Collection

- Programs represent and manipulate abstractions (chunks of information)
  - Examples: roster of students, deck of cards, a Tetromino

- One of the most universal abstractions is a collection
  - Represents an aggregation of multiple objects
  - Plus, perhaps, a relation between elements
  - Examples: list, set, ordered set, map, array, tree
  - Supporting different operations
Data Structures

Data structure
- A way of representing & storing information

Choice of data structure affects
- Abstractions supported
- Amount of storage required
- Which operations can be efficiently performed

Collections may be implemented using many different data structures
Graph Abstractions

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

- **Undirected graph**
  - Undirected edges

- **Directed graph**
  - Directed edges

- **Directed acyclic graph (DAG)**
  - Directed edges, no cycles
Tree abstractions

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

- **Forest**
  - DAG, but each node has at most one edge to it (from a parent)

- **Tree**
  - Forest with only one node (the root) that doesn’t have a parent

- **Binary Tree**
  - A tree where each node has at most 2 children
Sequence Abstractions

One-to-one relationship between elements

- Each element has unique predecessor
- Each element has unique successor
Sequences or Ordered Collections

List

- A sequence of elements
- The user of this interface has precise control over where in the list each element is inserted.
- The user can access elements by their integer index (position in the list), and search for elements in the list.
Limited Sequences

Queue
- Can add only at the tail
- Can only access or remove at the head
- First-in, First-out (FIFO)

Stack
- Can add only at the top
- Can only access or remove at the top
- Last-in, First-out (LIFO)

Deque: double ended queue
- Can add, access or remove at either end
Set Data Structures

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

Set A
Set B
Set C
Set Abstractions

- **Set**
  - E.g., \{Mitt, Mike, John, Ron\}

- **Map**
  - Like a set, but each element in the set is mapped to a value
  - E.g., \{Mitt=280, Mike=243, John=843, Ron=14\}

- **SortedSet**
  - Elements must be comparable, or a comparator must be provided
  - Elements can be accessed in order
Abstraction Taxonomy

Classification scheme for data structures
- Based on relationships between elements

<table>
<thead>
<tr>
<th>Category</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graph</td>
<td>many (\Rightarrow) many</td>
</tr>
<tr>
<td>Hierarchical</td>
<td>one (\Rightarrow) many</td>
</tr>
<tr>
<td>Linear</td>
<td>one (\Rightarrow) one</td>
</tr>
<tr>
<td>Set</td>
<td>no explicit relationship</td>
</tr>
</tbody>
</table>
Desert Island Abstraction

If you could have only one abstraction with you on a desert island...

Graph is the most general
- Can represent any of the other abstractions
  - E.g., A set is a graph with no edges

But more specific abstractions have advantages
- Some things are unique and well defined (e.g., first element)
- Implementations for more specific abstractions can support more efficient operations
Java Collection Framework (JCF)

Java provides several interfaces and classes for manipulating & organizing data
- Example: List, Set, Map interfaces

Java Collection Framework consists of
- Interfaces
  - Abstract data types
- Implementations
  - Reusable data structures
- Algorithms
  - Reusable functionality
Collection Hierarchy

- **Colors**
  - Interface (red)
  - Class (black)
Collection Interface

Core operations
- Add element
- Remove element
- Determine size (# of elements)
- Iterate through all elements

Additional operations supported by some collections
- Find first element
- Find k\text{th} element
- Find largest element
- Sort elements
Collection vs. Collections

- **Collection**
  - **Interface**
  - Root interface of collection hierarchy
  - Methods: `add()`, `contains()`, `remove()`, `size()`

- **Collections**
  - **Class**
  - Contains static methods that operate on collections
  - Methods: `shuffle()`, `copy()`, `list()`