Closed Lists and other Data Structures

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Open vs. Closed Lists

- Two general list models:
  - Open lists:
    - Elements and sublists can be shared
    - Mutation of lists is discouraged
    - Mathematically elegant
  - Closed lists:
    - Sharing generally not done
    - Mutation of lists is ok, because they are encapsulated
    - Mathematically less attractive
  - Closed lists can be built by wrapping open lists

Abstract Data Types (ADT's)

- "Abstract Data Type" means:
  - A data domain, with
  - Operations on elements of the domain
- This terminology has faded a bit with the increase in object-oriented programming, but the viewpoint is still worthwhile.
- Both Open and Closed Lists can be used to implement various Abstract Data Types

Example: Stack ADT

- Domain: Arbitrary
- Main Operations:
  - void push(Object)
  - Object pop()
  - boolean isEmpty()

Example: Queue ADT

- Domain: Arbitrary
- Main Operations:
  - void enqueue(Object)
  - Object dequeue()
  - boolean isEmpty()

Implementing Stacks and Queues

- Try using an OpenList

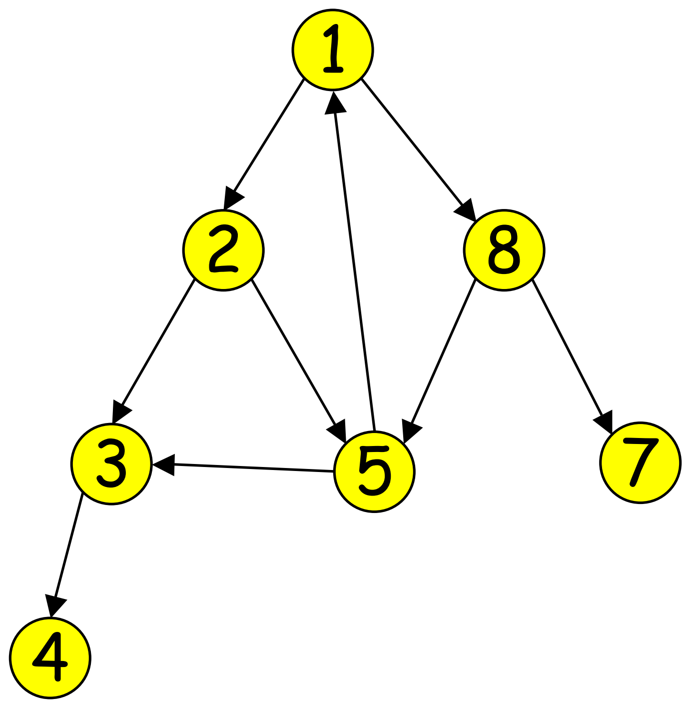
Application of Stacks and Queues

- Stacks are commonly used "under the hood" to implement recursion.
  - The arguments and other variables for successive recursive calls are stacked, so that they can be used following the return from the inner call.

- Stacks and Queues are useful in two distinct varieties of tree or graph search.

Depth- vs. Breadth- First in Graph

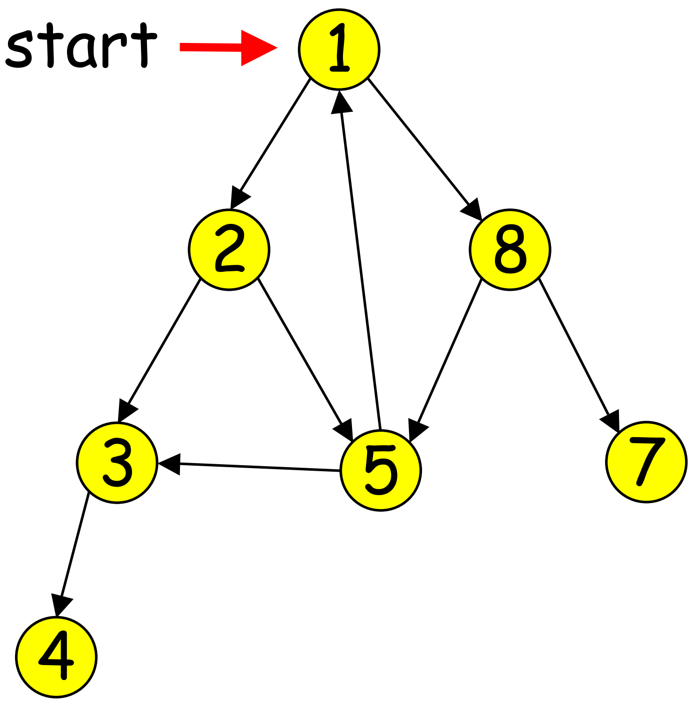
Example: Find even-numbered nodes



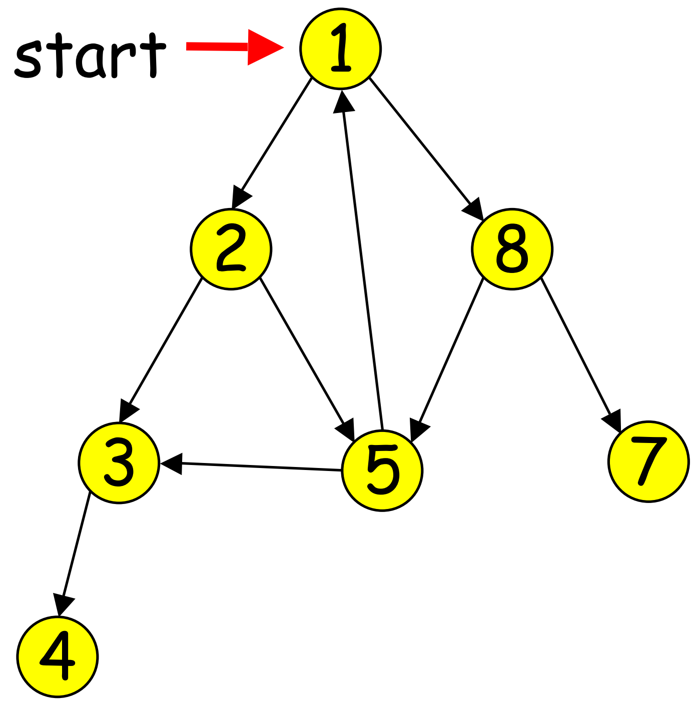
Depth- vs. Breadth- First in Graph

Example: Find even-numbered nodes

Depth-First



Breadth-First



Depth- vs. Breadth- First in Graph

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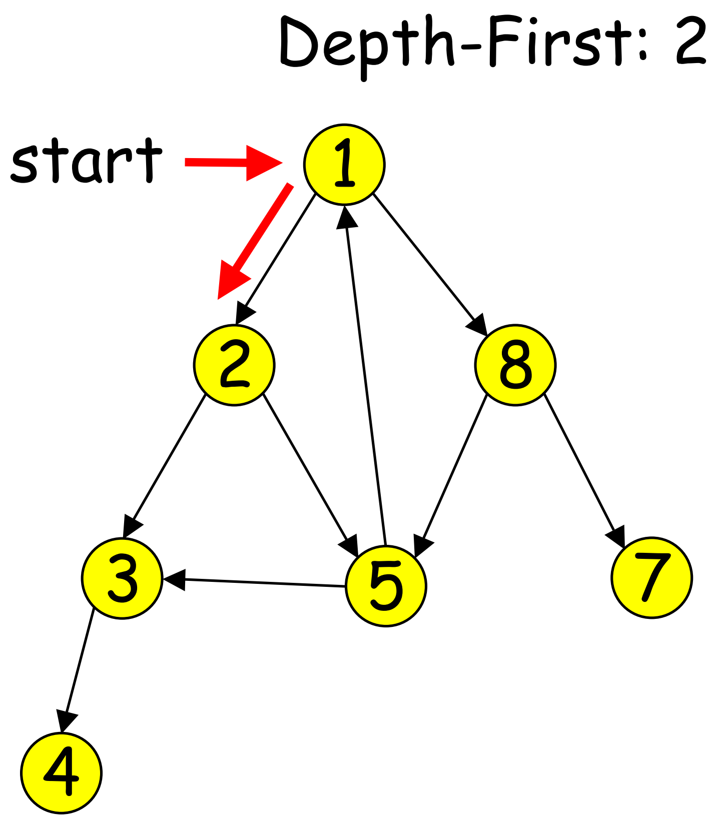
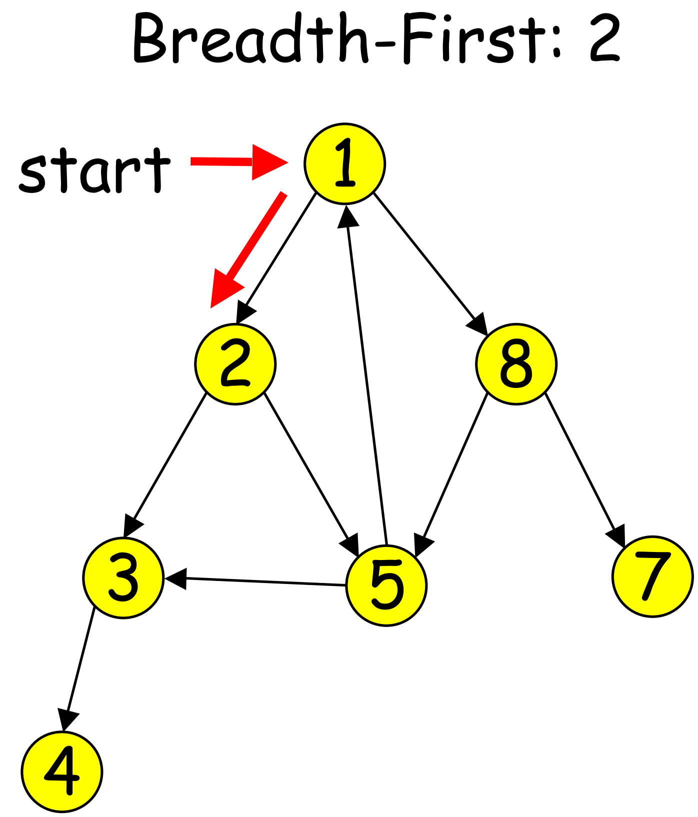
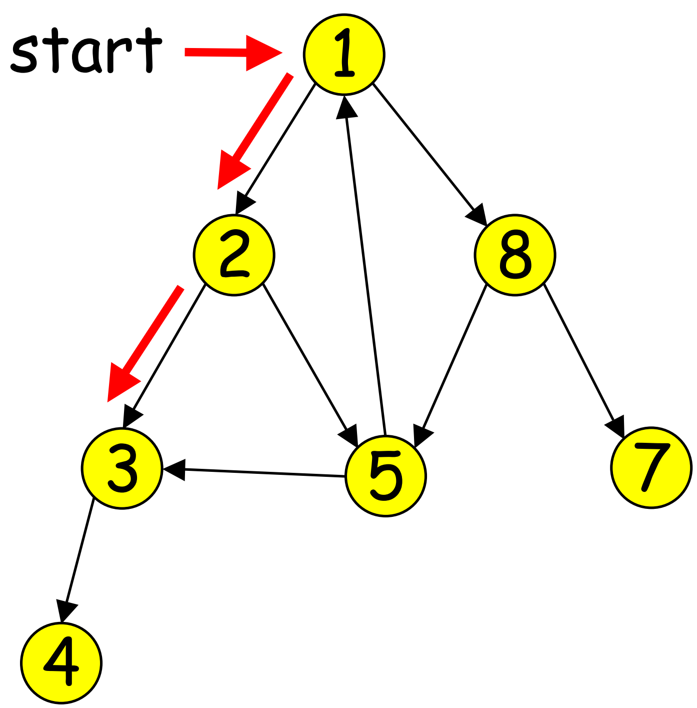




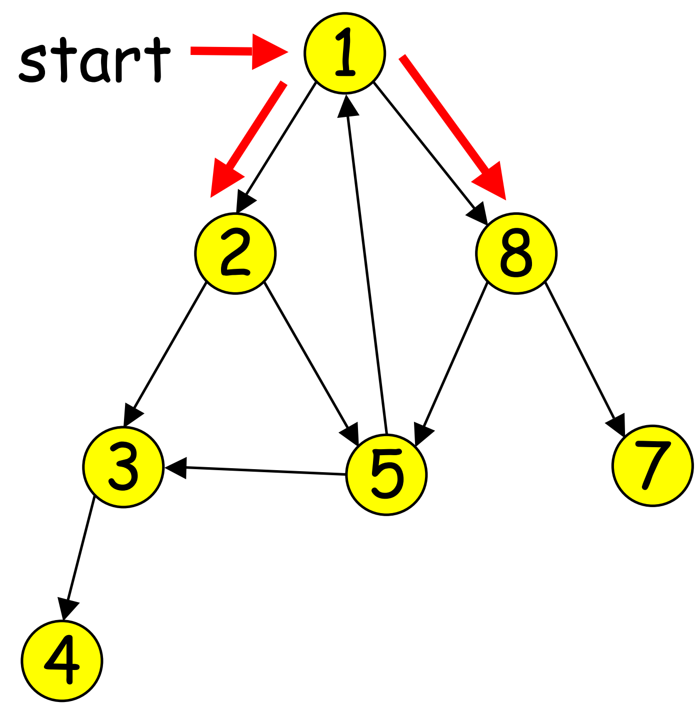
Depth- vs. Breadth- First in Graph

Example: Find even-numbered nodes

Depth-First: 2



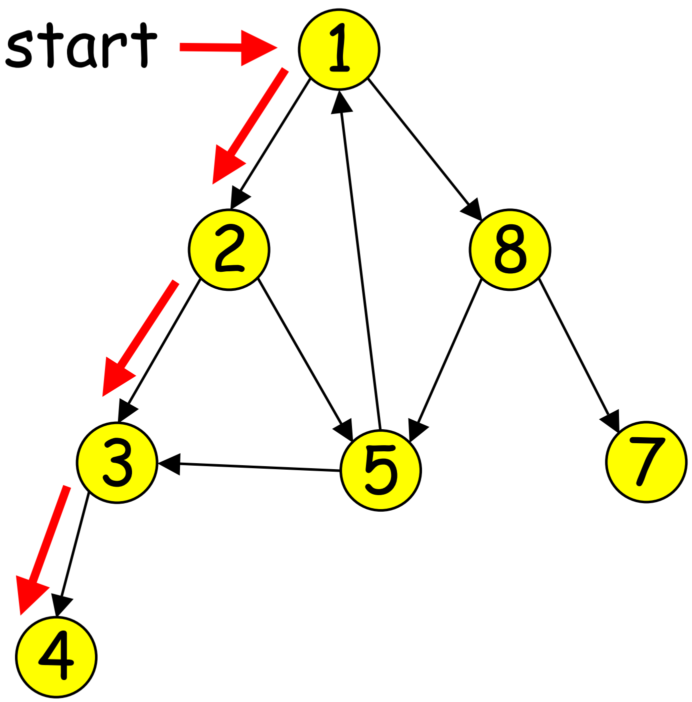
Breadth-First: 2 8



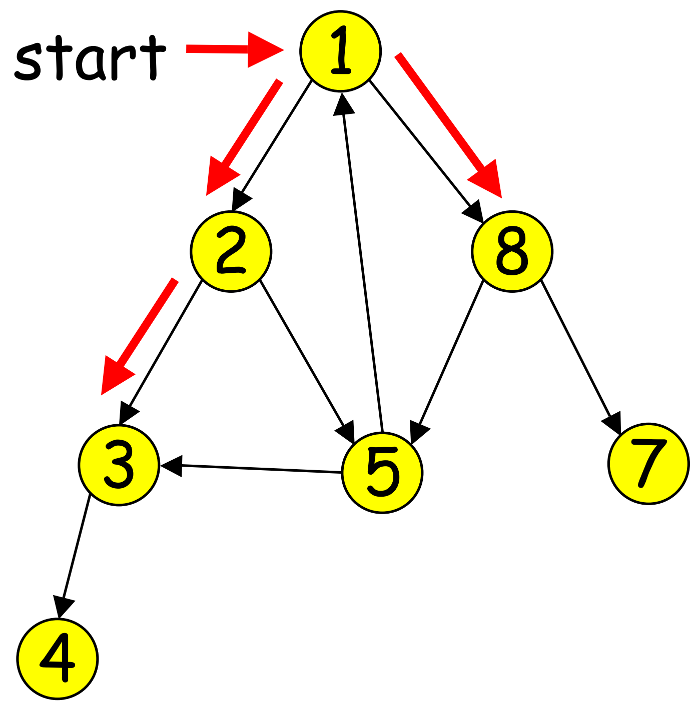
Depth- vs. Breadth- First in Graph

Example: Find even-numbered nodes

Depth-First: 2 4



Breadth-First: 2 8



Depth- vs. Breadth- First in Graph

Example: Find even-numbered nodes

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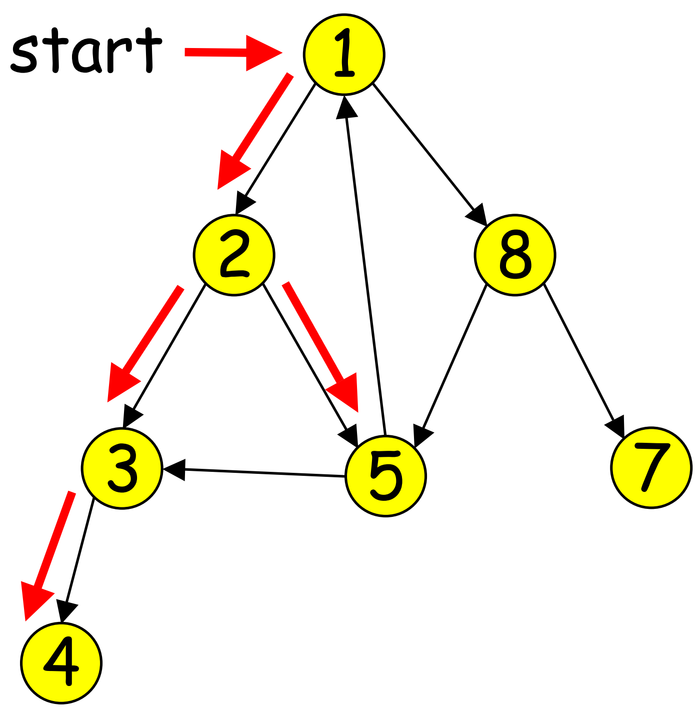
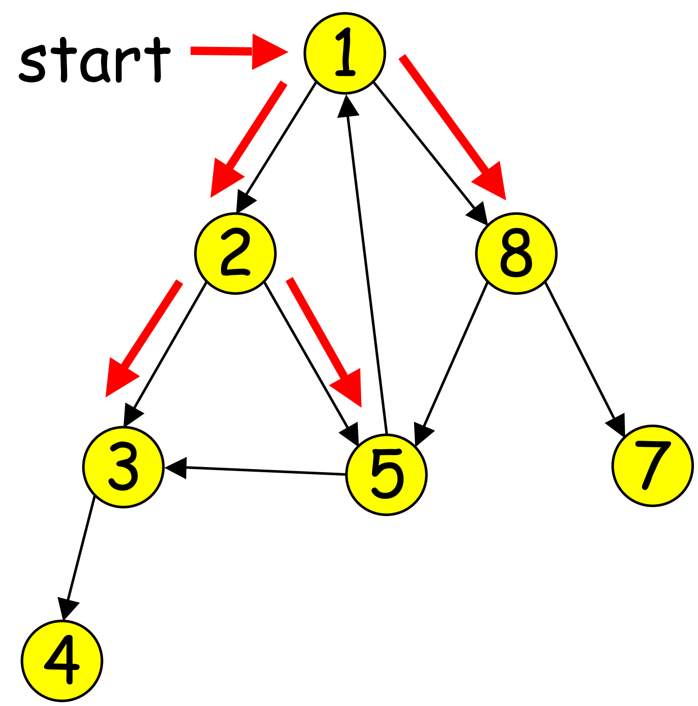


Breadth-First: 2 8



Depth- vs. Breadth- First in Graph

Example: Find even-numbered nodes

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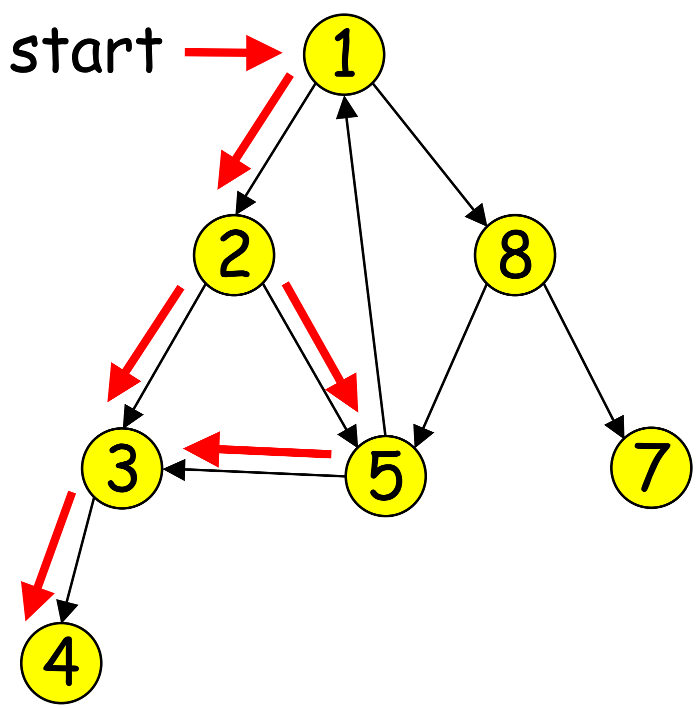
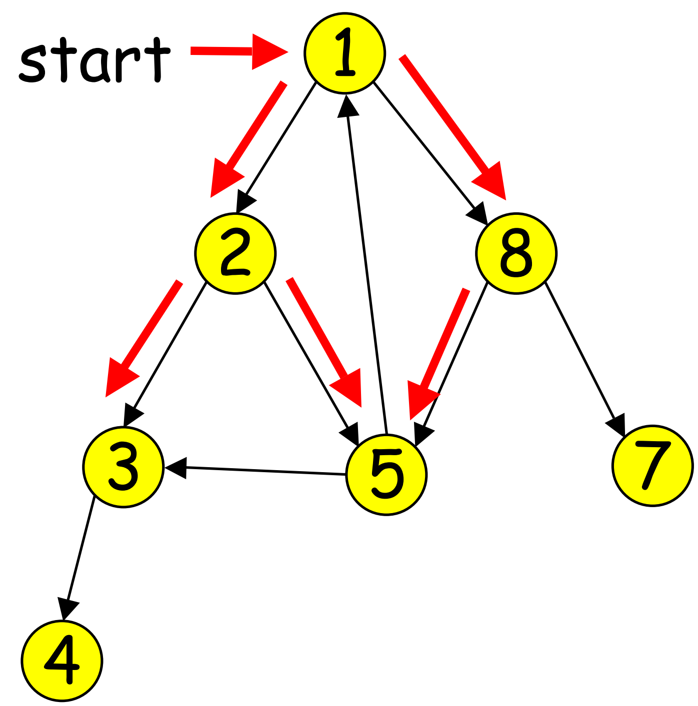


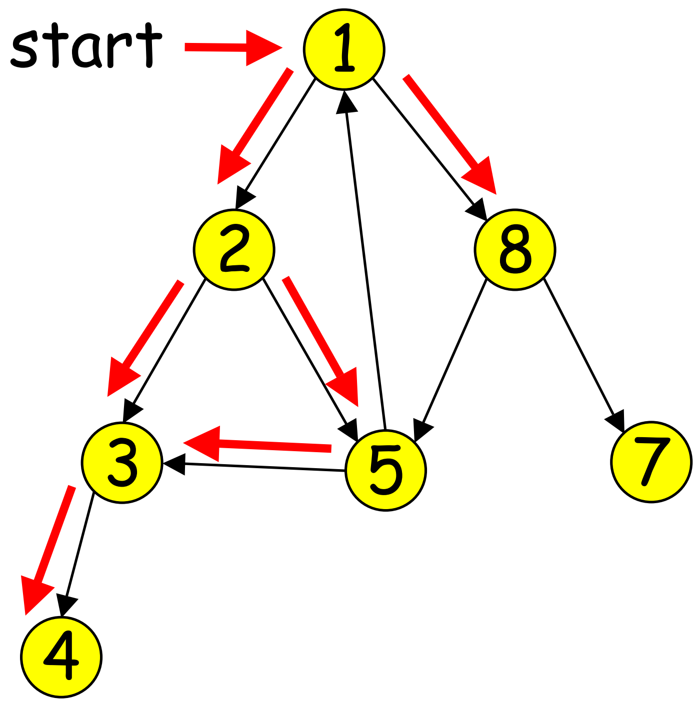
Breadth-First: 2 8



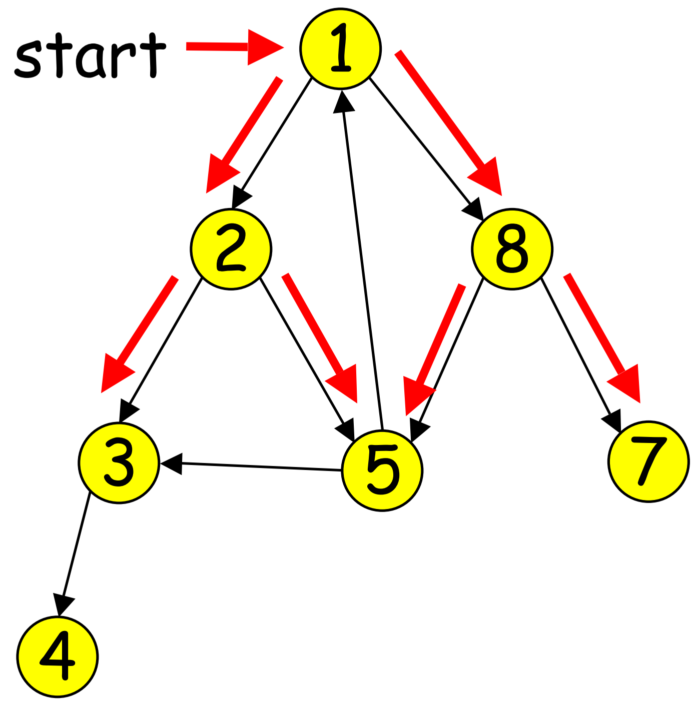
Depth- vs. Breadth- First in Graph

Example: Find even-numbered nodes

Depth-First: 2 4 8



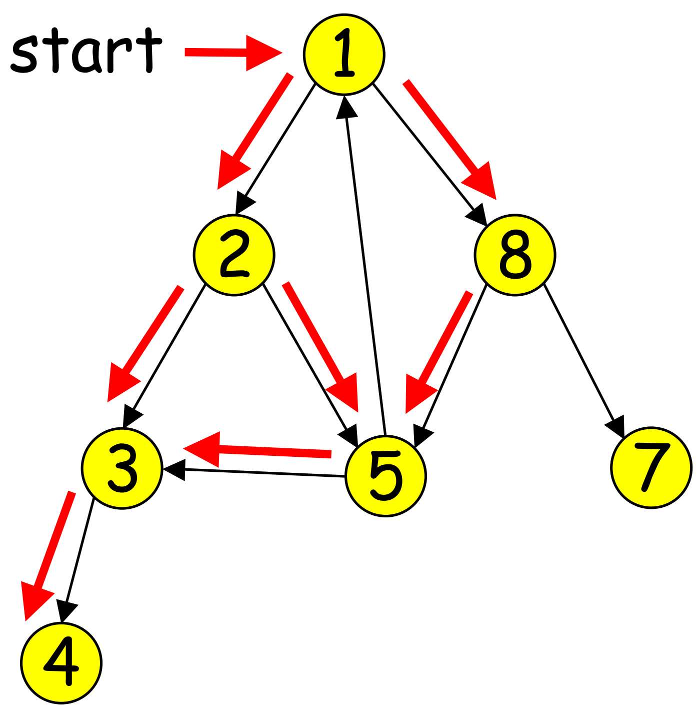
Breadth-First: 2 8



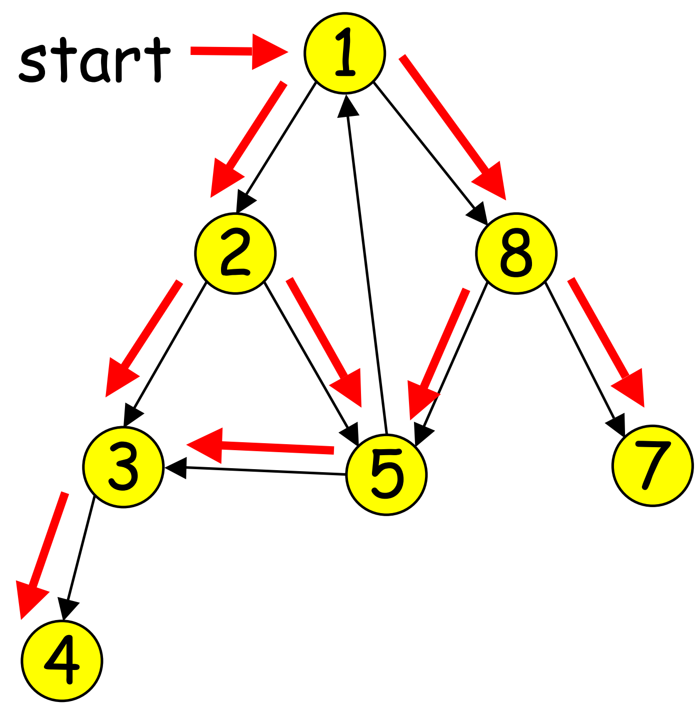
Depth- vs. Breadth- First in Graph

Example: Find even-numbered nodes

Depth-First: 2 4 8

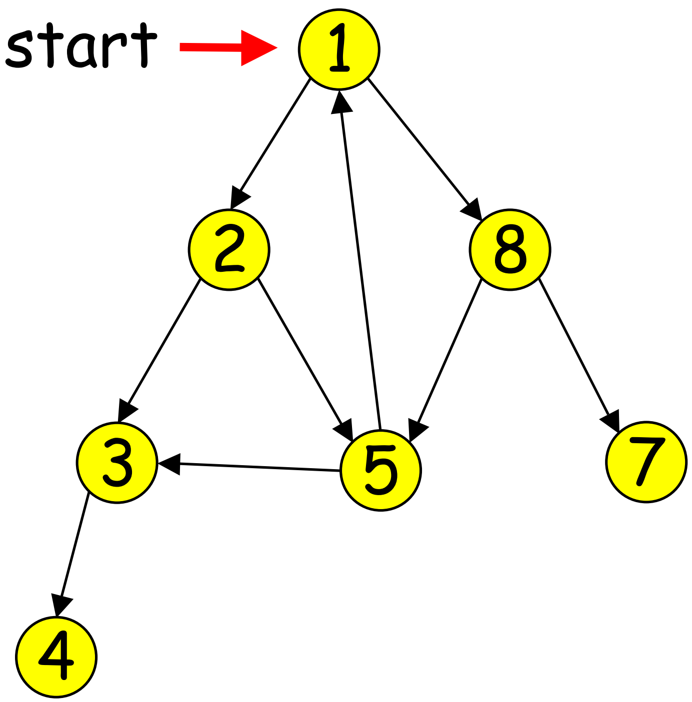


Breadth-First: 2 8 4

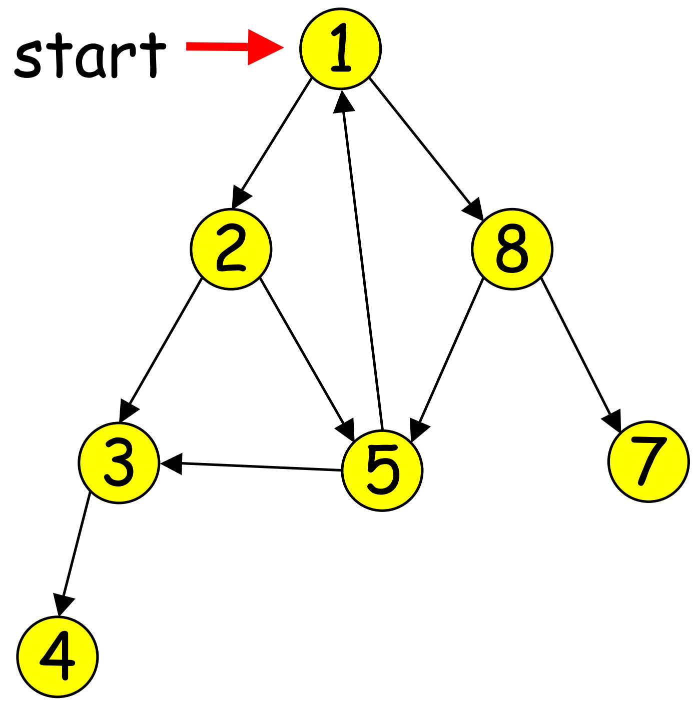


Quiz: Find an Element > 5

Depth-First

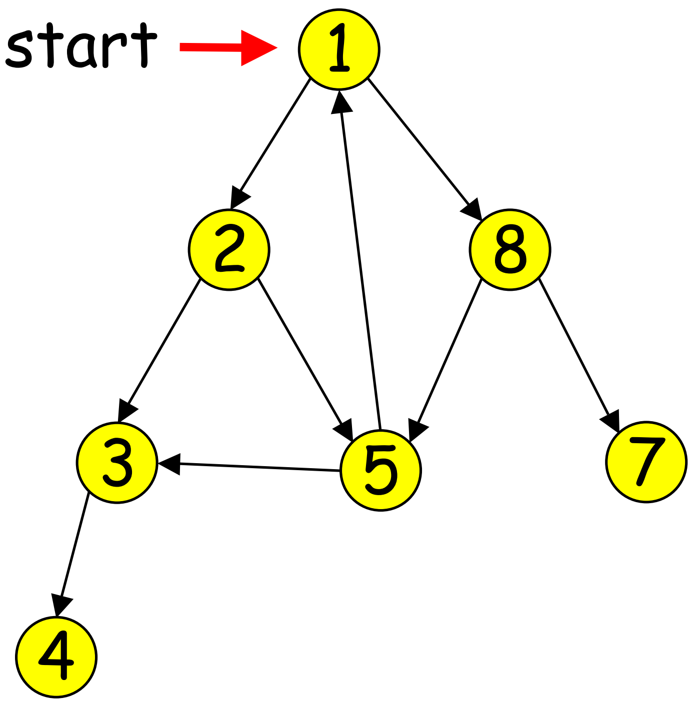


Breadth-First

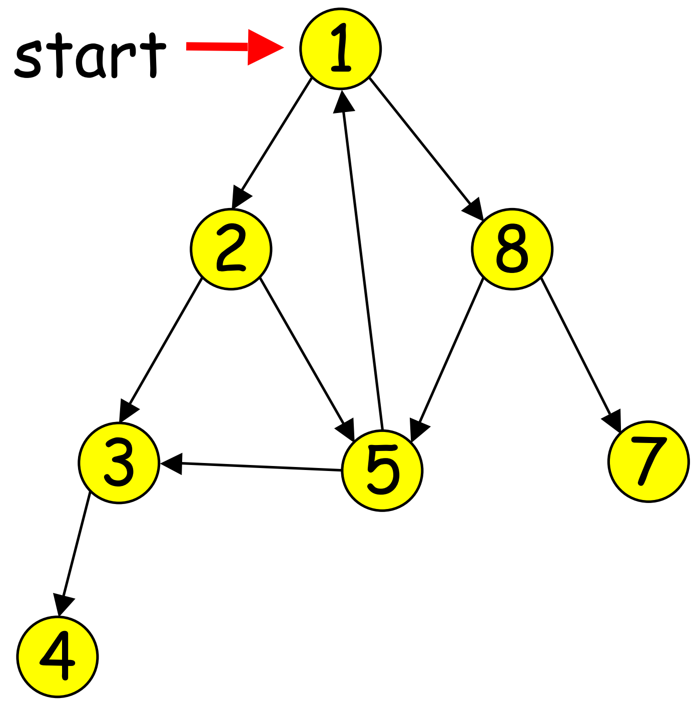


Quiz: Identify the Search Order

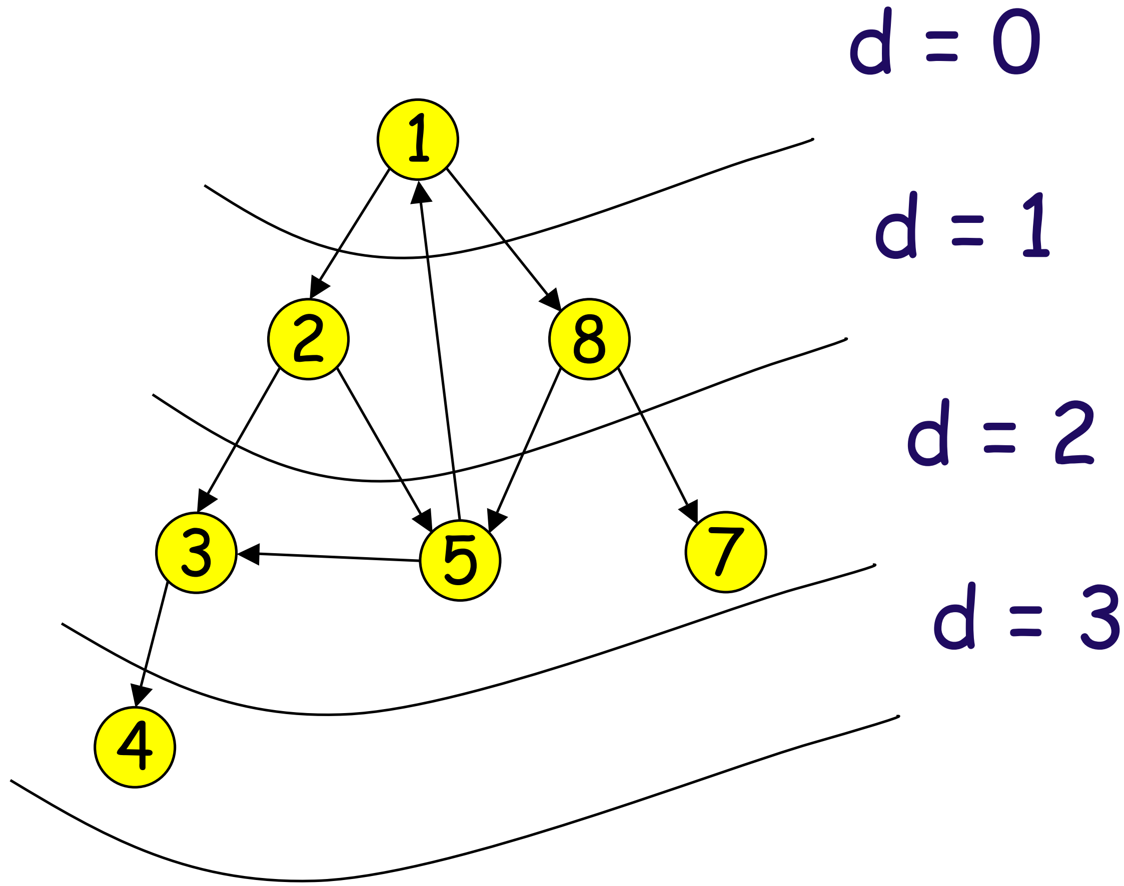
Depth-First



Breadth-First

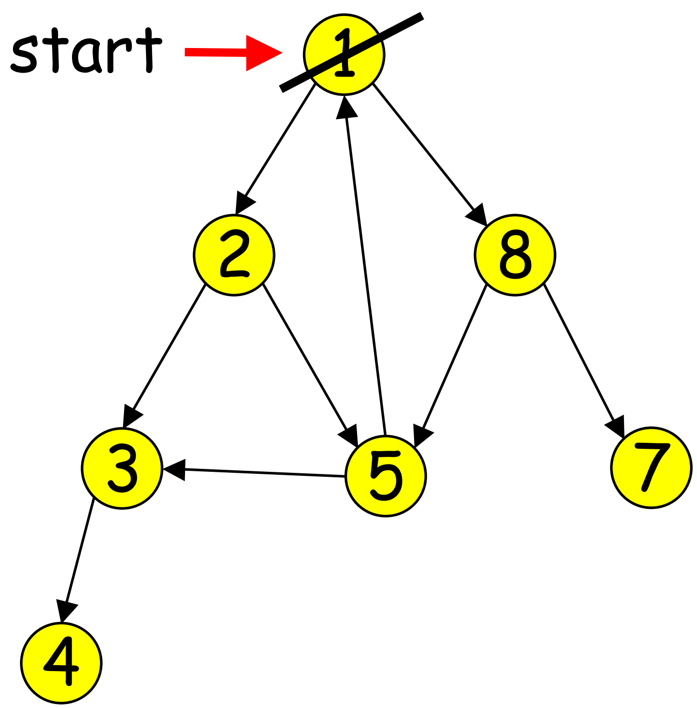


Breadth-First "Wave-Front"



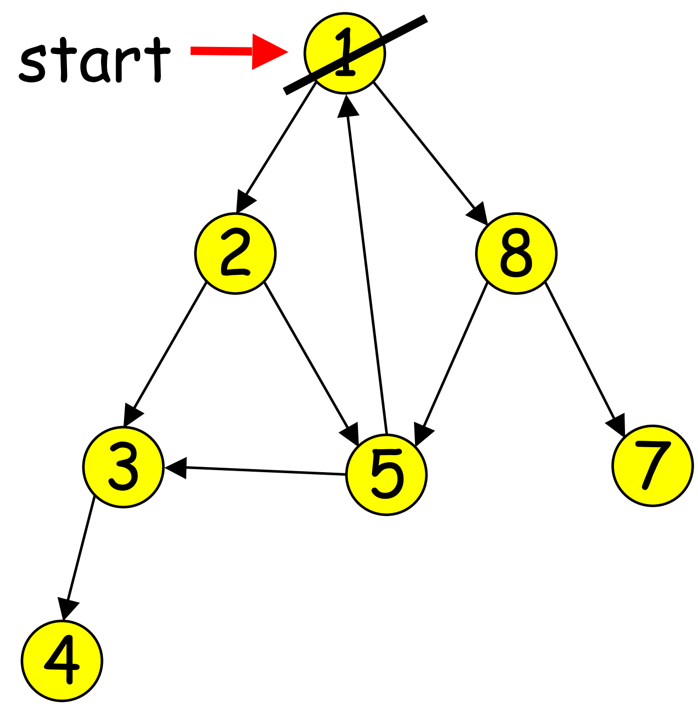
Stack vs. Queue

Depth-First: Stack: 1



DF Order: 1

Breadth-First: Queue: 1



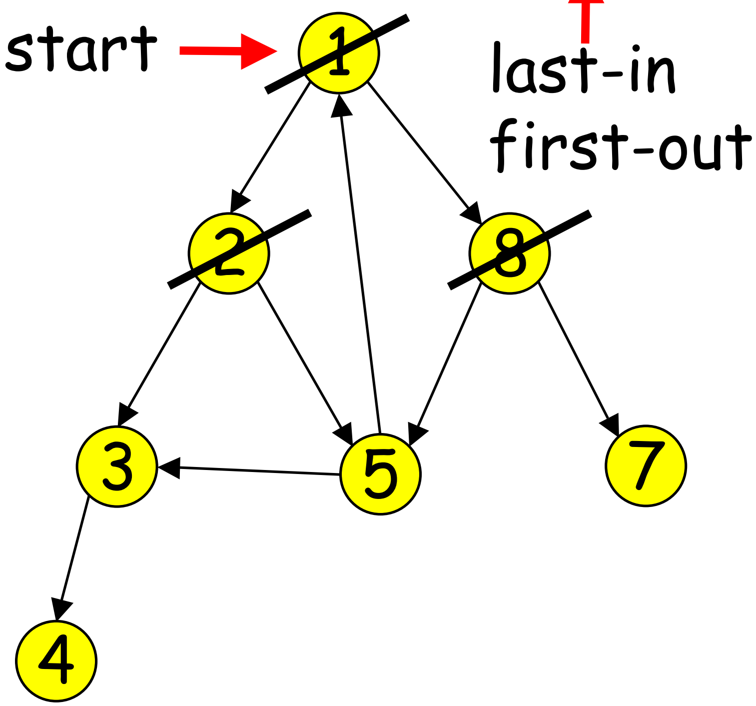
BF Order: 1

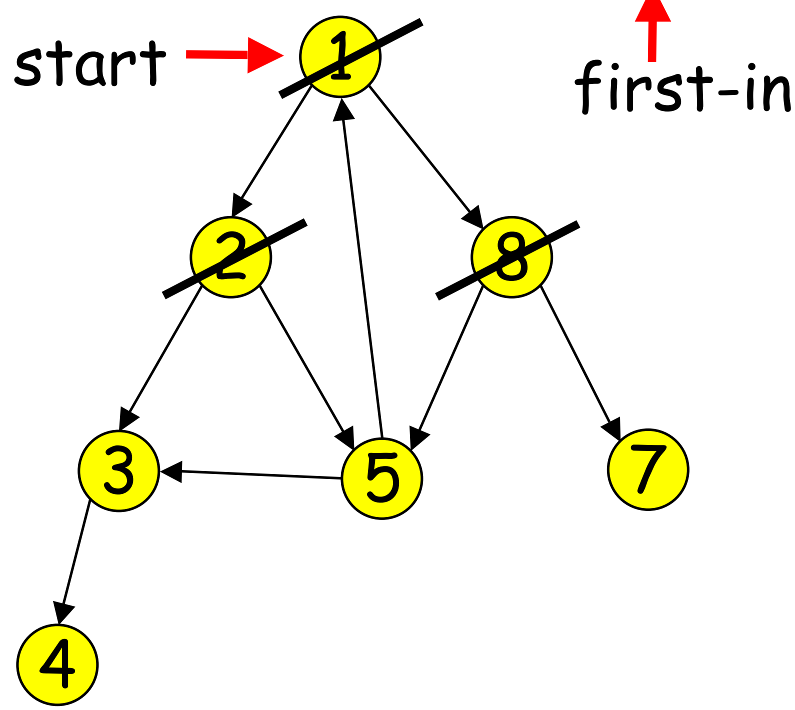
Stack vs. Queue

first-out

Depth-First: Stack: 8 2

Breadth-First: Queue: 8 2





DF Order: 1 8

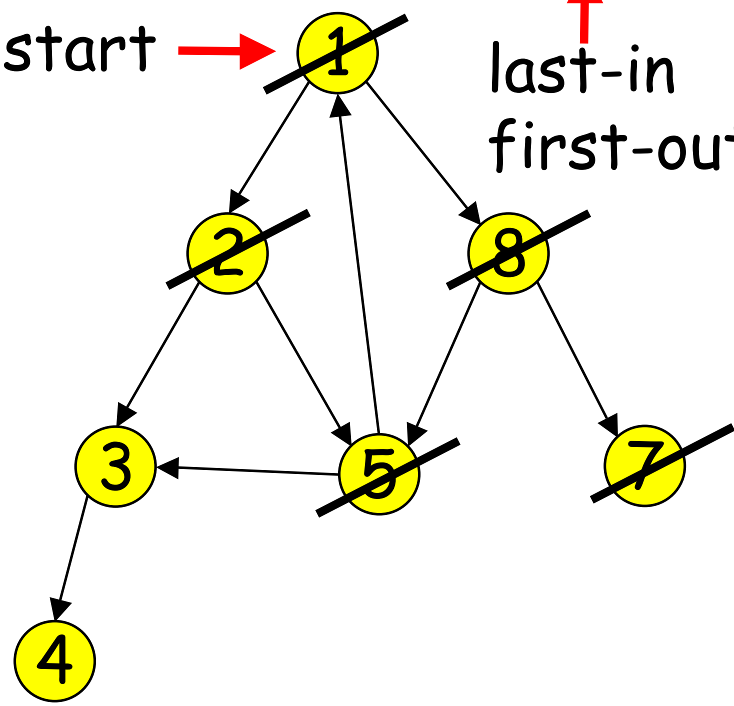
BF Order: 1 2

Stack vs. Queue

Depth-First: Stack: 7 5 2

start

last-in
first-out



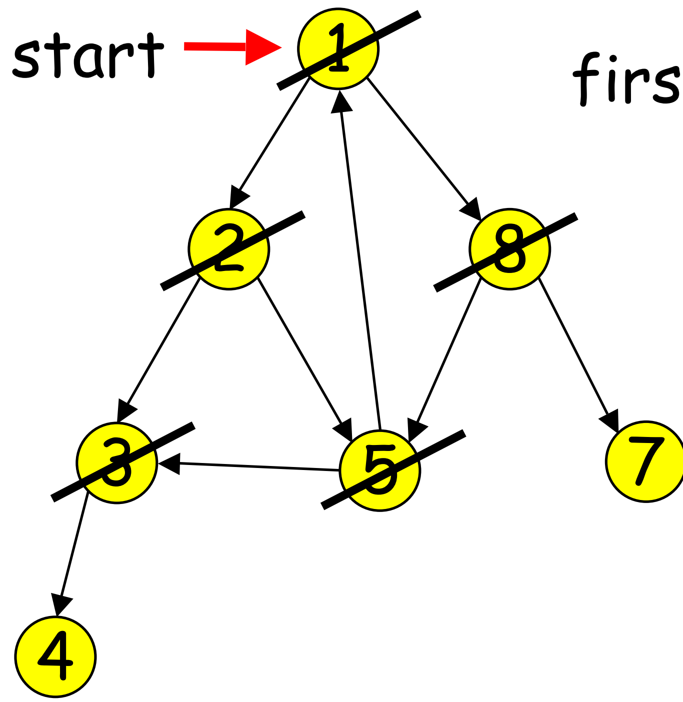
DF Order: 1 8 7

first-out

Breadth-First: Queue: 5 3 8

first-in

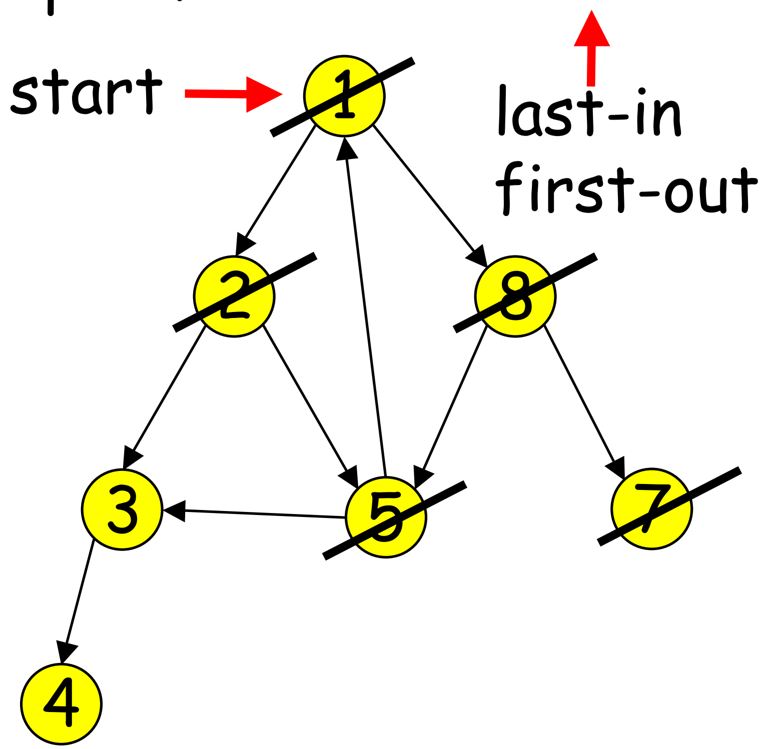
start



BF Order: 1 2 8

Stack vs. Queue

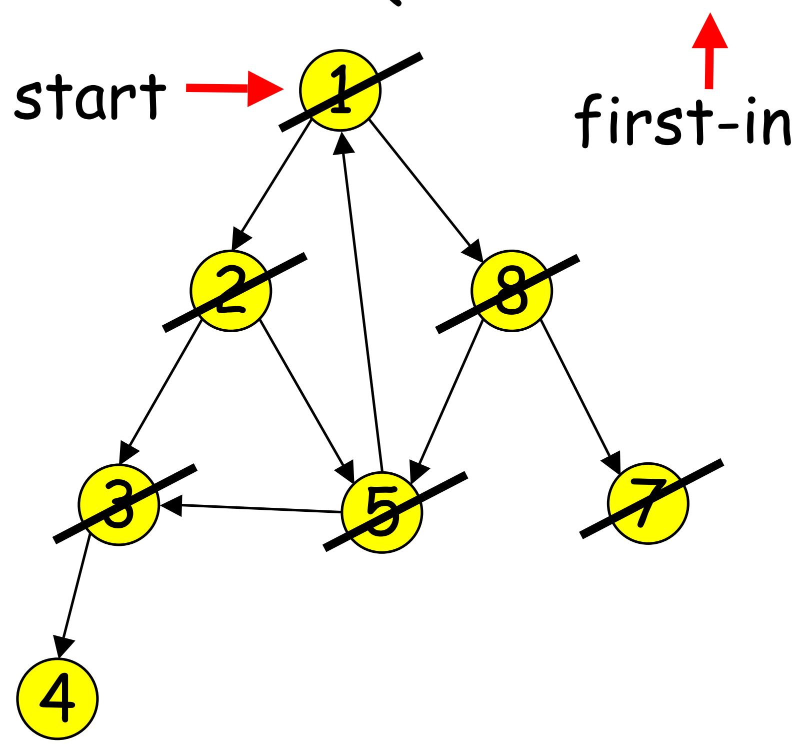
Depth-First: Stack: 5 2



DF Order: 1 8 7 5

first-out

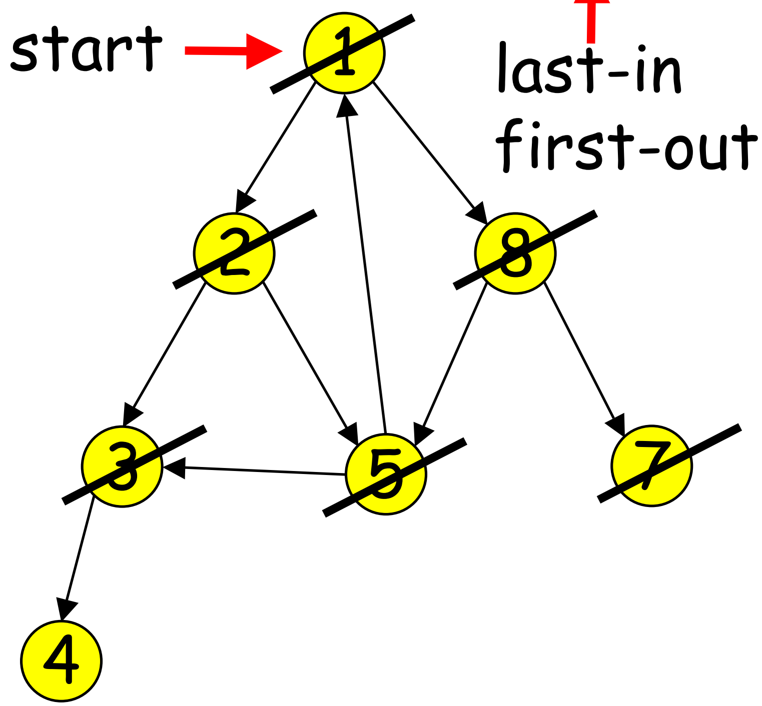
Breadth-First: Queue: 7 5 3



BF Order: 1 2 8 3

Stack vs. Queue

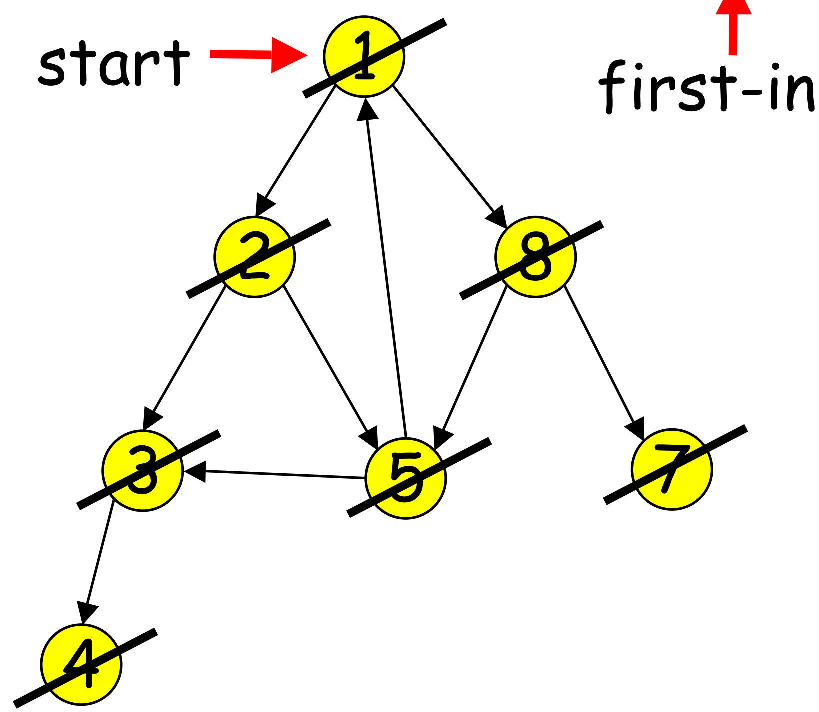
Depth-First: Stack: 3 2



DF Order: 1 8 7 5 3

first-out

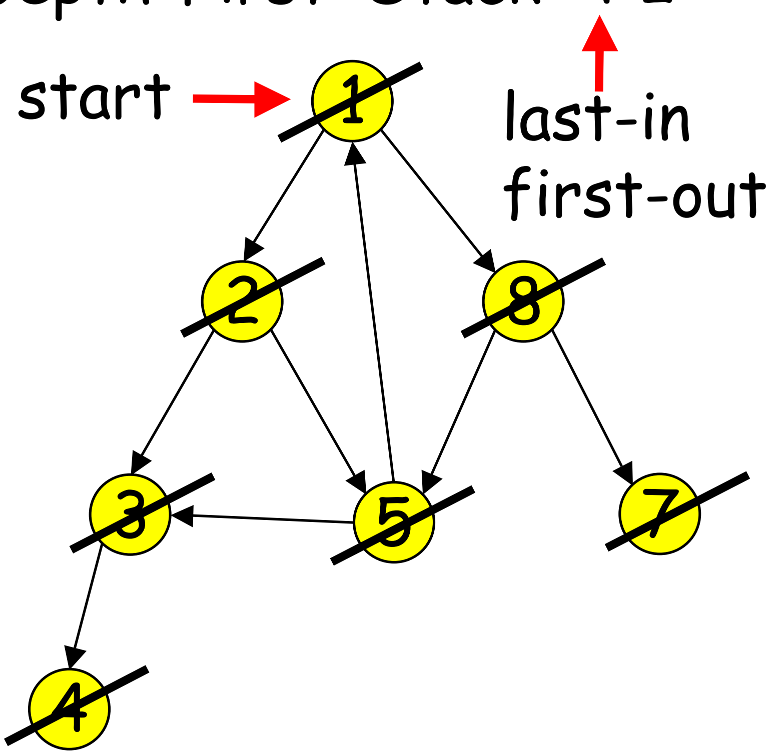
Breadth-First: Queue: 4 7 5



BF Order: 1 2 8 3 5

Stack vs. Queue

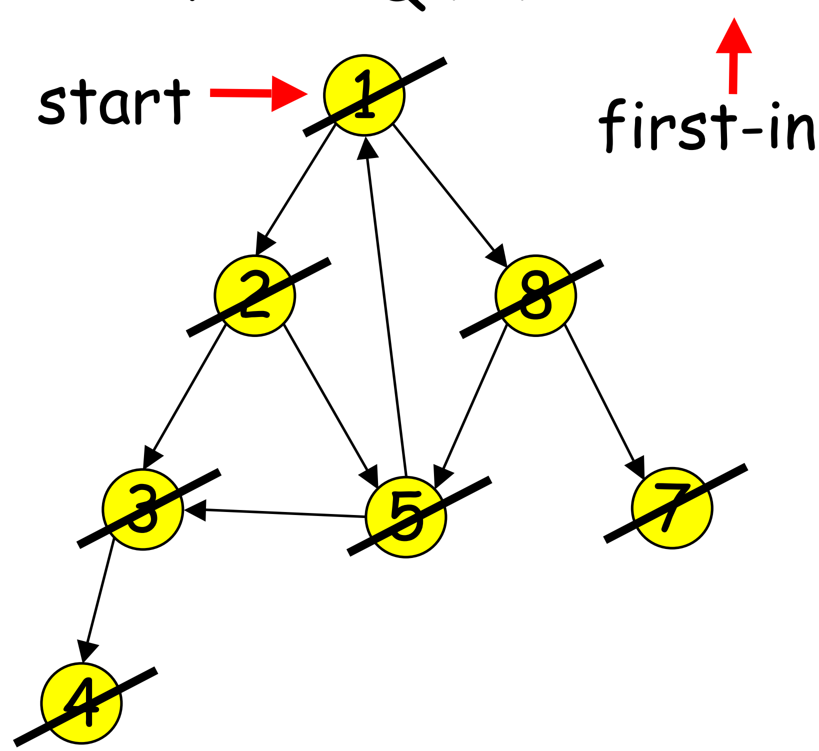
Depth-First: Stack: 4 2



DF Order: 1 8 7 5 3 4

first-out

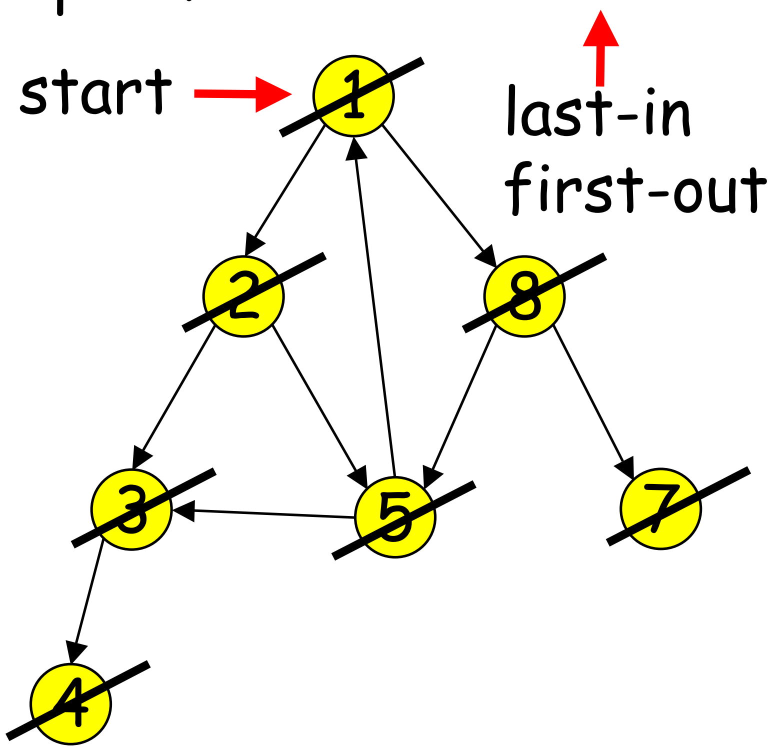
Breadth-First: Queue: 4 7



BF Order: 1 2 8 3 5 7

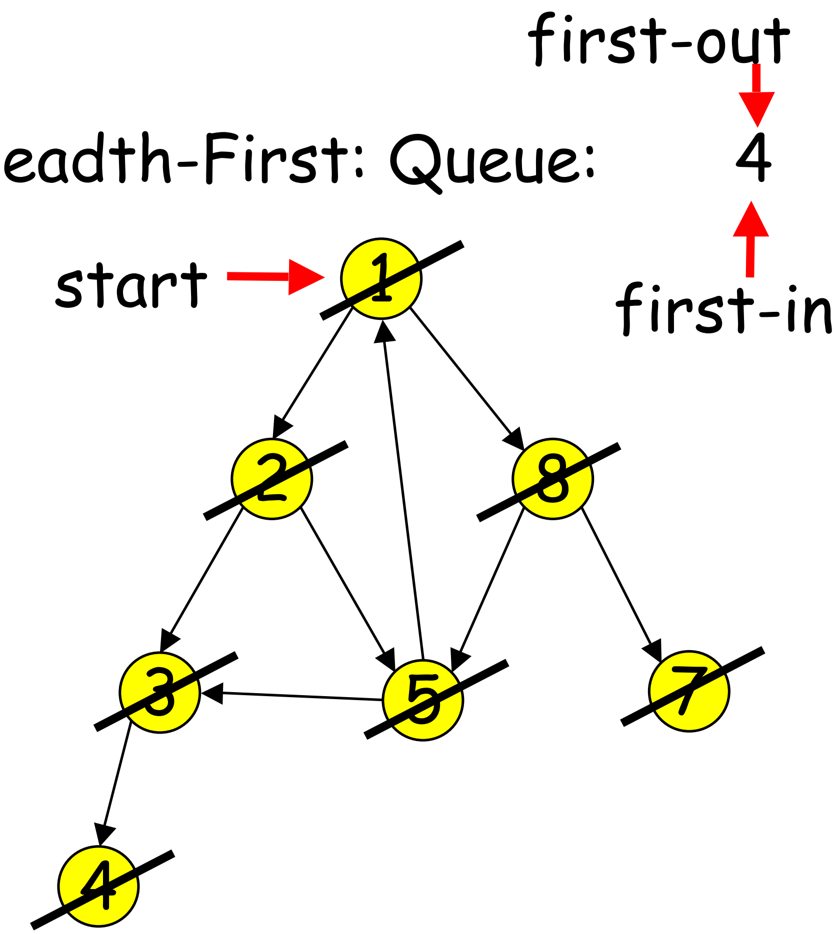
Stack vs. Queue

Depth-First: Stack: 2



DF Order: 1 8 7 5 3 4 2

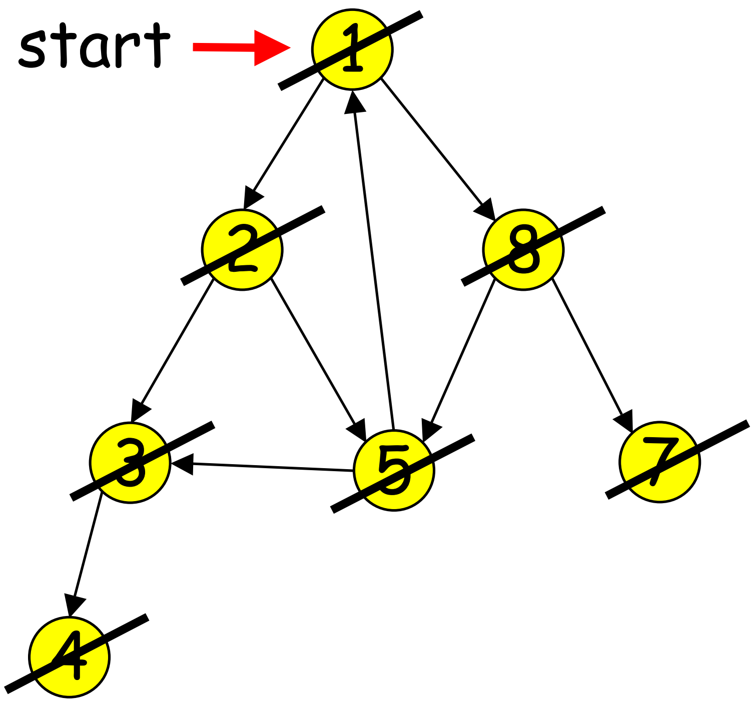
Breadth-First: Queue: 4



BF Order: 1 2 8 3 5 7 4

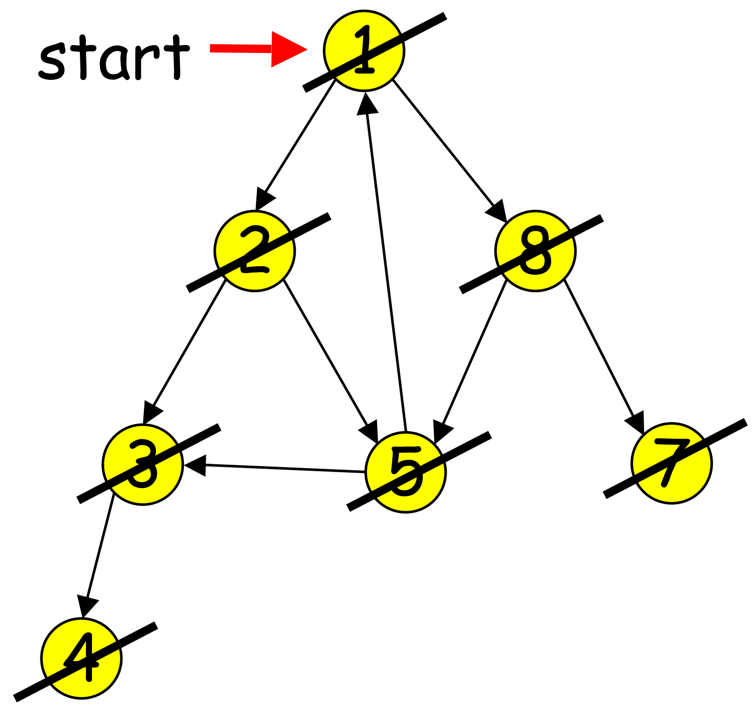
Stack vs. Queue

Depth-First: Stack: (empty)



DF Order: 1 8 7 5 3 4 2

Breadth-First: Queue: (empty)



BF Order: 1 2 8 3 5 7 4

Example: Array ADT

- Domain: Arbitrary
- Associates unique domain element with any index in range 0 to size()-1.
- Size is specified in constructor
- Main Operations:
  - void set(Index, Object)
  - Object get(Index)
  - size()

Extendable Arrays

- Classes such as ArrayList in Java augment the properties of an array with extendability.
  - void add(Object) adds a new position to the end of an existing array.

Arrays vs. Lists Complexity-Wise

- Access time for the i^{th} element of a List is O(n) worst-case, where n is the size of the list. [Slow]

- Access time for the i^{th} element of a List is O(1) worst-case, where n is the size of the array. [Fast]

- (These measures don't take into account such things as the hidden delay of virtual memory and paging, or the speedup offered by cache memory.)

Why the Disparity?

- Lists use pointers to get to the next element.
- Arrays exploit direct-access capabilities of main memory to get to the location in one memory cycle.

More on Arrays vs. Lists

- Lists are easier to extend element-by-element.
- Closed lists can be used for comparably fast **removal** of elements.
- Arrays are clumsier in this regard, as the array has to be **copied** into larger space.

Example: Priority Queue ADT

- Domain: A set S on which there is a linear ordering relation, say <
- Operations:
  - void insert(S)
  - S removeMin()
  - boolean isEmpty()

Implement a Priority Queue

- Requirements $O(n)$ operation time, where n is size()

Implement a Priority Queue

- Requirements $O(\log n)$ operation time, where n is size()

Example: Set ADT

- Domain: Arbitrary
- Main Operations:
  - void add(Object)
  - void remove(Object)
  - boolean isEmpty()
  - int size()

Example: Mapping ADT

- Domain: Arbitrary Pairs: $A \times B$ representing a **partial function** $A \rightarrow B$ (partial in that, for a given $a \in A$, there may be no corresponding element of B).
- Main Operations:
  - void map(A, B)
  - B find(A)
  - void unmap(A, B)
  - boolean isEmpty()
  - int size()

Example: Relation ADT

- Generalizes Mapping ADT
- Domain: Arbitrary Pairs: A x B
- Main Operations:
  - void relate(A, B)
  - iterator<B> find(A) // multiple elements
  - iterator<A> domain() // multiple elements
  - void unrelate(A, B)
  - boolean isEmpty()
  - int size()