# CIS 190: C/C++ Programming

Lecture 11

Polymorphism

# Outline

- Review of Inheritance
- Polymorphism
  - Limitations
  - Virtual Functions
  - Abstract Classes & Function Types
  - Virtual Function Tables
  - Virtual Destructors/Constructors
- Application of Polymorphism
- Project Alphas

# Review of Inheritance

- specialization through sub classes

- child class has direct access to
  - parent member functions and variables that are
    - ???

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- specialization through sub classes

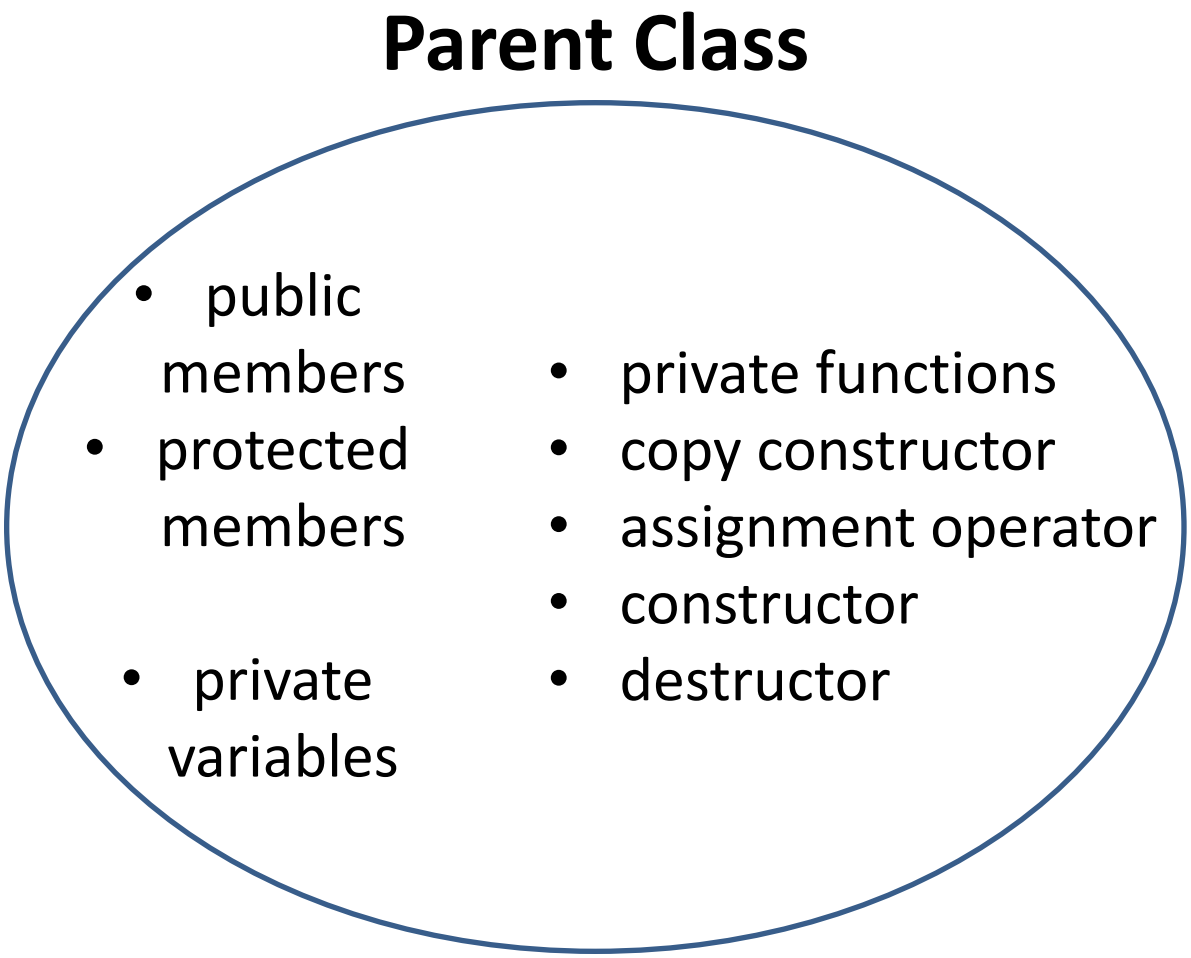
- child class has direct access to
  - parent member functions and variables that are:
    - public
    - protected
- parent class has direct access to:
  - **???** in the child class

# Review of Inheritance

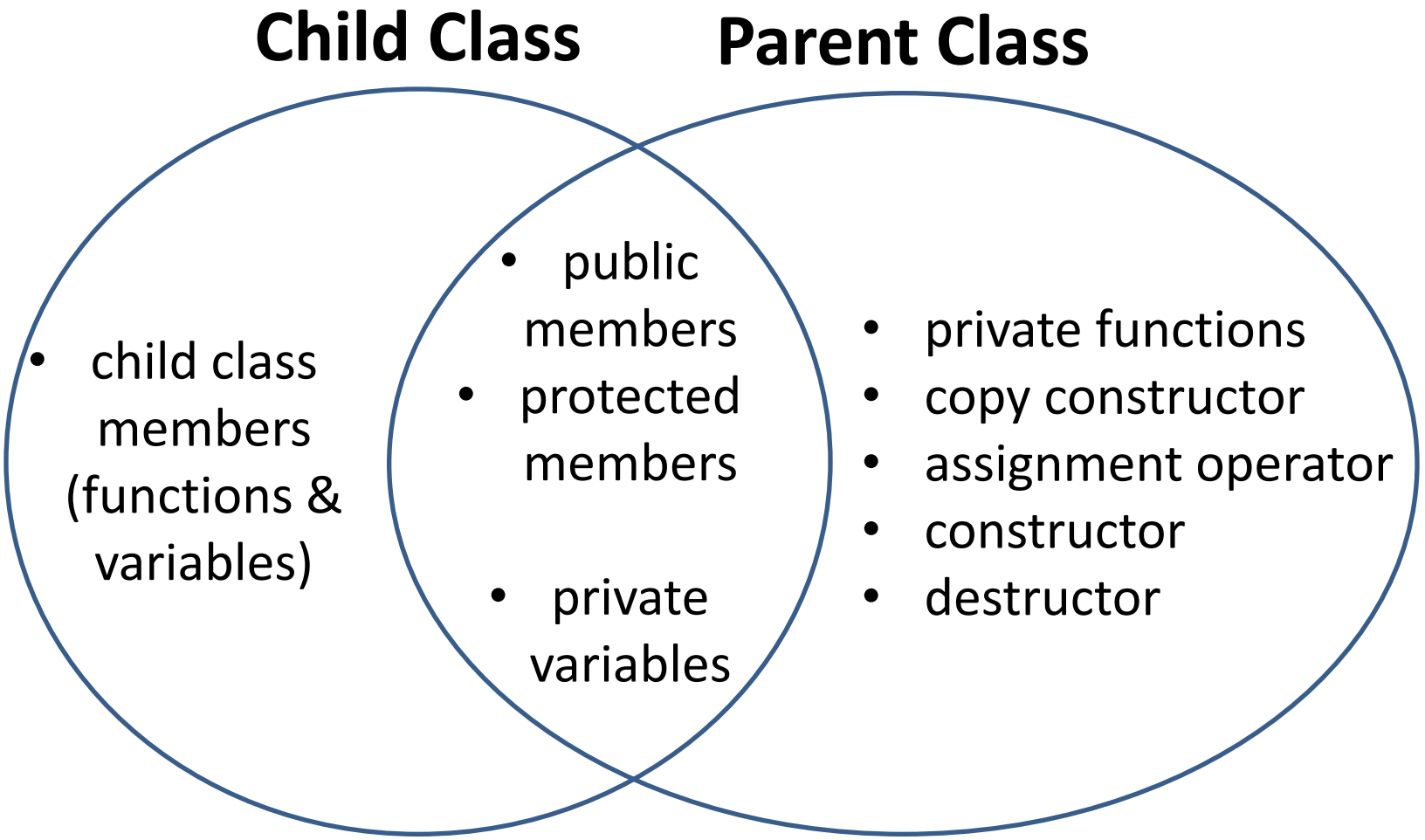
- specialization through sub classes

- child class has direct access to
  - parent member functions and variables that are:
    - public
    - protected
- parent class has direct access to:
  - **nothing** in the child class

# What is Inherited



# What is Inherited



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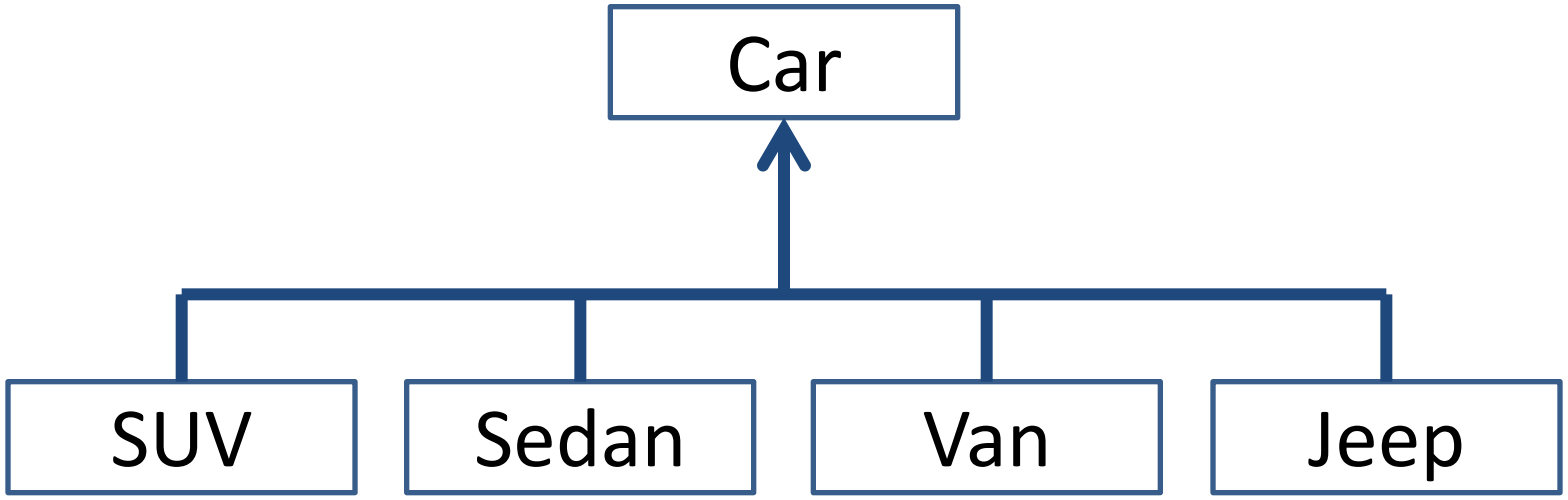
# Car Example




```
class SUV:   public Car {/*etc*/};
class Sedan: public Car {/*etc*/};
class Van:   public Car {/*etc*/};
class Jeep:  public Car {/*etc*/};
```

# Car Rental Example

- we want to implement a catalog of different types of cars available for rental

- how could we do this?

# Car Rental Example

- we want to implement a catalog of different types of cars available for rental
- how could we do this?
- can accomplish this with a single vector
  - using ***polymorphism***

# What is Polymorphism?

- ability to manipulate objects in a **type-independent** way

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- already done to an extent via ***overriding***
  - child class overrides a parent class function

# What is Polymorphism?

- ability to manipulate objects in a **type-independent** way
- already done to an extent via ***overriding***
  - child class overrides a parent class function
- can take it further using subtyping, AKA ***inclusion polymorphism***

# Using Polymorphism

- a pointer of a parent class type can point to an object of a child class type

```
Vehicle *vehiclePtr = &myCar;
```

- why is this valid?

# Using Polymorphism

- a pointer of a parent class type can point to an object of a child class type

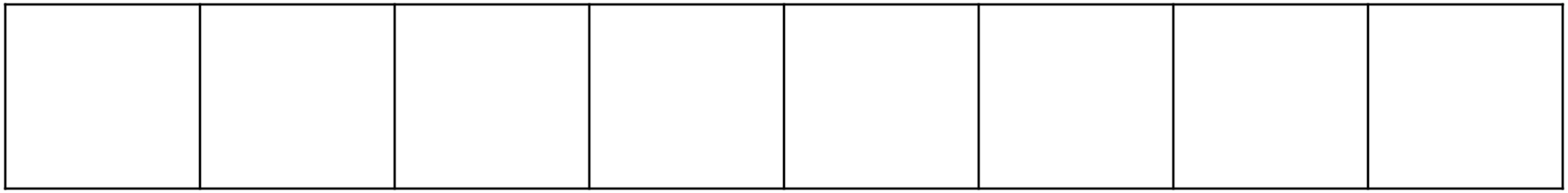
```
Vehicle *vehiclePtr = &myCar;
```

- why is this valid?
  - because **myCar** is-a **Vehicle**

# Polymorphism: Car Rental

```
vector <Car*> rentalList;
```

vector of **`Car*`** objects



# Polymorphism: Car Rental

```
vector <Car*> rentalList;
```

vector of **`Car*`** objects

| SUV | SUV | Jeep | Van | Jeep | Sedan | Sedan | SUV |
|---|---|---|---|---|---|---|---|

- can populate the vector with any of **`Car`**'s child classes

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# Limitations of Polymorphism

- parent classes **do not** inherit from child classes
  - what about public member variables and functions?

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```
Vehicle *vehiclePtr = &myCar;
```

- which version of **`PrintSpecs()`** does this call?

```
vehiclePtr->PrintSpecs();
```

# Limitations of Polymorphism

- parent classes **do not** inherit from child classes
  - **not even** public member variables and functions

```
Vehicle *vehiclePtr = &myCar;
```

- which version of **`PrintSpecs()`** does this call?

```
vehiclePtr->PrintSpecs();
```

```
Vehicle::PrintSpecs()
```

# Limitations of Polymorphism

- parent classes **do not** inherit from child classes
  - **not even** public member variables and functions

```
Vehicle *vehiclePtr = &myCar;
```

- will this work?

```
vehiclePtr->RepaintCar();
```

# Limitations of Polymorphism

- parent classes **do not** inherit from child classes
  - **not even** public member variables and functions

```
Vehicle *vehiclePtr = &myCar;
```

- will this work?

```
vehiclePtr->RepaintCar();
```

  - NO! `RepaintCar()` is a function of the Car child class, not the Vehicle class

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# Virtual Functions

- can grant access to child methods by using ***virtual functions***

- virtual functions are how C++ implements ***late binding***
  - used when the child class implementation is unknown or variable at parent class creation time

# Late Binding

- simply put, binding is determined at run time
  - as opposed to at compile time
- in the context of polymorphism, you're saying

  I don't know for sure how this function is going to be implemented, so wait until it's used and then get the implementation from the object instance.

# Using Virtual Functions

- declare the function in the parent class with the keyword **`virtual`** in front

```
virtual void Drive();
```

# Using Virtual Functions

- declare the function in the parent class with the keyword **`virtual`** in front

```
virtual void Drive();
```

- only use **`virtual`** with the prototype

```
// don't do this
virtual void Vehicle::Drive();
```

# Using Virtual Functions

- the corresponding child class function does not require the **`virtual`** keyword

- but…

# Using Virtual Functions

- the corresponding child class function does not require the **`virtual`** keyword

- should still include it, for clarity's sake
  - makes it obvious the function is virtual, even without looking at the parent class

```
// inside the Car class
virtual void Drive();
```

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# Function Types – Virtual

```
virtual void Drive();
```

- parent class **must** have an implementation
  - even if it's trivial or empty
- child classes may override if they choose to
  - if not overridden, parent class definition used

# Function Types – Pure Virtual

```
virtual void Drive() = 0;
```

- denote pure virtual by the “ = 0” at the end

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```
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- denote pure virtual by the "`= 0`" at the end
- the parent class has **no implementation** of this function
  - child classes **must** have an implementation

# Function Types – Pure Virtual

```
virtual void Drive() = 0;
```

- denote pure virtual by the "`= 0`" at the end
- the parent class has **no implementation** of this function
  - child classes **must** have an implementation
  - parent class is now an ***abstract class***

# Abstract Classes

- an ***abstract class*** is one that contains a function that is ***pure virtual***

# Abstract Classes

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- cannot declare abstract class objects
  - why?

# Abstract Classes

- an ***abstract class*** is one that contains a function that is ***pure virtual***
- cannot declare abstract class objects
  - why?
- this means abstract classes can only be used as base classes

# Applying Virtual to Shape, etc.

- how should we label the following functions? (virtual, pure virtual, or leave alone)

```
CalculateArea();
CalculatePerimeter();
Print();
SetColor();
```

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# Behind the Scenes

- if our **`Drive()`** function is virtual, how does the compiler know which child class's version of the function to call?

vector of Car* objects

| SUV | SUV | Jeep | Van | Jeep | Sedan | Sedan | SUV |
|---|---|---|---|---|---|---|---|

# Virtual Function Tables

- the compiler uses ***virtual function tables*** whenever we use polymorphism

- virtual function tables are created for:
  - what types of classes?

# Virtual Function Tables

- the compiler uses ***virtual function tables*** whenever we use polymorphism

- virtual function tables are created for:
  - classes with virtual functions
  - child classes of those classes

# Virtual Table Pointer

| SUV | SUV | Jeep | Van | Jeep | Sedan | Sedan | Van |
|---|---|---|---|---|---|---|---|

# Virtual Table Pointer

- the compiler adds a hidden variable

| SUV | SUV | Jeep | Van | Jeep | Sedan | Sedan | Van |
|---|---|---|---|---|---|---|---|
| *__vptr | *__vptr | *__vptr | *__vptr | *__vptr | *__vptr | *__vptr | *__vptr |

# Virtual Table Pointer

- the compiler also adds a virtual table of functions for each class

| SUV | SUV | Jeep | Van | Jeep | Sedan | Sedan | Van |
|---|---|---|---|---|---|---|---|
| *__vptr | *__vptr | *__vptr | *__vptr | *__vptr | *__vptr | *__vptr | *__vptr |

| SUV virtual table | Jeep virtual table | Van virtual table | Sedan virtual table |
|---|---|---|---|

# Virtual Table Pointer

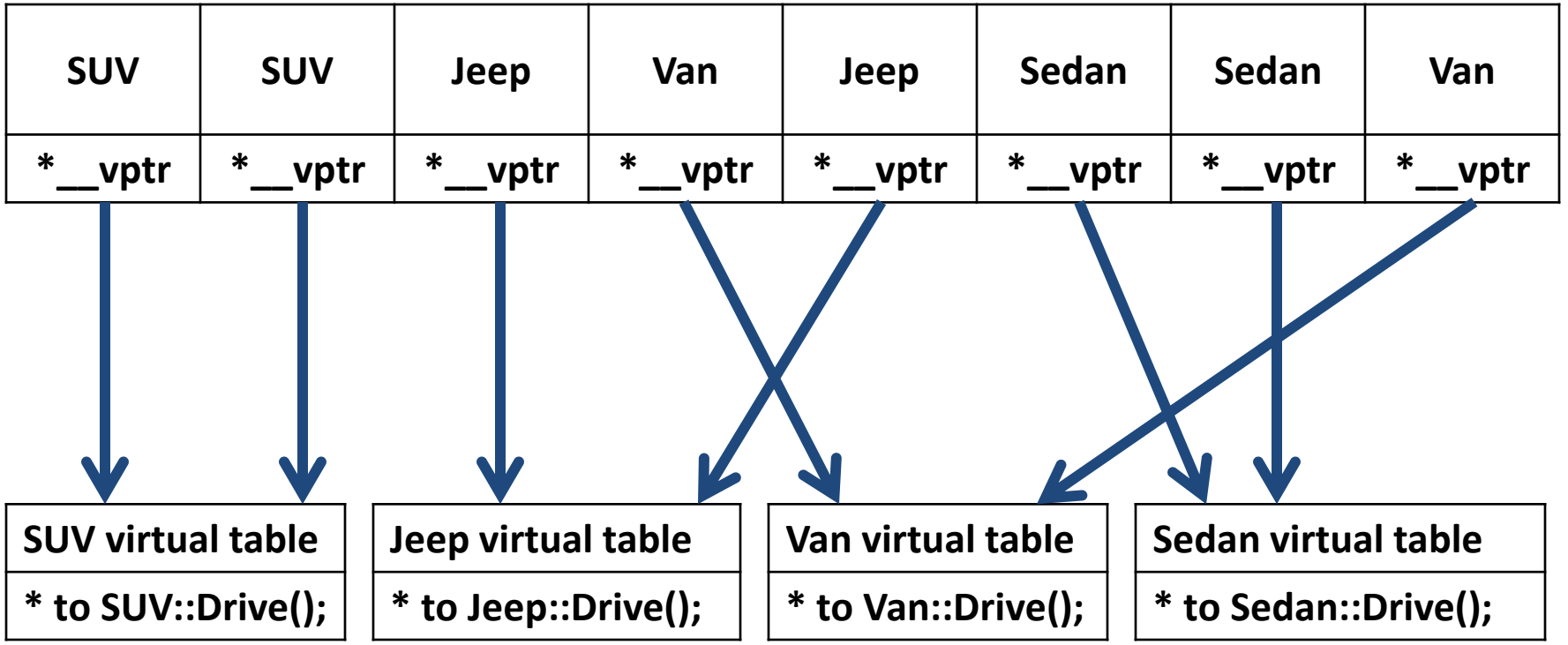
- each virtual table has pointers to each of the virtual functions of that class

| SUV | SUV | Jeep | Van | Jeep | Sedan | Sedan | Van |
|---|---|---|---|---|---|---|---|
| *__vptr | *__vptr | *__vptr | *__vptr | *__vptr | *__vptr | *__vptr | *__vptr |

| SUV virtual table | Jeep virtual table | Van virtual table | Sedan virtual table |
|---|---|---|---|
| * to SUV::Drive(); | * to Jeep::Drive(); | * to Van::Drive(); | * to Sedan::Drive(); |

# Virtual Table Pointer

- the hidden variable points to the appropriate virtual table of functions



# Virtual Everything!

- in Java, all functions are virtual by default
  - everything seems to work fine for Java

- why don't we make all our functions virtual in C++ classes?
  - ???

# Virtual Everything!

- in Java, all functions are virtual by default
  - everything seems to work fine for Java

- why don't we make all our functions virtual in C++ classes?
  - non-virtual functions can't be overridden (in the context of parent class pointers)
  - creates unnecessary overhead

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# Virtual Destructors

```
Vehicle *vehicPtr = new Car;
delete vehicPtr;
```

- for any class with virtual functions, you must declare a virtual destructor as well

- why?

# Virtual Destructors

```
Vehicle *vehicPtr = new Car;
delete vehicPtr;
```

- for any class with virtual functions, you must declare a virtual destructor as well

- non-virtual destructors will only invoke the base class's destructor

# Virtual Constructors

- not a thing... why?

# Virtual Constructors

- not a thing... why?
- we use polymorphism and virtual functions to manipulate objects **without** knowing type or having complete information about the object
- when we construct an object, we **have** complete information
  - there's no reason to have a virtual constructor

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# Application of Polymorphism

- examine polymorphism and virtual functions
- using these classes:
  - Animal
    - Bird
    - Cat
    - Dog

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# Project Alphas

- due next Sunday (November 23rd)
- doesn’t:
  - have to be working
  - a complete project
- in a folder named <your_team_name>

# Next Time

- take an (anonymous) in-class survey for 1% **overall** extra credit
- receive feedback on your project proposal
- have some say in what we cover during our last *(gasp! sob!)* class together