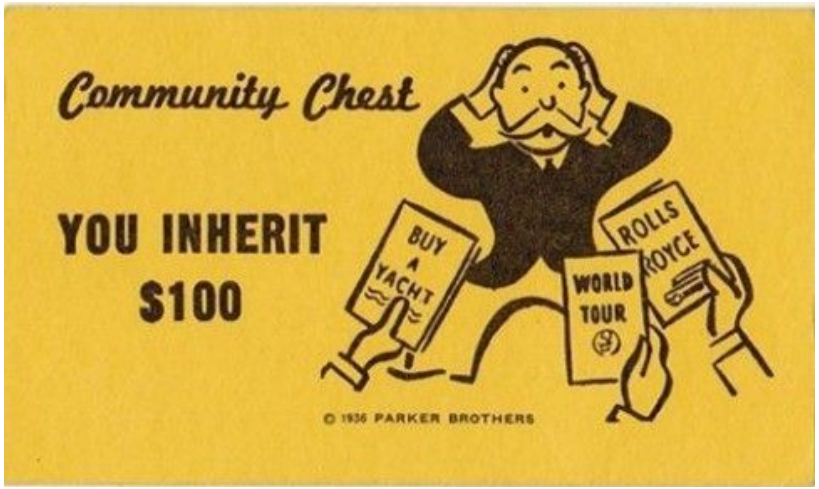
Lecture 35-36: Inheritance

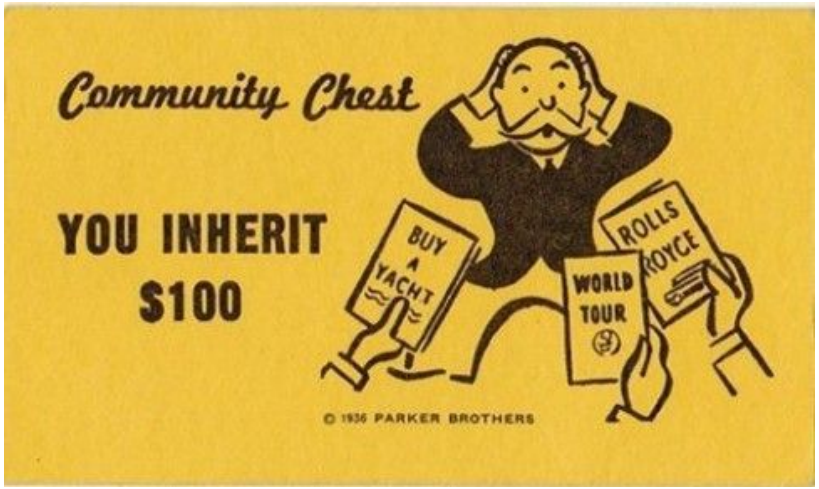


Announcements and reminders

- **Project 3!** A good goal:
  - **initialization/set-up** + **display** the whole “world”/game state -- by ~Monday
  - After that, you ***“just”*** have to move stuff around / calculate things / use mutators!

- Project 2 interview grading **by Monday April 15**

- Homework 9
  Due Wednesday April 17 by 11 PM



Last time on *Intro Computing…*

We looked at **what to do when we're handed a big project**

- Identify what are the key **structures**
- … and how those structures **relate** to one another
- Identify what are the key **functions**
- … and how these functions are related to our structures

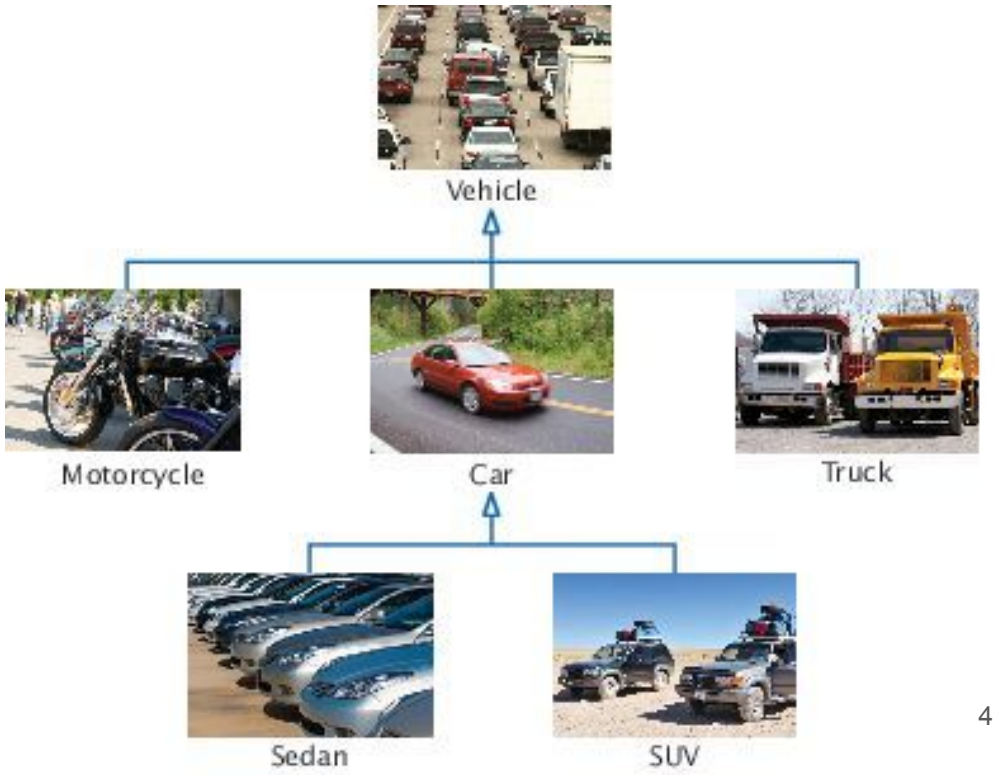
Inheritance -- what is it?

In the real-world, **inheritance** is the process by which one object (or ***class of objects***) is assigned traits/characteristics based on a larger class that it belongs to.

Can think of it as an "**is a**" relationship.

Examples:

- Every car **is a** vehicle.
- Every sedan **is a** car.



Inheritance -- what is it?

We call the more general class the **base class** and the more specialized class the **derived class**.

The derived class **inherits** data and behavior from the base class.

Examples:

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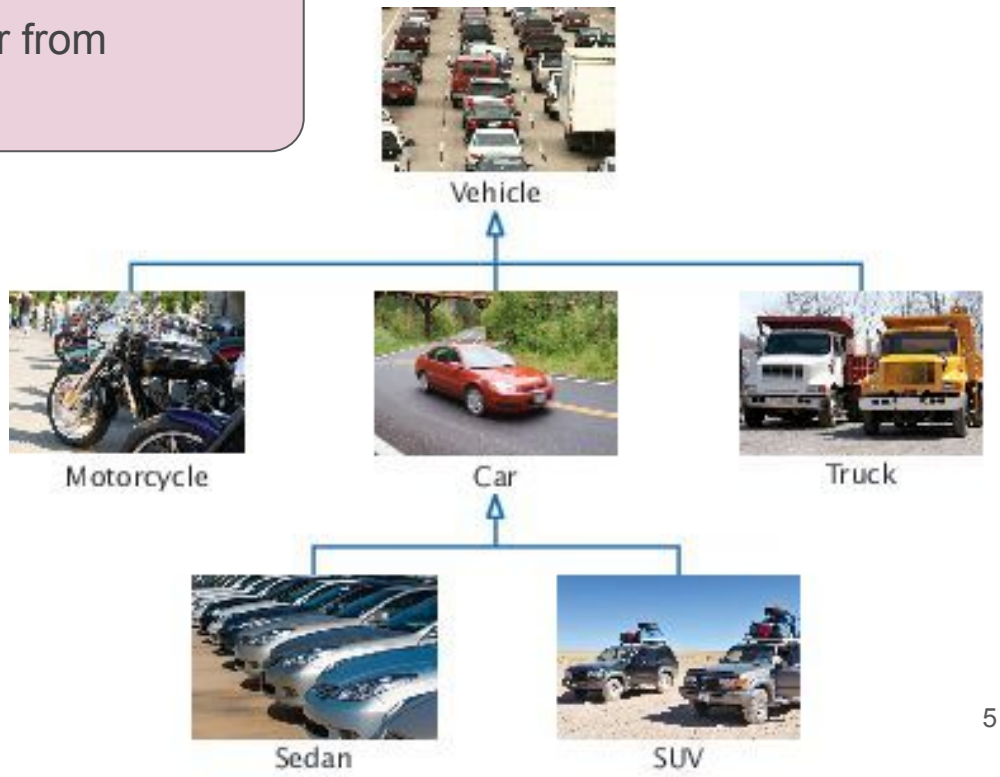
- Every sedan **is a** car.

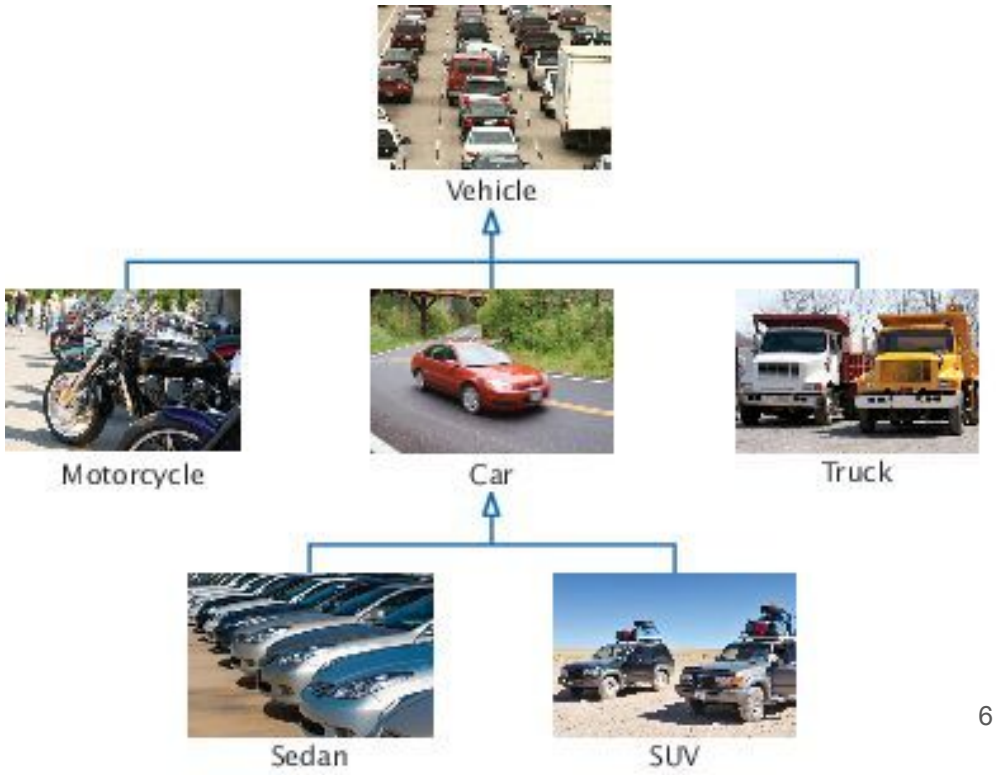


Question: In each of those examples, which is the base class and which is the derived class?

Inheritance -- what is it?

Classes become **more specific** as you go deeper into the **inheritance hierarchy**.

- Vehicle is most general
- Car **has all the properties of a vehicle**, plus some specific to cars
- Sedan **has all the properties of a car**, plus some specific to sedans
    - Sedans and SUVs **inherit** properties specific to cars



Substitution principle

The **substitution principle** states that you can always use a derived-class object when a base-class object is expected.

Example: `double gasMileage(Vehicle v) {...}` // fcn to return the gas mileage of a vehicle

→ We could send a `Car` object into this function and it'd work fine, because a `Car` ***is a*** `Vehicle`.

Quiz question hierarchy

Quizzes consist of different kinds of questions:

- Fill-in-the-blank
- Choice (single or multiple)
- Numeric
- Free response

Can we sketch out this
inheritance hierarchy?

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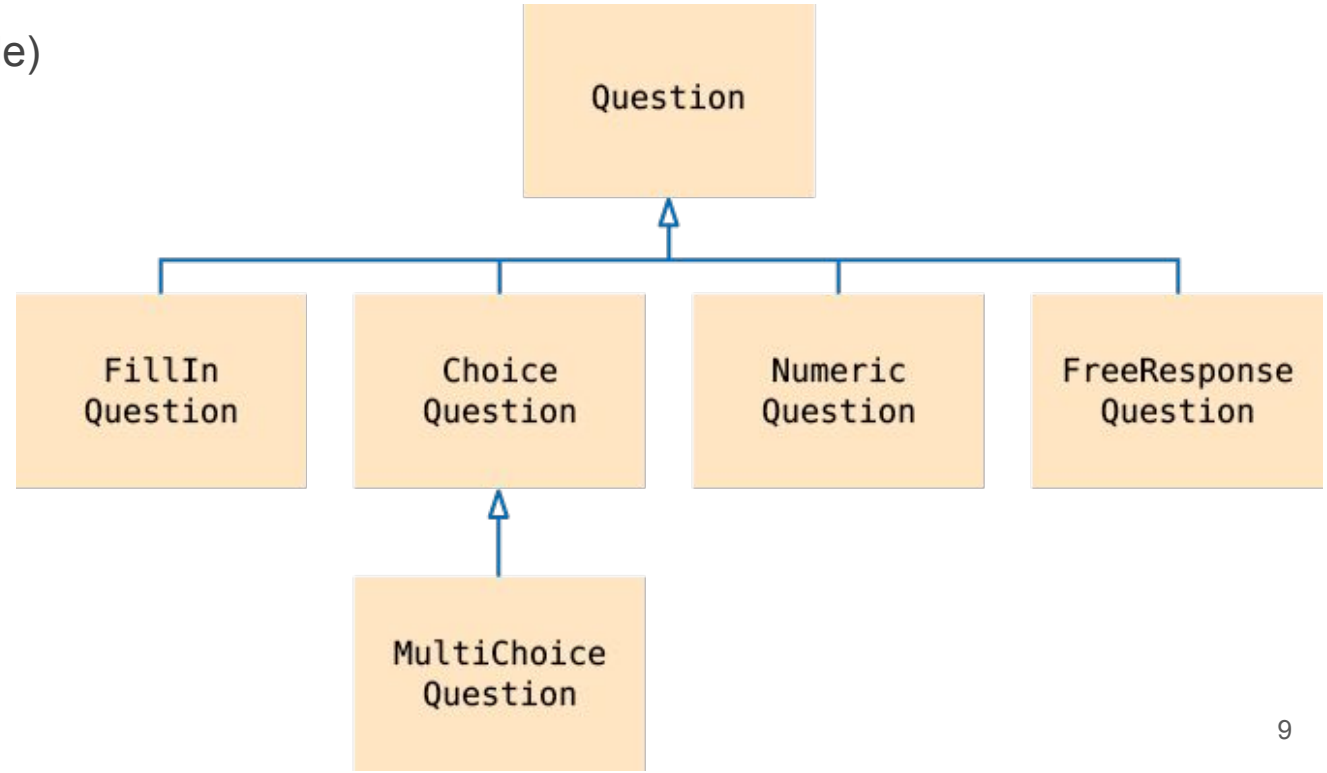

The base class: `Question`

We want an object of `Question` type to work like this:

1) First, the programmer sets the question text and the correct answer (stored in the `Question` object)

2) When a user takes the quiz, the programmer asks the `Question` to display the text of the question

3) The program gets the user's response and passes it to the `Question` object for evaluation, to display True or False

Member functions/data members we need:

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Member functions/data members we need:

Member functions: `set_text`, `set_answer`, `check_answer`, `display`, constructor(s)

Data members: `text`, `answer`

Coding it up: *question.cpp*

Implementing derived classes

Now that `Question` class was the bare bones, most basic version of a quiz question. We want different types of question!

- Each special type of question ***is a*** `Question`
  (e.g., a multiple choice question ***is a*** `Question`)
- So we start with the base class (`Question`) …
- … then write code for what makes each different type of question a ***special version*** of the more general `Question` type
  - Through inheritance, each of the derived classes have the **data members** and **member functions** that we set up in the base `Question` class
  - ***AND*** we can define new stuff that makes the derived classes special!

Derived classes: ChoiceQuestion

```
class ChoiceQuestion : public Question
{
public:
   // new and/or changed member functions go here
private:
   // additional data members go here
};
```

Notes:

- The : denotes **inheritance**
- The **public** reserved word is needed for technical reasons
    - *We want to inherit **publicly**, otherwise we wouldn't be able to use our `Question` member functions except within `ChoiceQuestion`*

Derived classes: ChoiceQuestion

Let's analyze what we need to do to make our **specialized derived class.**

1) Still need to set question text (done!)
2) But now need to set **several multiple choice answer options**…
3) … which means we need to **display the question a little bit differently**.

→ we will do what is called **overriding** a member function
(overriding = rewrite a specialized version for our derived class)

Member functions/data members we need to add/modify:

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3) … which means we need to **display the question a little bit differently**.

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Member functions/data members we need to add/modify:

Member functions: `add_choice`, `display`, constructor(s)

Data members: `choices`

Design question:

`add_choice()` will add a choice to our answer options

What kind of data type should `choices` be: **vector** or **array**?

Derived classes: ChoiceQuestion

```
class ChoiceQuestion : public Question
{
public:
   ChoiceQuestion();
   void add_choice(string choice, bool correct);
   void display() const;
private:
   vector<string> choices;
};
```

Notes:

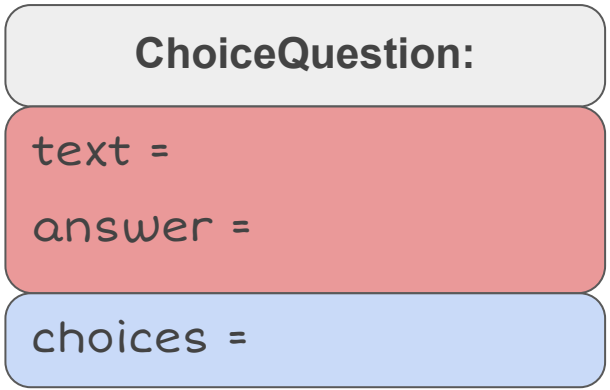
- We first specify the class we are inheriting from (**Question**) …
- … then only need to specify the differences (**new** or **modified**)
- You could slap this derived class definition right below the base class definition

Derived classes: ChoiceQuestion

ChoiceQuestion is **one type**, but made up of two parts:

- One part is inherited from Question (text, answer)
- Another part is new (choices)

But data members from the base class are **still private**:



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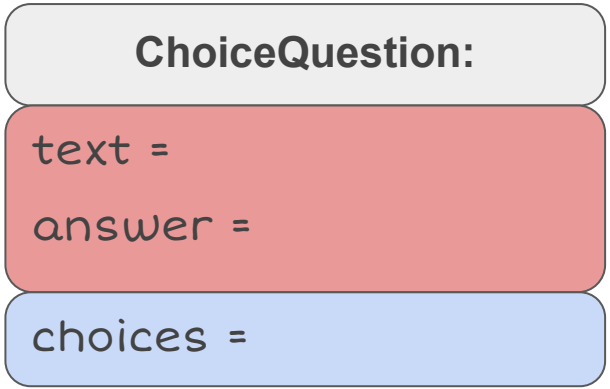


But data members from the base class are **still private**:

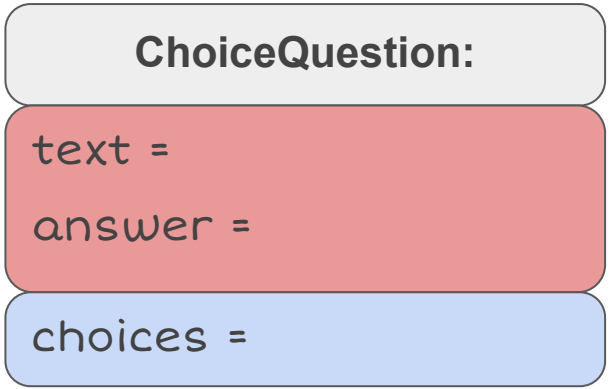
```
ChoiceQuestion q1;
q1.set_answer("2");    // calls public member fcn of base class - okay!


q1.answer = "2";     // ERROR!
```

^-- here, the answer data member is **private** to the Question class,
so even the derived type cannot access it

Moral of the story:

- When writing the ChoiceQuestion member functions, we cannot directly access the **private** data members from the Question class
- Just like any other function, we must **use our getters** from the base class



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New member function: add_choice

```
void ChoiceQuestion::add_choice(string choice, bool correct) {
   choices.push_back(choice);   // add the new choice
   if (correct) {               // change answer to this one's number
      // convert choices.size() to string
      string num_str = to_string(choices.size());
      // set num_str as the answer, using public member function:
      set_answer(num_str);
}
```

Notes:

New member function: add_choice

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void ChoiceQuestion::add_choice(string choice, bool correct) {
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      string num_str = to_string(choices.size());
      // set num_str as the answer, using public member function:
      set_answer(num_str);
}
```

Notes:

- We can directly call the member fcn **set_answer()** because it's **public**, and we're already in the **Question** class (by virtue of being in the **ChoiceQuestion** class!)
- That means we have the (Choice)Question object passed as an **implicit parameter**

Derived classes: overriding member functions

Recall that our design requires that the **display** member function be rewritten in the **ChoiceQuestion** class.

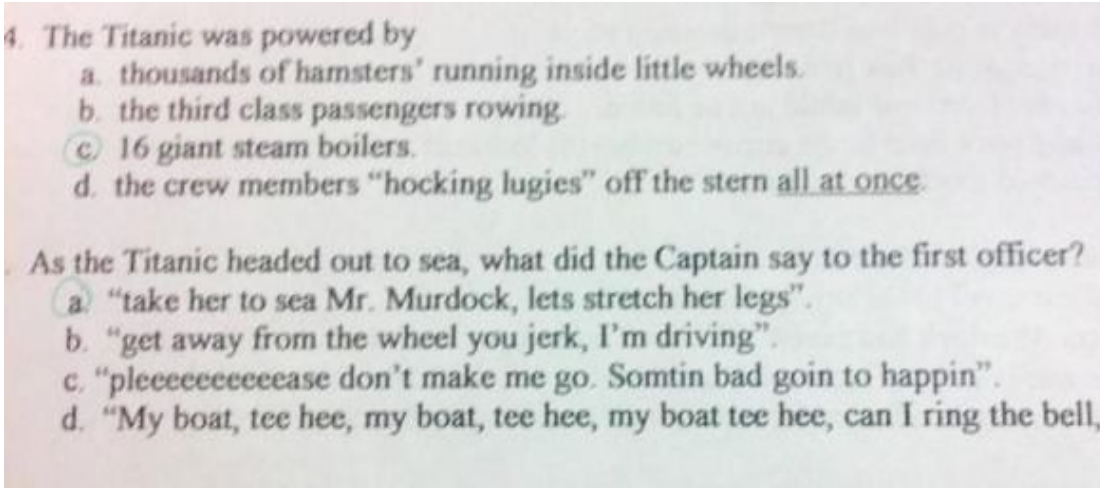
→ This is called **overriding** a member function

Question display member fcn:

1) cout the question text

ChoiceQuestion display member fcn:

1) cout the question text
2) **then cout the answer choices**



Derived classes: overriding member functions

The second part is easy -- just a loop to print out the derived-class **choices** data member:

```
void ChoiceQuestion::display() const {
    // Display the question text
    ...
    // Display the answer choices
    for (int i = 0; i < choices.size(); i++) {
        cout << i+1 << ": " << choices[i] << endl;
    }
}
```

Derived classes: overriding member functions

The first part ***seems*** easy -- just call the **display** member fcn in the **Question** class:

```
void ChoiceQuestion::display() const {
    // Display the question text
    display();    // ERROR: calls the ChoiceQuestion version of display
    // Display the answer choices
    for (int i = 0; i < choices.size(); i++) {
        cout << i+1 << ": " << choices[i] << endl;
    }
}
```

But the will call the ***ChoiceQuestion*** version of the **display** function!

Derived classes: overriding member functions

The first part ***seems*** easy -- just call the **display** member fcn in the **Question** class:

```
void ChoiceQuestion::display() const {
    // Display the question text
    Question::display();    // Yay! Calls the Question version of display
    // Display the answer choices
    for (int i = 0; i < choices.size(); i++) {
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    }
}
```

But the will call the ***ChoiceQuestion*** version of the **display** function!

→ We remedy this by forcing it to call the **Question** version by prefixing with **Question::**

Derived classes: overriding member functions

The first part ***seems*** easy -- just call the **display** member fcn in the **Question** class:

```
void ChoiceQuestion::display() const {
    // Display the question text
    Question::display();    // Yay! Calls the Question version of display

    // Display the answer choices
    for (int i = 0; i < choices.size(); i++) {
        cout << i+1 << ": " << choices[i] << endl;
    }
}
```

Note that we do not necessarily **need** to use the base class's function. We could have just rewritten the code to display the question text.

But in that case, we'd need a getter for the question **text** data member, which is **private**. So we would need a new getter for **text** in the **Question** class

What just happened?!

We just saw… **class inheritance!**

- ***Hierarchies*** showing an ***is a*** relationship
  - Ex: A car **is a** vehicle
  - Ex: An apartment **is a** household
- **Base class** vs **derived class**
  - Base = most general
  - Derived = more specific
- **Derived classes:**
  - New member fcns, data members
  - **Overriding** old member fcns