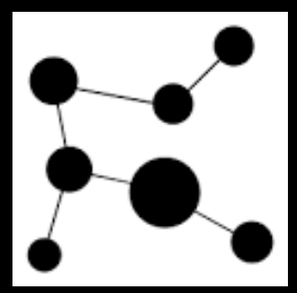
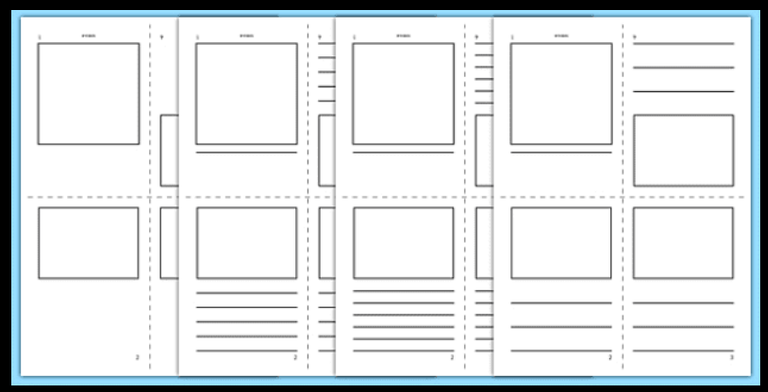
ADTs & Templates





Tiziana Ligorio
Hunter College of The City University of New York

Today's Plan

Recap

ADTs

Templates

Announcements

- git/GitHub, Unix command line, Makefile, testing and debugging local (IDE or command line) ARE A MUST, YOU CAN'T GET AWAY WITHOUT IT
  - Lookup in Course Materials/Resources on Blackboard

- Project 1 due THURSDAY 2/8

- VOE this week, no submissions on Gradescope = you get dropped from the class

Survey

- Today I have a very short survey for you to complete.
- I'm asking these questions because research in learning theory shows that the way people organize their studying affects what they learn.
- When you pay attention to your study skills, or self-regulate, your learning can improve. I'm asking you to answer these few questions now, so I can see if there are tips I can offer. Then I'll check in towards the end of the semester.
- Please think about how you study, and answer HONESTLY!

Please take this survey

bit.ly/study_skills_S24

Recap

C++ Review

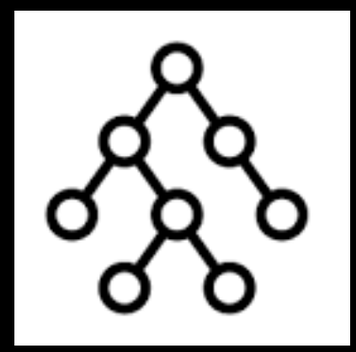
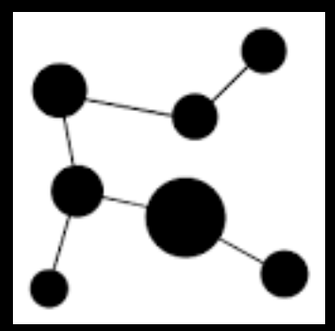
- Default arguments
- Overloading functions
- Friend functions
- Operator overloading
- Enum

Inheritance

- Overriding
- Protected
- Inheritance rules
- Constructors / Destructors call order

Abstract Data Type



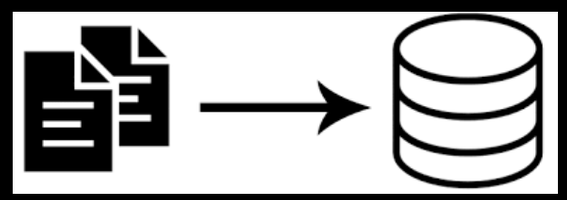
Data and Abstraction

Operations on data are central to most solutions

Think abstractly about data and its management

Typically need to

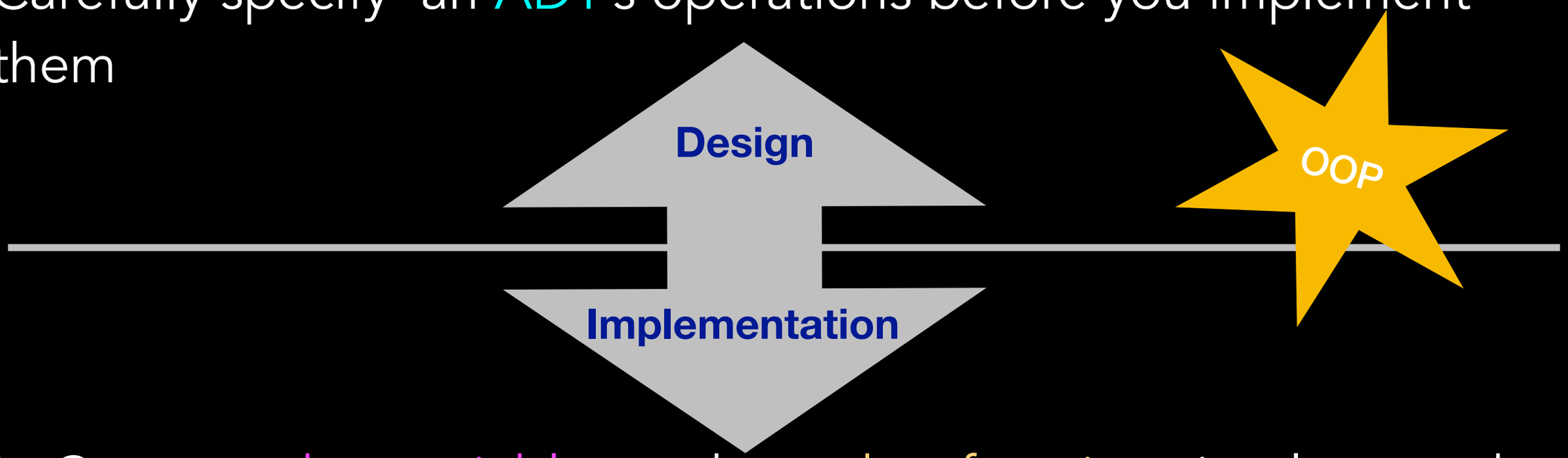
- Organize data
- Add data
- Remove data
- Retrieve
- Ask questions about data
- Modify data



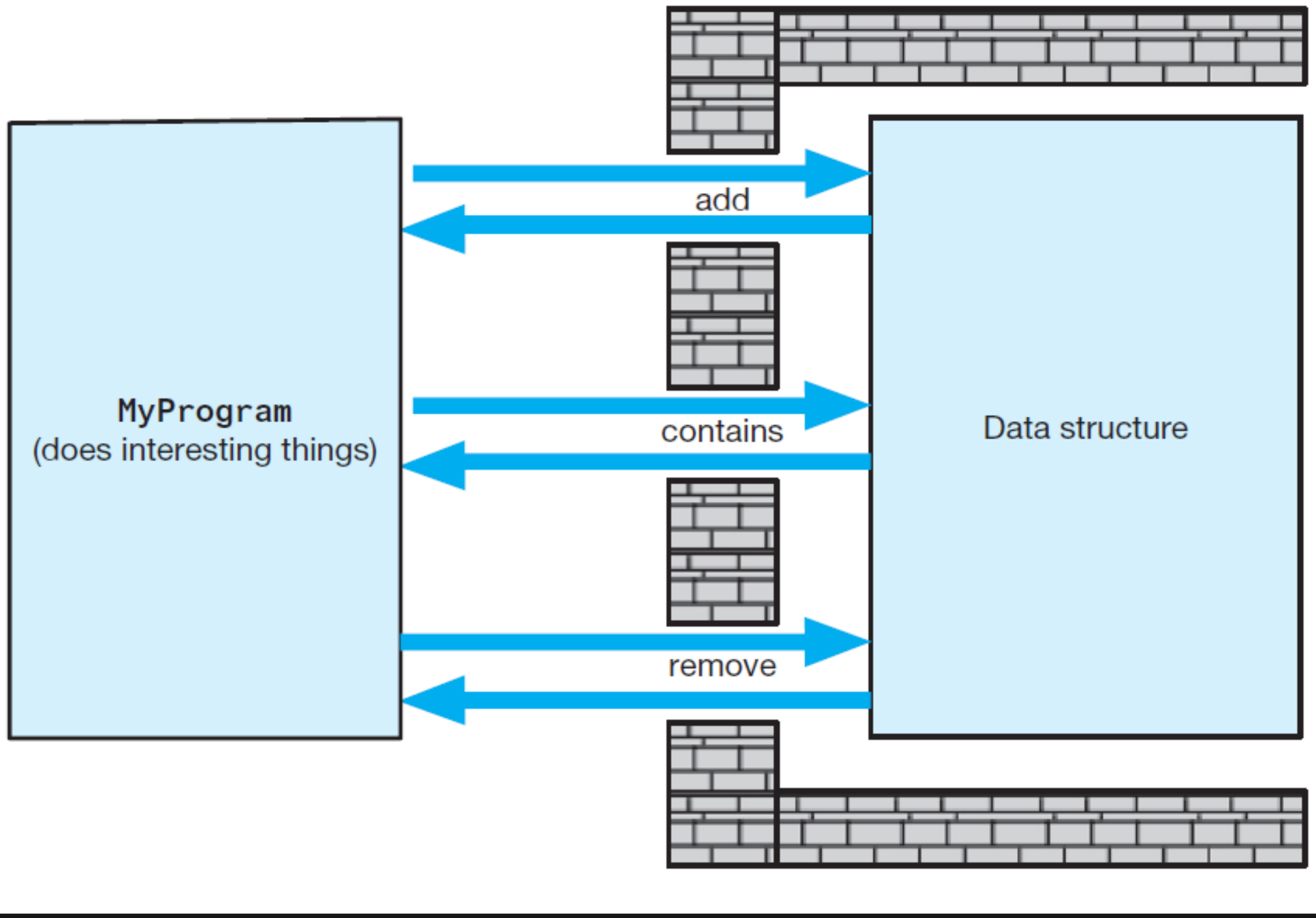
Abstract Data Type

A collection of data (container) and a set of operations on the data

Carefully specify an ADT's operations before you implement them



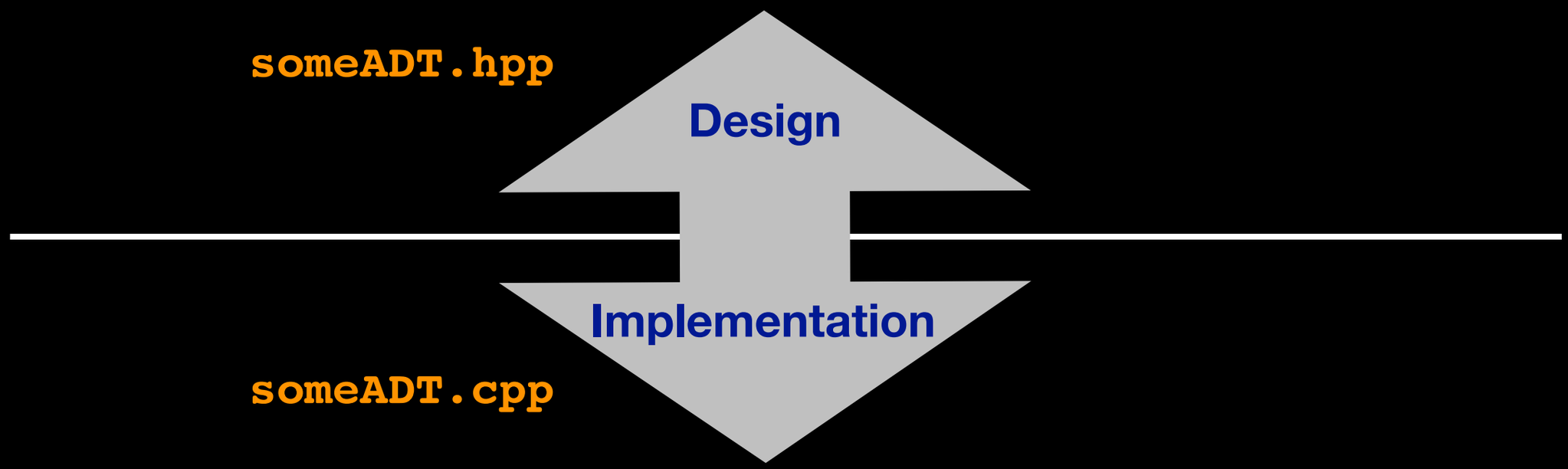
In C++ member variables and member functions implement the Abstract Data Type


MyProgram
(does interesting things)
add
contains
remove
Data structure

Class

```
class someADT
{
    access_specifier    // can be private, public or protected
    data_members        // variables used in class
    member_functions    // methods to access data members

};                      // end someClass
```



Designing an ADT

What data does the problem require?

- Data
- Organization

What operations are necessary on that data?

- Initialize
- Display
- Calculations
- Add
- Remove
- Change

Throughout the semester we will consider several ADTs

Let’s start from the simplest possible!

Design the Bag ADT

Contains things

Container or Collection of Objects

Objects are of same type

No particular order

Can contain duplicates

Design Step 1

Identify Behavior - i.e. Bag Operations:

1.
2.
3.
4.
5.
6.
...

Design step 1: Identify Behaviors

Bag Operations:

1. Add an object to the bag
2. Remove an occurrence of a specific object form the bag if it's there
3. Get the number of items currently in the bag
4. Check if the bag is empty
5. Remove all objects from the bag
6. Count the number of times a certain object is found in the bag
7. Test whether the bag contains a particular object
8. Look at all the objects that are in the bag

Specify Data and Operations

Pseudocode

```
//Task: reports the current number of objects in Bag
//Input: none
//Output: the number of objects currently in Bag
getCurrentSize()

//Task: checks whether Bag is empty
//Input: none
//Output: true or false according to whether Bag is empty
isEmpty()

//Task: adds a given object to the Bag
//Input: new_entry is an object
//Output: true or false according to whether addition succeeds
add(new_entry)

//Task: removes an object from the Bag
//Input: an_entry is an object
//Output: true or false according to whether removal succeeds
remove(an_entry)
```

Specify Data and Operations

```
//Task: removes all objects from the Bag
//Input: none
//Output: none
clear()

//Task: counts the number of times an object occurs in Bag
//Input: an_entry is an object
//Output: the int number of times an_entry occurs in Bag
getFrequencyOf(an_entry)

//Task: checks whether Bag contains a particular object
//Input: an_entry is an object
//Output: true of false according to whether an_entry is in Bag
contains(an_entry)

//Task: gets all objects in Bag
//Input: none
//Output: a vector containing all objects currently in Bag
toVector()
```

What's next?

Finalize the interface for your ADT => write the actual code

… but we have a problem!!!

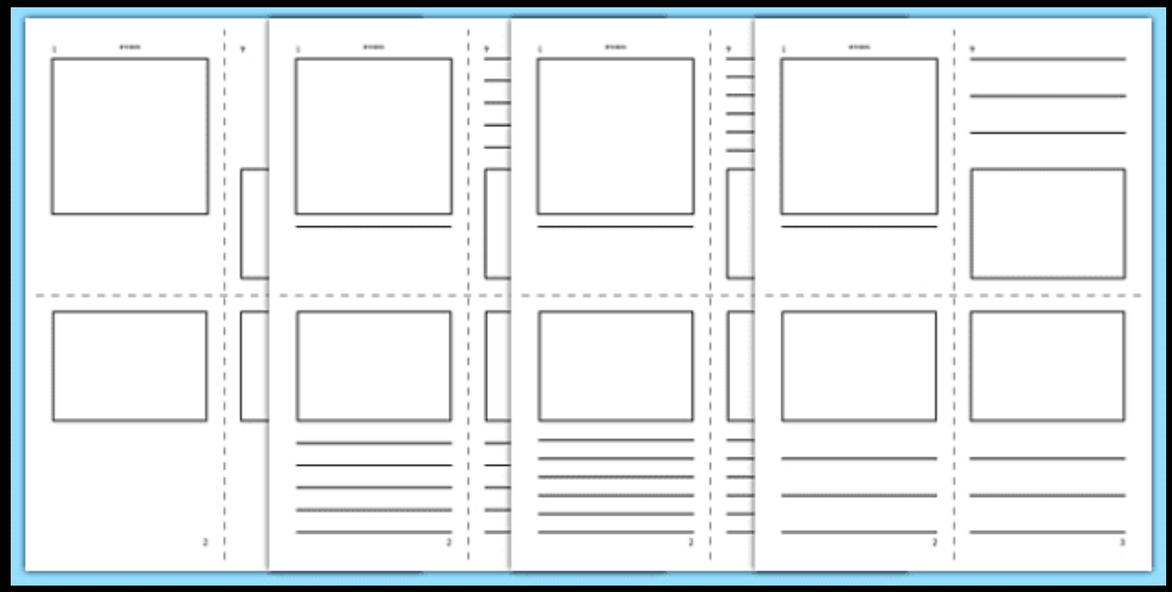
We said Bag contains objects of same type

What type?

To specify member function prototype we need to know

```
//Task: adds a given object to the Bag
//Input: new_entry is an object
//Output: true or false according to whether addition succeeds
bool add(type??? new_entry);
```

Templates



Motivation

We don’t want to write a new Bag ADT for each type of object we might want to store

Want to parameterize over some arbitrary type

Useful when implementing an ADT without locking the actual type

An example are STL containers

e.g. `vector<type>`

Vector

A container similar to a one-dimensional array

Different implementation and operations

STL (C++ Standard Template Library)

```
#include <vector>
…
std::vector<type> vector_name;

e.g.

std::vector<string> student_names;
```

Declaration

```
#ifndef BAG_H_
#define BAG_H_
template<class T> // this is a template definition
class Bag
{

    //class declaration here

};
#include “Bag.cpp”
#endif //BAG_H_
```

Explained next

Declaration

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```

The book uses `ItemType`
I’m going to change it to `T` which is often used

`class` here could be replaced by `typename`

for this course we will use `class`

Implementation

```
#include “Bag.hpp”

template<class T>
bool Bag<T>::add(const T& new_entry){
    //implementation here
}

    //more member function implementation here
```

Instantiation

```
#include “Bag.hpp”

int main()
{

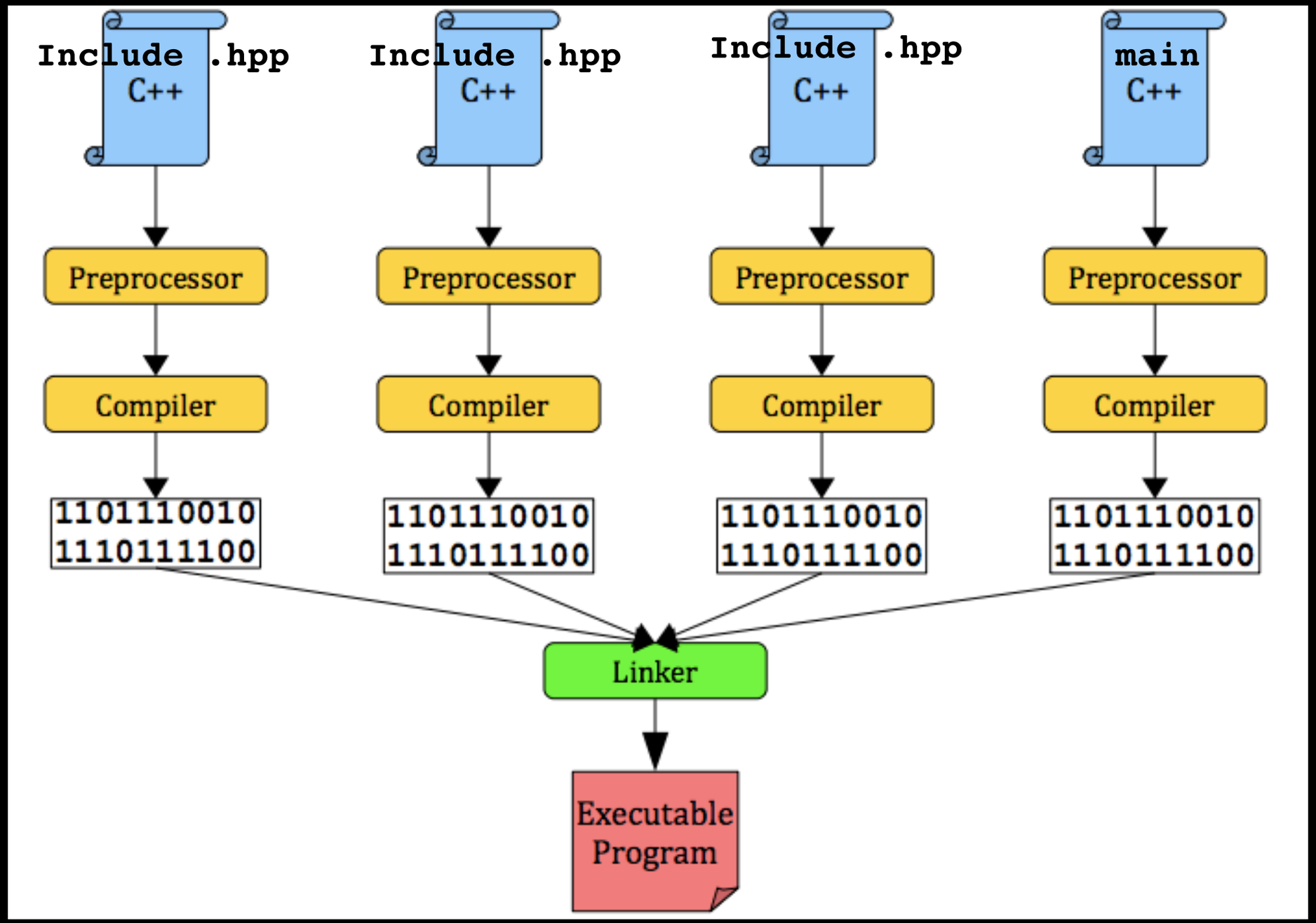
    Bag<string> string_bag;
    Bag<int> int_bag;
    Bag<someObject> some_object_bag;

    std::vector<int> numbers;
    //stuff here

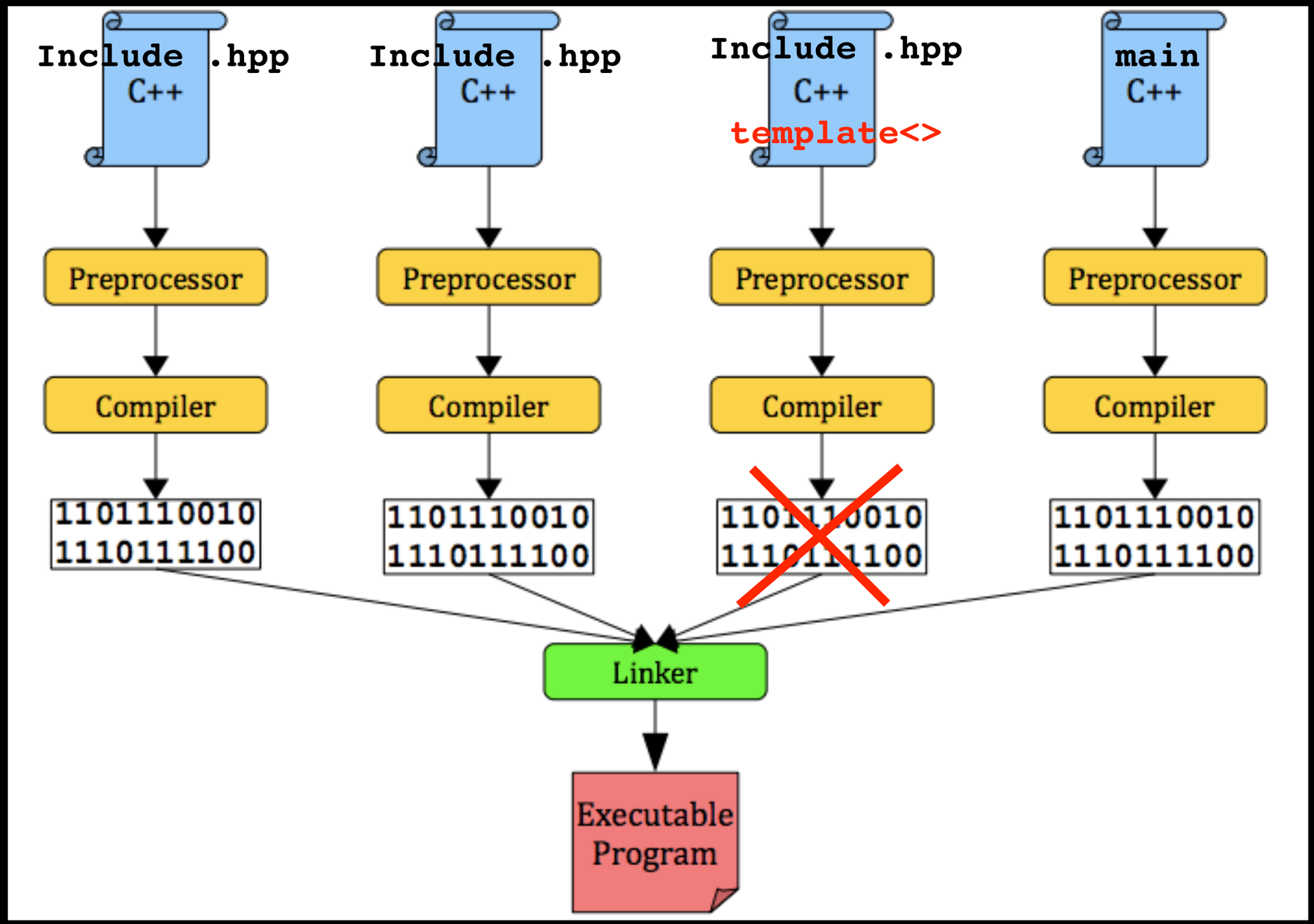
    return 0;

}; // end main
```

Separate Compilation



Linking with Templates



Linking with Templates

Always `#include` the `.cpp` file in the `.hpp` file

```
#ifndef MYTEMPLATE_H_
#define MYTEMPLATE_H_
template<class T>
class MyTemplate
{

//stuff here

} //end MyTemplate
#include “MyTemplate.cpp”
#endif  //MYTEMPLATE_H_
```

Linking with Templates

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Make sure you understand and don’t have problems with multi-file compilation using templates

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//stuff here

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```

Make sure you understand and don’t have problems with multi-file compilation using templates

Do not add `MyTemplate.cpp` to project in your environment and do not include it in the command to compile

```
g++ -o my_program main.cpp
```

NOT `g++ -o my_program MyTemplate.cpp main.cpp`

Alternatively

Entire class template with implementation in header

Only `MyTemplate.hpp`

We will stick with the previous strategy as per your textbook

Lecture Activity

```
template<class T> // this is a template definition
class MyTemplate
{
    MyTemplate();
     void setData(T some_data); //mutator
     T getData() const; //accessor

private:
     T my_data_; //this is the only private data member
};
```

Lecture Activity

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Write a `main()` function that instantiates 3 different `MyTemplate` objects with different types (e.g. `int`, `string, bool`) and makes calls to their member functions and show the output. E.g:

Lecture Activity

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```

Write a `main()` function that instantiates 3 different `MyTemplate` objects with different types (e.g. `int`, `string, bool`) and makes calls to their member functions and show the output. E.g:

```
MyTemplate<double> double_object;
double_object.setData(3.0);
cout << double_object.getData() << endl; // outputs 3.0
```

Try It At Home

Write a dummy `MyTemplate` interface and implementation
(`MyTemplate.hpp, MyTemplate.cpp`)
Test it in `main()`
Make sure you can compile a templated class
(REMEMBER YOU DON'T COMPILE IT!!!)
YOU WILL THANK ME

Now we can define the interface for the Bag class!!!

```
template<class T>
class Bag
{
public:
    /** Gets the current number of entries in this bag.
    @return The integer number of entries currently in the bag. */
    int getCurrentSize() const;

    /** Checks whether this bag is empty.
    @return True if the bag is empty, or false
    if not. */
    bool isEmpty() const;
```

Means: “this method will not modify the object”

```
/** Adds a new entry to this bag.
@post  If successful, new_entry is stored in the bag
and the count of items in the bag has increased by 1.
@param new_entry  The object to be added as a new entry.
@return  True if addition was successful, or false if not. */
bool add(const T& new_entry);

 /** Removes one occurrence of a given entry from this bag, if possible.
 @post  If successful, an_entry has been removed from the bag
 and the count of items in the bag has decreased by 1.
 @param an_entry  The entry to be removed.
 @return  True if removal was successful, or false i
 bool remove(const T& an_entry);
```

Means: “this method will not modify the parameter”

```
/** Removes all entries from this bag.
@post  Bag contains no items, and the count of items is 0. */
void clear();

/** Counts the number of times a given entry appears in bag.
@param an_entry  The entry to be counted.
@return  The number of times an_entry appears in the bag. */
int getFrequencyOf(const T& an_entry) const;

/** Tests whether this bag contains a given entry.
@param an_entry  The entry to locate.
@return  True if bag contains an_entry, or false otherwise. */
bool contains(const T& an_entry) const;


/** Fills a vector with all entries that are in this bag.
@return  A vector containing all the entries in the bag. */
std::vector<T> toVector() const;


}; // end BagInterface
```

Recap

We designed a Bag ADT by defining the operations on the data

We templatized it so we can store any data type

Next Time

Bag Implementation