Namespace, Pointers and References, Constants
Introduction to Class

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Computing Methods in Physics

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Output with **iostream**

```
// SimpleIO.cpp
#include <iostream>
using namespace std;

int main() { // main begins here

   // print message to STDOUT
   cout << "Moving baby steps in C++!" << endl;

   return 0;

} // end of main
```

End of line
start a new line!

```
$ g++ -o SimpleIO SimpleIO.cpp
$ ./SimpleIO
Moving baby steps in C++!
```

- **iostream** provides output capabilities to your program

Input with `iostream`

```
// SimpleInput.cpp
#include <iostream>
using namespace std;

int main() { // main begins here

   int nIterations;

   cout << "How many iterations? ";
   cin >> nIterations;

   // print message to STDOUT
   cout << "Number of requested iterations: " << nIterations << endl;

   return 0;
} // end of main
```

Put content of cin into variable nIterations

```
$ g++ -o SimpleInput SimpleInput.cpp
$ ./SimpleInput
How many iterations? 7
Number of requested iterations: 7
```

- **`iostream`** provides also input capabilities to your program

Problems with **cin**

```
// tinput_bad.cc
#include <iostream>
using namespace std;

int main() {

  cout << "iterations? ";

  int iters;
  cin >> iters;

  cout << "requested " << iters << " iterations" << endl;

  return 0;
}
```

```
$ g++ -Wall -o tinput_bad tinput_bad.cc
$ ./tinput_bad
iterations? 23
requested 23 iterations
$ ./tinput_bad
iterations? dfed
requested 134514793 iterations
```

Checking **cin** success or failure

```
//tinput.cc
#include <iostream>
using namespace std;

int main() {

  cout << "iterations? ";

  int iters = 0;
  cin >> iters;

  if(cin.fail()) cout << "cin failed!" << endl;

  cout << "requested " << iters << " iterations" << endl;

  return 0;
}
```

Fails if input data doesn't match expected data type

```
$ g++ -Wall -o tinput tinput.cc
$ ./tinput
iterations? 34
requested 34 iterations
$ ./tinput
iterations? sfee
cin failed!
requested 0 iterations
```

Scope of Variables

```
// scope.cc
#include <iostream>


double f1() {
  double y = 2;
  return y;
}

int main() {

   double x = 3;
   double z = f1();

   std::cout << "x: " << x << ", z: " << z << ", y: " << y
             << std::endl;
   return 0;
}
```

```
$ g++ -o scope scope.cc
scope.cc: In function `int main()':
scope.cc:16: error: `y' undeclared (first use this function)
scope.cc:16: error: (Each undeclared identifier is reported
 only once for each function it appears in.)
```

What is the difference between **`cout`** and **`std::cout`**?

- The scope of a name is the block of program where the name is valid and can be used
  - A block is delimited by { }
  - It can be the body of a method, or a simple scope defined by the user using { }

What is **namespace** ?

- A mechanism to group declarations that logically belong to each other

```
namespace physics {
  class vector;
  class unit;
  class oscillator;
  void sort(const vector& value);
}

namespace electronics {
  void sort(const vector& value);
  class oscillator;
}

namespace graphics {
  void sort(const vector& value);
  class unit;
}
```

- Provides an easy way for logical separation of parts of a big project

- Basically a ‘scope’ for a group of related declarations

How do I use **namespaces** ?

```
#include <iostream>

namespace physics {
  double mean(const double& a, const double& b) { return (a+b)/2.; }
}

namespace foobar {
  double mean(const double& a, const double& b) { return (a*a+b*b)/2.; }
}

int main() {
   double x = 3;
   double y = 4;

   double z1 = physics::mean(x,y);
   std::cout << "physics::mean(" << x << "," << y << ") = " << z1
             << std::endl;

   double z2 = foobar::mean(x,y);
   std::cout << "foobar::mean(" << x << "," << y << ") = " << z2
             << std::endl;
   return 0;
}
```

physics::mean

foobar::mean

Use "::" to specify the namespace

```
$ g++ -o namespace1 namespace1.cc
$ ./namespace1
physics::mean(3,4) = 3.5
foobar::mean(3,4) = 12.5
```

Defined in iostream

Common Errors with **namespaces**

```
// namespaceBad.cc
#include <iostream>

namespace physics {
  double mean(const double& a, const double& b) {
    return (a+b)/2.;
  }
}

int main() {

   double x = 3;
   double y = 4;

   double z1 = mean(x,y); // forgot the namespace!
   cout << "physics::mean(" << x << "," << y << ") = " << z1
             << std::endl;

   return 0;
}
```

If you forget to specify the namespace the compiler doesn't know where to find the method

```
$ g++ -o namespaceBad namespaceBad.cc
namespaceBad.cc: In function `int main()':
namespaceBad.cc:15: error: `mean' undeclared (first use this function)
namespaceBad.cc:15: error: (Each undeclared identifier is reported only
 once for each function it appears in.)
namespaceBad.cc:16: error: `cout' undeclared (first use this function)
```

using namespace directive

```
// namespace2.cc
#include <iostream>

namespace physics {
  double mean(const double& a, const double& b) {
    return (a+b)/2.;
  }
}

using namespace std; // make all names in std namespace available!

int main() {

   double x = 3;
   double y = 4;

   double z1 = physics::mean(x,y);
   cout << "physics::mean(" << x << "," << y << ") = " << z1
             << endl;

   return 0;
}
```

Provide default namespace for un-qualified names

Same concepts used also in python

Compiler looks for **cout** and **endl** first

if not found looks for **std::cout** and **std::endl**;

```
$ g++ -o namespace2 namespace2.cc
$ ./namespace2.exe
physics::mean(3,4) = 3.5
```

Be careful with **`using`** directive!

```
// namespaceBad2.cc
#include <iostream>

namespace physics {
  double mean(const double& a, const double& b) { return (a+b)/2.; }
}

namespace foobar {
  double mean(const double& a, const double& b) { return (a*a+b*b)/2.; }
}

using namespace foobar;
using namespace physics;
using namespace std;

int main() {
   double x = 3;
   double y = 4;

   double z1 = mean(x,y);
   double z2 = mean(x,y);

   return 0;
}
```

Ambiguous use of method **`mean`**!

Is it in **`foobar`** or in **`physics`**?

```
$ g++ -o namespaceBad2 namespaceBad2.cc
namespaceBad2.cc: In function `int main()':
namespaceBad2.cc:21: error: call of overloaded `mean(double&, double&)' is ambiguous
namespaceBad2.cc:5: note: candidates are: double physics::mean(const double&, const double&)
namespaceBad2.cc:9: note:  double foobar::mean(const double&, const double&)
namespaceBad2.cc:25: error: call of overloaded `mean(double&, double&)' is ambiguous
namespaceBad2.cc:5: note: candidates are: double physics::mean(const double&, const double&)
namespaceBad2.cc:9: note:  double foobar::mean(const double&, const double&)
```

Some tips on **using** directive

```
// namespace3.cc
#include <iostream>

namespace physics {
  double mean(const double& a, const double& b) {
    return (a+b)/2.;
  }
}

void printMean(const double& a, const double& b) {
  double z1 = physics::mean(a,b);

  using namespace std; // using std namespace within this method!
  cout << "physics::mean(" << a << "," << b << ") = " << z1 << endl;
}

int main() {

   double x = 3;
   double y = 4;
   printMean(x,y);

   cout << "no namespace available in the main!" << endl;
   return 0;
}
```

Namespace defined only within printMean

```
$ g++ -o namespace3 namespace3.cc
namespace3.cc: In function `int main()':
namespace3.cc:23: error: `cout' undeclared (first use this function)
namespace3.cc:23: error: (Each undeclared identifier is reported only
once for each function it appears in.)
namespace3.cc:23: error: `endl' undeclared (first use this function)
```

No default namespace in the main()

Another Example on Scopes

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

using std::cout;
using std::endl;

int main() {

  double x = 1.2;

  cout << "in main before scope, x: " << x << endl;

  { // just a local scope
     x++;
     cout << "in local scope before int, x: " << x << endl;

     int x = 4;
     cout << "in local scope after int, x: " << x << endl;
  }

  cout << "in main after local scope, x: " << x << endl;

  return 0;
}
```

Another way to declare ONLY classes and functions we are going to use instead of entire namespace

```
$ g++ -o scope scope.cc
$ ./scope
in main before scope, x: ???
in local scope before int, x: ???
in local scope after int, x: ???
in main after local scope, x: ???
```

What do you think the output is going to be?

Another Example on Scopes

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

using std::cout;
using std::endl;

int main() {

  double x = 1.2;

  cout << "in main before scope, x: " << x << endl;

  { // just a local scope
     x++;
     cout << "in local scope before int, x: " << x << endl;

     int x = 4;
     cout << "in local scope after int, x: " << x << endl;
  }

  cout << "in main after local scope, x: " << x << endl;

  return 0;
}
```

Another way to declare ONLY classes and functions we are going to use instead of entire namespace

Changed value of x from main scope

Define new variable in this scope

Back to the main scope

```
$ g++ -o scope scope.cc
$ ./scope
in main before scope, x: 1.2
in local scope before int, x: 2.2
in local scope after int, x: 4
in main after local scope, x: 2.2
```

Functions and Methods

- A function is a set of operations to be executed
  - Typically there is some input to the function
  - Usually functions have a return value
  - Functions not returning a specific type are **`void`**

```
// func1.cc
#include <iostream>

double pi() {
  return 3.14;
}

void print() {
  std::cout << "void function print()" << std::endl;
}

int main() {

   std::cout << "pi: " << pi() << std::endl;
   print();

   return 0;
}
```

```
$ g++ -o func1 func1.cc
$ ./func1
pi: 3.14
void function print()
```

Functions must be declared before being used

```
// func2.cc
#include <iostream>

double pi() {
  return 3.14;
}

int main() {

   std::cout << "pi: " << pi() << std::endl;
   print();

   return 0;
}

void print() {
  std::cout << "void function print()" << std::endl;
}
```

Compiler does not know what the name **`print`** stands for!

No declaration at this point!

```
$ g++ -o func2 func2.cc
func2.cc: In function `int main()':
func2.cc:11: error: `print' undeclared (first use this function)
func2.cc:11: error: (Each undeclared identifier is reported only
 once for each function it appears in.)
func2.cc: In function `void print()':
func2.cc:16: error: `void print()' used prior to declaration
```

Definition can be elsewhere

```
// func3.cc
#include <iostream>

double pi() {
  return 3.14;
}

extern void print(); // declare to compiler print() is a void method

int main() {

   std::cout << "pi: " << pi() << std::endl;
   print();

   return 0;
}

// now implement/define the method void print()
void print() {
  std::cout << "void function print()" << std::endl;
}
```

```
$ g++ -o func3 func3.cc
$ ./func3
pi: 3.14
void function print()
```

Pointers and References

- A variable is a label assigned to a location of memory and used by the program to access that location

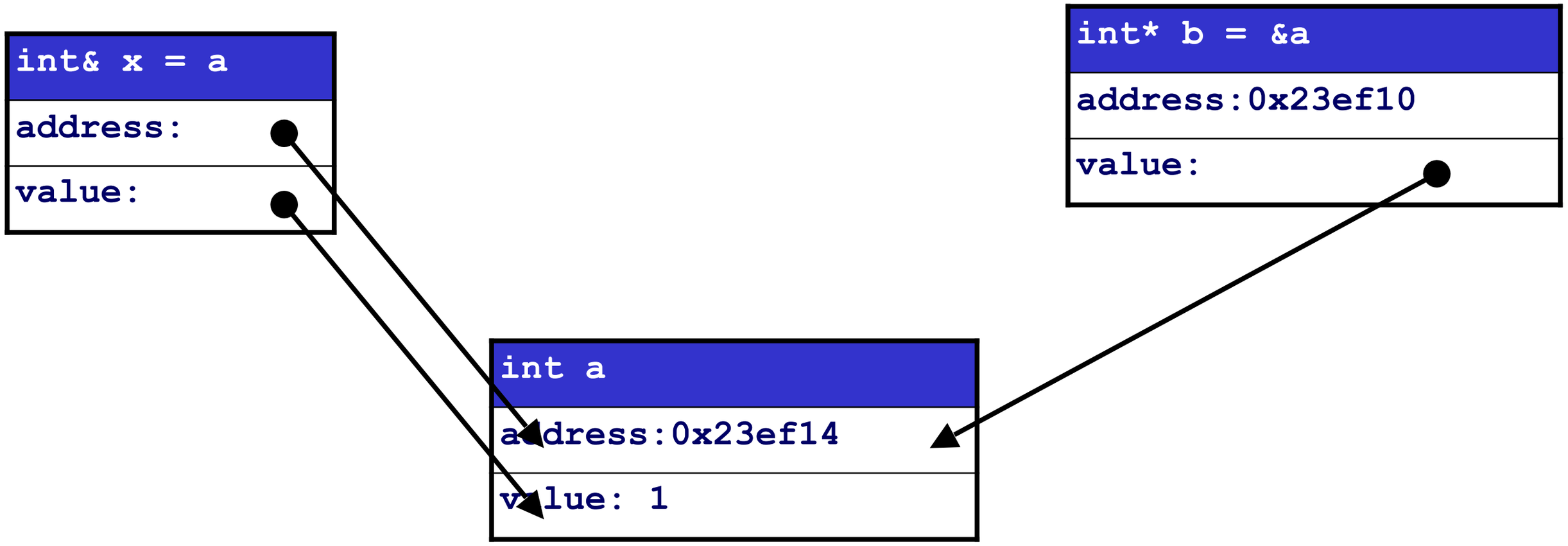
`int a` → 4 bytes==32bit of memory

```
// Pointers.cpp
#include <iostream>
using namespace std;

int main() { // main begins here

   int a; // a is a label for a location of memory dtor'ing an int value

   cout << "Insert value of a: ";
   cin >> a; // store value provided by user
             // in location of memory held by a

   int* b; // b is  a pointer to variable of
           // type a

   b  = &a; // value of b is the address of memory
            // location assigned to a

   cout << "value of a: " << a << endl;
   cout << "address of a: " << b << endl;

   return 0;
} // end of main
```

Same location in memory but different values!

```
$ g++ -o Pointers Pointers.cpp
$ ./Pointers
Insert value of a: 3
value of a: 3
address of a: 0x23ef14
$ ./Pointers
Insert value of a: 1.2
value of a: 1
address of a: 0x23ef14
```

Pointers and References



- **x** is a reference to **a**
  - A different name for the same physical location in memory
  - Using **x** or **a** is exactly the same!

- **b** is a pointer to location of memory named **x** or **a**

Pointers and References

```
// refs.cpp
#include <iostream>
using namespace std;

int main() {

   int a = 1;

   int* b; // b is  a pointer to variable of type int

   b  = &a; // value of b is the address of memory location assigned to a

   int& x = a; //

   cout << "value of a: " << a
        << ", address of a, &a: " << &a
        << endl;

   cout << "value of x: " << x
        << ", address of x, &x: " << &x
        << endl;

   cout << "value of b: " << b
        << ", address of b, &b: " << &b
        << ", value of *b: " << *b
        << endl;

   return 0;
}
```

```
$ ./refs
value of a: 1, address of a, &a: 0x23ef14
value of x: 1, address of x, &x: 0x23ef14
value of b: 0x23ef14, address of b, &b: 0x23ef10, value of *b: 1
```

Using pointers and references

```
// refs2.cpp
#include <iostream>
using namespace std;

int main() {

   int a = 1;

   int* b = &a;
   *b = 3;

   cout << "value of a: " << a
        << ", address of a, &a: " << &a
        << endl;

   int& x = a;
   x = 45;

   cout << "value of a: " << a
        << ", address of a, &a: " << &a
        << endl;

   return 0;
}
```

Change value of a with pointer b

Change value of a with reference x

```
$ g++ -o refs2 refs2.cc
$ ./refs2
value of a: 3, address of a, &a: 0x23ef14
value of a: 45, address of a, &a: 0x23ef14
```

Bad and Null Pointers

```
// badptr1.cpp
#include <iostream>
using namespace std;

int main() {

   int* b; // b is  a pointer to varible of type int

   int vect[3] = {1,2,3}; // vector of int

   int* c; // non-initialized pointer
   cout << "c: " << c << ", *c: " << *c <<endl;

   for(int i = 0; i<3; ++i) {
     c = &vect[i];
     cout << "c = &vect[" << i << "]: " << c << ", *c: " << *c << endl;
   }

   // bad pointer
   c++;
   cout << "c: " << c << ", *c: " << *c <<endl;

   // null pointer causing trouble
   c = 0;
   cout << "c: " << c << endl;
   cout << "*c: " << *c <<endl;

   return 0;
}
```

What is the size of an int in memory?

No problem compiling

```
$ g++ -o badptr1 badptr1.cc
$ ./badptr1
c: 0x7c90d592, *c: -1879046974
c = &vect[0]: 0x23eef0, *c: 1
c = &vect[1]: 0x23eef4, *c: 2
c = &vect[2]: 0x23eef8, *c: 3
c: 0x23eefc, *c: 1627945305
c: 0
Segmentation fault (core dumped)
```

Crash at runtime

Constants

- C++ allows to ensure value of a variable does not change within its scope
  - Can be applied to variables, pointers, references, vectors etc.
  - Constants must be ALWAYS initialized since they can't change at a later time!

```
// const1.cpp

int main() {

   const int a = 1;
   a = 2;

   const double x;

   return 0;
}
```

```
$ g++ -o const1 const1.cc
const1.cc: In function `int main()':
const1.cc:6: error: assignment of read-only variable `a'
const1.cc:8: error: uninitialized const `x'
```

Constant Pointer

Read from right to left:
`int * const b`:

`b` is a constant pointer to int

```
// const2.cpp

int main() {

   int a = 1;
   int * const b = &a; // const pointer to int

   *b = 5; // OK. can change value of what b points to

   int c = 3;
   b = &c; // Not OK. assign new value to c

   return 0;
}
```

```
$ g++ -o const2 const2.cc
const2.cc: In function `int main()':
const2.cc:11: error: assignment of read-only variable `b'
```

Pointer to Constant

`a` is not a constant!
But we can treat it as such when pointing to it

```
// const3.cpp

int main() {

   int a = 1;
   const int * b = &a; // pointer to const int

   int c = 3;
   b = &c; // assign new value to c ... OK!

   *b = 5; // assign new value to what c point to ... NOT OK!

   return 0;
}
```

Read from right to left:
`const int * b`:

`b` is a pointer to constant int

```
$ g++ -o const3 const3.cc
const3.cc: In function `int main()':
const3.cc:11: error: assignment of read-only location
```

NB: the error is different!

Constant Pointer to Constant Object

- Most restrictive access to another variable
  - Specially when used in function interface
- Can not change neither the pointer nor what it points to!

```
// const4.cpp

int main() {

   float a = 1;
   const float * const b = &a; // const pointer to const float

   *b = 5; // Not OK. can't change value of what b points to

   float c = 3;
   b = &c; // Not OK. can't change what b points to!

   return 0;
}
```

```
$ g++ -o const4 const4.cc
const4.cc: In function `int main()':
const4.cc:8: error: assignment of read-only location
const4.cc:11: error: assignment of read-only variable
```

Bad Use of Pointers

```
int vect[3] = {1,2,3};
int v2[3];
int v3[] = { 1, 2, 3, 4, 5, 6, 7 };
```

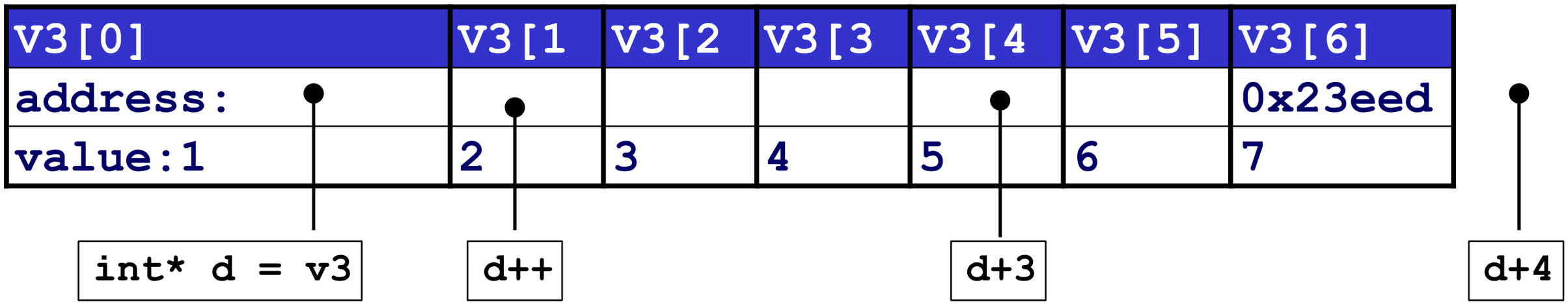
```
$ g++ -o array array.cc
$ ./array
i: 0, d = 0x23eec0, *d: 1, c = 0x23eef0, *c: 1, e = 0x23eee0, *e: -1
i: 1, d = 0x23eec4, *d: 2, c = 0x23eef4, *c: 2, e = 0x23eee4, *e: 2088773120
i: 2, d = 0x23eec8, *d: 3, c = 0x23eef8, *c: 3, e = 0x23eee8, *e: 2088772930
i: 3, d = 0x23eecc, *d: 4, c = 0x23eefc, *c: 1627945305, e = 0x23eeec, *e:
2089866642
i: 4, d = 0x23eed0, *d: 5, c = 0x23ef00, *c: 1876, e = 0x23eef0, *e: 1
```

V3[0]	V3[1	V3[2	V3[3	V3[4	V3[5]	V3[6]
address:						0x23eed
value:1	2	3	4	5	6	7

How many bytes in memory between v3[6] and v2[0] ?

V2[0]	V2[1]	V2[2]		vect[0]	vect[1]	Vect[2]
0x23eee	0x23eee	0x23eee	0x23eee	0x23eef	0x23eef	0x23eef
-1	2	3		1	2	3

Pointer Arithmetic




```
// ptr.cc
#include <iostream>
using namespace std;

int main() {

   int v3[] = { 1, 2, 3, 4, 5, 6, 7 }; // array of size 7
   int* d = v3;
   cout << "d = " << d << ", *d: " << *d <<endl;

   d++;
   cout << "d = " << d << ", *d: " << *d <<endl;

   d = d+3;
   cout << "d = " << d << ", *d: " << *d <<endl;

   d = d+4;
   cout << "d = " << d << ", *d: " << *d <<endl;

   return 0;
}
```

```
$ g++ -o ptr ptr.cc
$ ./ptr
d = 0x23eef0, *d: 1
d = 0x23eef4, *d: 2
d = 0x23ef00, *d: 5
d = 0x23ef10, *d: 1628803505
```

+ and – operators with Pointers

```
// ptr2.cc
#include <iostream>
using namespace std;

int main() {

   int v3[] = { 1, 2, 3, 4, 5, 6, 7 }; // array of size 7

   int* d = v3;
   int*c = &v3[4];
   cout << "d = " << d << ", *d: " << *d <<endl;
   cout << "c = " << c << ", *c: " << *c <<endl;

   //int* e = c + d;  // not allowed

   cout << "c-d: " << c - d << endl;
   cout << "d-c: " << d - c << endl;

   //int* e = c-d; // wrong!

   int f = c - d;
   float g = c - d;

   cout << "f: " << f << " g: " << g << endl;

   int *  h = &v3[6] + (d-c);
   cout << "int *  h = &v3[6] + (d-c): " << h << " *h: " << *h << endl;

   return 0;
}
```

Arguments of Functions

- Arguments of functions can be passed in two different ways

```
// funcarg1.cc
#include <iostream>

using namespace std;

void emptyLine() {
  cout
  << "\n--------------------------------\n"
       << endl;
}

void f1(double x) {
  cout << "f1: input value of x = "
       << x << endl;
  x = 1.234;
  cout << "f1: change value of x in f1(). x =
"
       << x << endl;
}
```

– By value
  - x is a local variable in f1()

– Pointer or reference
  - x is reference to argument used by caller

```
void f2(double& x) {
  cout << "f2: input value of x = "
       << x << endl;
  x = 1.234;
  cout << "f2: change value of x in f2(). x =
"
       << x << endl;
}
```

Pointers and References in Functions

```
int main() {

   double a = 1.; // define a

   emptyLine();
   cout << "main: before calling f1, a = " << a<< endl;
   f1(a);  // void function
   cout << "main: after calling f1, a = " << a<< endl;

   emptyLine();
   cout << "main: before calling f2, a = " << a<< endl;
   f2(a);  // void function
   cout << "main: after calling f2, a = " << a<< endl;

   return 0;
}
```

f1 has no effect on variables in main

Because a is passed by value

x is a copy of a

f2 modifies the value of the variable in the main!

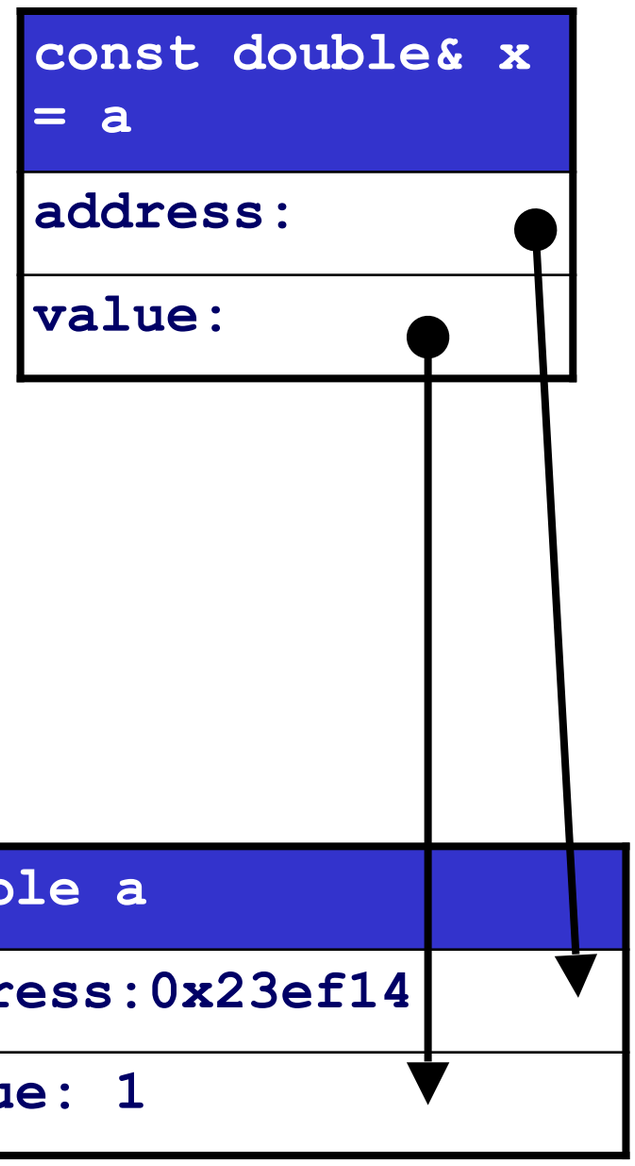
Because a is passed by reference

double& x = a;

```
$ ./funcarg1
-----------------------------------
main: before calling f1, a = 1
f1: input value of x = 1
f1: change value of x in f1(). x = 1.234
main: after calling f1, a = 1
-----------------------------------

main: before calling f2, a = 1
f2: input value of x = 1
f2: change value of x in f2(). x = 1.234
main: after calling f2, a = 1.234
```

Constant Pointers and References in Functions

```
// funcarg2.cc
#include <iostream>

using namespace std;

void f2(const double& x) {
  cout << "f2: input value of x = "
       << x << endl;
  x = 1.234;
  cout << "f2: change value of x in f2(). x = "
        << x << endl;
}

int main() {

   double a = 1.;
   f2(a);

   return 0;
}
```




```
$ g++ -o funcarg2  funcarg2.cc
funcarg2.cc: In function `void f2(const double&)':
funcarg2.cc:9: error: assignment of read-only reference `x'
```

Pointers, References and Passing by Value in Functions

```
// mean.cc
#include <iostream>
using namespace std;

void computeMean(const double* data, int nData, double& mean) {
  mean = 0.;
  for(int i=0; i<nData; ++i) {
    cout << "data: " << data << ", *data: " << *data << endl;
    mean += *data;
    data++;
  }
  mean /= nData; // divide by number of data points
}

int main() {

   double pressure[] = { 1.2, 0.9, 1.34, 1.67, 0.87, 1.04, 0.76 };
   double average;

   computeMean( pressure, 7, average );

   cout << "average pressure: "
        << average << endl;
   return 0;
}
```

```
$ g++ -o mean mean.cc
$ ./mean
data: 0x23eed0, *data: 1.2
data: 0x23eed8, *data: 0.9
data: 0x23eee0, *data: 1.34
data: 0x23eee8, *data: 1.67
data: 0x23eef0, *data: 0.87
data: 0x23eef8, *data: 1.04
data: 0x23ef00, *data: 0.76
average pressure: 1.11143
```

Closer Look at **computeMean()**

```
void computeMean(const double* data, int nData, double& mean) {
  mean = 0.;
  for(int i=0; i<nData; ++i) {
    cout << "data: " << data << ", *data: " << *data << endl;
    mean += *data;
    data++;
  }
  mean /= nData; // divide by number of data points
}
```

- Input data passed as constant pointer
  - Good: can't cause trouble to caller! Integrity of data guaranteed
  - Bad: No idea how many data points we have!

- Number of data pointer passed by value
  - Simple int. No gain in passing by reference
  - Bad: separate variable from array of data. Exposed to user error

- Very bad: void function with no return type
  - Good: appropriate name. computeMean() suggests an action not a type

New implementation with Return Type

```
double mean(const double* data, int nData) {
  double mean = 0.;
  for(int i=0; i<nData; ++i) {
    cout << "data: " << data << ", *data: " << *data << endl;
    mean += *data;
    data++;
  }
  mean /= nData; // divide by number of data points
  return mean
}
```

- Make function return the computed mean
- New name to make it explicit function returns something
  - Not a rule, but simple courtesy to users of your code
- No need for variables passed by reference to be modified in the function
- Still exposed to user error…

Possible Problems with use of Pointers

```
// mean2.cc
#include <iostream>
using namespace std;

double mean(const double* data, int nData) {

  double mean = 0.;
  for(int i=0; i<nData; ++i) {
    cout << "data: " << data << ", *data: " << *data << endl;
    mean += *data;
    data++;
  }
  mean /= nData; // divide by number of data points
  return mean;
}

int main() {
   double pressure[] = { 1.2, 0.6, 1.8 }; // only 3 elements
   double average = mean(pressure, 4); // mistake!
   cout << "average pressure: " << average << endl;

   return 0;
}
```

```
$ g++ -o mean2 mean2.cc
$ ./mean2
data: 0x23eef0, *data: 1.2
data: 0x23eef8, *data: 0.6
data: 0x23ef00, *data: 1.8
data: 0x23ef08, *data: 8.48798e-314
average pressure: 0.9
```

Simple luck!
Additional value not changing the average!

No protection against possible errors!

What about computing other quantities?

- What if we wanted to compute also the standard deviation of our data points?

```
void computeMean(const double* data, int nData, double& mean, double& stdDev) {
 // two variables passed by reference to void function
 // not great. But not harmful.
}


double meanWithStdDev(const double* data, int nData, double& stdDev) {
  // error passed by reference to mean function! ugly!! anti-intuitive
}

double mean(const double* data, int nData) {
  // one method to compute only average
}

double stdDev(const double* data, int nData) {
  // one method to compute standard deviation
  // use mean() to compute average needed by std deviation
}
```

What if we had a new C++ type?

- Imagine we had a new C++ type called **`Result`** including data about both mean and standard deviation

- We could then simply do the following

```
Result mean(const double* data, int nData) {
  Result result;
  // do your calculation
  return result;
}
```

- *This is exactly the idea of classes in C++!*

Classes in C++

- A class is a set of data and functions that define the characteristics and behavior of an object
  - Characteristics also known as attributes
  - Behavior is what an object can do and is referred to also as its interface

Interface
or
Member Functions

Data members or attributes

```
class Result {
  public:

    // constructors
    Result() { }
    Result(const double& mean, const double& stdDev) {
      mean_ = mean;
      stdDev_ = stdDev;
    }

    // accessors
    double getMean() { return mean_; };
    double getStdDev() { return stdDev_; };

  private:
    double mean_;
    double stdDev_;
};
```

Don’t’s forget ; at the end of definition!

Using class **Result**

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

class Result {
  public:

    // constructors
    Result() { };
    Result(const double& mean, const double& stdDev) {
      mean_ = mean;
      stdDev_ = stdDev;
    }

    // accessors
    double getMean() { return mean_; };
    double getStdDev() { return stdDev_; };

  private:
    double mean_;
    double stdDev_;
};
```

```
int main() {

  Result r1;
  cout << "r1, mean: " << r1.getMean()
       << ", stdDev: " << r1.getStdDev()
       << endl;

  Result r2(1.1,0.234);
  cout << "r2, mean: " << r2.getMean()
       << ", stdDev: " << r2.getStdDev()
       << endl;

  return 0;
}
```

```
$ g++ -o results2 result2.cc
$ ./results2
r1, mean: NaN, stdDev: 8.48798e-314
r2, mean: 1.1, stdDev: 0.234
```

`r1` is ill-defined. Why?

What is wrong with Result::Result() ?

C++ Data Types

Name	Description	Size*	Range*
`char`	Character or small integer.	1byte	signed: -128 to 127 unsigned: 0 to 255
`short int (short)`	Short Integer.	2bytes	signed: -32768 to 32767 unsigned: 0 to 65535
`int`	Integer.	4bytes	signed: -2147483648 to 2147483647 unsigned: 0 to 4294967295
`long int (long)`	Long integer.	4bytes	signed: -2147483648 to 2147483647 unsigned: 0 to 4294967295
`bool`	Boolean value. It can take one of two values: true or false.	1byte	true or false
`float`	Floating point number.	4bytes	3.4e +/- 38 (7 digits)
`double`	Double precision floating point number.	8bytes	1.7e +/- 308 (15 digits)
`long double`	Long double precision floating point number.	8bytes	1.7e +/- 308 (15 digits)
`wchar_t`	Wide character.	2 *or* 4 bytes	1 wide character

- Size is architecture dependent!
  - Difference between 32-bit and 64-bit machines
  - Above table refers to typical 32-bit architecture
- **`int`** is usually has size of 'one word' on a given architecture

- Four integer types: **`char`**, **`short`**, **`int`**, and **`long`**
  - Each type is at least as large as previous one
    - **`size(char) <= size(short) <= size(int) <= size(long)`**

- Long **`int == int`**; similarly **`short int == short`**

Size of Objects/Types in C++

```
// cpptypes.cc
#include <iostream>
using namespace std;

int main() {
  char*       aChar = "c"; // char
  bool        aBool = true; // boolean
  short       aShort = 33; // short
  long        aLong  = 123421; // long
  int         anInt = 27; // integer
  float       aFloat = 1.043; // single precision
  double      aDbl = 1.243e-234; // double precision
  long double aLD = 0.432e245; // double precision

  cout << "char* aChar = " << aChar << "\tsizeof(" << "*char" << "): " << sizeof(*aChar) << endl;
  cout << "bool aBool = " << aBool << "\tsizeof(" << "bool" << "): " << sizeof(aBool) << endl;
  cout << "short aShort = " << aShort << "\tsizeof(" << "short" << "): " << sizeof(aShort) << endl;
  cout << "long aLong = " << aLong << "\tsizeof(" << "long" << "): " << sizeof(aLong) << endl;
  cout << "int aInt = " << anInt << "\tsizeof(" << "int" << "): " << sizeof(anInt) << endl;
  cout << "float aFloat = " << aFloat << "\tsizeof(" << "float" << "): " << sizeof(aFloat) << endl;
  cout << "double aDbl = " << aDbl << "\tsizeof(" << "double" << "): " << sizeof(aDbl) << endl;
  cout << "long double aLD = " << aLD << "\tsizeof(" << "long double" << "): " << sizeof(aLD) << endl;

  return 0;
}
```

```
$ g++ -o cpptypes cpptypes.cc
$ ./cpptypes
char* aChar = c                    sizeof(*char): 1
bool aBool = 1                     sizeof(bool): 1
short aShort = 33                  sizeof(short): 2
long aLong = 123421                sizeof(long): 4
int aInt = 27                      sizeof(int): 4
float aFloat = 1.043               sizeof(float): 4
double aDbl = 1.243e-234           sizeof(double): 8
long double aLD = 4.32e+244        sizeof(long double): 12
```