Data Structures and Algorithms

Welcome!

Today’s Plan

- Abstract Data Type
  - Stack
  - List
  - Queue
- Inheritance

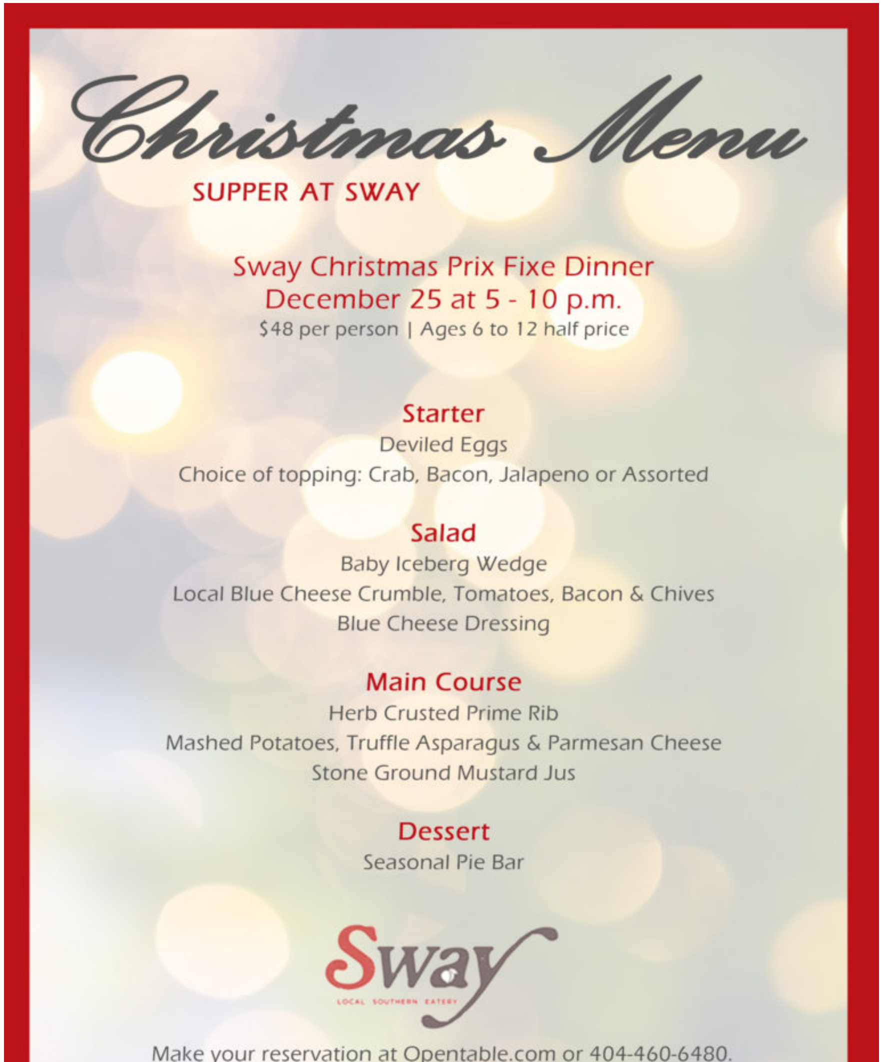
How do you decide what to cook?

- See what ingredient you have in your fridge
- See what can you cook
- Look up some recipes
- Modify/improvise during cooking

Result

How does a 5-stars hotel decides

- The Christmas Dinner Menu?



Christmas Menu

SUPPER AT SWAY

Sway Christmas Prix Fixe Dinner
December 25 at 5 - 10 p.m.
$48 per person | Ages 6 to 12 half price

Starter
Deviled Eggs
Choice of topping: Crab, Bacon, Jalapeno or Assorted

Salad
Baby Iceberg Wedge
Local Blue Cheese Crumble, Tomatoes, Bacon & Chives
Blue Cheese Dressing

Main Course
Herb Crusted Prime Rib
Mashed Potatoes, Truffle Asparagus & Parmesan Cheese
Stone Ground Mustard Jus

Dessert
Seasonal Pie Bar

Sway
LOCAL SOUTHERN EATERY

Make your reservation at Opentable.com or 404-460-6480.

How does a 5-stars hotel decides

- The Christmas Dinner Menu?
  - They decide what will be on the menu first
  - Then they find the
    - recipe
    - ingredient
    - cook
- And usually the manager who design the menu
  - Doesn't care too much about how to buy the ingredient, where to find the cook, how is the food cooked

Difference

- How hotel decides what’s on the menu
  - Design what is the outcome first

What customers will get

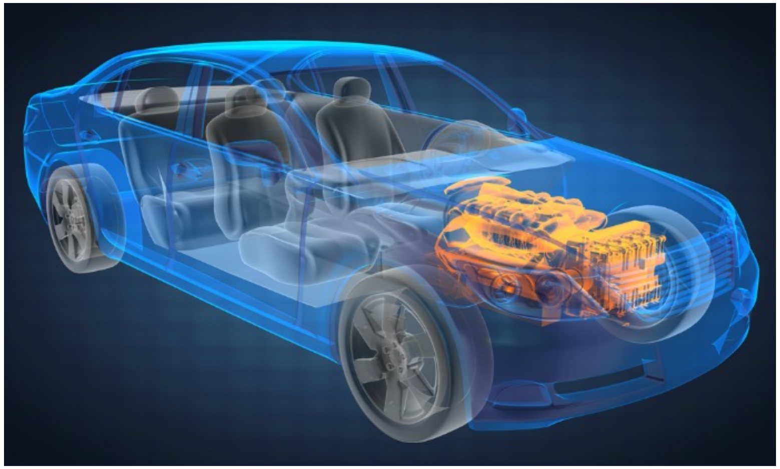
- How we cook
  - See what can you cook
  - Look up some recipes
  - what ingredient in the fridge
  - Modify/improvise during cooking

Implementation

Cars

- Interface

- Implementation



Abstract Data Types

- Interface/behavior
  - How the others use/communicate with it

- Implementation
  - The details of how you implement it

Abstract Data Types: Symbol Table

- Interface/behavior

```
   void  insert(Key k, Value v)  insert (k,v) into table
  Value  search(Key k)           get value paired with k
   void  delete(Key k)           remove key k (and value)
boolean  contains(Key k)         is there a value for k?
    int  size()                  number of (k,v) pairs
```

- Implementation
  - Use Linked List? Hash Tables? Trees?

Abstract Data Types

Specification:

- Interface
- Behavior

Implementation:

- Algorithm
- State

The Turk

- Our story starts in the year 1770 in the Kingdom of Hungary within the Habsburg Empire. There, Wolfgang von Kempelen is building a machine capable of playing the game of chess. His plan is to compete against the best chess players of the time.
- With his machine finished, he impresses the court of Maria Theresa of Austria. Kempelen and his chess playing automaton are quickly becoming famous, defeating most of their opponents during demonstrations around Europe. The audience includes statesmen such as Napoleon Bonaparte and Benjamin Franklin.

The Turk

- The machine, seemingly operated by a torso and head dressed in Turkish robes was, in fact, a mechanical illusion. It was controlled by a human operator hidden inside. The Turk was a very elaborate parlor trick. A hoax, designed to make others think they are competing against a real machine. The secret was fully revealed only in 1850

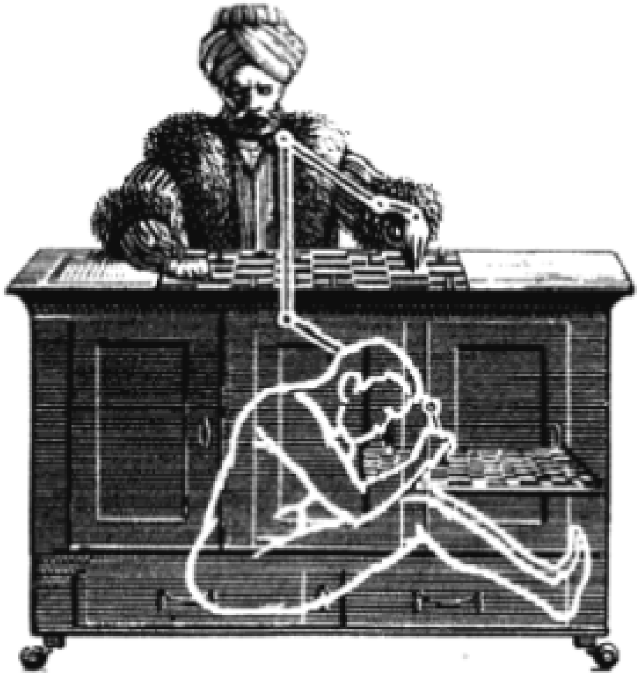


Plate 1.

The Turk

- Ever since we use the term *"Mechanical Turk"* for a system that appears to be autonomous but in fact, it needs a human aid to operate

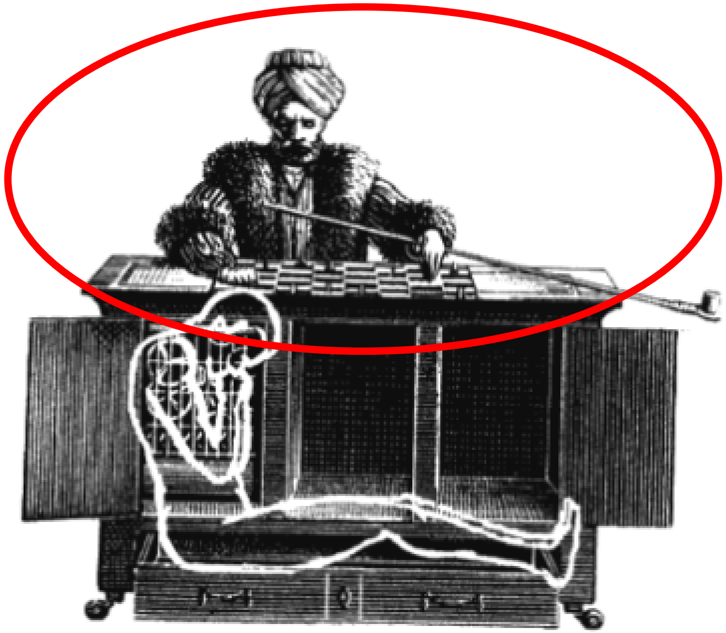


Plate 3.

- So this "Turk machine" is only an interface!

Abstract Data Types

Stack

Interface:

- void push(element x)
- element pop()

Behavior: (LIFO: last-in, first-out)

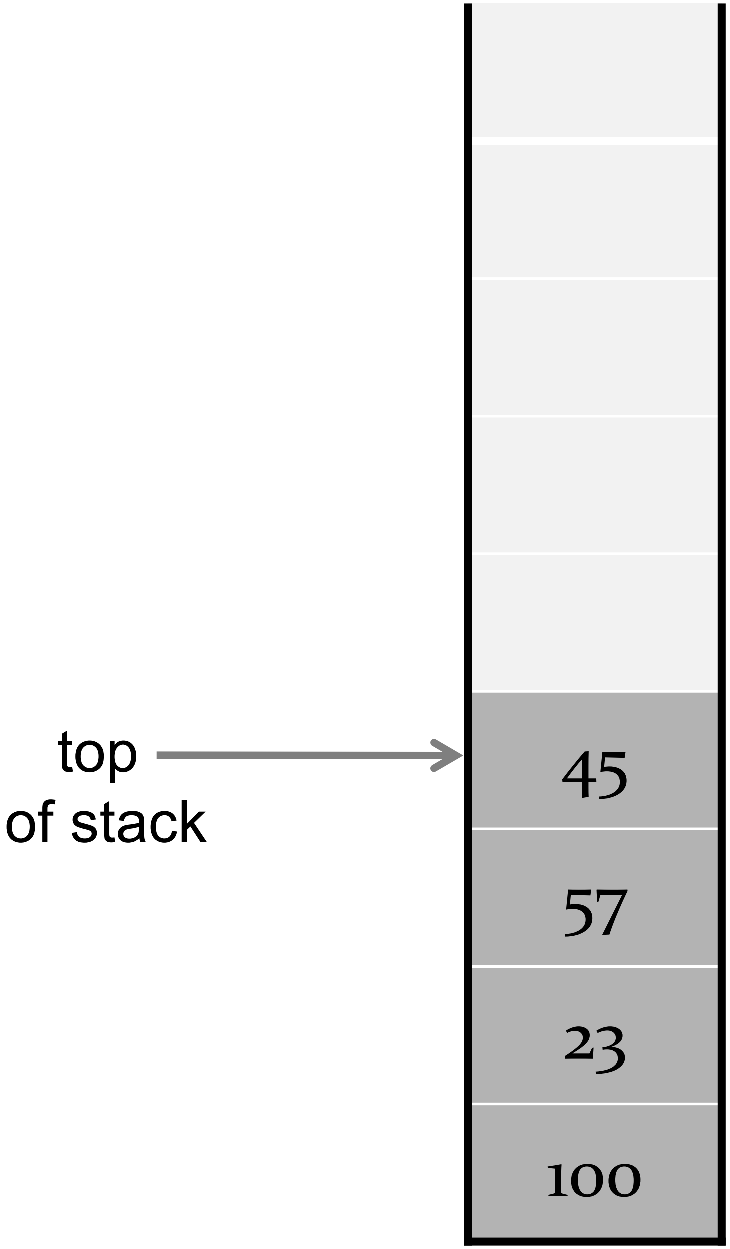
- push(x) : adds element x to the stack
- pop() : removes the mostly recently added element and returns it

Abstract Data Types

Stack

Interface:

- void push(element x)
- element pop()
- empty()

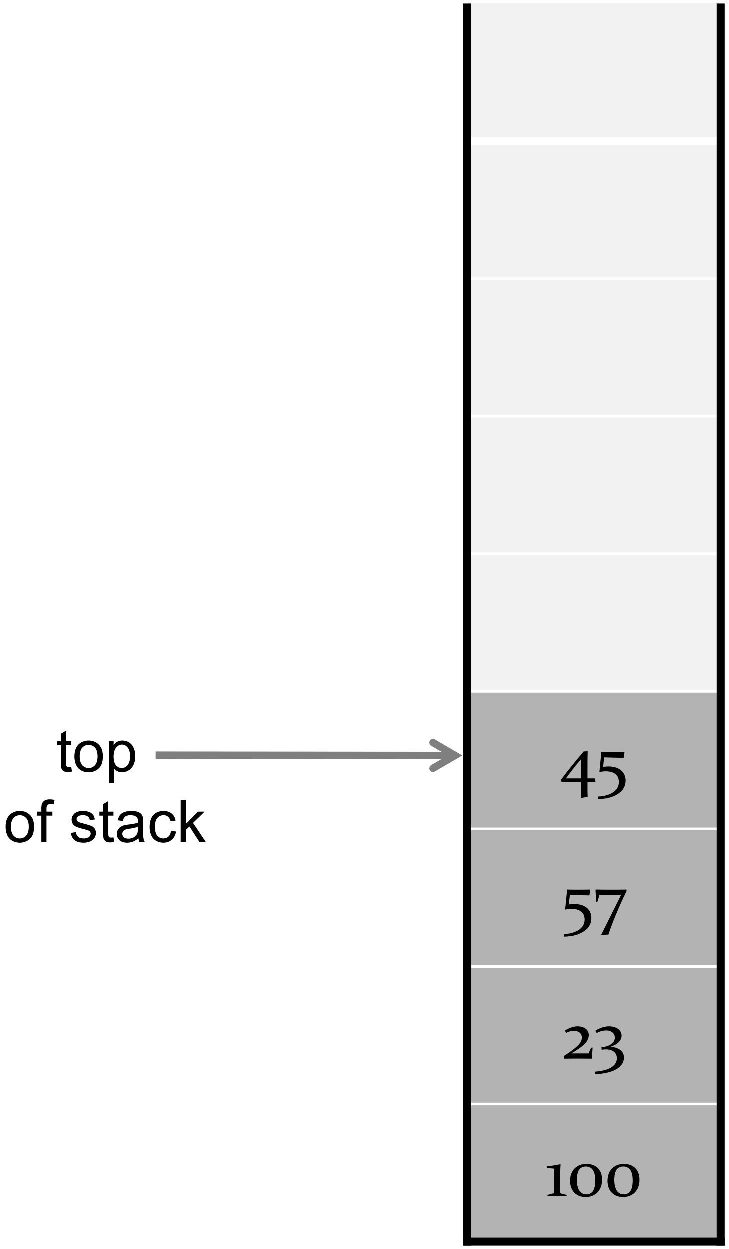


Abstract Data Types

Stack

Execution:

- push(77)

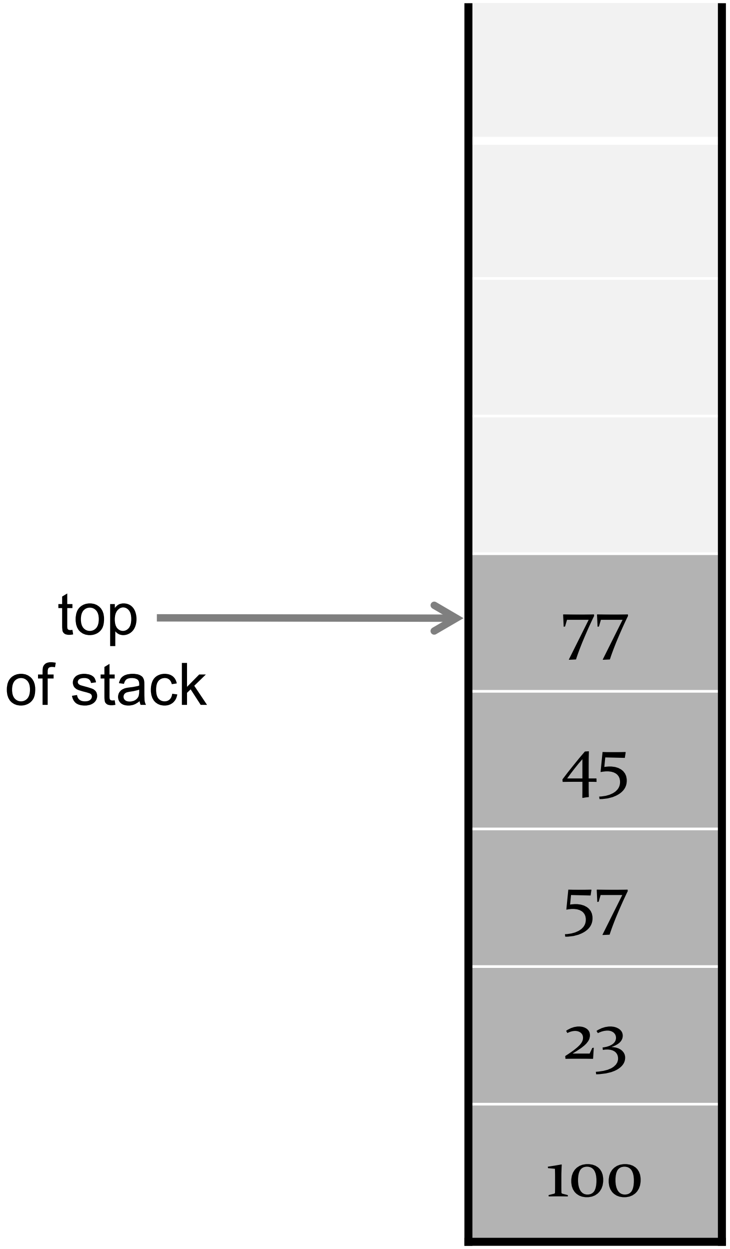


Abstract Data Types

Stack

Execution:

- push(77)

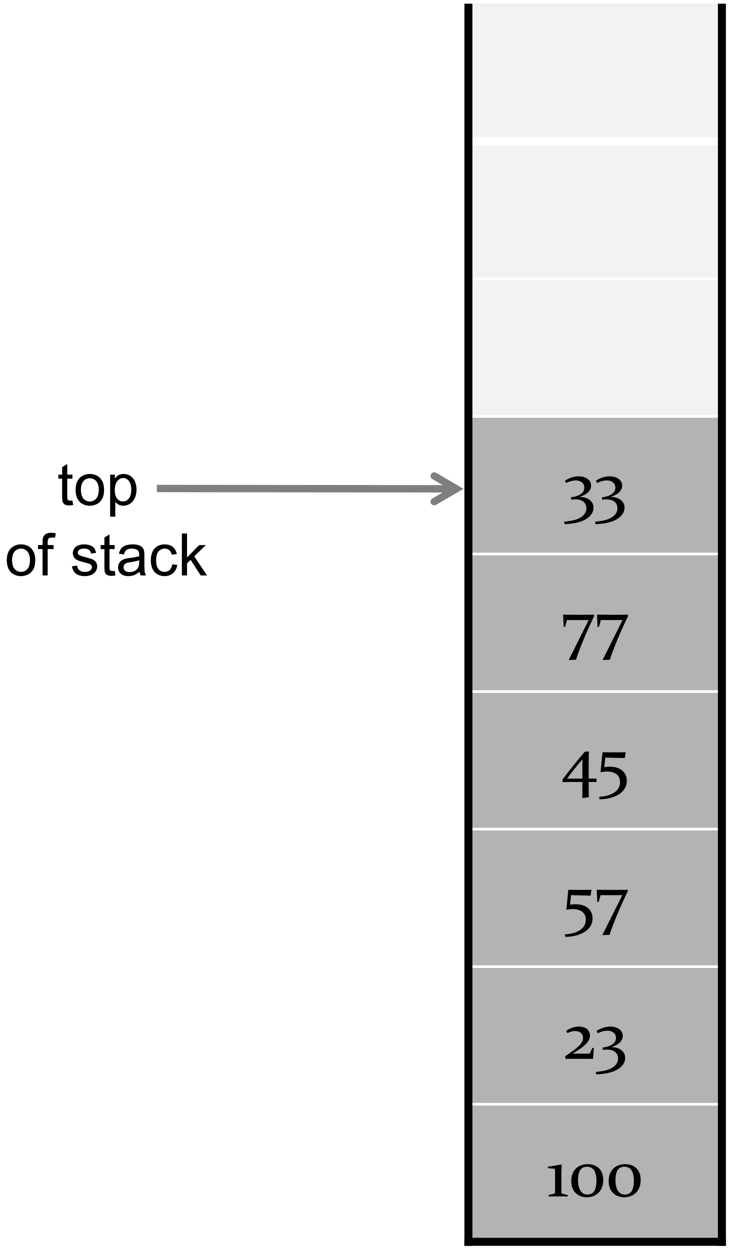


Abstract Data Types

Stack

Execution:

- push(77)
- push(33)

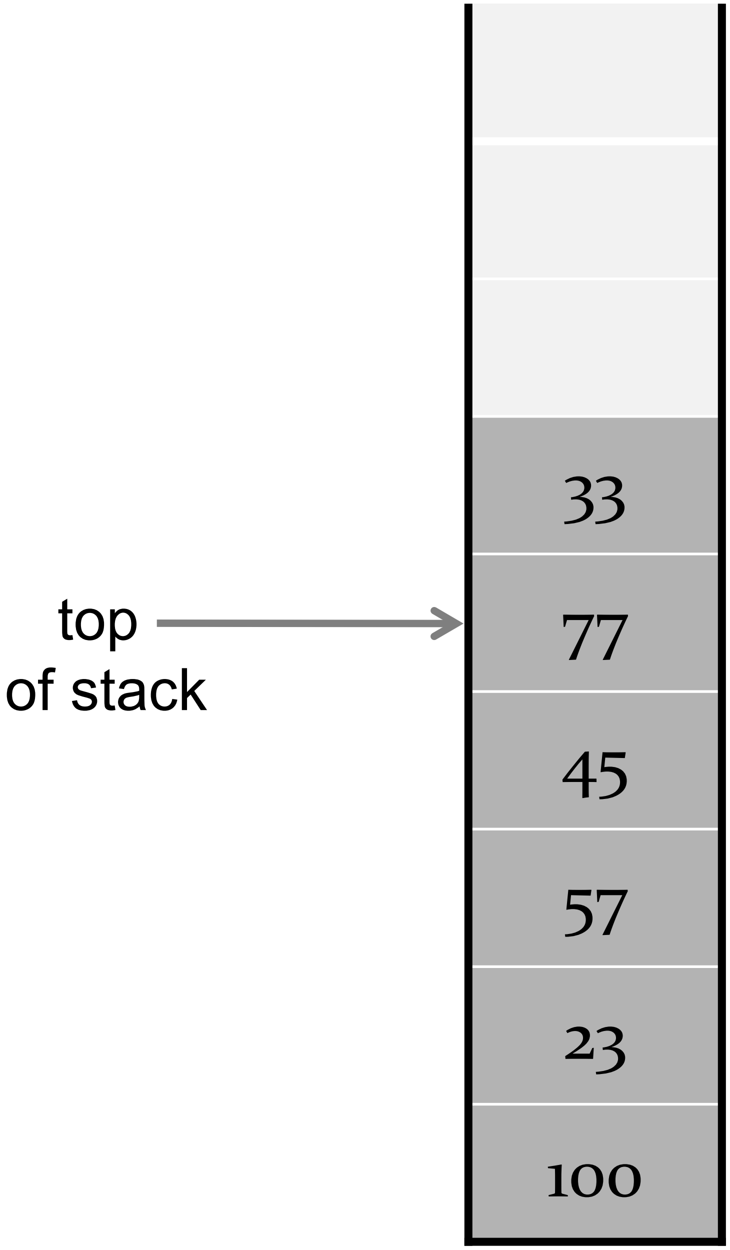


Abstract Data Types

Stack

Execution:

- push(77)
- push(33)
- pop() → ??

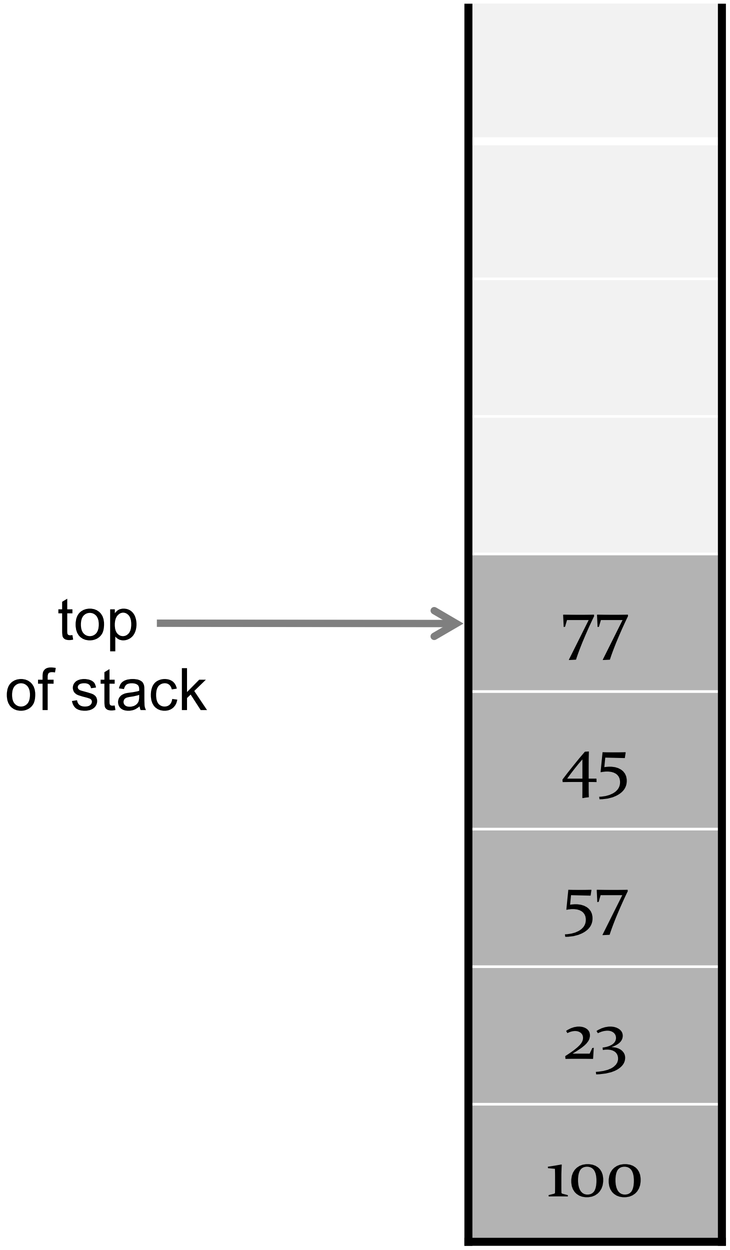


Abstract Data Types

Stack

Execution:

- push(77)
- push(33)
- pop() → 33

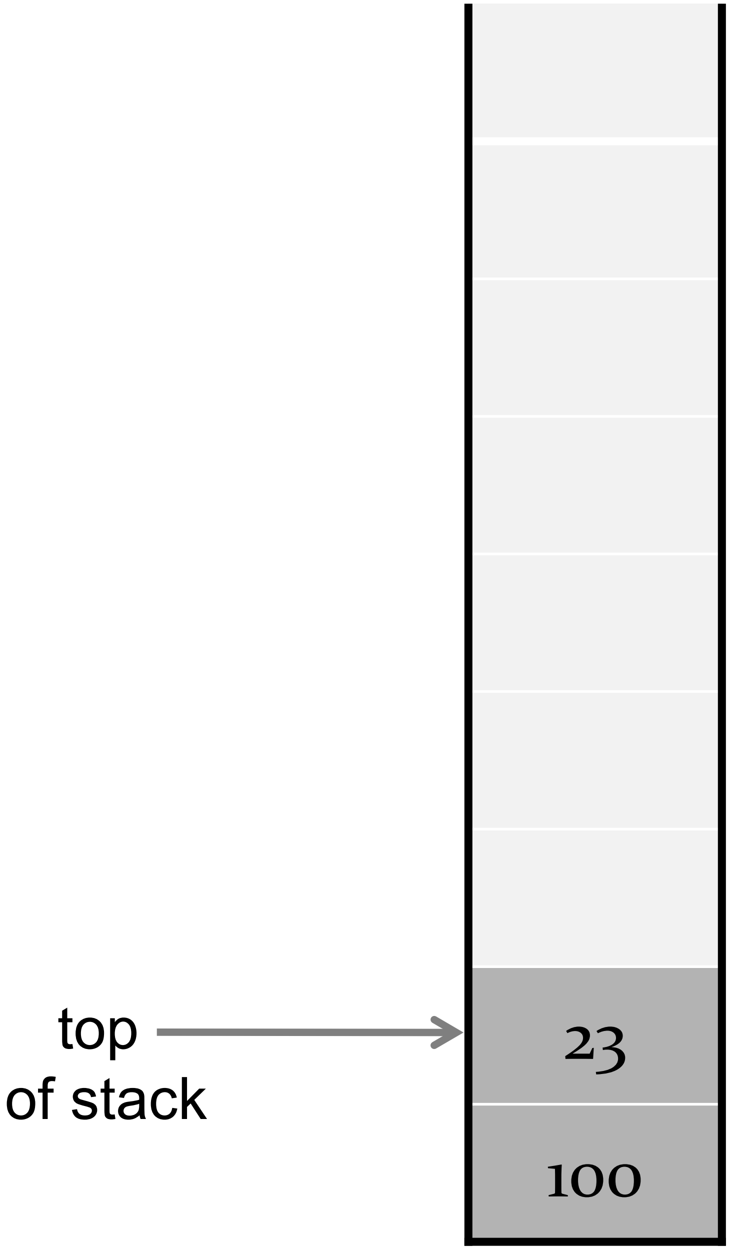


Abstract Data Types

Stack

Execution:

- push(77)
- push(33)
- pop() → 33
- pop() → 77
- pop() → 45
- pop() → 57

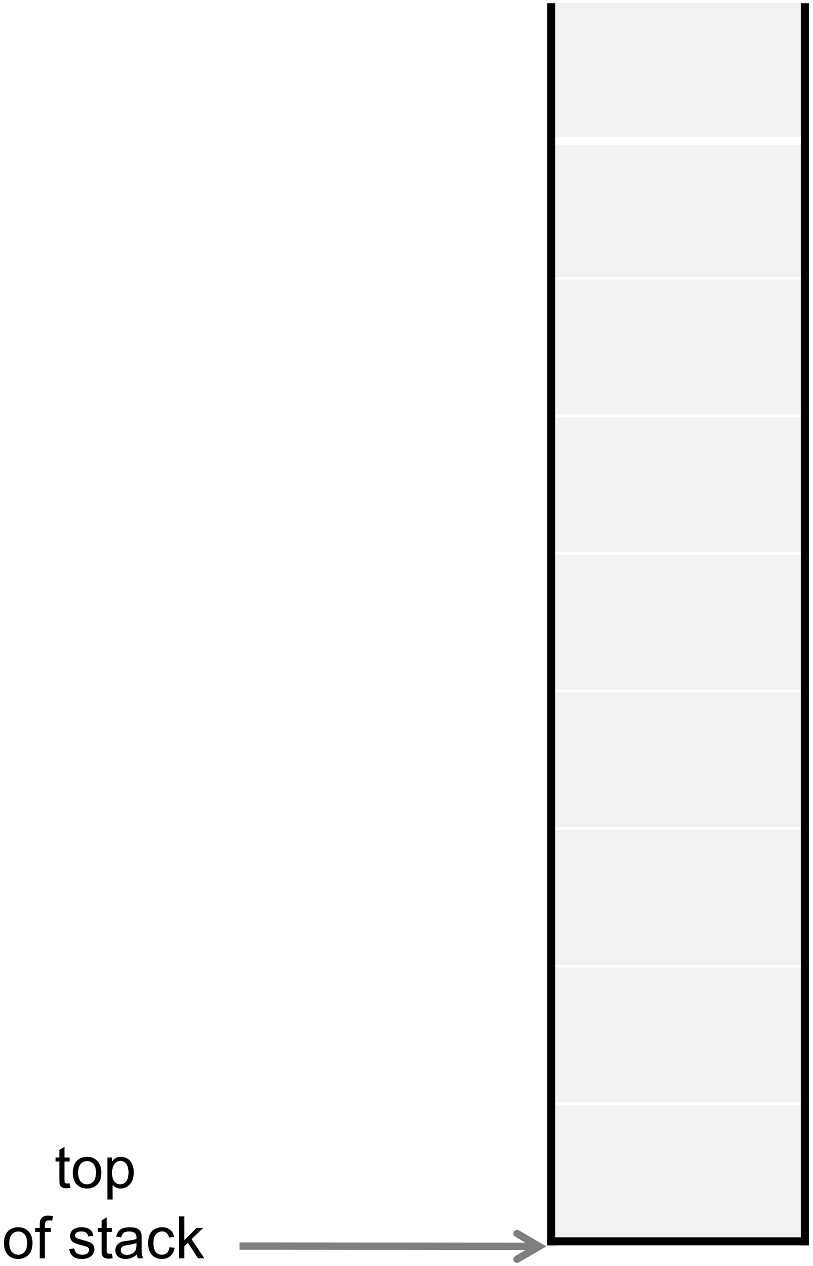


Abstract Data Types

Stack

Execution:

- pop() → 23
- pop() → 100

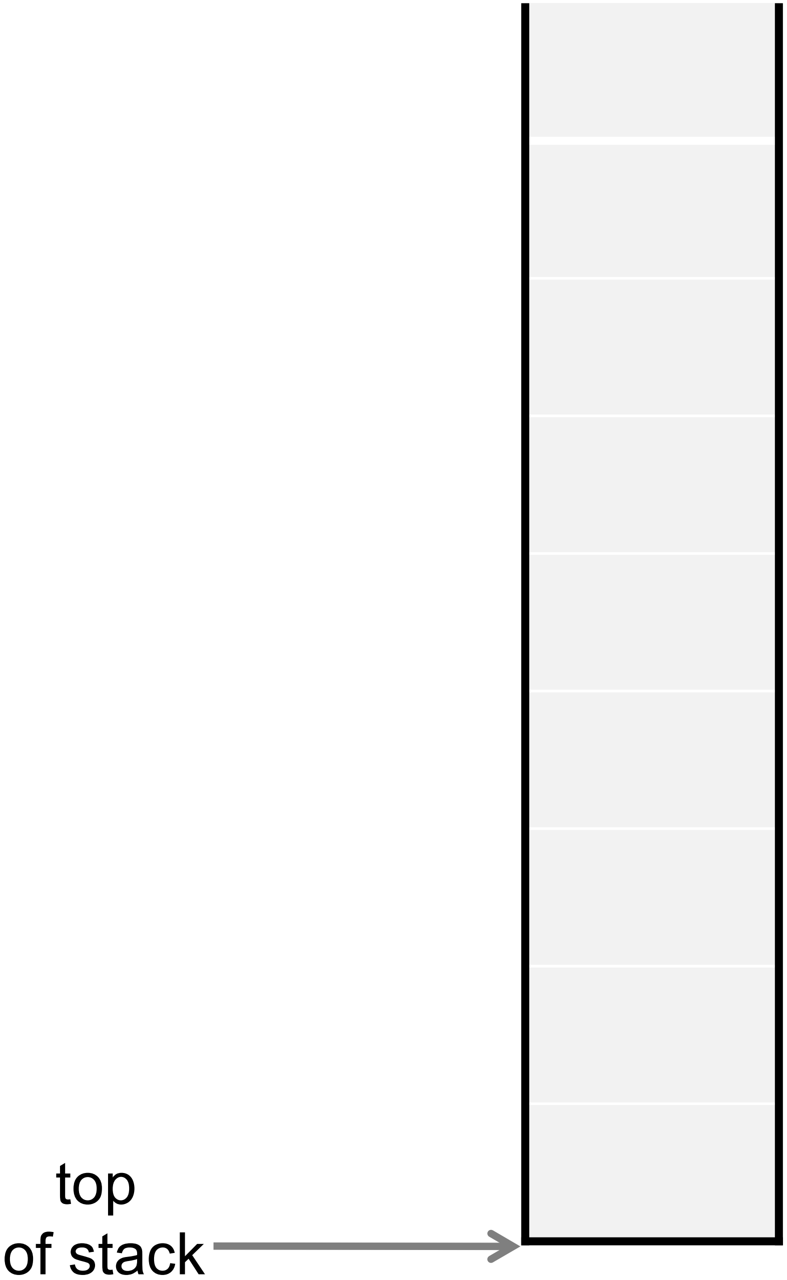


Abstract Data Types

Stack

Execution:

- pop() → 23
- pop() → 100
- pop() → ??



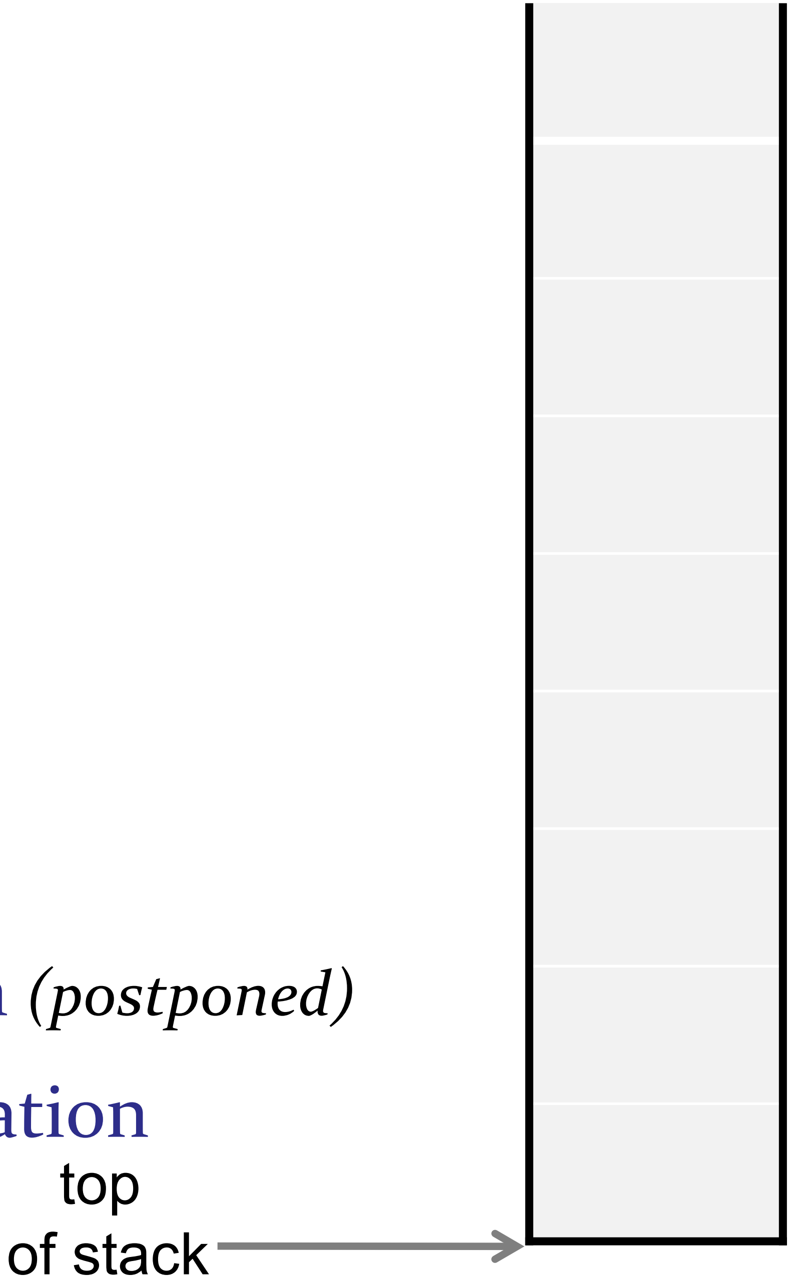
Abstract Data Types

Stack

Execution:

- pop() → 23
- pop() → 100
- pop() → ??

- Error!
  - Option 1: throw exception *(postponed)*
  - Option 2: modify specification

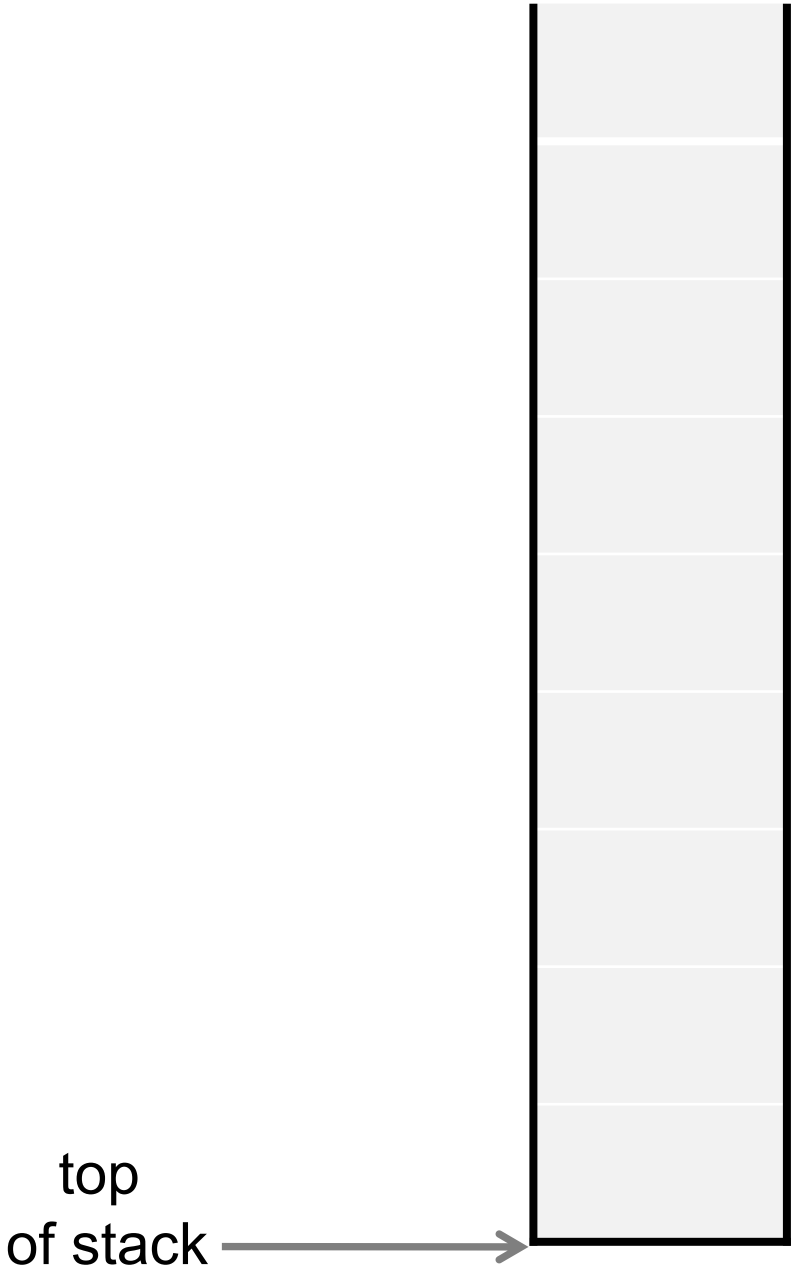


Abstract Data Types

Stack

Execution:

- pop() → 23
- pop() → 100
- empty() → true



Implementation of an ADT

- How do you implement a Stack?
- Hint:
  - The skeleton code for Assignments 1 and 2 are almost done for a stack!

Implementation of the ADT Stack

- Any idea?

```
template <class T>
class Stack {
private:
  List<T> _ll;

public:
  void push(T x);
  T pop();
  bool isEmpty();
};
```

Implementation of the ADT Stack

- Any idea?

```
template <class T>
void Stack<T>::push(T x) {
  _ll.insertHead(x);
}

template <class T>
T Stack<T>::pop() {
  T item = _ll.headItem();
  _ll.removeHead();
  return item;
}
```

Abstract Data Types

Queue

Interface:

- void enqueue(element x)
- element dequeue()

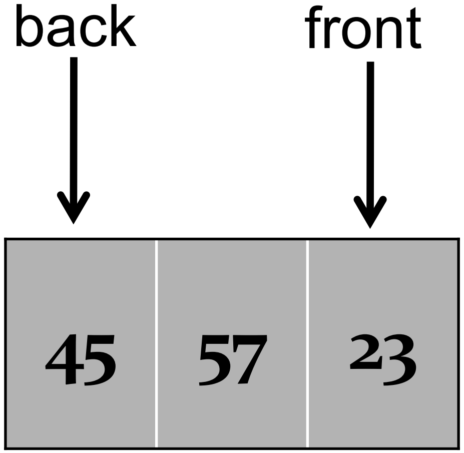
Behavior: (FIFO: first-in, first-out)

- enqueue(x) : adds element x to the front of the queue
- dequeue() : removes and returns element at the end of the queue

Abstract Data Types

Queue

Execution:

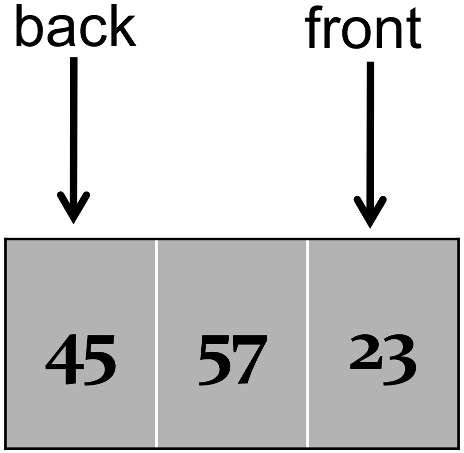


Abstract Data Types

Queue

Execution:

- enqueue(7)

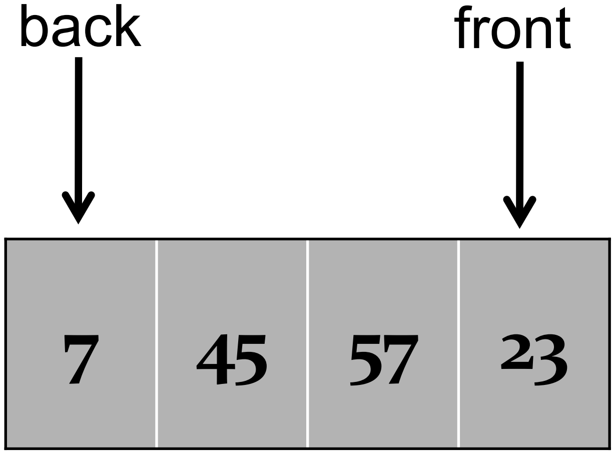


Abstract Data Types

Queue

Execution:

- enqueue(7)



back

front

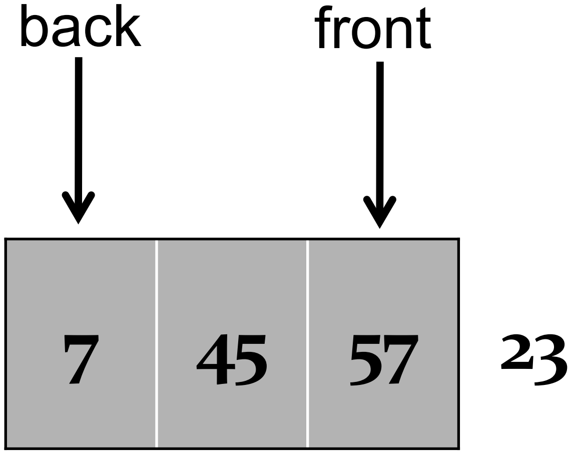
7	45	57	23

Abstract Data Types

Queue

Execution:

- enqueue(7)
- dequeue() → 23



Implementation of ADT Queue?

- Let you think about it

Which abstract data type appears most frequently in practice?

a. Lists

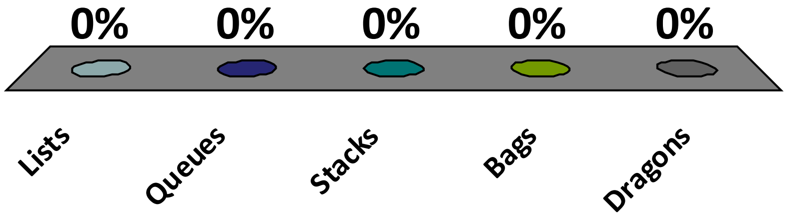
b. Queues

[✓ c. Stacks]

d. Bags

e. Dragons

Response Counter

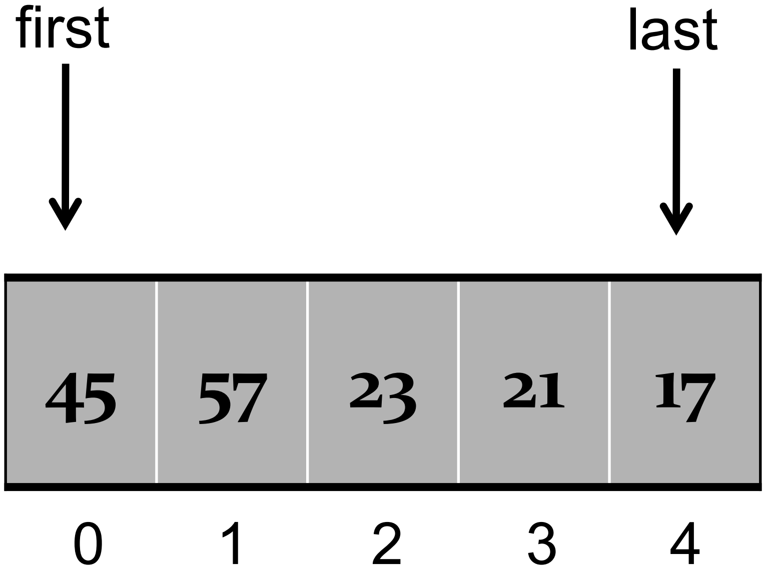


Abstract Data Types

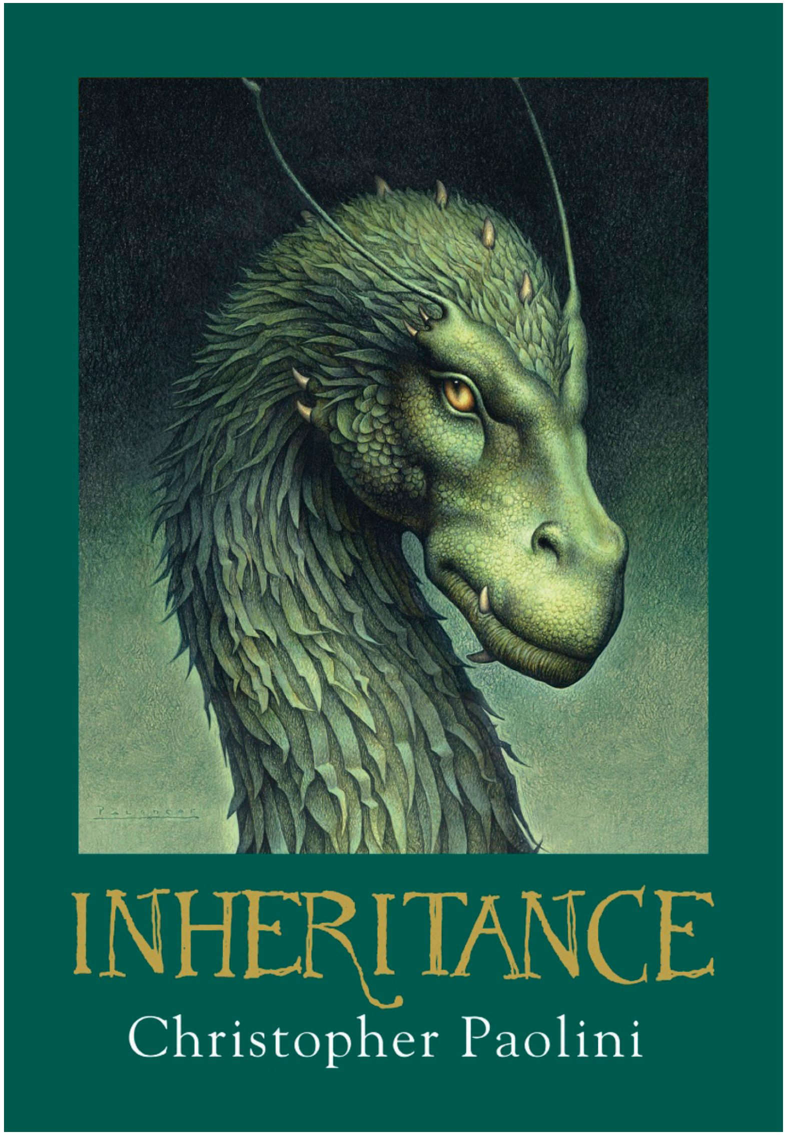
List

Interface:

```
void append(int x)
void prepend(int x)
void put(int x, int slot)
void remove(int x)
int getFirst()
int getLast()
int get(int slot)
boolean isEmpty()
```



Inheritance



Building a better stack

What if I want to build a better stack?

- Add functionality
- Improve efficiency
- Or I just want the computer to play a “bee” sound when something is pushed and a “do” sound when something is popped.....
- But someone thinks that’s annoying and wants to use the original stack..

Building a better stack

What if I want to build a better stack?

- Add functionality
- Improve efficiency

Solutions:

- Implement from scratch
- Modify original class
- Copy-paste old code to new class

Building a better stack

What if I want to build a better stack?

- Option 1: implement stack **again**

```
template <class T>
class BeeBooStack {
  // implement everything again
}
```

- Useful when:

  Entirely new implementation (e.g., don’t use an array, use fractional cascading on a buffered tree).

Building a better stack

Inheritance

- BeeBooStack is a subclass (child) of Stack
- Stack is the superclass(parent) of BeeBooStack

```
template <class T>
class BeeBooStack:public Stack<T> {

public:
  void push(T);
  T pop();

};
```

Building a better stack

Inheritance

- Subclass has all the functionality of the parent!

```
BeeBooStack<Food> s_food;

if (s_food.isEmpty())
  cout << "I am hungry" << endl;
```

Building a better stack

Inheritance

- Subclass can override parent class

```
template <class T>
class BeeBooStack:public Stack<T> {

public:
  void push(T);
  T pop();

};
```

Building a better stack

Inheritance

- Subclass can override parent class

```
template <class T>
void BeeBooStack<T>::push(T x) {
  cout << "Bee" << endl;
  Stack<T>::push(x);
}

template <class T>
T BeeBooStack<T>::pop() {
  cout << "Boo" << endl;
  return Stack<T>::pop();
}
```

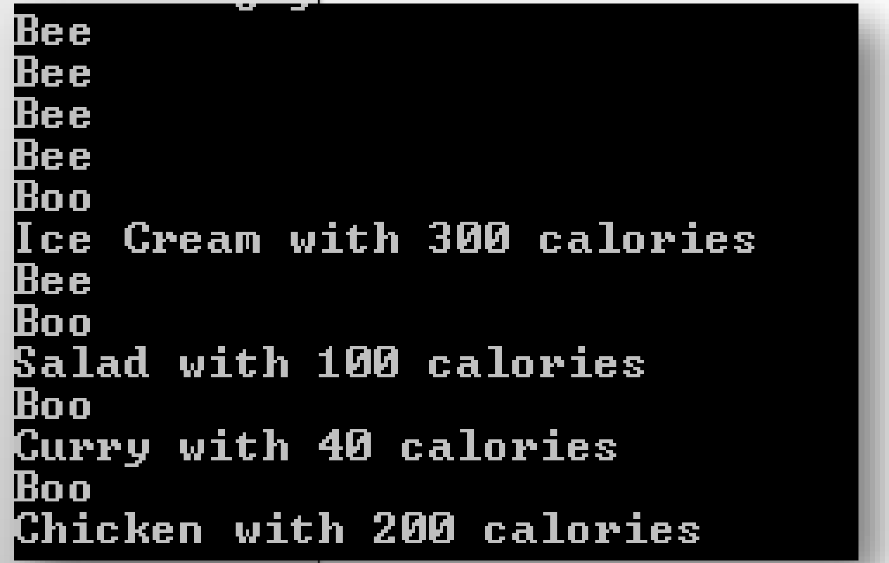
Building a better stack

Inheritance

- Subclass can override parent class

```
BeeBooStack<Food> s_food;
Food food1("Salad", 100);
Food food2("Chicken", 200);
Food food3("Curry", 40);
Food food4("Ice Cream", 300);

s_food.push(food1);
s_food.push(food2);
s_food.push(food3);
s_food.push(food4);
cout << s_food.pop() << endl;
s_food.push(food1);
cout << s_food.pop() << endl;
cout << s_food.pop() << endl;
cout << s_food.pop() << endl;
```



```
Bee
Bee
Bee
Bee
Boo
Ice Cream with 300 calories
Bee
Boo
Salad with 100 calories
Boo
Curry with 40 calories
Boo
Chicken with 200 calories
```

Polymorphism

- What if

```
Stack<int> *s;

BeeBooStack<int> bbsi;

s = &bbsi;

s->push(10);
```

- Which “push” will be called?
  - Stack<int> , or
  - BeeBooStack<int> ?

Polymorphism

- What if

```
Stack<int> *s;

BeeBooStack<int> bbsi;

s = &bbsi;

s->push(10);
```

- It will call
  - `Stack<int>::push()`
- But it doesn’t make sense!?

Polymorphism

- A power technique when you make the function virtual

```
template <class T>
class Stack {

public:
  virtual void push(T x);
  virtual T pop();
  virtual bool isEmpty();

};
```

Polymorphism

```
template <class T>
class Stack {

public:
  virtual void push(T x);
  virtual T pop();
  virtual bool isEmpty();

};
```

```
Stack<int> *s;

BeeBooStack<int> bbsi;

s = &bbsi;

s->push(10);
```

- s->push(10) will call the push from BeeBooStack<int>

Polymorphism

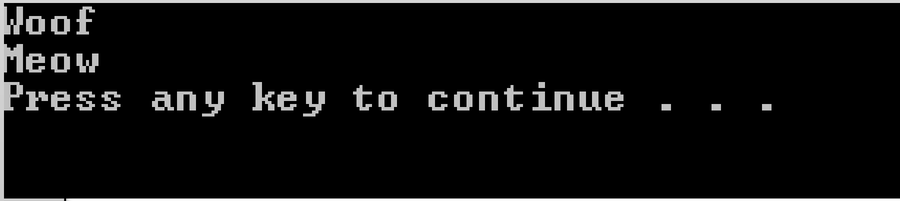
```
class Animal {
public:
  virtual void talk()
  { cout << "*Nothing*" << endl;
};

class Dog :public Animal {
public:
  virtual void talk()
  { cout << "Woof" << endl; }
};

class Cat :public  Animal {
public:
  virtual void talk()
  { cout << "Meow" << endl; }
};
```

```
Animal *dolly = new Dog();
Animal *orange = new Cat();

dolly->talk();
orange->talk();
```



```
Woof
Meow
Press any key to continue . . .
```

Polymorphism

- Another exmaple:
- Parent class: Shape
  - calArea()
  - drawOnScreen()
  - scale(x,y)
- Children classes:
  - Circle, Triangle, Rectangles, etc.

Access Control in Inheritance

- What if

```
template <class T>
T BeeBooStack<T>::pop() {

   if (_ll.empty())
      cout << "No more item to pop!" << endl;

   cout << "Boo" << endl;
   return Stack<T>::pop();
}
```

- Compilation Error!
  - `error C2248: 'Stack<Food>::_ll': cannot access private member declared in class 'Stack<Food>`

Access Control in Inheritance

- In the parent class

```
template <class T>
class Stack {
private:
  List<T> _ll;

public:
  virtual void push(T x);
  virtual T pop();
  virtual bool isEmpty();
};
```

- the variable _ll is private

Access Control in Inheritance

- Let’s face it
  - A child class cannot access the private member/method of its parent class
- But what if the child really need to access some members of the parents, that are NOT public?

```
template <class T>
class Stack {
protected:
  List<T> _ll;

public:
  virtual void push(T x);
  virtual T pop();
  virtual bool isEmpty();
};
```