C++

What is C++?

- Compiled
- Statically-typed
- Supports: procedural, object oriented, and generic programming

Compiled		Interpreted
C++		Ruby
Objective-C		MATLAB
Fortran	Python	Perl
D		Scheme
Java		

Static typing

```
int x = 4;
int y = 10;
int z;
float f;
vector<int> v;

(x + y); // the type of every expression is known at
         // compile time

z = x + y; // assignments can only occur between
           // matching types,

f = x + y; // and types for which conversion is defined;

v = x + y; // attempts to do otherwise will be caught
           // at compile time
```

Multi-paradigm: Procedural

```
int signum(float a)
{
  if ( a < 0 )
    return -1;
  else
    return 1;
}


int main()
{
  float a = 4.5;
  int s = signum(a);

  return 0;
}
```

Multi-paradigm: Procedural

```
int str_length(char* str)
{
   ...
}

int str_find(char* str, char* substr)
{
   ...
}

int main()
{
   char str1[10] = “Alpha”;
   char str2[10] = “Beta”;

   int len1 = str_length(str1);
   int len2 = str_length(str2);

   int index = str_find(str1, “a”);

   return 0;
}
```

Multi-paradigm: Object oriented

```
#include <string>

int main()
{
  std::string str1(“Alpha”);
  std::string str2(“Beta”);

  int len1 = str1.length();
  int len2 = str2.length();

  int index = str1.find(“a”);

  return 0;
}
```

Multi-paradigm: Generic programming

```
template <typename T>
T max(T x, T y)
{
  return x < y ? y : x;
}


int main()
{
  float m1 = max(4.0, 5.4);
  int m2 = max(-2, 32);
  string lastInDictionary = max(string(“Alpha”), string(“Beta”);

  return 0;
}
```

What is C++?

- The language (syntax, semantics, and behaviour)
- A standard library (generic containers, algorithms, strings, streams, etc., and the c standard library)

Features

- C syntax
- Operators
- Program components
- Classes
- Inheritance and polymorphism
- Templates

C Syntax

- C++ designed to be as compatible with C as possible
- Some exceptions.. for example:
  - no implicit cast from `void*`
  - new keywords introduced

Operators

Arithmetic

Unary plus	+a	
Addition	a + b	
Prefix increment (decrement)	++a	--a
Postfix increment (decrement)	a++	a--
Assignment by addition	a += b	
Unary minus (negation)	-a	
Subtraction	a - b	
Assignment by subtraction	a -= b	
Multiplication	a * b	
Assignment by multiplication	a *= b	
Division	a / b	
Assignment by division	a /= b	
Modulus	a % b	
Assignment by modulus	a %= b	

Comparison

Less than	a < b
Less than or equal to	a <= b
Greater than	a > b
Greater than or equal to	a >= b
Not equal to	a != b
Equal to	a == b

Logical

Logical negation	!a
Logical AND	a && b
Logical OR	a || b

Operators

Other operators

Assignment	`a = b`
Function call	`a()`
Array subscript	`a[b]`
Indirection (dereference)	`*a`
Address-of (reference)	`&a`
Member by pointer	`a->b`
Member	`a.b`
Bind pointer to member by pointer	`a->*b`
Bind pointer to member by reference	`a.*b`
Cast	`(type) a`
Comma	`a , b`
Ternary conditional	`a ? b : c`
Scope resolution	`a::b`
Pointer to member	`a::*b`

size-of	**sizeof**(a)
	sizeof(type)
Type identification	**typeid**(a)
	typeid(type)
Allocate storage	**new** type
Allocate storage (array)	**new** type**[**n**]**
Deallocate storage	**delete** a
Deallocate storage (array)	**delete[]** a

const_cast	
static_cast	
dynamic_cast	
reinterpret_cast	

Program components

- Structure
- Control structures
- Functions
- Memory management

Structure

```
int main()
{


    return 0;
}
```

Structure

```
#include <iostream>
using namespace std;

int main()
{


  return 0;
}
```

Structure

```
#include <iostream>

int main()
{
  std::cout << “Hello world” << std::endl; // a comment

  return 0;
}
```

Structure

```
#include <iostream>
using namespace std;

int main()
{
  cout << “Hello world” << endl; // a comment

  return 0;
}
```

Control structures

```
#include <iostream>
using namespace std;

int main()
{
  cout << “Hello world” << endl; // a comment

  for ( int i = 0; i < 10; ++i )
  {
    cout << i << endl;
  }

  return 0;
}
```

Control structures

```
#include <iostream>
using namespace std;

int main()
{
  cout << “Hello world” << endl; // a comment

  for ( int i = 0; i < 10; ++i )
  {
    if ( i % 3 == 0 )
    {
      cout << i << endl;
    }
  }

  return 0;
}
```

Functions

```
int multiply(int a, int b)
{
  return a * b;
}

int main()
{
  int x = 3;
  int y = 5;
  int z = multiply(x,y);

  return 0;
}
```

Scope

```
int multiply(int a, int b)
{
  return a * b;
}

int main()
{
  int x = 3;
  int y = 5;
  int z = multiply(x,y);

  return 0;
}
```

symbols x, y, and z
are not in scope here

symbols a and b are
not in scope here

Scope

```
int c = 10;

int funky_multiply(int a, int b)
{
  return a * (b+c);
}

int main()
{
  int x = 3;
  int y = c+2;
  int z = funky_multiply(x,y);

  return 0;
}
```

c is in scope throughout; it has global scope

Function arguments

```
int multiply(int a, int b)
{
  return a * b;
}

int main()
{
  int x = 3;
  int y = 5;
  int z = multiply(x,y);

  return 0;
}
```

x and y are passed "by copy" to the multiply function

Function arguments

```
int multiply(int & a, int & b)
{
  return a * b;
}

int main()
{
  int x = 3;
  int y = 5;
  int z = multiply(x,y);

  return 0;
}
```

x and y are passed "by reference" to the multiply function

Function arguments

```
BigObject multiply(BigObject & a, BigObject & b)
{
  return a * b;
}

int main()
{
  BigObject x();
  BigObject y();
  BigObject z = multiply(x,y);

  return 0;
}
```

more efficient when the arguments are large objects

Function arguments

```
BigObject multiply(BigObject & a, BigObject & b)
{
  a = a + 15;

  return a * b;
}

int main()
{
  BigObject x();
  BigObject y();
  BigObject z = multiply(x,y);

  return 0;
}
```

problem: a and b are now references to the original objects

Function arguments

```
BigObject multiply(const BigObject & a, const BigObject & b)
{
  a = a + 15; // this line causes a compiler error

  return a * b;
}

int main()
{
  BigObject x();
  BigObject y();
  BigObject z = multiply(x,y);

  return 0;
}
```

const arguments are not modifiable within the function

Function arguments

```
Example: operator arguments

Type1& operator+=(Type1& a, const Type2& b); // example: a += b

Type1 operator*(const Type1& a, const Type2& b); // example a * b
```

Memory management

You are responsible for deallocating (`delete`) memory that you allocate (`new`)

```
template <typename T>
void some_function(std::vector<T> & input)
{
  T* temp_object = new T; // allocates memory and calls constructor

  // do some things

  delete(T); // calls T's destructor and deallocates memory
}
```

Classes

- Class definitions define the object types

Modularity

Class definition declares member variables and functions

```
class Point
{
   int x, y;
public:
   void setLocation(int,int);
   void getX()
   {
      return x;
   }
   void getY()
   {
      return y;
   }
};

void Point::setLocation(int new_x, int new_y)
{
   x = new_x;
   y = new_y;
}

int main()
{
   Point p;
   p.setLocation(5,15);
   cout << "X coordinate: " << p.getX() << endl;

   return 0;
}
```

```
class Point
{
   int x, y;
public:
   void setLocation(int,int);
   void getX()
   {
      return x;
   }
   void getY()
   {
      return y;
   }
};
```

```
void Point::setLocation(int new_x, int new_y)
{
   x = new_x;
   y = new_y;
}

int main()
{
   Point p;
   p.x = 5; // this line causes a compiler error
   p.setLocation(5,15);
   cout << "X coordinate: " << p.getX() << endl;

   return 0;
}
```

Encapsulation

Members and functions are 'private' by default

```
class Point
{
   int x, y;
public:
   void setLocation(int,int);
   void getX()
   {
      return x;
   }
   void getY()
   {
      return y;
   }
};
```

Encapsulation

The 'public' access specifier makes visible only the members you want visible

```
void Point::setLocation(int new_x, int new_y)
{
   x = new_x;
   y = new_y;
}

int main()
{
   Point p;
   p.setLocation(5,15);
   cout << "X coordinate: " << p.getX() << endl;

   return 0;
}
```

Syntax details

Function definitions can occur with their delcaration (getX, getY), or be declared later (setLocation)

```
class Point
{
   int x, y;
public:
   void setLocation(int,int);
   void getX()
   {
      return x;
   }
   void getY()
   {
      return y;
   }
};

void Point::setLocation(int new_x, int new_y)
{
   x = new_x;
   y = new_y;
}

int main()
{
   Point p;
   p.setLocation(5,15);
   cout << "X coordinate: " << p.getX() << endl;

   return 0;
}
```

```
class Point
{
   int x, y;
public:
   void setLocation(int,int);
   void getX()
   {
      return x;
   }
   void getY()
   {
      return y;
   }
};

void Point::setLocation(int new_x, int new_y)
{
   x = new_x;
   y = new_y;
}

int main()
{
   Point p;
   p.setLocation(5,15);
   cout << "X coordinate: " << p.getX() << endl;

   return 0;
}
```

Syntax details

setLocation isn't in the global scope

use the scope resolution operator to refer to Point's setLocation function

```
class Point
{
   int x, y;
public:
   Point(int, int);
   void setLocation(int,int);
   void getX();
   void getY();
};



int main()
{
   Point p(5,10);

   ...
```

Object creation

a constructor is automatically called when a new object of this class is created

```
class Point
{
   int *x, *y;
public:
   Point(int, int);
   ~Point();
   void setLocation(int,int);
   void getX();
   void getY();
};

Point::Point(int a, int b)
{
   x = new int;
   y = new int;
   *x = a;
   *y = b
}

Point::~Point()
{
   delete a;
   delete b;
}
```

Object destruction

You are responsible for deallocating memory that you allocate

Destructors allow you to take care of that responsibility

Called when that object goes out of scope or is deleted itself

```
class Point
{
   int x, y;
public:
   Point();
   Point(int, int);
   Point operator+(Point other);
};

Point Point::operator+(Point other)
{
   Point temp();
   temp.x = x + other.x;
   temp.y = y + other.y;
   return temp;
}


int main()
{
   Point a(2,4);
   Point b(5,-2);
   Point c = a + b;

   return 0;
}
```

Language detail

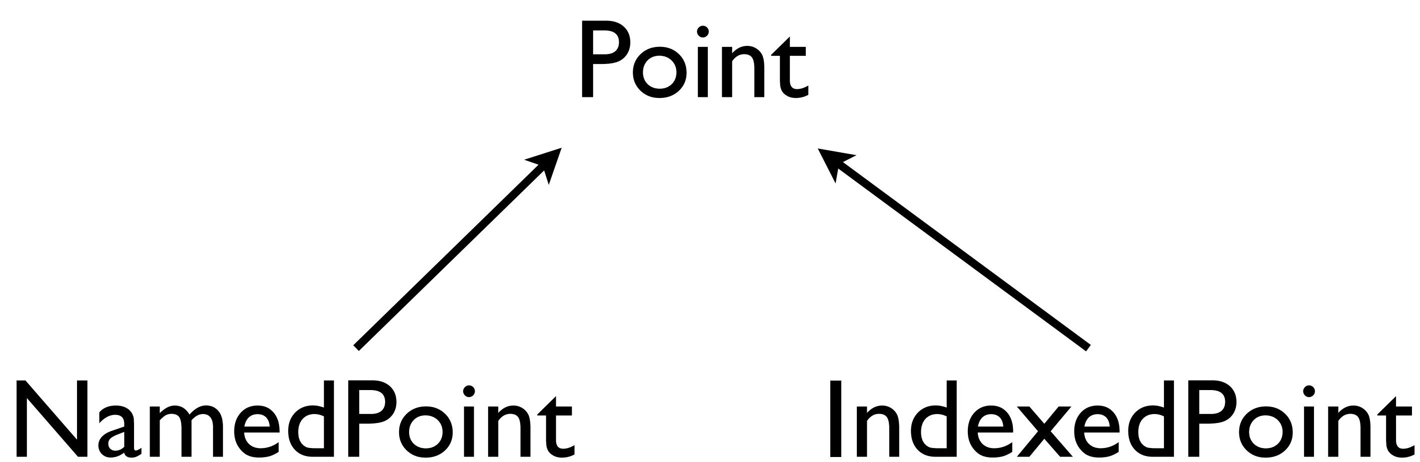
Most of C++'s operators can be 'overloaded': redefined for your particular class

```
class Point
{
   int x, y;
public:
   Point();
   Point(int, int);
   Point operator+(const Point & other) const;
};

Point Point::operator+(const Point & other) const
{
   Point temp();
   temp.x = x + other.x;
   temp.y = y + other.y;
   return temp;
}


int main()
{
   Point a(2,4);
   Point b(5,-2);
   Point c = a + b;

   return 0;
}
```

Language detail

Just for correctness

Inheritance



Inheritance

NamedPoint inherits all of the members of Point

```
class NamedPoint : public Point
{
   std::string name;
public:
   NamedPoint(int, int);
   NamedPoint(int, int, const std::string &);
   void print() const;
};

NamedPoint::NamedPoint(int x, int y) : Point(x,y)
{
   name = std::string(“”);
}

NamedPoint::NamedPoint(int x, int y, const std::string & newName) : Point(x,y)
{
   name = newName;
}

void NamedPoint::print() const
{
   std::cout << x << “,” << y << “,” << “name: “ << name << std::endl;
}
```

Inheritance

New members can be added to the derived class

```
class NamedPoint : public Point
{
   std::string name;
public:
   NamedPoint(int, int);
   NamedPoint(int, int, const std::string &);
   void print() const;
};

NamedPoint::NamedPoint(int x, int y) : Point(x,y)
{
   name = std::string("");
}

NamedPoint::NamedPoint(int x, int y, const std::string & newName) : Point(x,y)
{
   name = newName;
}

void NamedPoint::print() const
{
   std::cout << x << "," << y << "," << "name: " << name << std::endl;
}
```

Constructors need to be redefined

Derived classes can defer some of the initialization to the base class

```
class NamedPoint : public Point
{
   std::string name;
public:
   NamedPoint(int, int);
   NamedPoint(int, int, const std::string &);
   void print() const;
};

NamedPoint::NamedPoint(int x, int y) : Point(x,y)
{
   name = std::string(“”);
}

NamedPoint::NamedPoint(int x, int y, const std::string & newName) : Point(x,y)
{
   name = newName;
}

void NamedPoint::print() const
{
   std::cout << x << “,” << y << “,” << “name: “ << name << std::endl;
}
```

Polymorphism

Point

```
class Point
{
   int x, y;
public:
   Point(int, int);
};
```

NamedPoint

```
class NamedPoint : public Point
{
   std::string name;
public:
   NamedPoint(int, int);
   NamedPoint(int, int, const std::string &);
   void print() const; // prints x,y,name
};
```

IndexedPoint

```
class IndexedPont : public Point
{
   int index;
public:
   IndexedPoint(int, int);
   IndexedPoint(int, int, int);
   void print() const; // prints x,y,id
};
```

```
int main()
{
   Point* p1 = new NamedPoint(0,0,"Zero Point");
   Point* p2 = new IndexedPoint(4,2,5423);
   NamedPoint* n = new NamedPoint(-1,-5,"Negative Point");

   n->print(); // works
   p1->print(); // doesn't work
   p2->print(); // doesn't work
}
```

Polymorphism

Point

```
class Point
{
   int x, y;
public:
   Point(int, int);
   void print() const; // prints x,y
};
```

NamedPoint

```
class NamedPoint : public Point
{
   std::string name;
public:
   NamedPoint(int, int);
   NamedPoint(int, int, const std::string &);
   void print() const; // prints x,y,name
};
```

IndexedPoint

```
class IndexedPont : public Point
{
   int index;
public:
   IndexedPoint(int, int);
   IndexedPoint(int, int, int);
   void print() const; // prints x,y,id
};
```

```
int main()
{
   Point* p1 = new NamedPoint(0,0,”Zero Point”);
   Point* p2 = new IndexedPoint(4,2,5423);
   NamedPoint* n = new NamedPoint(-1,-5,”Negative Point”);

   n->print(); // works
   p1->print(); // works, but only prints x,y
   p2->print(); // works, but only prints x,y
}
```

Polymorphism

Point

```
class Point
{
   int x, y;
public:
   Point(int, int);
   virtual void print() const; // prints x,y
};
```

NamedPoint

```
class NamedPoint : public Point
{
   std::string name;
public:
   NamedPoint(int, int);
   NamedPoint(int, int, const std::string &);
   void print() const; // prints x,y,name
};
```

IndexedPoint

```
class IndexedPont : public Point
{
   int index;
public:
   IndexedPoint(int, int);
   IndexedPoint(int, int, int);
   void print() const; // prints x,y,id
};
```

```
int main()
{
   Point* p1 = new NamedPoint(0,0,"Zero Point");
   Point* p2 = new IndexedPoint(4,2,5423);
   NamedPoint* n = new NamedPoint(-1,-5,"Negative Point");

   n->print(); // works
   p1->print(); // works, prints x,y,name
   p2->print(); // works, prints x,y,id
}
```

Classes: Summary

- Modularity
- Encapsulation
- Inheritance
- Polymorphism

Template classes

Allow classes to be written that operate on generic types.

```
template <typename T>
class Point
{
  T x, y;
public:
  typedef T result_type;

  Point(T x, T y) : x(x), y(y) {}

  template <typename U>
  Point<T> operator+(const Point<U> & other)
  {
    Point<T> temp(0,0);
    temp.x = x + other.getX();
    temp.y = y + other.getY();
    return temp;
  }

  T getX() const { return x; }
  T getY() const { return y; }
  void print() const;

};

int main()
{
   Point<int> a(1,2);
   Point<float> b(0.1, 0.2);

   Point< Point<int>::result_type > c = a + b;

   return 0;
}
```

Features

- C syntax
- Operators
- Program components
- Classes
- Inheritance and polymorphism
- Templates

How to use C++

- Only when you need to
- Use the standard template library
- Use the Boost C++ libraries

Standard Template Library

- Generic containers (queues, vectors, lists, sets, stacks)
- Iterators over those containers
- Generic algorithms

Standard Template Library

```
#include <vector>

int main()
{
   vector<int> a(10,0);
   ...
```

Boost C++ Libraries

- High quality, peer reviewed, generic libraries
- Eventual standardization (10 libraries will be part of the new C++ standard)

Boost C++ Libraries

Accumulators
Bind
Date Time
Filesystem
Foreach
Generic Image Library
Interval values
Lambda functions
Math
Octonions
Quaterions
Statistical Distributions
Program Options
Random
Smart Pointers
Thread

Questions

Interpreting code

```
bool int_ptr_less (int* a, int* b)
{
    return *a < *b;
}

int main()
{
    int x = 17;
    int y = 42;
    int* px = &x;
    int* py = &y;
    int* pmax;

    pmax = std::max (px, py, int_ptr_less);
    std::cout << *pmax;
}
```

Interpreting code

```
template <class Type1, class Type2>
class myclass
{
  Type1 i;
  Type2 j;
public:
  myclass(Type1 a, Type2 b) {
     i = a;
     j = b;
  }
  void show() {
     cout << i << ' ' << j << '\n';
  }
};

int main()
{
  myclass<int, double> object1(10, 0.23);
  myclass<char, char *> object2('X', "This is a test");

  object1.show();
  object2.show();

  return 0;
}
```

```
#include <iostream>
using namespace std;

class CPolygon {
  protected:
    int width, height;
  public:
    void set_values (int a, int b)
      { width=a; height=b; }
    virtual int area (void) =0;
};

class CRectangle: public CPolygon {
  public:
    int area (void)
      { return (width * height); }
};

class CTriangle: public CPolygon {
  public:
    int area (void)
      { return (width * height / 2); }
};

int main () {
  CRectangle rect;
  CTriangle trgl;
  CPolygon * ppoly1 = &rect;
  CPolygon * ppoly2 = &trgl;
  ppoly1->set_values (4,5);
  ppoly2->set_values (4,5);
  cout << ppoly1->area() << endl;
  cout << ppoly2->area() << endl;
  return 0;
}
```