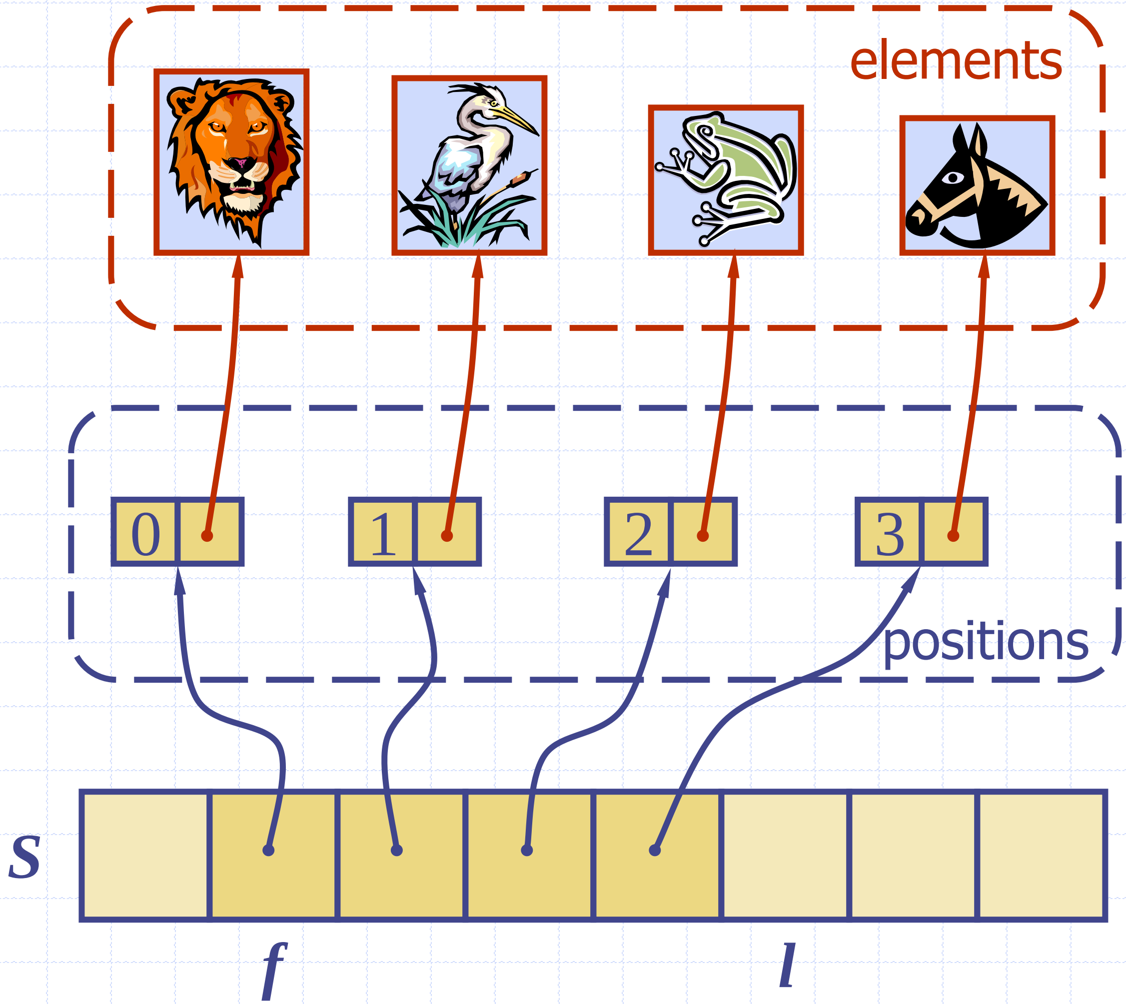
Linked List Implementation

- A doubly linked list provides a reasonable implementation of the Sequence ADT
- Nodes implement Position and store:
  - element
  - link to the previous node
  - link to the next node
- Special trailer and header nodes
- Position-based methods run in constant time
- Index-based methods require searching from header or trailer while keeping track of indices; hence, run in linear time



Array-based Implementation

- We use a circular array storing positions
- A position object stores:
  - Element
  - Index
- Indices *f* and *l* keep track of first and last positions



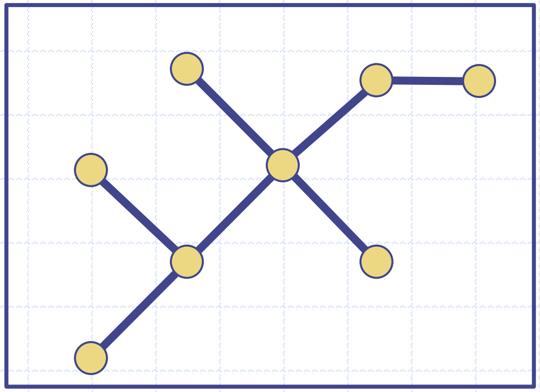
Comparing Sequence Implementations

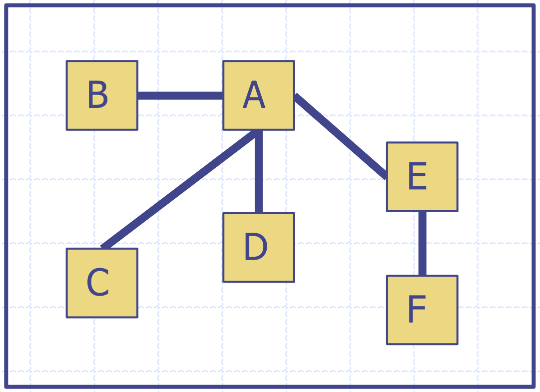
Operation	Array	List
size, empty	1	1
atIndex, indexOf, at	1	n
begin, end	1	1
set(p,e)	1	1
set(i,e)	1	n
insert(i,e), erase(i)	n	n
insertBack, eraseBack	1	1
insertFront, eraseFront	n	1
insert(p,e), erase(p)	n	1

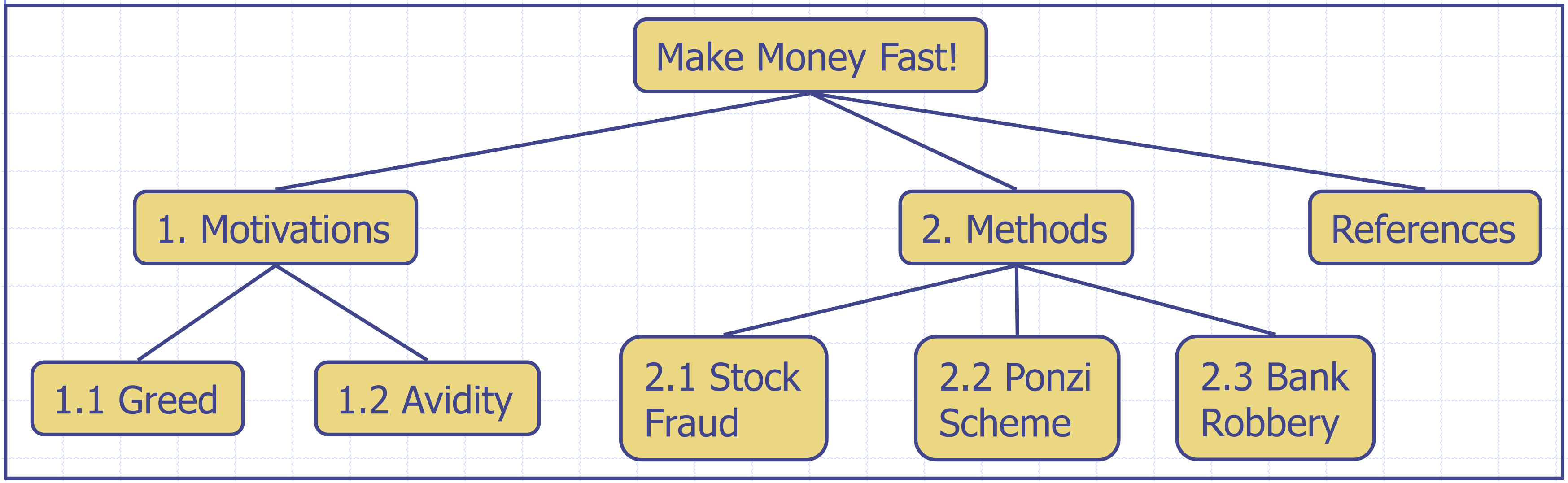
Trees

- A tree is a mathematical object that models hierarchical structures and acyclic relations.
- A tree consists of a set of vertices (a.k.a. nodes) and a set of edges (a.k.a. arcs).
- The vertices can be anything. We typically draw a vertex as a dot, a circle, or a box.
- The edges are equivalent to pairs of vertices. We typically draw an edge as a line segment between two vertices.
- The tree must be connected and have no cycles.

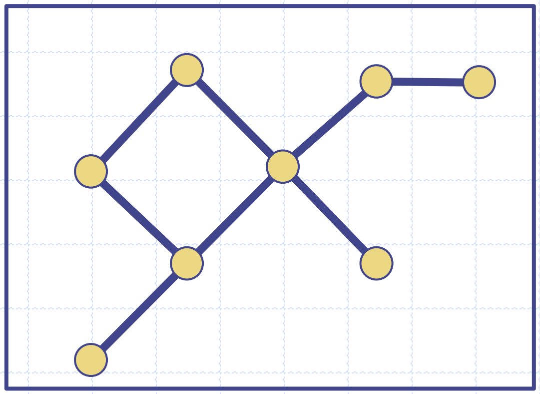
Some Drawings of Trees





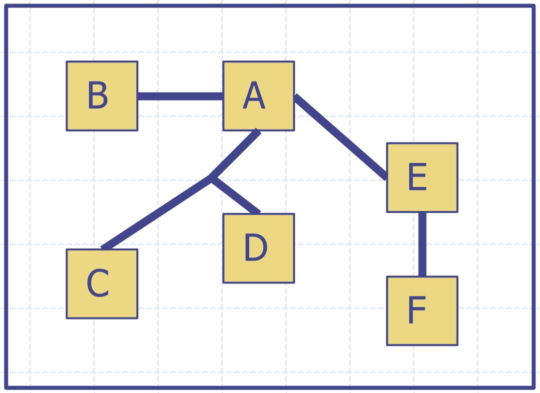


Some Not-Trees

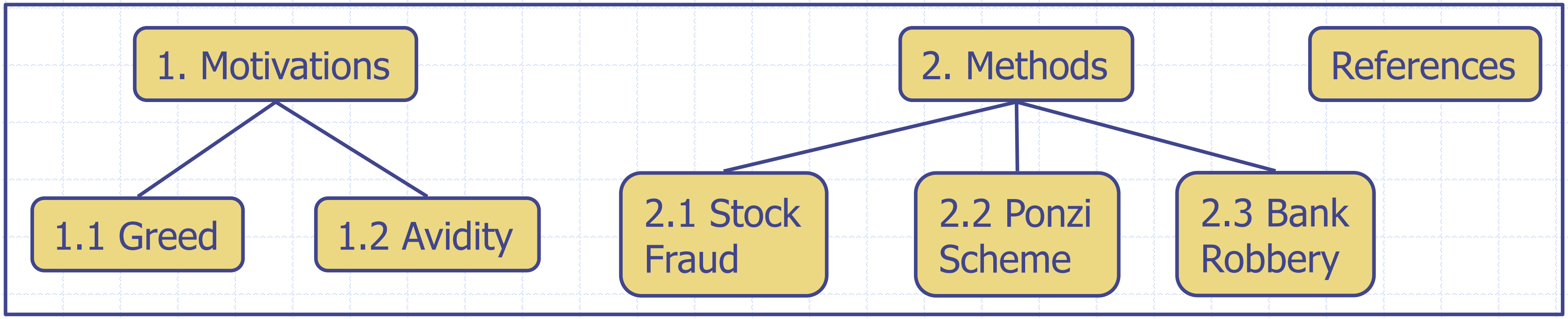


has a cycle

has a three-way edge

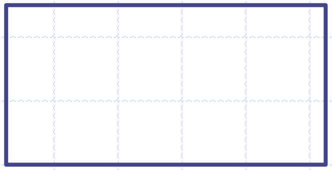


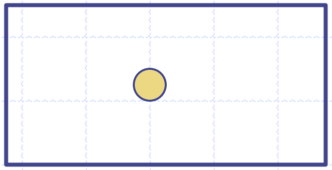
is not connected

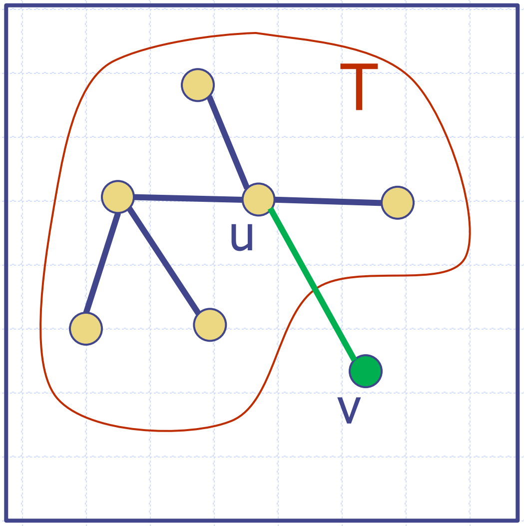


Recursive Definition of Trees

- An empty vertex set is a tree (the empty tree).
- A single vertex with no edges is a tree.
- Any object created by starting with a tree T, selecting one vertex u of T, and adding a new vertex v to T along with the edge uv is a tree.

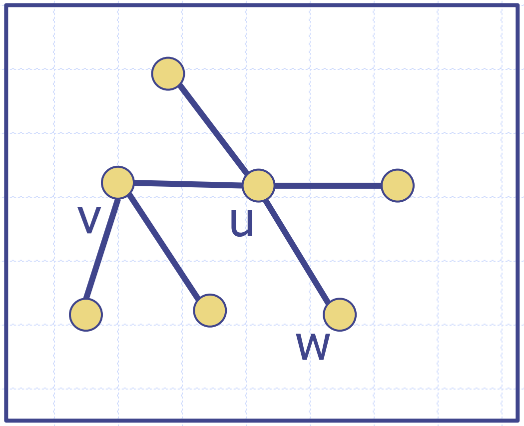






Tree Terminology

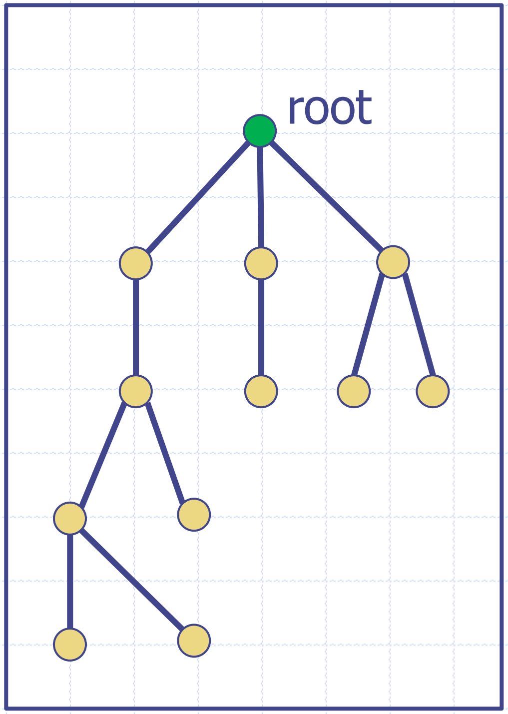
- Two vertices that share an edge are said to be adjacent (and are called neighbors). Here, u and v are neighbors.
- The degree of a vertex is the number of edges that include it. Here, u has degree 4 and w has degree 1.
- A vertex with degree 1 is called a leaf. Here, w is a leaf, and so are the four unlabeled vertices.



- The vertices with degree higher than 1 are called internal nodes. Here, u and v are internal.
- The distance between two nodes is the number of edges on the path in the tree between the nodes. Here, v and w have distance 2.

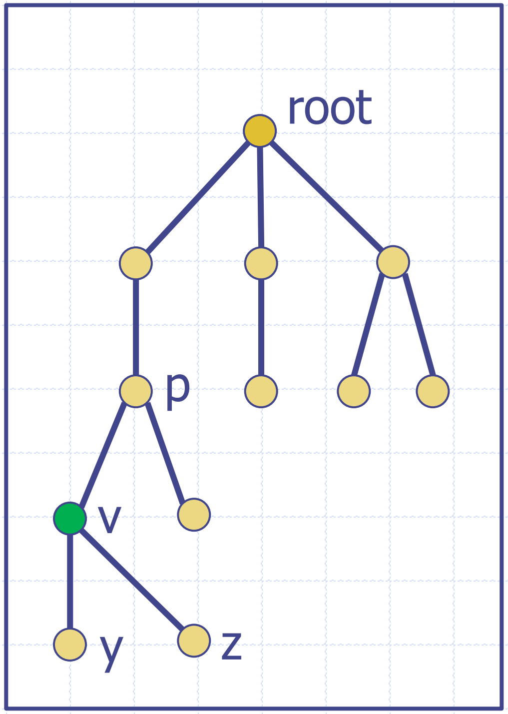
Rooted Trees

- In computing, when we say tree we often mean what mathematicians call a rooted tree.
- A rooted tree is a tree with a special vertex called the root.
- Typically we draw a rooted tree with the root at the top, and the other vertices at a height denoting their distance from the root.



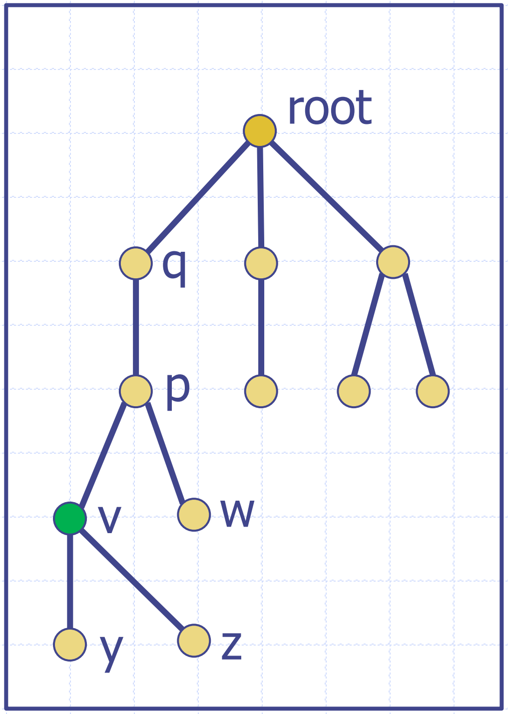
Rooted Tree Terminology

- We use family terms for the relations amongst nodes in a rooted tree.
- The parent of a node is the neighbor that is closer to the root (i.e. above). The root has no parent. Other nodes have one parent. Here the parent of v is p.
- A child of a node is any neighbor that is farther from the root (i.e. below). Here the children of v are y and z.



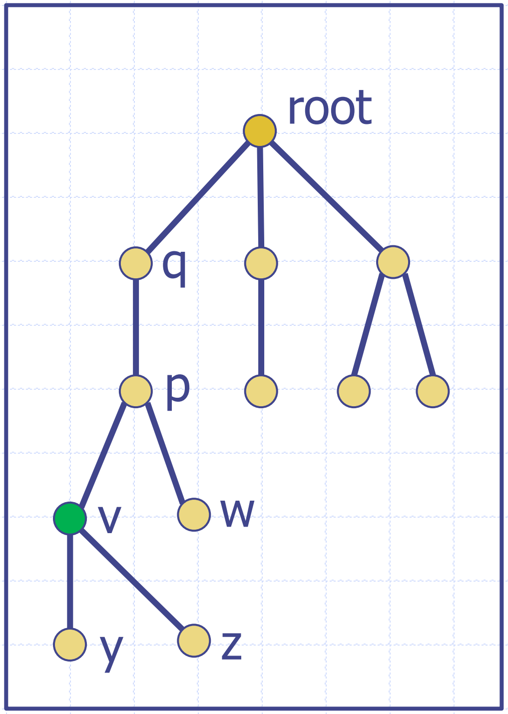
Rooted Tree Terminology

- The grandparent of a node is that node's parent's parent. Here the grandparent of v is q.
- A grandchild of a node is any of the node's children's children. Here v and w are the grandchildren of q.
- A sibling of a node is a node that has the same parent. Here w is a sibling of v; we also say that v and w are siblings.



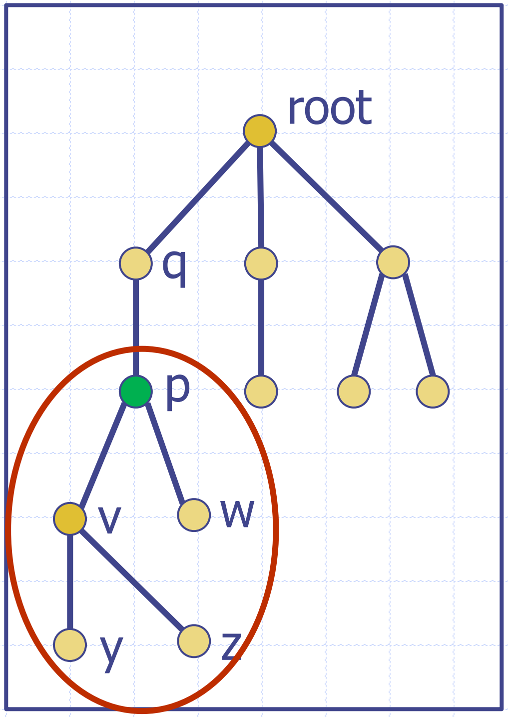
Rooted Tree Terminology

- The ancestors of a node v are all nodes on the path to the root. Here the ancestors of v are p, q, and the root.
- The descendants of a node v are all nodes whose path to the root includes v. Here the descendants of q are p, v, w, y, and z.
- Sometimes v is included in the ancestors and descendants; be careful which definition you work with.



Rooted Tree Terminology

- The subtree of a node v is a tree that consists of v, the descendants of v, and any tree edges inbetween them. Here the subtree of p is circled.
- The depth of a node is the number of edges required to go from that node to the root. Here the depth of p is 2, and the depth of w is 3.



- The height of the tree is the maximum depth of any node (here 4).