Pointers

Comp Sci 1570 Introduction to C++

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Definition of a pointer

- A pointer is a variable whose value is the address of another variable.
- What is an address?
- How do you get the memory address of a variable?

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Address of an int?

How do you get the memory address of an int for example?

```
int genePos = 435;
cout << &genePos << endl; // 0x7ffcb158c144
```

- & is the "address of" operator
- What is that weird number?
- How is memory structured?

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Memory as a tape


```
int genePos = 435;
cout << &genePos << endl; // 0x7ffcb158c144
```

Name of variable	Storage address	Value
	0x7ffcb158c140	
genePos	0x7ffcb158c144	435
	0x7ffcb158c148	
	0x7ffcb158c14c	
	0x7ffcb158c150	
	0x7ffcb158c154	

- Variable name is an alias for address, accessible via the & operator

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What is a pointer?


```
int genePos = 435;
int *p1 = &genePos;
cout << p1 << endl; // 0x7ffcb158c144
```

Name of variable	Storage address	Value
	0x7ffcb158c140	
genePos	0x7ffcb158c144	435
	0x7ffcb158c148	
	0x7ffcb158c14c	
p1	0x7ffcb158c150	0x7ffcb158c144
	0x7ffcb158c154	

- p1 is a pointer – a variable whose value is the address of another variable.

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Pointer declaration (type specific)

- Like other variables or constants, pointers must be declared
- General pointer variable declaration is:
  $type * pointerName = \&varName$
  where type is the pointer's base type
- Pointers have a type (of the thing they address) restriction (e.g., type is "pointer to an int" or "pointer to a double")
- Can cast between pointer types, e.g., static cast, but should not generally to non-pointer types.

Declaring types of pointers:

```
int *numberObject;
char *characterObject;
double *decimalObject;
```

Pointer declaration


```
int *p1, *p2; // both p1 and p2 are pointers
int *p1, p2; // p2 is not a pointer!
```

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Pointer initialization variations


```
int genePos; // whas is the value of genePos?
int *p1 = &genePos;

int genePos;
int *p1; // what does p1 point to?
p1 = &genePos;

int genePos;
int *p1 = &genePos;
int *p2 = p1;

// 0, NULL, or nullptr for no target
int genePos;
int *p1 = 0;
```

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Contents of object being pointed to


```
int genePos = 435;
int *p1 = &genePos;
cout << *p1 << endl; // outputs: 435
int x = *p1;
cout << x << endl; // outputs: 435
```

Name of variable	Storage address	Value
	0x7ffcb158c140	
genePos	0x7ffcb158c144	435
	0x7ffcb158c148	
	0x7ffcb158c14c	
p1	0x7ffcb158c150	0x7ffcb158c144
	0x7ffcb158c154	

- Contents of operator also known as derefernece operator, *
- This is not the same as the * used during initialization; the * on lines 2 and 3 are different

Assignment via dereferenced pointer


```
int genePos = 435;
int *p1 = &genePos;
cout << *p1 << endl; // outputs: 435
*p1 = 248;
cout << *p1 << endl; // outputs: 248
```

Name of variable	Storage address	Value
	0x7ffcb158c140	
genePos	0x7ffcb158c144	435 changed to 248
	0x7ffcb158c148	
	0x7ffcb158c14c	
p1	0x7ffcb158c150	0x7ffcb158c144
	0x7ffcb158c154	

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Why are pointers useful?

- Used for new memory during execution,
  e.g., dynamic memory
- Can refer/pass large data structures without copying,
  for efficiency
- Can specify relationships among data,
  e.g., linked lists coming up

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Address of address of?


```
int genePos = 435;
int *p1 = &genePos;
int **metaP = &p1;
cout << metaP << endl; // ??
cout << *metaP << endl; // ??
cout << **metaP << endl; // ??
```

Name of variable	Storage address	Value
	0x7ffcb158c140	
genePos	0x7ffcb158c144	435
	0x7ffcb158c148	
	0x7ffcb158c14c	
p1	0x7ffcb158c150	0x7ffcb158c144
metaP	0x7ffcb158c154	0x7ffcb158c150

Remember, ** on lines 3 and 6 are different,
as are the * on lines 2 and 5.

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What about these statements?


```
cout << &*p1 << endl; // ??
cout << *&p1 << endl; // ??
cout << &*&*p1 << endl; // ??
cout << *&*&p1 << endl; // ??
```

Name of variable	Storage address	Value
	0x7ffcb158c140	
genePos	0x7ffcb158c144	435
	0x7ffcb158c148	
	0x7ffcb158c14c	
p1	0x7ffcb158c150	0x7ffcb158c144
metaP	0x7ffcb158c154	0x7ffcb158c150

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Pointers and arrays

What is an array really?

```
int a[6] = {1,7,3,4,2,8};
cout << a[2] << endl; // outputs: 3
cout << a << endl; // ??
```

Pointers and arrays

- Arrays are like pointers, but const, addressing the first element of the array
- Below, mypointer can be assigned a different address, but myarray can't.

```
int myarray[20];
cout << myarray << endl; // 0x7ffcb158c140

int *mypointer;

// Valid, but why no & operator?
// Recall passing arrays by reference?
mypointer = myarray;
cout << mypointer << endl; // 0x7ffcb158c140

// Invalid, why?
myarray = mypointer;
```

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Pointers and arrays

- The following have the same result:

```
int a[6] = {1,7,3,4,2,8};

a[5] = 0;          // a[offset of 5] = 0
cout << a[5] << endl; // outputs: 0
cout << *(a+5)<< endl; // outputs: 0

*(a+5) = 1;          // a[offset of 5] = 1
cout << a[5] << endl; // outputs: 1
cout << *(a+5) << endl; // outputs: 1
```

Why does adding 5 to array a work?

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Pointer arithmetic


```
int a[6] = {1,7,3,4,2,8};
int *pa = a;
cout << pa + 2 << endl; // 0x7ffcb158c148
cout << *(pa + 2) << endl; // 3
cout << pa++ << endl; // 0x7ffcb158c144
cout << *pa << endl; // 7
```

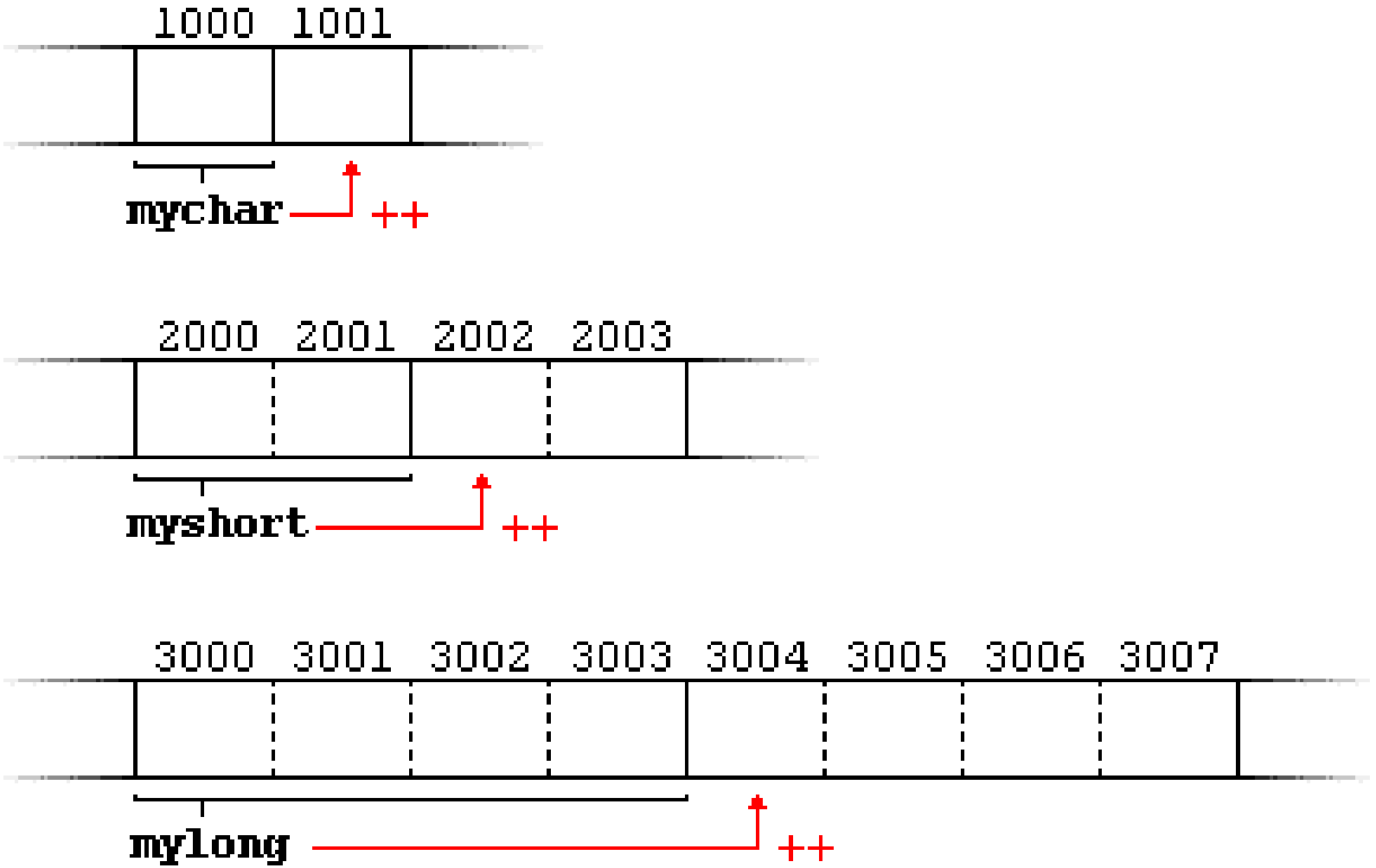
Name of variable	Storage address	Value
a[0] or *a	0x7ffcb158c140	1
a[1] or *(a+1)	0x7ffcb158c144	7
a[2] or *(a+2)	0x7ffcb158c148	3
a[3] or *(a+3)	0x7ffcb158c14c	4
a[4] or *(a+4)	0x7ffcb158c150	2
a[5] or *(a+5)	0x7ffcb158c154	8
a	0x...	0x7ffcb158c140
pa	0x...	0x7ffcb158c140

- Why increments of 4?

Pointer and array arithmetic


```
int *pa = a;
cout << pa + 2 << endl; // 0x7ffcb158c148
cout << a + 2 << endl; // 0x7ffcb158c148

cout << *(pa+2) << endl; // 3
cout << *(a+2) << endl; // 3

cout << pa[2] << endl; // 3
cout << a[2] << endl; // 3

cout << pa++ << endl; // 0x7ffcb158c144
//cout << a++ << endl; // not valid, array const

cout << *pa << endl; // 7
cout << *a << endl; // 1
```

Each type is a different size



Use sizeof(p) without the '*' operator to determine the memory utilized on your system for types like int, which are different per system.

Messy pointer arithmetic

Postfix operators (- - , ++), have higher precedence than prefix operators (dereference *).

```
int genePos[3] = {435,123,987};
int *p = genePos;
cout << p << endl; // 0x7ffe35b36ee0
cout << *(p++) << p << endl; // 435 0x7ffe35b36ee4
p = genePos;
cout << *p++ << p << endl; // 435 0x7ffe35b36ee4
p = genePos;
cout << *(++p) << p << endl; // 123 0x7ffe35b36ee4
p = genePos;
cout << *++p << p << endl; // 123 0x7ffe35b36ee4
p = genePos;
cout << ++(*p) << p << endl; // 436 x7ffe35b36ee0
p = genePos;
cout << ++*p << p << endl; // 437 x7ffe35b36ee0
p = genePos;
cout << (*p)++ << p << endl; // 437 x7ffe35b36ee0
```

Next time

Dynamic memory (heap, stack, garbage collection, dangling pointers), pointers to classes and structs, const pointers, arrays of pointers, void pointers, pointers to functions, returning pointers from functions