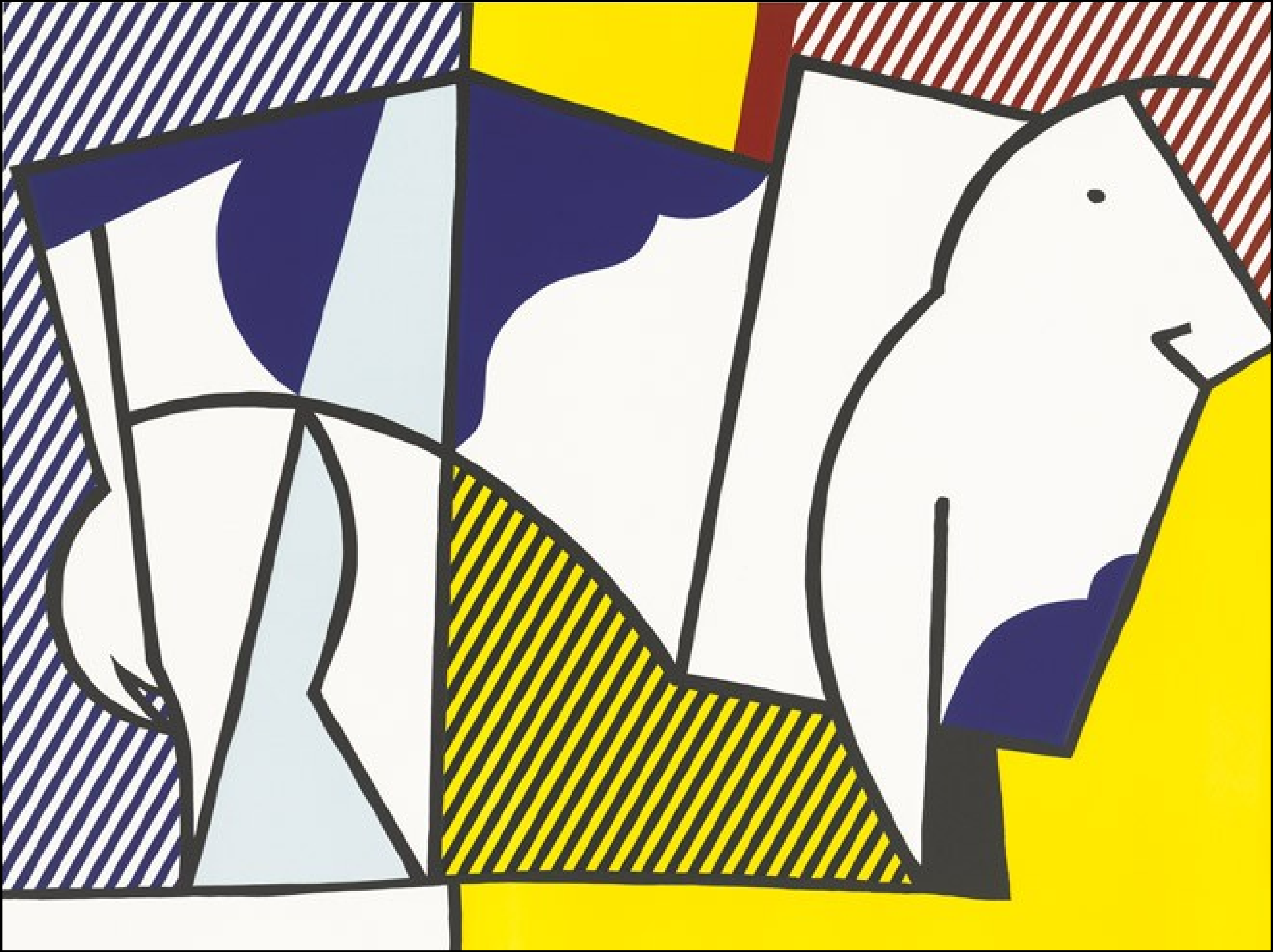
Designing Abstractions

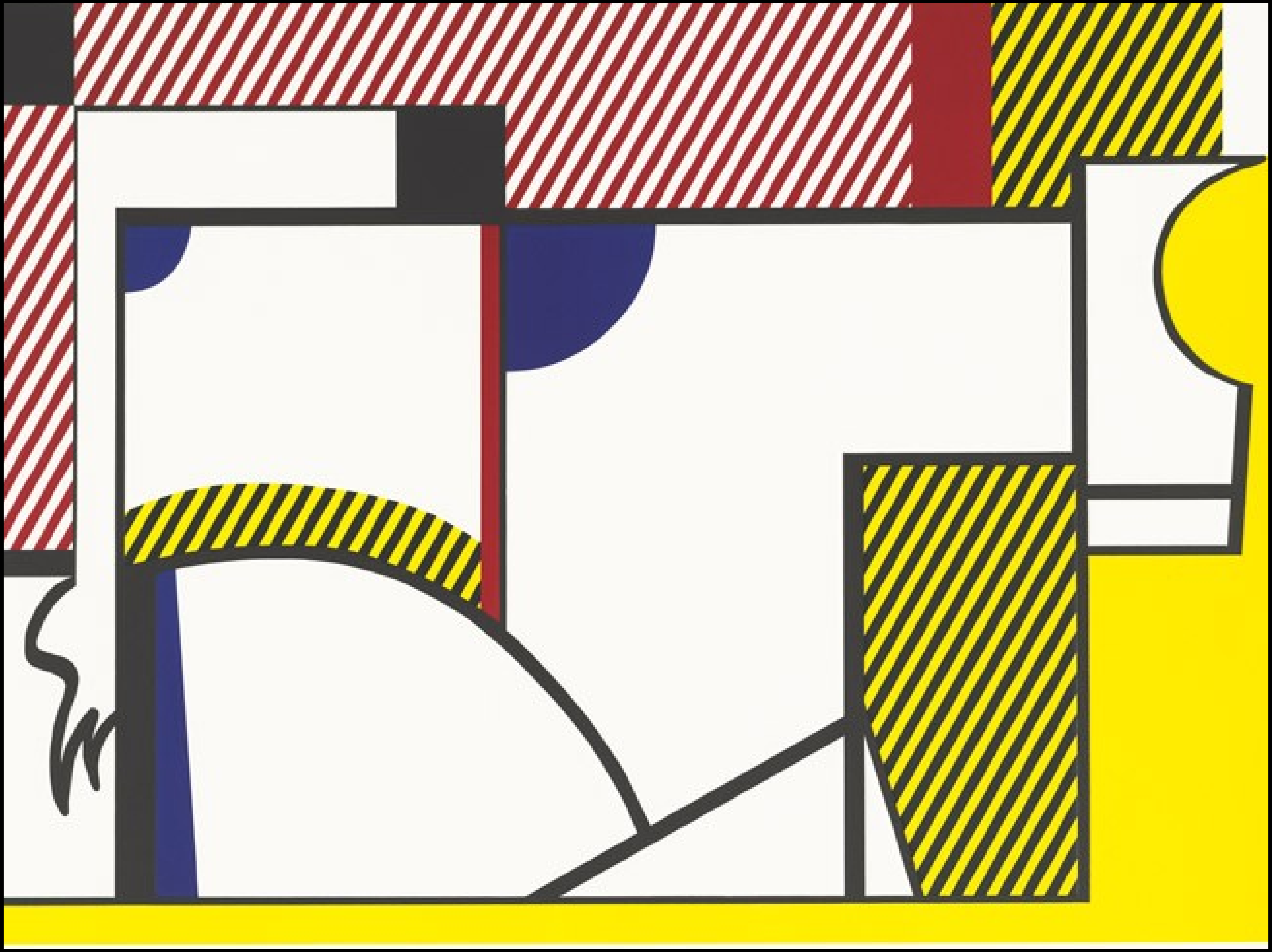
ab·strac·tion

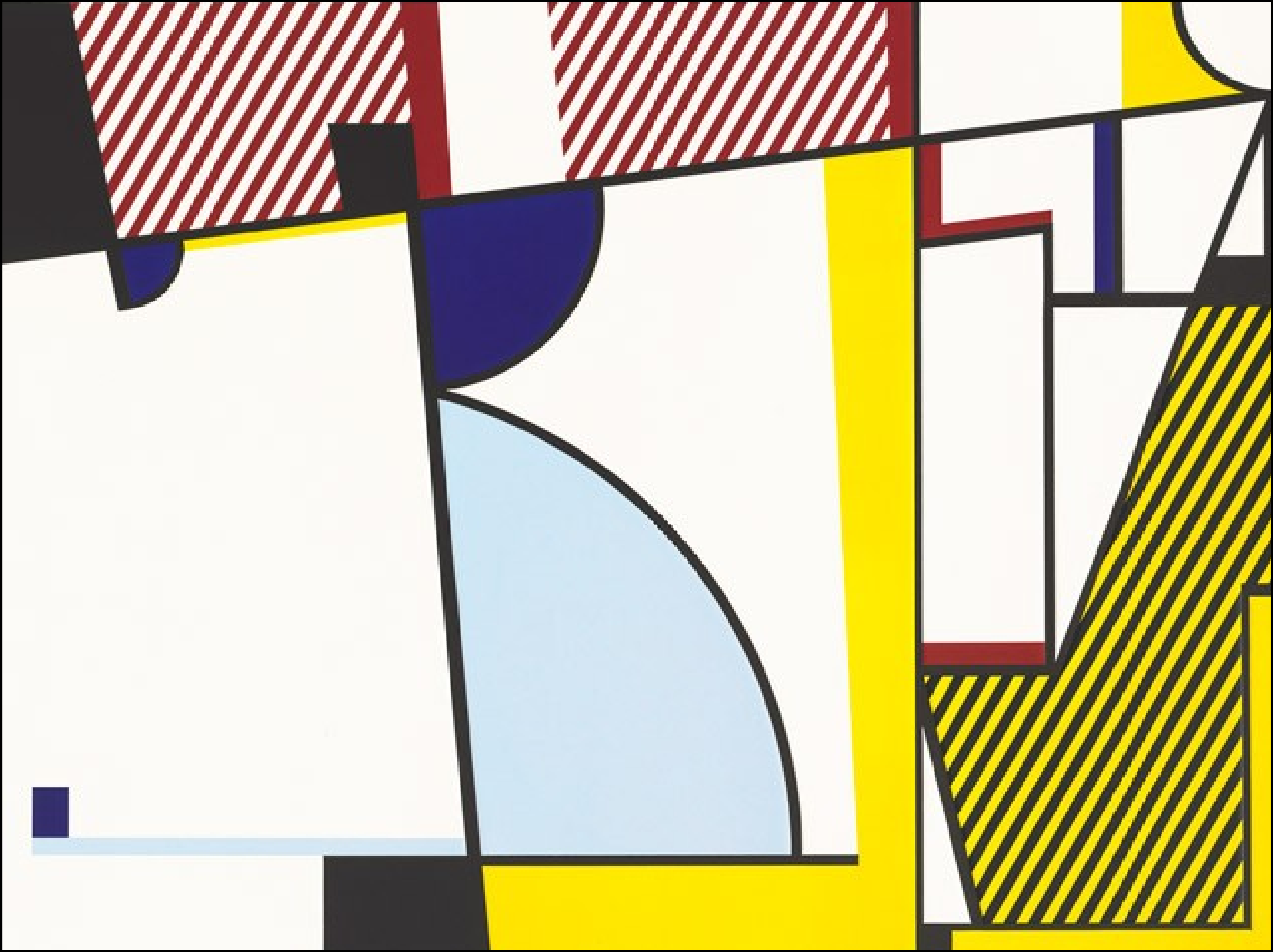
[…]

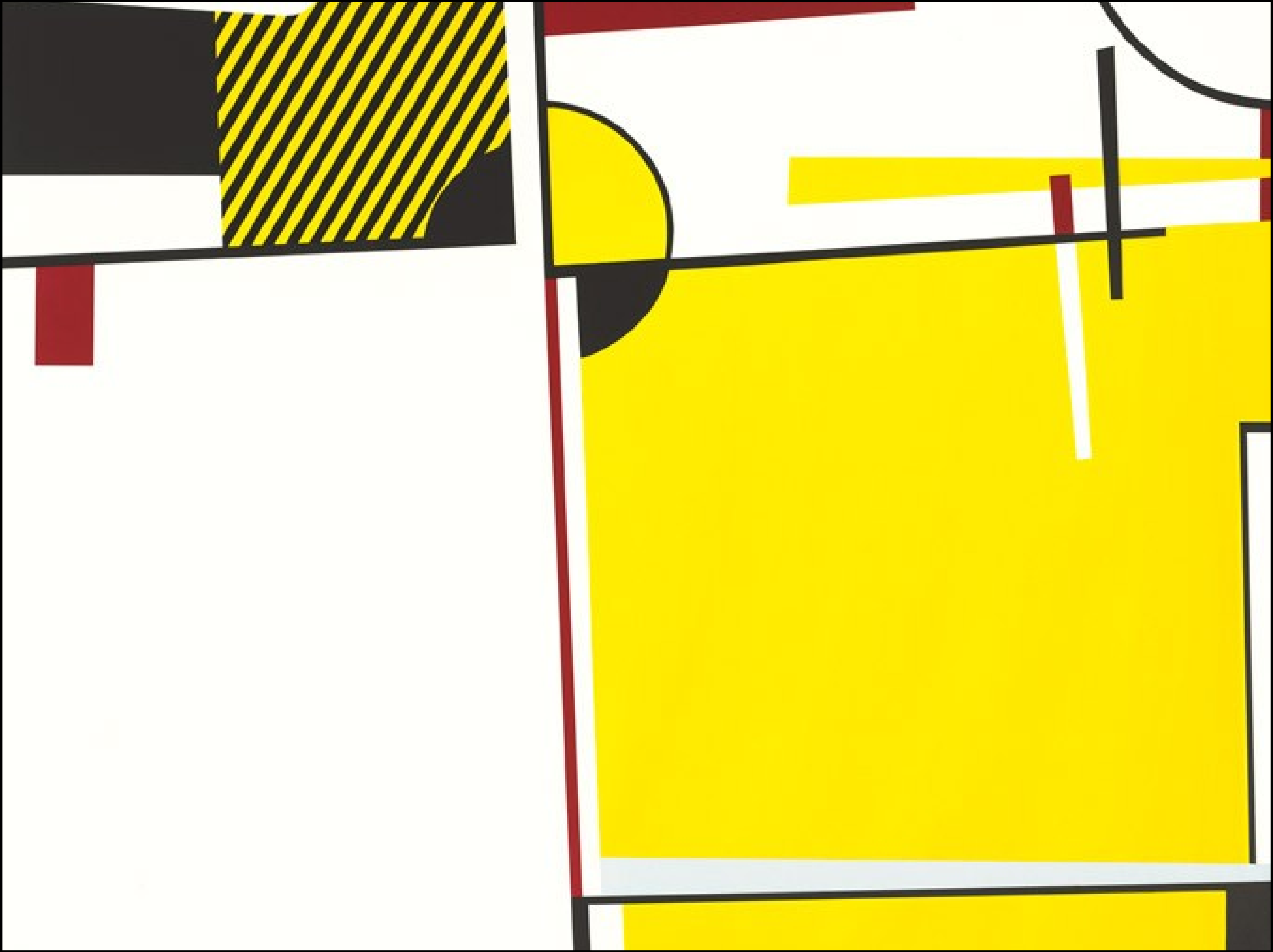
freedom from representational qualities in art

Source: Google









ab·strac·tion

[...]

the process of considering something independently of its associations, attributes, or concrete accompaniments.

Source: Google

Vector HashMap

Lexicon Queue

Building a rich vocabulary of abstractions makes it possible to ***model and solve*** a wider class of problems.

Question One:

How do we create new abstractions to model ideas not precisely captured by the standard container types?

Question Two:

How do the abstractions we’ve been using so far work, and how can we use that knowledge to build richer abstractions?

Classes in C++

Classes

- `Vector`, `Stack`, `Queue`, `HashMap`, etc. are ***classes*** in C++.
- Classes contain
  - an ***interface*** specifying what operations can be performed on instances of the class.

Interface
(What it looks like)

Classes

- `Vector`, `Stack`, `Queue`, `HashMap`, etc. are ***classes*** in C++.
- Classes contain
  - an ***interface*** specifying what operations can be performed on instances of the class, and
  - an ***implementation*** specifying how those operations are to be performed.

Where we've been

Interface
(What it looks like)

Implementation
(How it works)

Where we're going

Creating our own Classes

Random Bags

- A ***random bag*** is a data structure similar to a stack or queue. It supports two operations:
  - ***add***, which puts an element into the random bag, and
  - ***remove random***, which returns and removes a random element from the bag.
- Random bags have a number of applications:
  - Simpler: Shuffling a deck of cards.
  - More advanced: generating artwork, designing mazes, and training self-driving cars to park and change lanes. *(Curious how? Come talk to me after class!)*
- Let’s go create our own custom `RandomBag` type!

Classes in C++

- Defining a class in C++ (typically) requires two steps:
  - Create a ***header file*** (typically suffixed with `.h`) describing what operations the class can perform and what internal state it needs.
  - Create an ***implementation file*** (typically suffixed with `.cpp`) that contains the implementation of the class.
- Clients of the class can then include the header file to use the class.

What’s in a Header?

What’s in a Header?

```
#ifndef RandomBag_Included
#define RandomBag_Included



#endif
```

This boilerplate code is called an ***include guard***. It’s used to make sure weird things don’t happen if you include the same header twice.

Curious how it works? Come talk to me after class!

What’s in a Header?

```
#ifndef RandomBag_Included
#define RandomBag_Included




class RandomBag {









};

#endif
```

This is a ***class definition***. We’re creating a new class called `RandomBag`. Like a `struct`, this defines the name of a new type that we can use in our programs.

What’s in a Header?

```
#ifndef RandomBag_Included
#define RandomBag_Included



class RandomBag {









};

#endif
```

Don’t forget to add this semicolon! You’ll get some Hairy Scary Compiler Errors if you leave it out.

What’s in a Header?

```
#ifndef RandomBag_Included
#define RandomBag_Included



class RandomBag {
public:






private:

};

#endif
```

What’s in a Header?

```
#ifndef RandomBag_Included
#define RandomBag_Included



class RandomBag {
public:






private:

};

#endif
```

The ***public interface*** specifics what functions you can call on objects of this type.

Think things like the `Vector`’s `.add()` function or the `string`’s `.find()`.

The ***private implementation*** contains information that objects of the class type will need in order to do their job properly. This is invisible to people using the class.

What’s in a Header?

```
#ifndef RandomBag_Included
#define RandomBag_Included




class RandomBag {
public:
   void add(int value);
   int  removeRandom();




private:

};

#endif
```

These are ***member functions*** of the `RandomBag` class. They’re functions you can call on objects of the type `RandomBag`.

All member functions need to be declared in the class definition. We’ll implement them in our .cpp file.

What’s in a Header?

```
#ifndef RandomBag_Included
#define RandomBag_Included

#include "vector.h"

class RandomBag {
public:
   void add(int value);
   int  removeRandom();




private:
   Vector<int> elems;
};

#endif
```

This is a ***data member*** of the class. This tells us how the class is implemented. Internally, we’re going to store a `Vector<int>` holding all the elements. The only code that can access or touch this `Vector` is the `RandomBag` implementation.

What’s in a Header?

```
#ifndef RandomBag_Included
#define RandomBag_Included

#include "vector.h"

class RandomBag {
public:
   void add(int value);
   int  removeRandom();




private:
   Vector<int> elems;
};

#endif
```

```
#include "RandomBag.h"
```

If we’re going to implement the `RandomBag` type, the .cpp file needs to have the class definition available. All implementation files need to include the relevant headers.

```
class RandomBag {
public:
   void add(int value);
   int  removeRandom();




private:
   Vector<int> elems;
};
```

```
#include "RandomBag.h"


void RandomBag::add(int value) {
   elems += value;
}
```

The syntax

```
RandomBag::add
```

means “the `add` function defined inside of `RandomBag`.” The `::` operator is called the ***scope resolution operation*** in C++ and is used to say where to look for things.

```
class RandomBag {
public:
   void add(int value);
   int  removeRandom();




private:
   Vector<int> elems;
};
```

```
#include "RandomBag.h"


void ~~RandomBag::~~add(int value) {
    elems += value;
}
```

If we had written something like this instead, then the compiler would think we were just making a free function named add that has nothing to do with `RandomBag`'s version of `add`. That's an easy mistake to make!

```
class RandomBag {
public:
    void add(int value);
    int  removeRandom();




private:
    Vector<int> elems;
};
```

```cpp
#include "RandomBag.h"


void RandomBag::add(int value) {
   elems += value;
}
```

We don’t need to say what `elems` is. The compiler knows we’re inside `RandomBag`, and so it knows that this means “the current `RandomBag`’s collection of elements.”

```cpp
class RandomBag {
public:
   void add(int value);
   int  removeRandom();




private:
   Vector<int> elems;
};
```

```
#include "RandomBag.h"
#include "random.h"

void RandomBag::add(int value) {
   elems += value;
}

int RandomBag::removeRandom() {
   if (elems.isEmpty()) {
      error("Aaaaahhh!");
   }

   int index  = randomInteger(0, elems.size() - 1);
   int result = elems[index];
   elems.remove(index);

   return result;
}
```

```
class RandomBag {
public:
   void add(int value);
   int  removeRandom();




private:
   Vector<int> elems;
};
```

```
#include "RandomBag.h"
#include "random.h"

void RandomBag::add(int value) {
   elems += value;
}

int RandomBag::removeRandom() {
   if (elems.isEmpty()) {
      error("Aaaaahhh!");
   }

   int index  = randomInteger(0, elems.size() - 1);
   int result = elems[index];
   elems.remove(index);

   return result;
}
```

```
class RandomBag {
public:
   void add(int value);
   int  removeRandom();

   int  size();
   bool isEmpty();

private:
   Vector<int> elems;
};
```

```cpp
#include "RandomBag.h"
#include "random.h"

void RandomBag::add(int value) {
   elems += value;
}

int RandomBag::removeRandom() {
   if (elems.isEmpty()) {
      error("Aaaaahhh!");
   }

   int index  = randomInteger(0, elems.size() - 1);
   int result = elems[index];
   elems.remove(index);

   return result;
}

int RandomBag::size() {
   return elems.size();
}
```

```cpp
class RandomBag {
public:
   void add(int value);
   int  removeRandom();

   int  size();
   bool isEmpty();

private:
   Vector<int> elems;
};
```

```
#include "RandomBag.h"
#include "random.h"

void RandomBag::add(int value) {
   elems += value;
}

int RandomBag::removeRandom() {
   if (elems.isEmpty()) {
      error("Aaaaahhh!");
   }

   int index  = randomInteger(0, elems.size() - 1);
   int result = elems[index];
   elems.remove(index);

   return result;
}

int RandomBag::size() {
   return elems.size();
}

bool RandomBag::isEmpty() {
   return size() == 0;
}
```

This code calls our own size() function. The class implementation can use the public interface.

```
mBag {

(int value);
oveRandom();

   int  size();
   bool isEmpty();

private:
   Vector<int> elems;
};
```

```
#include "RandomBag.h"
#include "random.h"

void RandomBag::add(int value) {
    elems += value;
}

int RandomBag::removeRandom() {
    if (isEmpty()) {
        error("Aaaaahhh!");
    }

    int index  = randomInteger(0, size() - 1);
    int result = elems[index];
    elems.remove(index);

    return result;
}

int RandomBag::size() {
    return elems.size();
}

bool RandomBag::isEmpty() {
    return size() == 0;
}
```

That’s such a good idea, let’s do this up here as well.

```
class RandomBag {
public:
    void add(int value);
    int  removeRandom();

    int  size();
    bool isEmpty();

private:
    Vector<int> elems;
};
```

```
#include "RandomBag.h"
#include "random.h"

void RandomBag::add(int value) {
   elems += value;
}

int RandomBag::removeRandom() {
   if (isEmpty()) {
      error("Aaaaahhh!");
   }

   int index  = randomInteger(0, size() - 1);
   int result = elems[index];
   elems.remove(index);

   return result;
}

int RandomBag::size() {
   return elems.size();
}

bool RandomBag::isEmpty() {
   return size() == 0;
}
```

```
class Random
public:
   void add(int value);
   int  removeRandom();

   int  size() const;
   bool isEmpty() const;

private:
   Vector<int> elems;
};
```

This use of the const keyword means “I promise that this function doesn’t change the object.”

```
#include "RandomBag.h"
#include "random.h"

void RandomBag::add(int value) {
   elems += value;
}

int RandomBag::removeRandom() {
   if (isEmpty()) {
      error("Aaaaahhh!");
   }

   int index  = randomInteger(0, size() - 1);
   int result = elems[index];
   elems.rem

   return re
}

int RandomBag::size() const {
   return elems.size();
}

bool RandomBag::isEmpty() const {
   return size() == 0;
}
```

We have to remember to put it here too as well!

```
class RandomBag {
public:
   void add(int value);
   int  removeRandom();

   int  size() const;
   bool isEmpty() const;

private:
   Vector<int> elems;
};
```

```cpp
#include "RandomBag.h"
#include "random.h"

void RandomBag::add(int value) {
   elems += value;
}

int RandomBag::removeRandom() {
   if (isEmpty()) {
      error("Aaaaahhh!");
   }

   int index  = randomInteger(0, size() - 1);
   int result = elems[index];
   elems.remove(index);

   return result;
}

int RandomBag::size() const {
   return elems.size();
}

bool RandomBag::isEmpty() const {
   return size() == 0;
}
```

```cpp
class RandomBag {
public:
   void add(int value);
   int  removeRandom();

   int  size() const;
   bool isEmpty() const;

private:
   Vector<int> elems;
};
```

Your Action Items

- ***Read Chapter 6 of the textbook.***
  - There’s a ton of goodies in there about class design that we’ll talk about later on.
- ***Study for the Midterm***
  - Seriously, best of luck on the exam! We hope you all knock it out of the park.
  - Don’t forget that you can bring a double-sided 8.5” × 11” sheet of notes with you to the exam. Fill it with whatever you’d like!
  - Get a good night’s sleep tonight, eat dinner, get some exercise, and rock the exam!

Next Time

- ***Dynamic Allocation***
  - Where does memory come from?
- ***Constructors and Destructors***
  - Taking things out and putting them away.
- ***Implementing the Stack***
  - Peering into our tools!