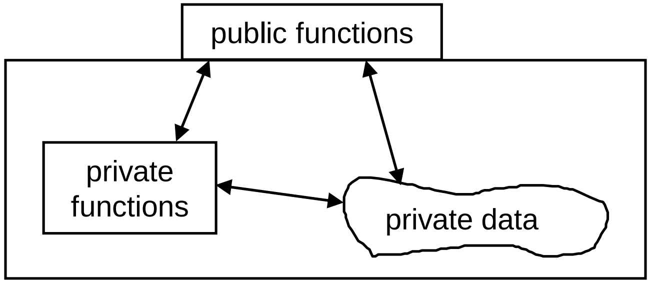
Encapsulation in C++

Spring 2017

Encapsulation

- Encapsulation Requires that functions, modules and classes:
  - Have clearly defined external interfaces
  - Hide implementation details



- Encapsulation is all about coupling – coupling happens through interfaces.
- Exactly what is an interface?

Function Interfaces

- Functions have four ways to interact with the external world:
  - Parameter list – local coupling:
    - Value parameters and const references are input only
      - Functions with these parameters don't have parametric side-affects.
    - Non-const reference paramters and pointers are both input and output
      - We say that a function with non-const reference parameters has side-affects.
  - Returned items – local coupling:
    - Return by value has no after-affects inside the function.
    - Return by reference can change the state of an object to which the function belongs.
  - Global data – remote coupling:
    - Functions that use global data create remote and untraceable side effects.
  - Static local data – temporal coupling:
    - An invocation affects later invocations.
- The strongest encapsulation is with only pass-by-value or constant reference in and out.
- However, the indirection allowed by non-constant references is just too powerful. We can't live without it.
- We can, and should, live without global data and we should minimize the use of static local data.

C++ References versus Pointers

- Prefer returning C++ references over pointers.
  - References provide access to objects. You only get to use the object's interface with a reference.
  - Pointers provide access to memory. Their proper use demands that the client understand the design of the function, and perhaps the class:
    - Does the pointer point to an object or an array of objects?
    - Does it point to the heap or some other persistant object?
    - Whose responsibility is destruction?
- This is not a manifesto to eliminate all pointer use!
  - Pointers do a great job of capturing relationships:
    - Arrays, Graphs, trees, lists, repositories
    - Their big brothers, iterators, are an essential part of the STL
  - It is appropriate to return them from creational functions that act like sophisticated new calls.

Classes

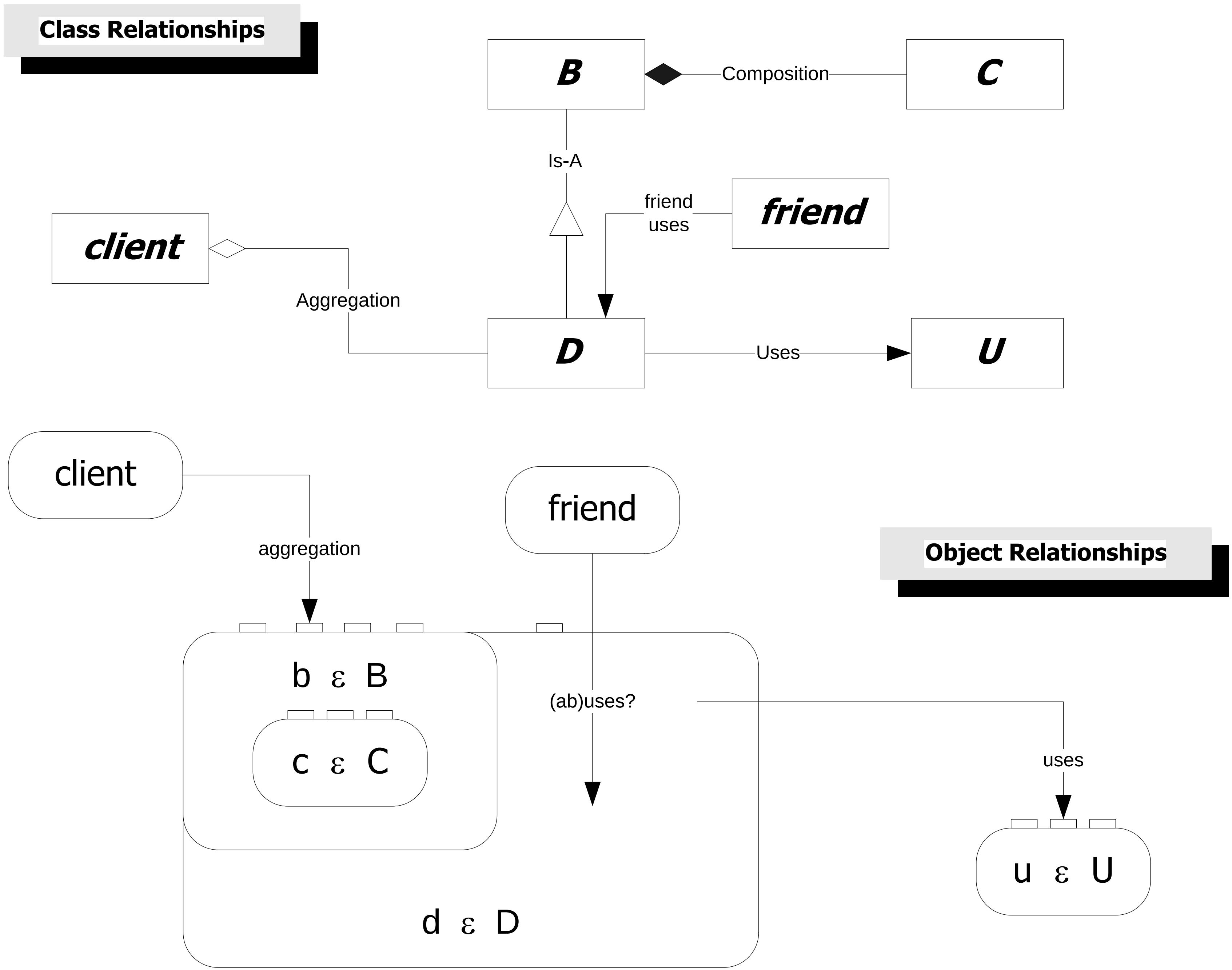
- All the same issues hold for classes, via the member functions they provide.
- Classes also support three accessibility levels: public, protected, and private.
  - Public members define the client interface and should be immutable – changing the interface breaks client designs.
  - Protected members define an interface for derived classes only. They also should be immutable once some of the derived classes are no longer under your control.
  - Private members consist of all those helper functions that manage the class’s internal state.
- For proper class encapsulation:
  - Don’t use public or global data
  - Encapsulate member functions well, as discussed in earlier slides.
  - Decide carefully which functions will be public, protected, and private.
  - Never make member data public.

Role of Constructors and Destructor

- Constructors and destructors
  - Objects are created from a class pattern only by calling a constructor.
  - Whenever the thread of execution leaves a scope, all objects created in that scope are destroyed. Part of that destruction is the execution of the objects’ destructor and the destructors of all its parts.
  - A constructor’s job is to allocate whatever resources the class needs on startup.
  - The destructor returns any allocated resources.
  - These actions mean that the class encapsulates its own resource management. That is a very big deal!

Class Relationships

- Composition is the best encapsulated relationship:
  - Only member functions of the class have access to the interface of private data member objects.
  - Only member functions of the class and its derived classes have access to the interface of a protected data member object.
- Inheritance gives derived classes access to the protected data members of the base class.
  - Behavior of a correct base class can be made incorrect by incorrect derived class objects.
- Using relationships may badly break encapsulation.
  - If you pass an object of a class to a member function of an object of the same class, the receiving object has access to all the used object's private and protected state.
  - Friend relationships extend this behavior to objects of other classes.


Class Relationships
B
C
Composition
Is-A
friend
friend
uses
client
Aggregation
D
Uses
U
client
friend
aggregation
Object Relationships
b ε B
c ε C
(ab)uses?
uses
u ε U
d ε D

Bad Designs

- What makes a design bad? Robert Martin suggests[1]:
  - ***Rigidity***
    It is hard to change because every change affects too many other parts of the system.
  - ***Fragility***
    When you make a change, unexpected parts of the system break.
  - ***Immobility***
    It is hard to reuse a part of the existing software in another application because it cannot be disentangled from the current application.

- Many of these “Bad Design” issues stem very directly from poor encapsulation.

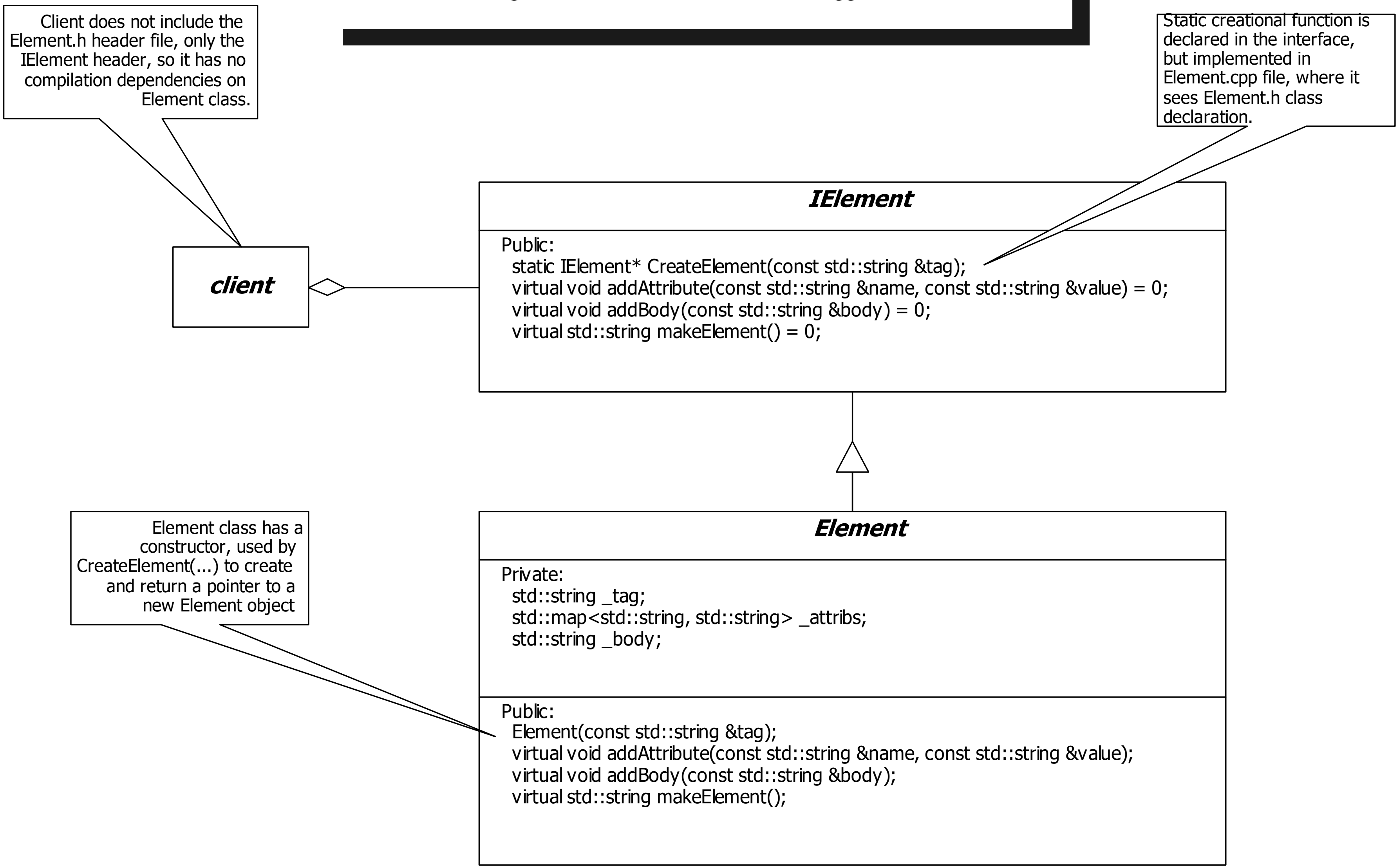
C++ Class Encapsulation Problem

- The C++ object model has the source text of a user of an object responsible for carrying the object's type information by including a header file.
  - If class A refers to class B, then A must include B's header.
  - This is the way a C++ compiler does static type checking.
  - Remember, in contrast, that C# carries its type information in the assembly metadata of the object itself.
- A direct consequence of this fact is that, unless we do something special to prevent it, the client is welded to specific versions of the objects it uses.
  - If the object changes anything in its class declaration, adding a new member datum, for example, then the client has to acquire its new header and recompile.

Programming to Interfaces

- The something special we do, mentioned on the previous slide, is to:
  - Program to an Interface not an Implementation
  - Use an Object Factory to create the object.
- Here, interface means more than the public interface of a class.
  - An interface is an abstract base class, often a struct actually, containing at least one pure virtual function.
  - It usually has no constructors and no data.
  - It has a destructor, only to qualify it as virtual.
  - It often has a static factory function so the client does not have to directly instantiate an object of the class it represents.
- This interface shields its clients from all of the implementation details of the class it represents.

Client Using IElement Interface to Build Tagged Elements



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- Designing to Interfaces and using factory functions completely eliminates the coupling of client to the implementation of its serving objects.

End of Presentation