IS311

Data Structures and Java Collections Framework

Algorithms and Data Structures

- Algorithm
  - Sequence of steps used to solve a problem
  - Operates on collection of data
  - Each element of collection -> data structure
- Data structure
  - Combination of simple / composite data types
  - Design -> information stored for each element
  - Choice affects characteristic & behavior of algorithm
  - May severely impact efficiency of algorithm

Data Structures

- Taxonomy
  - Classification scheme
  - Based on relationships between element
- Category Relationship
  - Linear one -> one
  - Hierarchical one -> many
  - Graph many -> many
  - Set none -> none

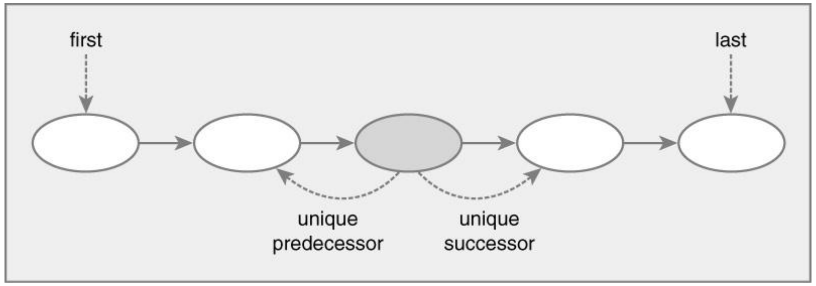
Data Structures

- Core operations
  - Add element
  - Remove element
  - Iterate through all elements
  - Compare elements

Linear Data Structures

One-to-one relationship between elements (ส่วนย่อย, องค์ประกอบมูลฐาน)

– Each element has unique predecessor (ตัวนำหน้า)
– Each element has unique successor (ตัวตามหลัง)

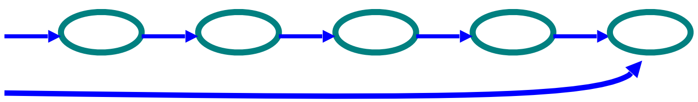


Linear Data Structures

- Core operations
  – Find first element (head - หัว)
  – Find next element (successor)
  – Find last element (tail - หาง)
- Terminology
  – Head -> no predecessor
  – Tail -> no successor

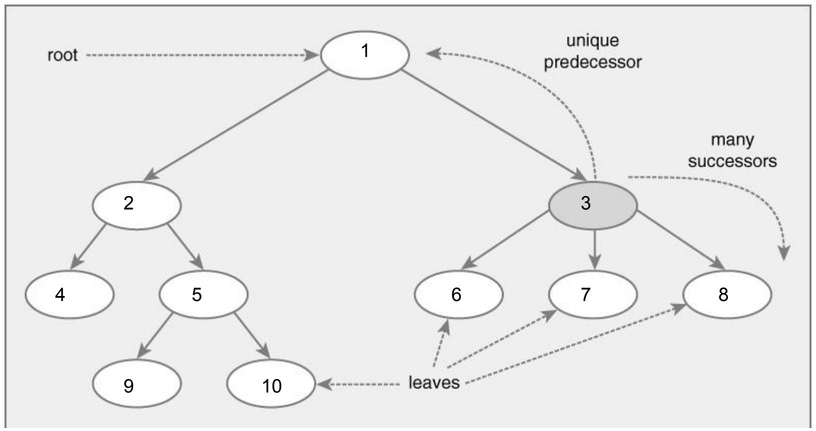
Example Linear Data Structures

- List
  – Collection of elements in order
- Queue
  – Elements removed in order of insertion
  – First-in, First-out (FIFO)
- Stack
  – Elements removed in opposite order of insertion
  – First-in, Last-out (FILO)



Hierarchical Data Structures

- One-to-many relationship between elements
  – Each element has unique predecessor
  – Each element has multiple successors

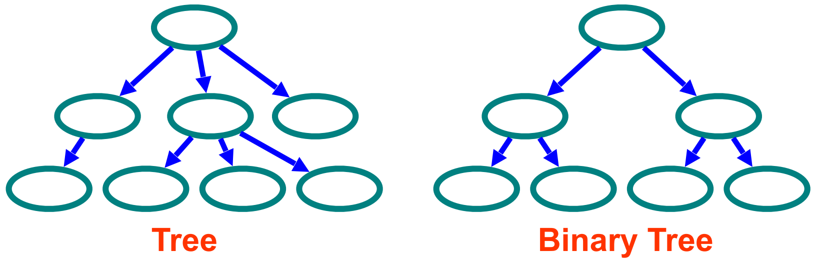


Hierarchical Data Structures

- Terminology
  - Root -> no predecessor
  - Leaf -> no successor
  - Interior -> non-leaf
  - Children -> successors
  - Parent -> predecessor
- Core operations
  - Find first element (root)
  - Find successor elements (children)
  - Find predecessor element (parent)

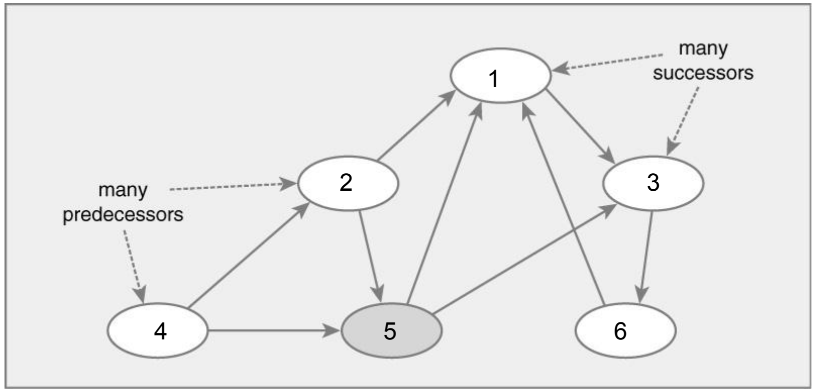
Example Hierarchical Data Structures

- Tree
  - Single root
- Forest
  - Multiple roots
- Binary tree
  - Tree with 0–2 children per node



Graph Data Structures

- Many-to-many relationship between elements
  - Each element has multiple predecessors
  - Each element has multiple successors

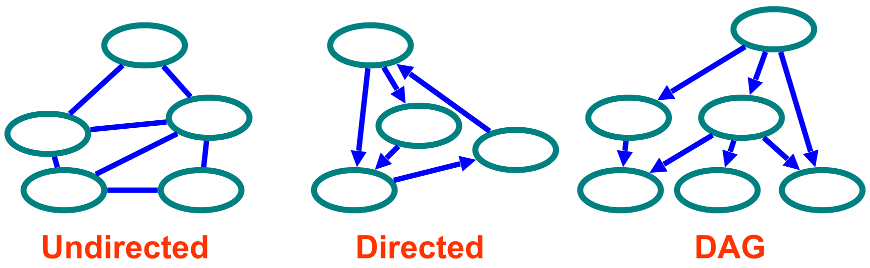


Graph Data Structures

- Terminology
  - Directed -> traverse edges in one direction
  - Undirected -> traverse edges in both directions
  - Neighbor -> adjacent node
  - Path -> sequence of edges
  - Cycle -> path returning to same node
  - Acyclic -> no cycles
- Core operations
  - Find successor nodes
  - Find predecessor nodes
  - Find adjacent nodes (neighbors)

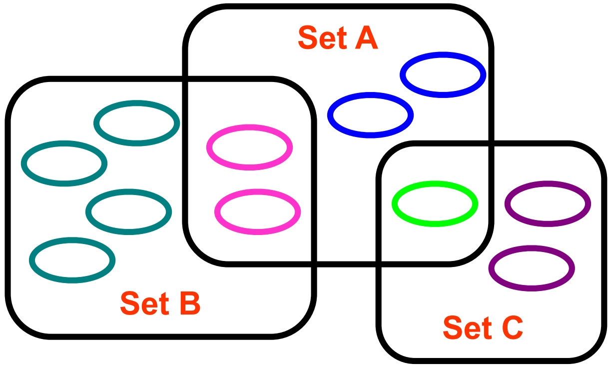
Example Graph Data Structures

- Undirected graph
  - Undirected edges
- Directed graph
  - Directed edges
- Directed acyclic graph (DAG)
  - Directed edges, no cycles



Set Data Structures

- No relationship between elements
  - Elements have no predecessor / successor
  - Only one copy of element allowed in set

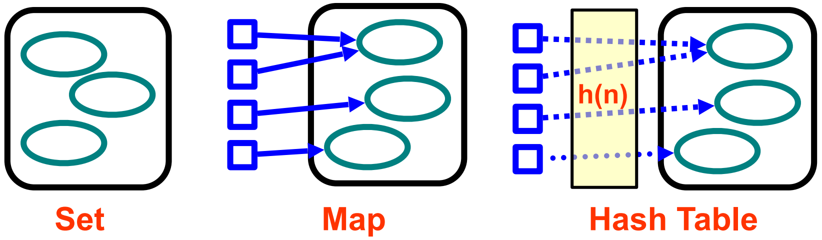


Set Data Structures

- Terminology
  - **Subset** -> elements contained by set
  - **Union** -> select elements in either set
  - **Intersection** -> select elements in both sets
  - **Set difference** -> select elements in one set only
- Core operations
  - Add set, remove set, compare set

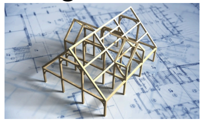
Example Set Data Structures

- Set
  - Basic set
- Map
  - Map value to element in set
- Hash Table
  - Maps value to element in set using hash function



Software Framework

software framework is an abstraction in which software providing generic functionality can be selectively changed by additional user-written code, thus providing application-specific software. A software framework is a universal, reusable software environment that provides particular functionality as part of a larger software platform to facilitate development of software applications, products and solutions. Software frameworks may include support programs, compilers, code libraries, tool sets, and application programming interfaces (APIs) that bring together all the different components to enable development of a project or solution.



ดูเพิ่มเติมที่ https://en.wikipedia.org/wiki/Software_framework

Java Collections Framework

- Collection
  - Object that groups multiple elements into one unit
  - Also called container
- Collection framework consists of
  - Interfaces
    - Abstract data type
  - Implementations
    - Reusable data structures
  - Algorithms
    - Reusable functionality

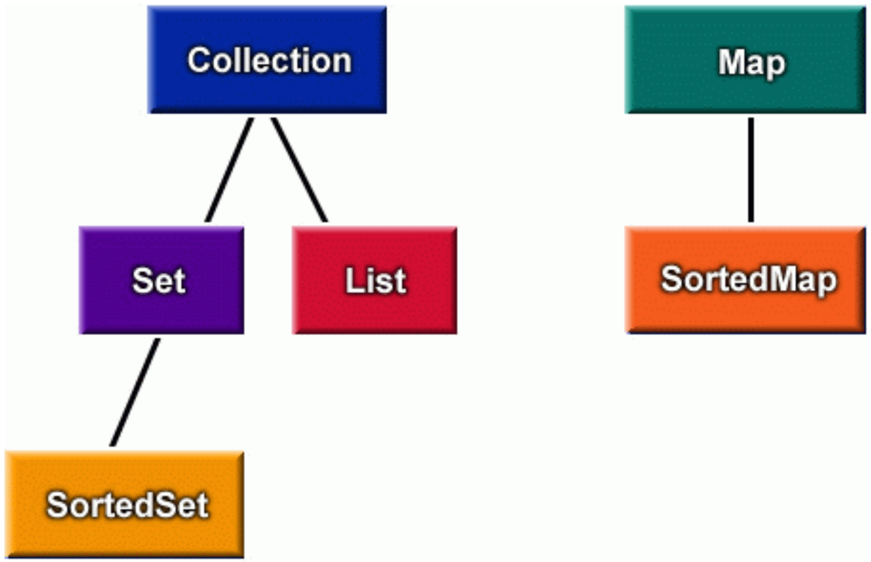
Java Collections Framework

- Goals
  - Reduce programming effort
  - Make APIs easier to learn
  - Make APIs easier to design and implement
  - Reuse software
  - Increase performance

Core `Collection` Interfaces

- `Collection`
  - Group of elements
- `Set`
  - No duplicate elements
- `List`
  - Ordered collection
- `Map`
  - Maps keys to elements
- `SortedSet`, `SortedMap`
  - Sorted ordering of elements

Core Collection Hierarchy



Collections Interface Implementations

- General implementations
  - Primary public implementation
  - Example
    - List – `ArrayList, LinkedList`
    - Set – `TreeSet`, `HashSet`
    - Map – `TreeMap`, `HashMap`

`Collection` Interface Methods

คลาสต่าง ๆ ที่เป็น collection ของจาวา สามารถใช้เมท็อดต่อไปนี้ซึ่งกำหนดไว้ในอินเทอร์เฟส `Collection` ได้

- `boolean add(Object o)`
  - Add specified element
- `boolean contains(Object o)`
  - True if collection contains specified element
- `boolean remove(Object o)`
  - Removes specified element from collection
- `boolean equals(Object o)`
  - Compares object with collection for equality

`Collection` Interface Methods

- `boolean addAll(Collection c)`
  - Adds all elements in specified collection
- `boolean containsAll(Collection c)`
  - True if collection contains all elements in collection
- `boolean removeAll(Collection c)`
  - Removes all elements in specified collection
- `boolean retainAll(Collection c)`
  - Retains only elements contained in specified collection
- `void clear()`
  - Removes all elements from collection

`Collection` Interface Methods

- `boolean isEmpty()`
  – True if collection contains no elements
- `int size()`
  – Returns number of elements in collection
- `Object[] toArray()`
  – Returns array containing all elements in collection
- `Iterator iterator()`
  – Returns an iterator over the elements in collection

`Collection` เป็น subinterface ของ **`Iterable`** ซึ่งได้กำหนดเมท็อด `iterator()` ไว้

ดูเพิ่มรายละเอียดเติมได้ที่
https://docs.oracle.com/javase/8/docs/api/java/util/Collection.html

`Iterator` Interface

- `Iterator`
  – Common interface for all Collection classes
  – Used to examine all elements in collection
- Properties
  – Order of elements is unspecified (may change)
  – Can remove current element during iteration
  – Works for any

iterate แปลว่า ทำซ้ำ หรือ ทำอีก

`Iterator` Interface

- Interface

```
public interface Iterator {
    boolean hasNext();
    Object next();
    void remove(); // optional, called once per next()
}
```

- Example usage

```
Iterator i = myCollection.iterator();
while (i.hasNext()) {
        myCollectionElem x = (myCollectionElem)
  i.next();
}
```


New Features in Java 1.5

- Enumerated types
- Enhanced for loop
- Autoboxing & unboxing
- Scanner
- **Generic types** ←
- Variable number of arguments (varargs)
- Static imports
- Annotations

Generics – Motivating Example

- Problem
  - Utility classes handle arguments as Objects
  - Objects must be cast back to actual class
  - Casting can only be checked at runtime
- Example

```
class A { … }
class B { … }
List myL = new List();
myL.add(new A());     // Add an object of type A
…
B b = (B) myL.get(0);// throws runtime exception
// java.lang.ClassCastException
```


Solution – Generic Types

- Generic types
  - Provides abstraction over types
  - Can parameterize classes, interfaces, methods
  - Parameters defined using <x> notation
- Examples
  - `public class foo<x, y, z> { … }`
  - `public class List<String> { … }`
- Improves
  - Readability & robustness
- Used in Java Collections Framework

Generics – Usage

- Using generic types
  - Specify <*type parameter*> for utility class
  - Automatically performs casts
  - Can check class at compile time
- Example

```
class A { … }
class B { … }
List<A> myL = new List<A>();
myL.add(new A());      // Add an object of type A
myL.add(new B());        // cause compile time error
A a = myL.get(0);      // myL element -> class A
…
B b = (B) myL.get(0); // causes compile time error
```


Generics – Issues

- Generics and subtyping
  - Even if class `A` extends class `B`
  - `List<A>` does not extend `List<B>`
- Example

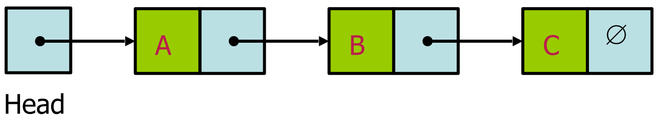
```
class B { … }
class A extends B { … }     // A is subtype of B
B b = new A();              // A used in place of B
List<B> myL = new List<A>();  // compile time error
                      // List<A> used in place of List<B>
                      // List<A> is not subtype of List<B>
```

Linear Data Structures

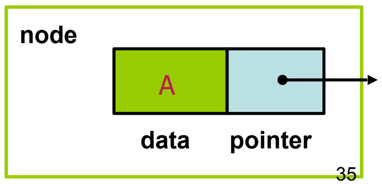
Static vs. Dynamic Structures

- A *static* data structure has a fixed size
- This meaning is different from the meaning of the `static` modifier
- Arrays are static; once you define the number of elements it can hold, the number doesn't change
- A *dynamic data structure* grows and shrinks at execution time as required by its contents
- A dynamic data structure is implemented using *links*

Linked Lists

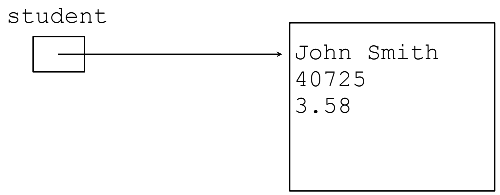


- A *linked list* is a series of connected *nodes*
- Each node contains at least
  - A piece of data (any type)
  - Pointer to the next node in the list
- *Head*: pointer to the first node
- The last node points to `NULL`



Object References

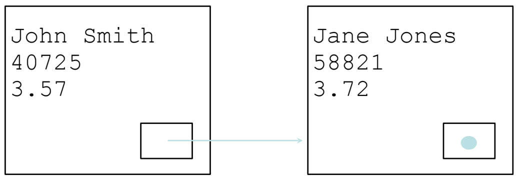
- Recall that an *object reference* is a variable that stores the address of an object
- A reference also can be called a *pointer*
- References often are depicted graphically:



References as Links

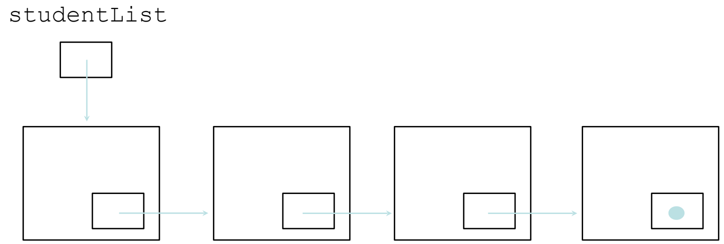
- Object references can be used to create *links* between objects

- Suppose a `Student` class contains a reference to another `Student` object



References as Links

- References can be used to create a variety of linked structures, such as a *linked list*:



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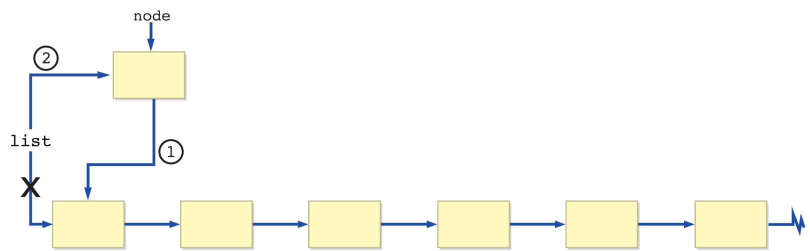
Intermediate Nodes

- The objects being stored should not be concerned with the details of the data structure in which they may be stored
- For example, the `Student` class should not have to store a link to the next `Student` object in the list
- Instead, we can use a separate node class with two parts: 1) a reference to an independent object and 2) a link to the next node in the list
- The internal representation becomes a linked list of nodes

Inserting a Node

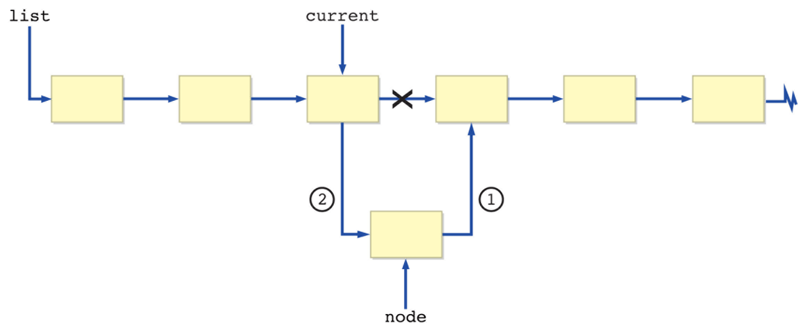
- A method called `insert` could be defined to add a node anywhere in the list, to keep it sorted, for example

- Inserting at the front of a linked list is a special case



Inserting a Node

- When inserting a node in the middle of a linked list, we must first find the spot to insert it
- Let `current` refer to the node before the spot where the new node will be inserted



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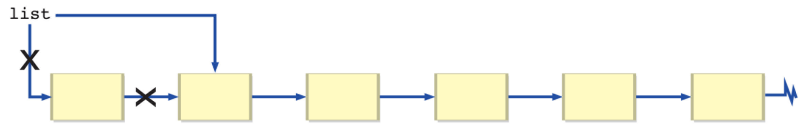
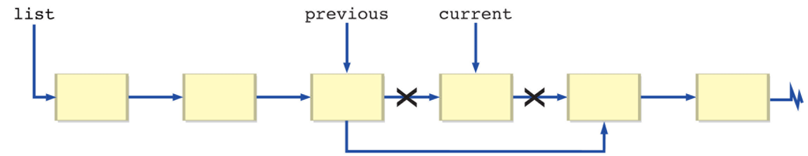
Deleting a Node

- A method called `delete` could be defined to remove a node from the list
- Again the front of the list is a special case:

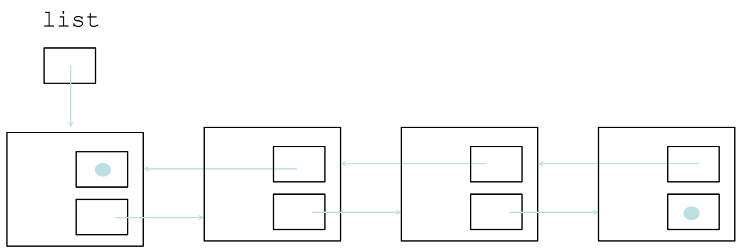


➢ Deleting from the middle of the list:



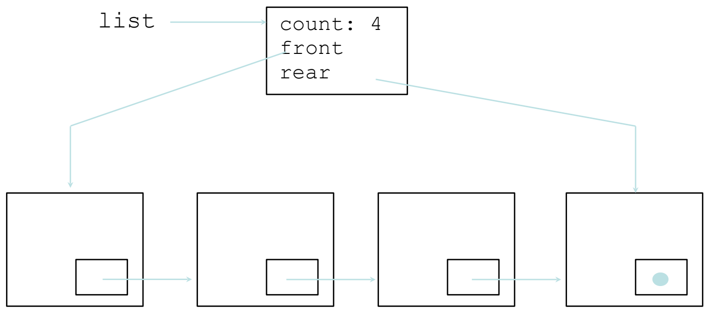
Other Dynamic List Representations

It may be convenient to implement as list as a *doubly linked list*, with `next` and `previous` references



Other Dynamic List Implementations

It may be convenient to use a separate *header node*, with a count and references to both the front and rear of the list

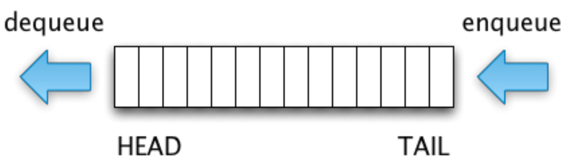


Other Dynamic List Implementations

- A linked list can be *circularly linked* in which case the last node in the list points to the first node in the list
- If the linked list is doubly linked, the first node in the list also points to the last node in the list
- The representation should facilitate the intended operations and should make them easy to implement

Queues

- A *queue* is similar to a list but adds items only to the rear of the list and removes them only from the front
- It is called a FIFO data structure: First-In, First-Out
- Analogy: a line of people at a bank teller's window



Queues

- We can define the operations for a queue
  - `enqueue()` - add an item to the rear of the queue
  - `dequeue()` - remove an item from the front of the queue
  - `isEmpty()` - returns true if the queue is empty
- Queues often are helpful in simulations or any situation in which items get "backed up" while awaiting processing
- Java provides a `Queue` interface, which the `LinkedList` class implements:

```
Queue<String> q = new LinkedList<String>();
```


public interface Queue<E> extends Collection<E>

```
public interface Queue<E> extends Collection<E> {
    boolean add(E e) เพิ่มรายการใหม่เข้าไปในคิว
    boolean offer(E e) เพิ่มรายการใหม่เข้าไปในคิว
    E element();          คืนค่าเป็นอ๊อบเจ็กต์ตัวหน้าสุดโดยไม่ลบออก
  E peek();               คืนค่าเป็นอ๊อบเจ็กต์ตัวหน้าสุดโดยไม่ลบออก
  boolean offer(E e);     ใส่รายการใหม่ e เข้าไปในคิว
  E remove();             คืนค่าเป็นอ๊อบเจ็กต์ตัวหน้าสุดและลบออก
  E poll();               คืนค่าเป็นอ๊อบเจ็กต์ตัวหน้าสุดและลบออก
}
```

	Throws exception	*Returns special value*
Insert	`add(e)`	`offer(e)`
Remove	`remove()`	`poll()`
Examine	`element()`	`peek()`

Priority Queues

- In a priority queue, some elements get to “cut in line”
- The `enqueue` and `isEmpty` operations behave the same as with normal queues
- The `dequeue` operation removes the element with the highest priority

กองซ้อน (Stacks)

- A *stack* ADT is also linear, like a list or a queue
- Items are added and removed from only one end of a stack
- It is therefore LIFO: Last-In, First-Out
- Analogies: a stack of plates in a cupboard, a stack of bills to be paid, or a stack of hay bales in a barn

Stacks

- Stacks often are drawn vertically:

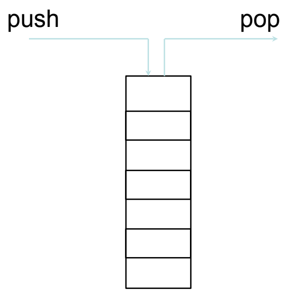


Plate Lowerator/Stacker
ภาพจาก http://www.southernhospitality.co.nz/

Stacks

- Some stack operations:
  - `push()` - add an item to the top of the stack
  - `pop()` - remove an item from the top of the stack
  - `peek()` - retrieves the top item without removing it
  - `isEmpty()` - returns true if the stack is empty
  - `search(Object o)` - Returns the 1-based position
- A stack can be represented by a singly-linked list; it doesn’t matter whether the references point from the top toward the bottom or vice versa
- A stack can be represented by an array

Stacks

- The `Stack` class is part of the Java Collections API and thus is a generic class

```
Stack<String> strStack = new Stack<String>();
```


อินเทอร์เฟส `ListIterator <E>`

- เป็น subinterface ของ `Iterator <E>` สำหรับใช้กับ LinkedList
- มีเมท็อดเพิ่มเติมจาก Iterator คือ
  - `void add(E e)` เพิ่มส่วนย่อยลงใน list ตรงตำแหน่งก่อนที่จะเรียกเมท็อด `next()`
  - `boolean hasPrevious()` มีตัวที่มาก่อนหน้าหรือไม่
  - `E previous()` เดินถอยหลัง 1 ตำแหน่งแล้วคืนค่าเป็นอ๊อบเจ๊กต์ ณ ตำแหน่งนั้น
  - `void remove()` ลบส่วนย่อยตัวล่าสุดที่ได้จากการเรียกเมท็อด `next()` หรือ `previous` ออกจาก list
  - `void set(E e)` นำส่วนย่อย e เข้าแทนที่ตำแหน่งส่วนย่อยตัวล่าสุดที่ได้จากการเรียกเมท็อด `next()` หรือ `previous()`
  - `int nextIndex()` คืนค่าเป็น index ของส่วนย่อยที่จะได้จากการเรียกเมท็อด `next()` ในลำดับถัดไป
  - `int previousIndex()` คืนค่าเป็น index ของส่วนย่อยที่จะได้จากการเรียกเมท็อด `previous()` ในลำดับถัดไป