Pointers, Memory, Abstractions

- A pointer is the a variable/value that is a memory address
  - Addresses like 1, 2, 3, ..., 0x0024ab03
    * Hexadecimal or base-16 digit represents 4 bits
    * Character is 8 bits, integer is 32 bits
  - Every variable is stored somewhere in memory, typically we can ignore where
  
  ```
  double x = 32.6;
  int y = 18;
  string s = "hello";
  ```

- What about a permanent, but forwardable email address?
- Other kinds of references?

Pointers

- Using pointers presents some of the same problems as being Spiderman
  - With great power comes great responsibility...
  - New, more ugly, and harder to detect bugs
- Why pointers?
  - Allow different sections of code to share data easily
  - Enable linked data structures
- The BIG pointer concepts
  - Pointer declaration
  - NULL (0) pointer
  - BAD (uninitialized) pointers
  - Memory allocation from heap
  - Pointer dereference
  - Pointer assignment

Binky Code

```c
void main() {
    int *x; // Allocate the pointers x and y
    int *y; // but not the _pointee_

    x = new int;

    *x = 42; // Dereference x - store 42 in pointee
    *y = 13; // CRASH!

    y = x; // Pointer assignment
    *y = 13; // Store 13 in its (shared) pointee
}
```

What's a pointer, why good, why bad?

- Pointer is a memory address, it's an indirect reference to memory or an object.
  - Rather than say we have an int, we say we have a pointer to an int
  - If x is an int, xptr can be a pointer to x
    * Same thing works with Date, Dice, Student, ...
    * Not much use to have pointer to int, but pointer to class!!
- Pointers force us to think about the machine and memory
  - Knowledge is powerful, freedom from it liberating
- Pointers allow us to work at a lower level, but permit inheritance and a higher level of design/programming
  - Built-in array and tvector, C-style string and <string>
**Pointer example**

- new, dereference, selector operator, copy semantics

```cpp
CD c1("Beatles", "Rubber Soul", 1965);
CD c2("Nirvana", "Nevermind", 1991);
CD * c3 = new CD("REM", "Reveal", 2001);
CD * c4; // what is the value of c4?
CD c5; // what is the value of c5?
cout << c1.title() << endl;
cout << c3->title() << endl;
cout << (*c3).title() << endl;
c5 = c2; c2.changeTitle("Incesticide");
cout << c5.title() << endl;
c4 = c3; c3->changeTitle("Out of Time");
cout << c4->title() << endl;
```

- What happens if we print `c4->title()` on first line? Why?

---

**What's the point?**

- What's the difference between a vector of Dates and a vector of pointers to Dates? What about Courses, Students, etc.?

```cpp
tvector<Date> tv(1000);
tvector<Date *> tvp(1000);
```

- Which takes up more space? What are values in vectors?

- What happens when we write
  ```cpp
tv[0] = tv[2]; // if we change tv[2], affect tv[0]?
tvp[0] = tvp[3]; // change *(tv[3]), affect tvp[0], *tpv[0]?
```

- Consider example of sorting by both name and age
  - Should we have two vectors of students?
  - Should we have two vectors of student pointers?
  - Is there a reason to prefer one to the other?

---

**Thinking about pointersort.cpp**

- The class Group uses a `tvector<Student>` myList
  - What changes if this is `tvector<Student *> myList`?
    - Changes to Group::add
    - Changes to Group::print
  - Other changes needed?

- What if we want to sort by age to print, leaving original order the same (why would we want to do this?)
  - Use another vector, sort it differently
  - Why is another vector a good idea?
  - Could use vector of indexes
    - Both are indirect references

---

**Local memory is ephemeral...**

```cpp
// -- The Ampersand Bug function
// Returns a pointer to an int TAB
int* TAB() {
    int temp;
    return(&temp); // return a pointer to the local int
}
void Victim() {
    int* ptr;
    ptr = TAB();
    *ptr = 42; // Runtime error! Pointee local to TAB
}
```
The trouble with pointers

- Local vs. Heap allocation
- Another address of bug

```cpp
dice * makeDie(int sides) {
    return new Dice(sides);
}
```

What about the code below with different versions?

```cpp
dice * cube = makeDie(4);
cout << cube->numSides() << endl;
```

- Pointer Advice
  - Always initialize pointer variables, 0/NULL or new
    - 0/NULL means errors are reproduceable
    - Possible to assign another pointer value too
  - Don't call new unless you want another object allocated