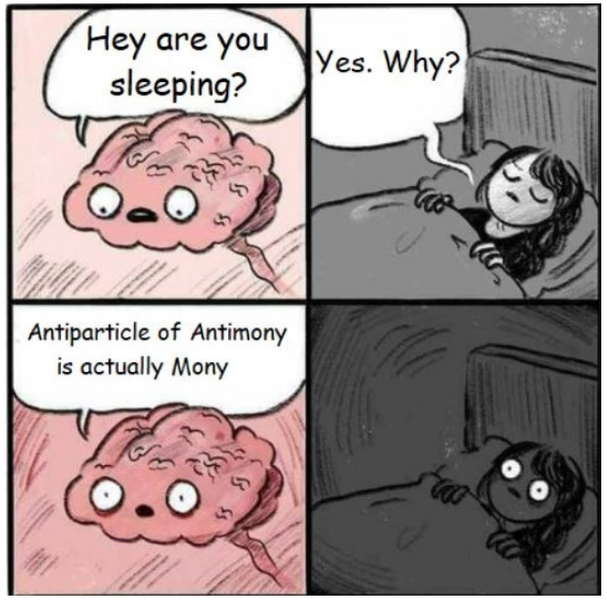
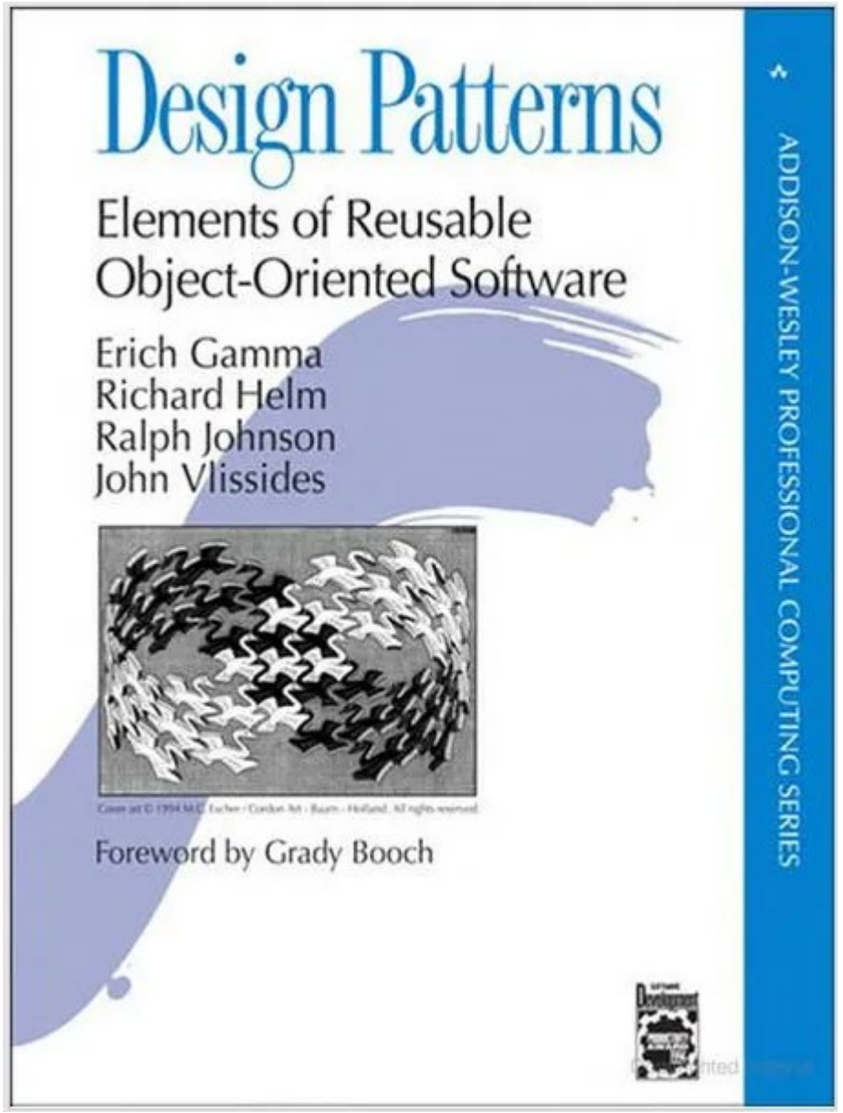
Patterns and Anti-Patterns

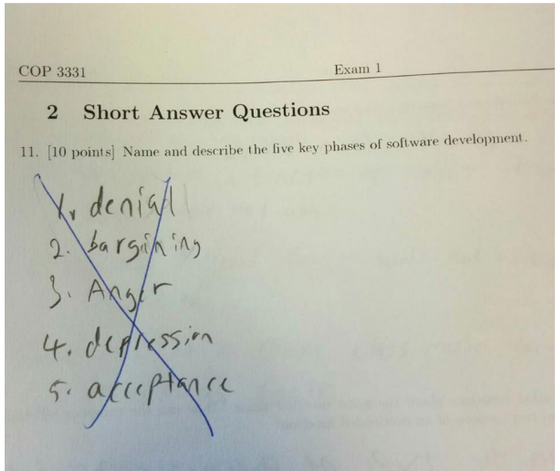




Special thanks for James Perretta!

The Story So Far …

- We want to deliver and support a quality software product
  - We understand the stakeholder requirements
  - We understand process and maintainability
  - We understand quality assurance
- How should we make process and design designs the first time?


COP 3331 Exam 1

2 Short Answer Questions

11. [10 points] Name and describe the five key phases of software development.

1. denial
2. bargaining
3. Anger
4. depression
5. acceptance

One-Slide Summary

- Software **design patterns** are general, reusable solutions to commonly-occurring problems. They separate the structure of a system from its implementation. They apply in almost all OO languages.
- Every design has tradeoffs. Object-oriented design patterns often trade verbosity or efficiency for extensibility.
- We'll consider **structural**, **creational** and **behavioral** design patterns.

Patterns in Non-Software Design

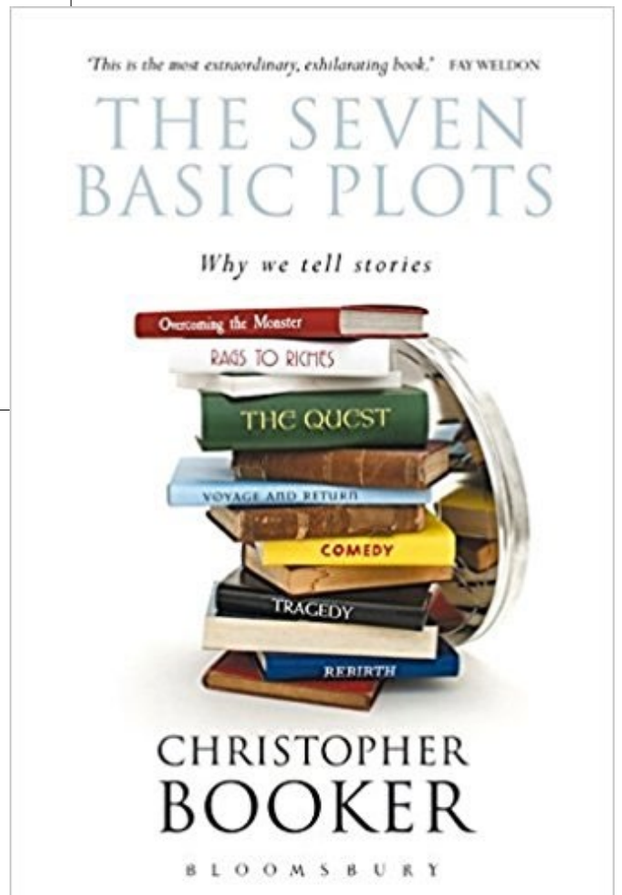
Multiple choice question

1. Rick Astley's never gonna: ← Question Stem

Options
- Give you up
- Let you down
- Run around and
- Desert you
- All of the above ← Correct

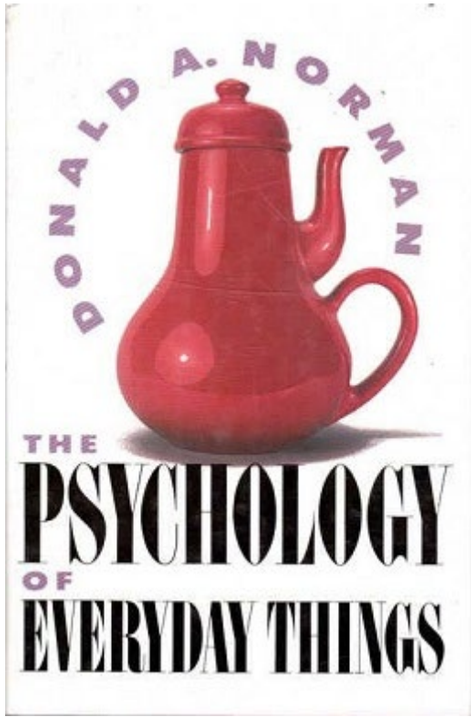
Distractors

VERSE	CHORUS	VERSE	CHORUS	BRIDGE	CHORUS
A	B	A	B	C	B



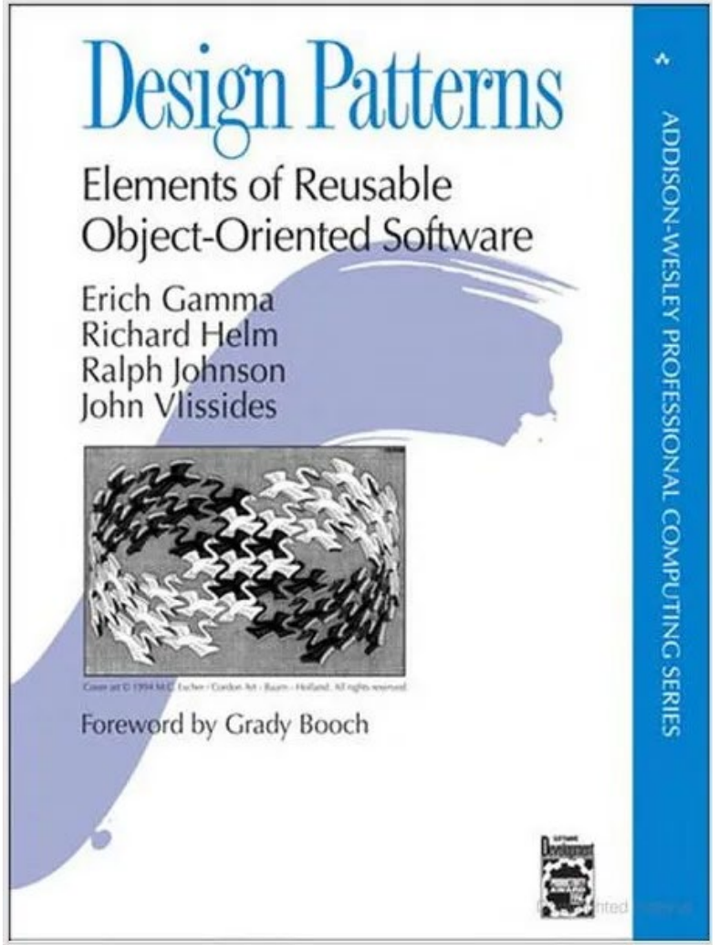
Further Real-World Reading

- **The Design of Everyday Things**
  - *design* serves as the *communication* between *object* and *user*
  - although people often blame themselves when objects appear to malfunction, it is not the fault of the user but rather the lack of intuitive guidance that should be present in the design
  - behavioral psych + ergonomics



Jargon

- The book popularizing software design patterns is often called the **Gang of Four** book after its four authors
- (Sometimes handy for talking to interviewers or practitioners.)



High-Level Design Pattern Advice

- Consider code change as a certainty
  - Redesign is expensive. Choosing the right pattern helps avoid it.
- Consider your requirements and their changes
  - Use patterns that fit your current or anticipated needs.
- Consider multiple designs
  - Diagram your designs before writing code.

Structural Patterns

- **Structural design patterns** ease design by identifying simple ways to realize relationships among entities.
- In software, they usually
  - Build new classes or interfaces
  - from existing ones
  - Hide implementation details
  - Provide cleaner or more
  - specialized interfaces

Adapter Design Pattern

- The **adapter design pattern** is a structural design pattern that converts the interface of a class into another interface clients expect.

Adapter Examples (1/2)

- Implementing a Stack interface using a LinkedList interface

Stack
- push()
- top()
- pop()

LinkedList
- push_front()
- front()
- pop_front()
- push_back()
- back()
- pop_back()
- insert()

Adapter Examples (2/2)

- Early implementations of **fstream** in C++
  - … were simply adapters around the C **FILE** macro
- The autograder used for this course “securely” runs student code
- It does this via an adapter around a containerization library (e.g., **docker**)
  - Handles quirks of the library
  - Makes sure that certain options are always used

Creational Design Patterns

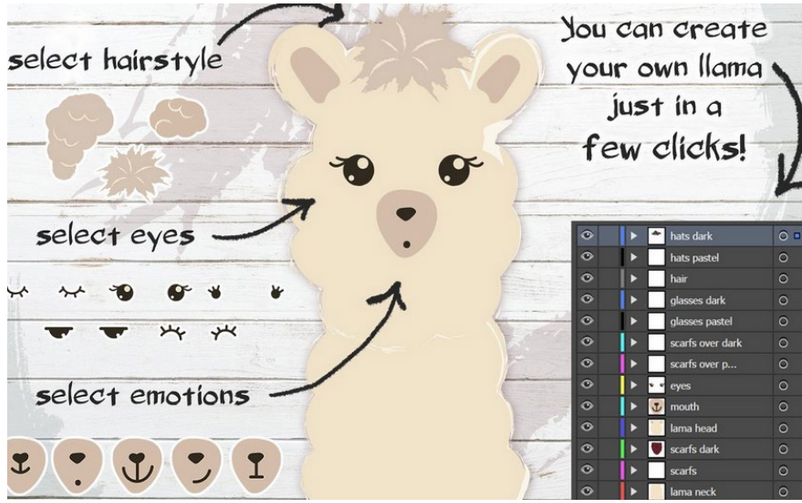
- **Creational design patterns** avoid complexity by controlling object creation so that objects are created in a manner suitable for the situation. They make a system independent of how its objects are created.
- A plain constructor may not allow you to
  - Control how and when an object is used
  - Overcome language limitations (e.g., no default arguments)
  - Hide polymorphic types

The Named Constructor Idiom

- In the **Named Constructor Idiom** you declare the class's normal constructors to be private or protected and make a public static creation method.

```
class Llama {
public:
  static Llama* create_llama(string name) {
    return new Llama(name);
  }

private:  // Making ctor private
  Llama(string name_in): name(name_in) {}
  string name;
};
```



A Common Problem

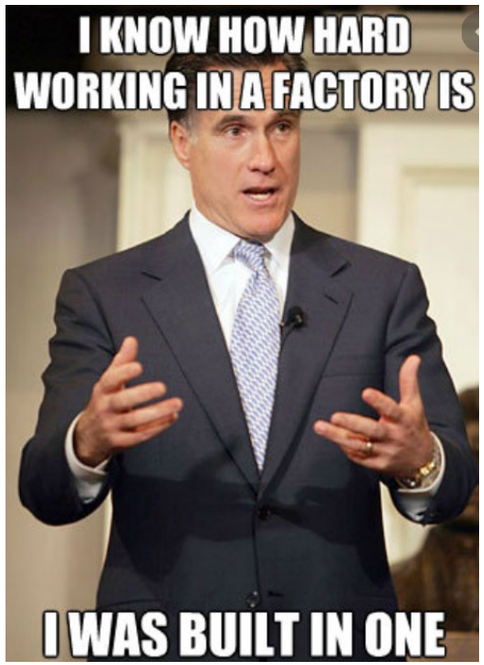
- Suppose we need to create and use polymorphic objects without exposing their types to the client
  - Recall: design for maintainability and extensibility. We don't want the client to depend on (and thus “lock in”) the actual subtypes.
- The typical solution is to write a function that creates objects of the type we want but returns that object so that it appears to be (“cast to”) a member of the base class

The Factory Pattern

- The **factory method pattern** is a creational design pattern that uses factory methods to create objects without having the return type reveal the exact subclass created.

```
Payment * payment_factory(string name, string type) {
  if (type == “credit_card”)
    return new CreditCardPayment(name);
  else if (type == “bitcoin”)
    return new BitcoinPayment(name);
  …
}

Payment * webapp_session_payment =
    payment_factory(customer_name, “credit_card”);
```



Factory Pattern Variant

- You may also encounter implementations in which special methods create the right type:

```
class PaymentFactory {
public:
  static Payment* make_credit_payment(string name){
    return new CreditCardPayment(name);
  }
  static Payment* make_bc_payment(string name){
    return new BitcoinPayment(name);
  }
};

Payment * webapp_session_payment =
PaymentFactory::make_credit_payment(customer_name);
```

Scenario: Difficulty-Based Enemies

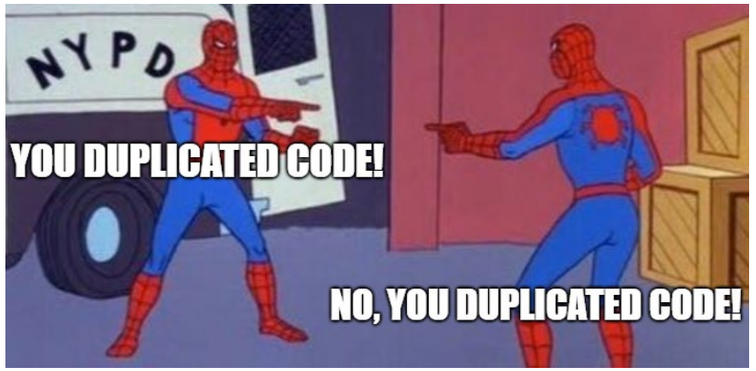
- Suppose we're implementing a computer game with a polymorphic Enemy class hierarchy, and we want to spawn different versions of enemies based on the difficulty level.
- Normal Difficulty → Goomba

- Hard Difficulty → Spiked Goomba

Anti-Patterns

- An **anti-pattern** is a common response to a recurring problem that is usually ineffective and risks being counterproductive.
- A *bad* solution (anti-pattern) would be to check the difficulty at each of the many places in the code related to spawning enemies:

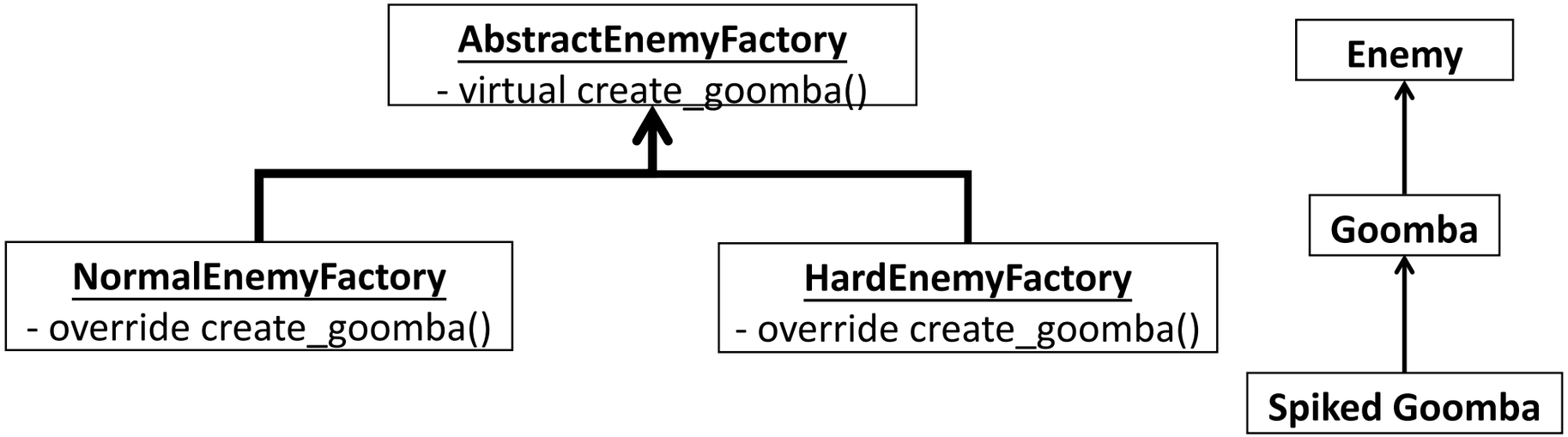
```
Enemy* goomba = nullptr;
if (difficulty == “normal”)
  goomba = new Goomba();
else if (difficulty == “hard”)
  goomba = new SpikedGoomba();
```



Abstract Factory Design Pattern

- The **abstract factory pattern** encapsulates a group of factories that have a common theme *without* specifying their concrete classes.

```
// Only have to do this once!
AbstractEnemyFactory* factory = nullptr;
if (difficulty == “normal”)
  factory = new NormalEnemyFactory();
else if (difficulty == “hard”)
  factory = new HardEnemyFactory();
Enemy* goomba = factory->create_goomba();
```



Scenario: Global Application State

- Suppose we have some application state that needs to be globally accessible. However, we need to control how that data is accessed and updated.
- The anti-pattern (bad) solution is to have a naked global variable.
  - Fails to control access or updates!
- A “less bad” solution is to put all of the state in one class and have a global instance of that class.

Acceptability of Global Variables

- Global variables are usually a poor design choice. However:
- If you need to access some state everywhere, passing it as a parameter to *every* function clutters the code (readability vs. …)
  - This is not an argument for using global variables to avoid passing a *few* parameters.
- Or if you need to access state stored outside your program (e.g., database, web API)
- Then global variables may be acceptable

Singleton Design Pattern

- The **singleton pattern** restricts the instantiation of a class to exactly one logical instance. It ensures that a class has only one logical instance at runtime and provides a global point of access to it.

Singleton

public:

- static ***get_instance***() *// named ctor*

private:

- static ***instance*** *// the one instance*
- Singleton() *// ctor*

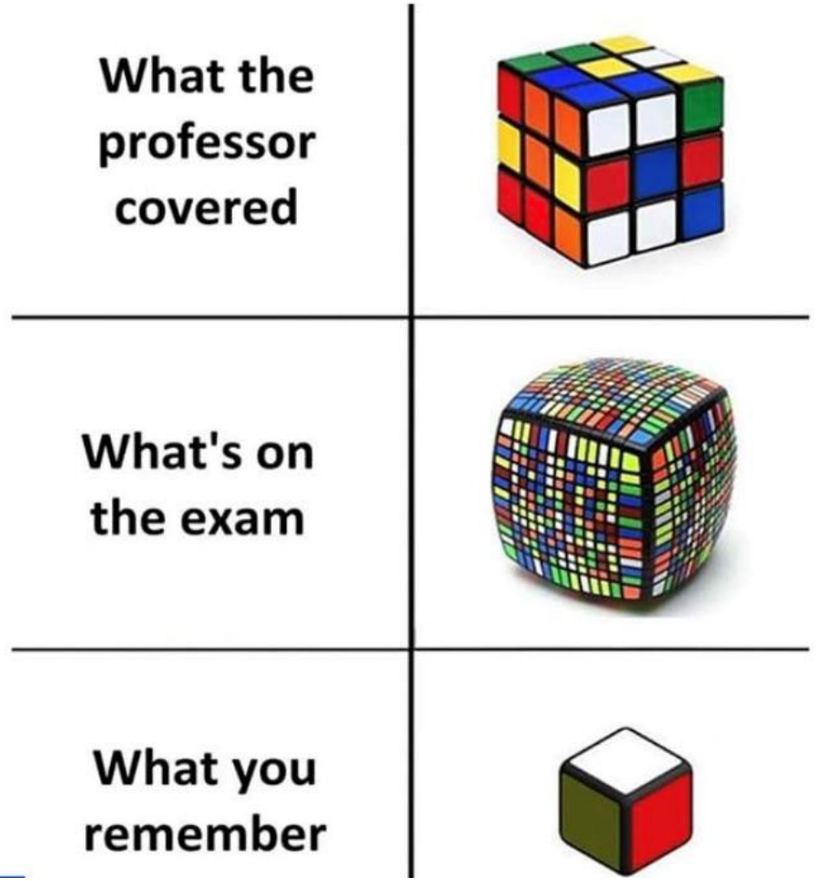
Okay gang, lets see who the design pattern really is

Singleton Implementation Example

```
class Singleton {
  // public way to get "the one logical instance"
  public static Singleton get_instance() {
    if (Singleton.instance == null)
      Singleton.instance = new Singleton();
    return Singleton.instance;
  }
  private static Singleton instance = null;

  private Singleton() { // only runs once
    billing_database = 0;
    System.out.println("Singleton DB created");
  }

  // Our global state
  private int billing_database;
  public int get_billing_count() {
    return billing_database;
  }
  public void increment_billing_count() {
    billing_database += 1;
  }
}
```



Single Use Example

- What is the output
- of this code?

Singleton

public:
- static ***get_instance***() *// named ctor*
- get_billing_count()
- increment_billing_count() *// adds 1*

private:
- static ***instance*** *// the one instance*
- Singleton() *// ctor, prints message*
- billing_database

```
class Main {
  public static void main(String[] args) {
    int bills = Singleton.get_instance().get_billing_count();
    System.out.println(bills);

    Singleton.get_instance().increment_billing_count();
    spams = Singleton.get_instance().get_billing_count();
    System.out.println(bills);
  }
}
```

Single Use Example

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Singleton

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- static ***get_instance***() *// named ctor*
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class Main {
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    int bills = Singleton.get_instance().get_billing_count();
    System.out.println(bills);

    Singleton.get_instance().increment_billing_count();
    spams = Singleton.get_instance().get_billing_count();
    System.out.println(bills);
  }
}
```

Output:

```
Singleton DB created
0
1
```

Singleton.get_instance()

- Could we avoid typing Single.get_instance() so many times by doing this at all of the points in our program that use the singleton?

```
Single s = Singleton.get_instance();
System.out.println(s.get_billing_count());
… // later
System.out.println(s.get_billing_count());
```

- Is this a good idea or not?

Singleton.get_instance() Warning


```
Single s = Singleton.get_instance();
System.out.println(s.get_billing_count());
… // later
System.out.println(s.get_billing_count());
```

- This is a bad idea. There is no guarantee that Singleton.get_instance() will return the same pointer (same object) every time it is called. (It may return different *concrete* copies of the same *logical* item.)

Singleton Design Scenario

- Suppose we are implementing a computer version of the card game Euchre. In addition to a few abstract datatypes, we have a **Game** class that stores the state needed for a game of Euchre. When started, our application prototype plays one game of Euchre and then exits.

- Should we make **Game** a singleton?

Scenario Considerations

- Making Game a Singleton is tempting
  - There is only one Game instance in our application
- However, there only *happens* to be one instance of Game. There's no *requirement* that we only have one instance.
- We should only use the Singleton pattern when current or future requirements dictate that only one instance should exist.
  - Singleton is not a license to make everything global.

Trivia: Toys and Collectibles

- This card game started in 1996 as a simplified spin off of Magic: The Gathering that featured characters from a popular cartoon and Japanese manga.
- With nearly 30 billion cards sold as of 2019, it holds 82% of the card game market share in Europe.
- Gotta catch ‘em all

Psychology: Reaction and Information

- How long does it take you to choose from among multiple stimuli, even when you know the right answer?
- An early experiment presented subjects with a few lamps. Each lamp was labeled (e.g., A, B, C, etc.). Every five seconds, one of the lamps would light up. The subject was asked to press the key, as quickly and as accurately as possible, corresponding to the lamp that lit up.
- While only one lamp was ever lit, the experimenter varied the total number of other lamps (e.g., from 2 to 10).
- How does your reaction time vary as a function of the number of choices?

Psychology: Hick's Law

- Given n equally probable choices, the average reaction time T required for a human to choose among them is: $T = b \cdot \log_2(n+1)$
  - b is an empirically-learned constant
- Increasing the number of choices increases decision time logarithmically. The amount of time taken to process a certain amount of bits is known as the rate of gain of information.

[Hick, W. E. (1 March 1952). *"On the rate of gain of information".* Quarterly Journal of Experimental Psychology. 4 (1): 11–26]
[Hyman, R (March 1953). *"Stimulus information as a determinant of reaction time".* Journal of Experimental Psychology. 45 (3): 188–96.]

Psychology: Hick's Law

- Implications for SE:
- Hick's Law is often used to justify menu design decisions in human interfaces – from restaurant menus to UI design in computing. Users given many choices have to take time to interpret and decide, work they typically don't want (cf. analysis paralysis, Mac vs. Windows design philosophy, etc.). Why don't we like voluminous bug-finding tool output again?

Behavioral Design Patterns

- **Behavioral design patterns** that support common communication patterns among objects. They are concerned with algorithms and the assignment of responsibilities between objects.
- The **iterator pattern** is a common behavioral design pattern. It provides a uniform interface for traversing containers regardless of how they are implemented.

Scenario: Binge-Watching on Video Website

- Suppose we're implementing a video streaming website in which users can “binge-watch” (or “lock on”) to one channel. The user will then see that channel's videos in sequence. When the last such video is watched, the user should stop binge-watching that channel.

Binge-Watch Anti-Pattern

- When the last video is watched, call release_binge_watch() on the user.

```
class User {
  public void release_binge_watch(Channel c) {
    if (c == binge_channel) {
      binge_channel = null;
    }
  }
  private Channel binge_channel;
}
```

```
class Channel {
  // Called when the last video is shown
  public void on_last_video_shown() {
    // Global accessor for the user
    get_user().release_binge_watch(this);
  }
}
```

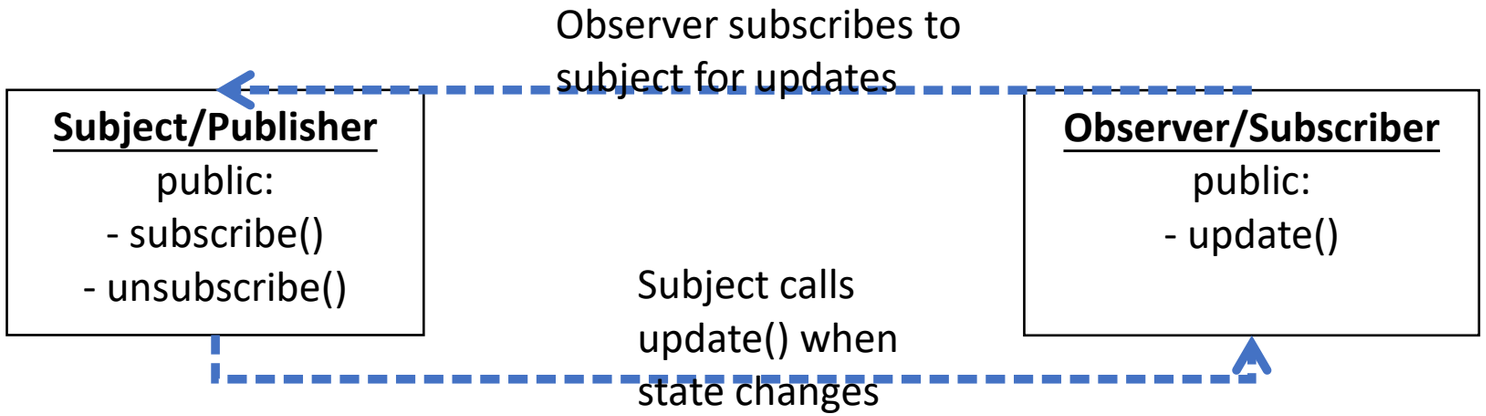
- What are some problems with this approach?

Anti-Pattern Discussion

- User and Channel are tightly coupled
  - Changing one likely requires a change to the other
- The design does not support multiple users
- What if we later want to update a user's “recommendation queue” when they finish binge-watching a channel?
- Whenever requirements change and we want to do something else when a video finishes (e.g., update advertising) we must update the Channel class and couple it to the new feature

Observer Design Pattern

- The **observer pattern** (also called “publish-subscribe”) allows dependent objects to be notified automatically when the state of a subject changes. It defines a one-to-many dependency between objects so that when one object changes state, all of it dependents are notified.



Note: subscribe and unsubscribe can be static or non-static, depending on implementation.

Observer Pattern Exercise

- How many times is “Received update” printed?

```
class Subject {
  public static void subscribe(Observer obs) {
    subscribers.Add(obs);
  }
  public static void unsubscribe(Observer obs) {
    subscribers.Remove(obs);
  }
  public static void change_state() {
    foreach (Observer obs in subscribers) {
      obs.update();
    }
  }
  private static List<Observer> subscribers
      = new List<Observer>();
}
```

```
class Observer {
  public void update() {
    Console.WriteLine("Received update");
  }
}
```

```
class MainClass {
  public static void Main(string[] args) {
    Observer observer1 = new Observer();
    Observer observer2 = new Observer();

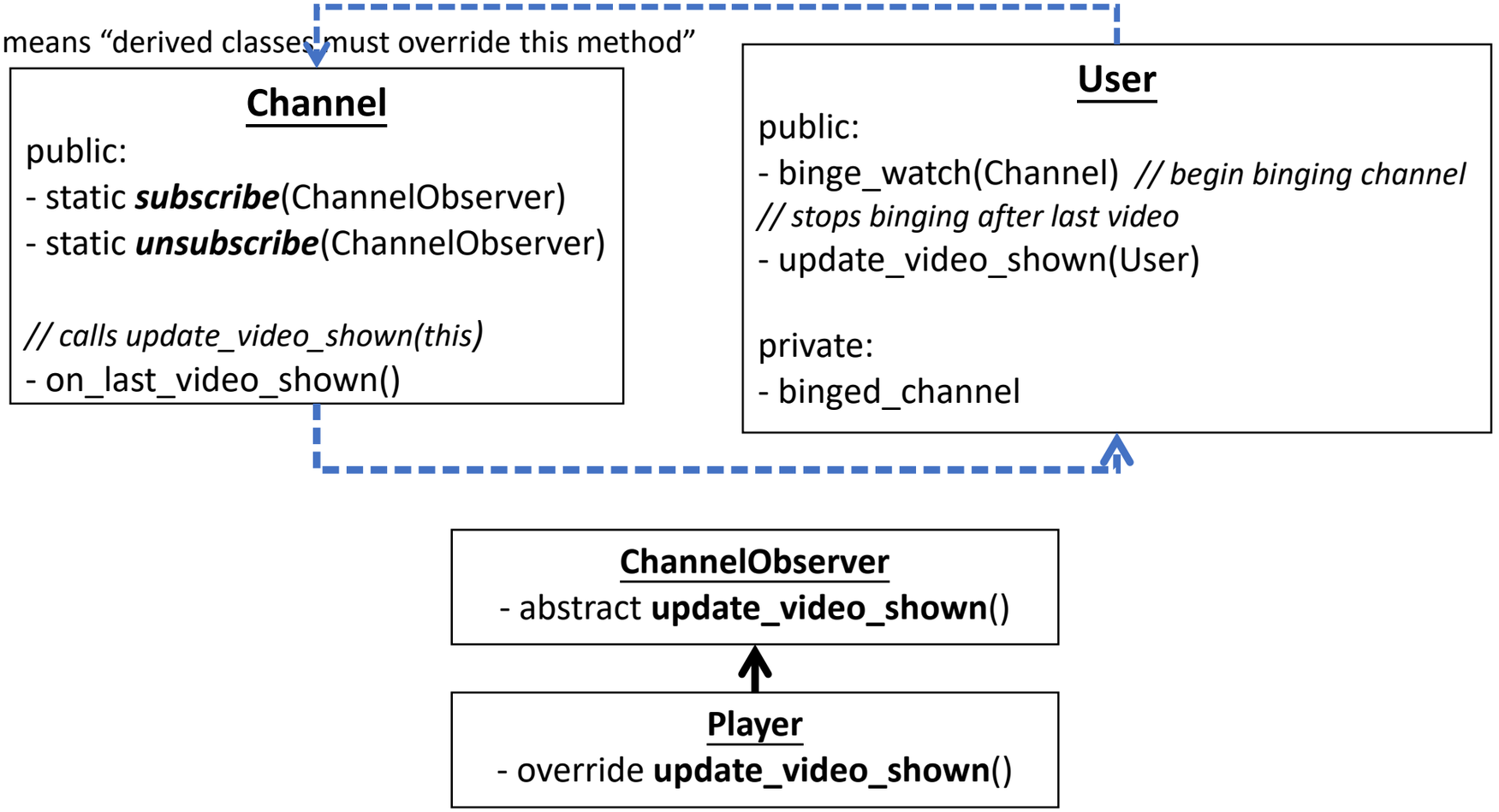
    Subject.subscribe(observer1);
    Subject.change_state();

    Subject.subscribe(observer2);
    Subject.change_state();

    Subject.unsubscribe(observer2);
    Subject.change_state();
  }
}
```

Observer Pattern for Binge-Watch Scenario

- *Abstract means “derived classes must override this method”



Observer for Binge-Watch Implementation

```
interface ChannelObserver {
  void update_video_shown(Channel channel);
}
```

```
class Channel {
  public static void subscribe(ChannelObserver obs) {
    subscribers.Add(obs);
  }
  public static void unsubscribe(ChannelObserver obs) {
    subscribers.Remove(obs);
  }

  public void on_last_video_shown() {
    foreach (ChannelObserver obs in subscribers) {
      observer.update_video_shown(this);
    }
  }

  private static List<ChannelObserver>
subscribers = new
      List<ChannelObserver>();
}
```

```
class User: ChannelObserver {
  public void update_video_shown(Channel c) {
    if (c == binged_channel)
      binged_channel = null;
  }

  public void binge_watch(Channel c) {
    binged_channel = c;
  }

  private Channel binged_channel;
}
```

Observer “update_” Functions

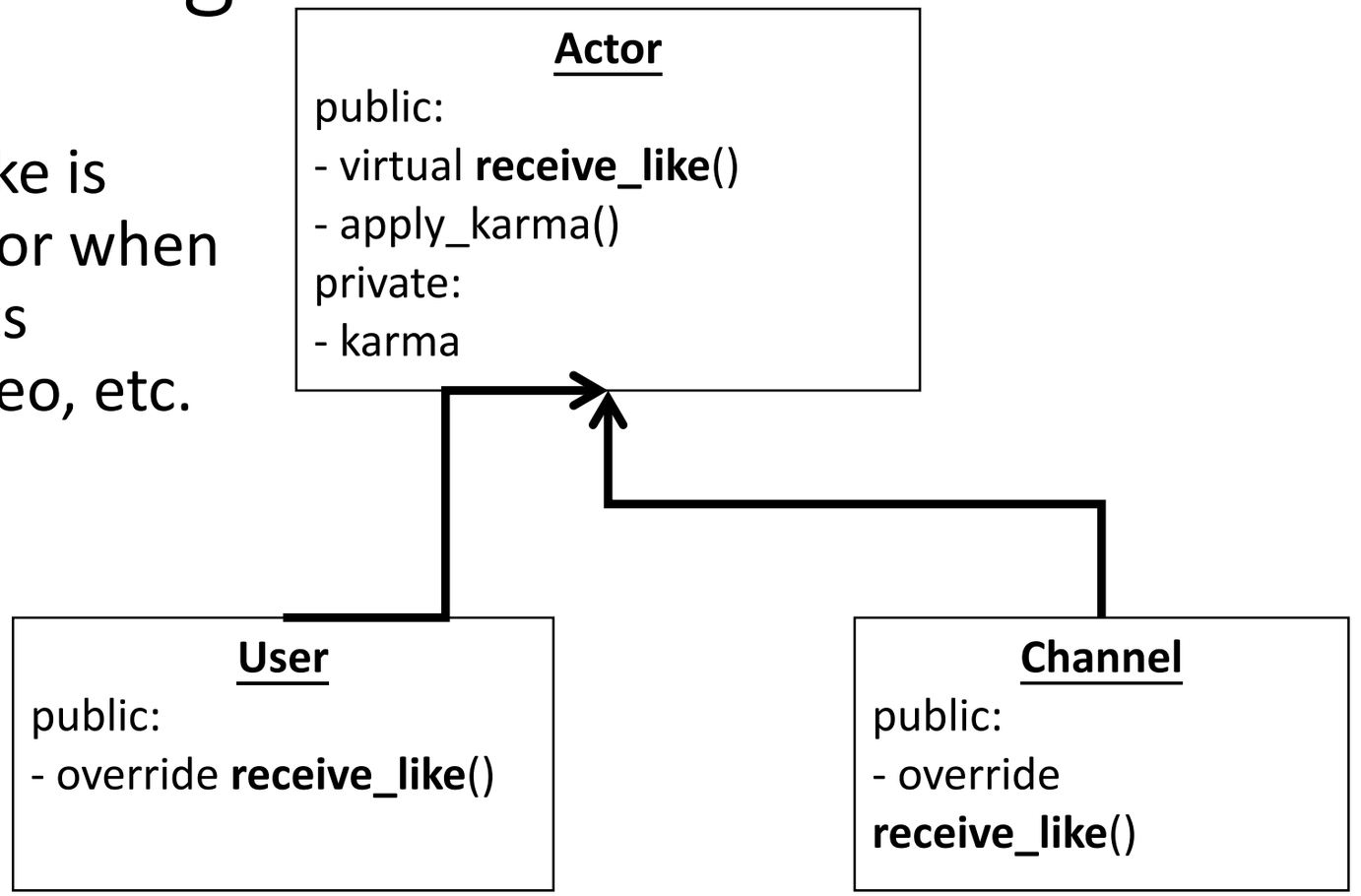
- Having multiple “update_” functions, one for each type of state change, keeps messages granular
  - Observers that do not care about a particular type of update can ignore it (via an empty implementation of the update function)
- Generally it is better to pass the newly-updated data as a parameter to the update function (**push**) as opposed to making observers fetch it each time (**pull**)

Scenario: “Likes” In Social Streaming Website

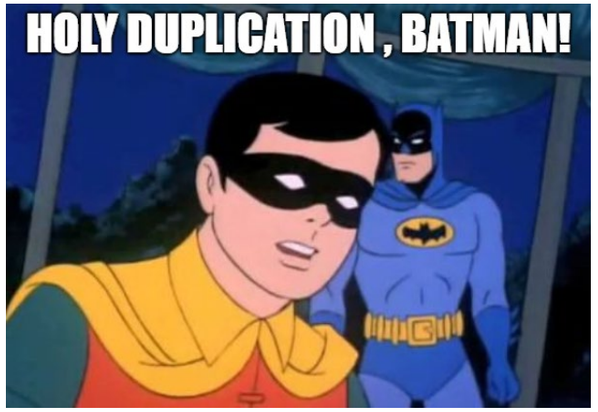
- Suppose we're building a social video streaming website where both users and channels can receive *likes* (for good comments or good videos). When a user or channel receives a like, it gets karma. At 50,000 karma, a channel gets a trophy. At 50,000 karma, a user gets ad-free access.

Likes: Fist Design

- Note: receive_like is called on an Actor when someone likes its comment or video, etc.



Likes: Anti-Pattern Observations




```
class Actor {
  public virtual void receive_like() {
    karma += 1;
  }
  public float get_karma() { return karma; }
  private float karma = 42;
  public void note_karma() {
    Console.WriteLine("Some karma
received!");
  }
}
```

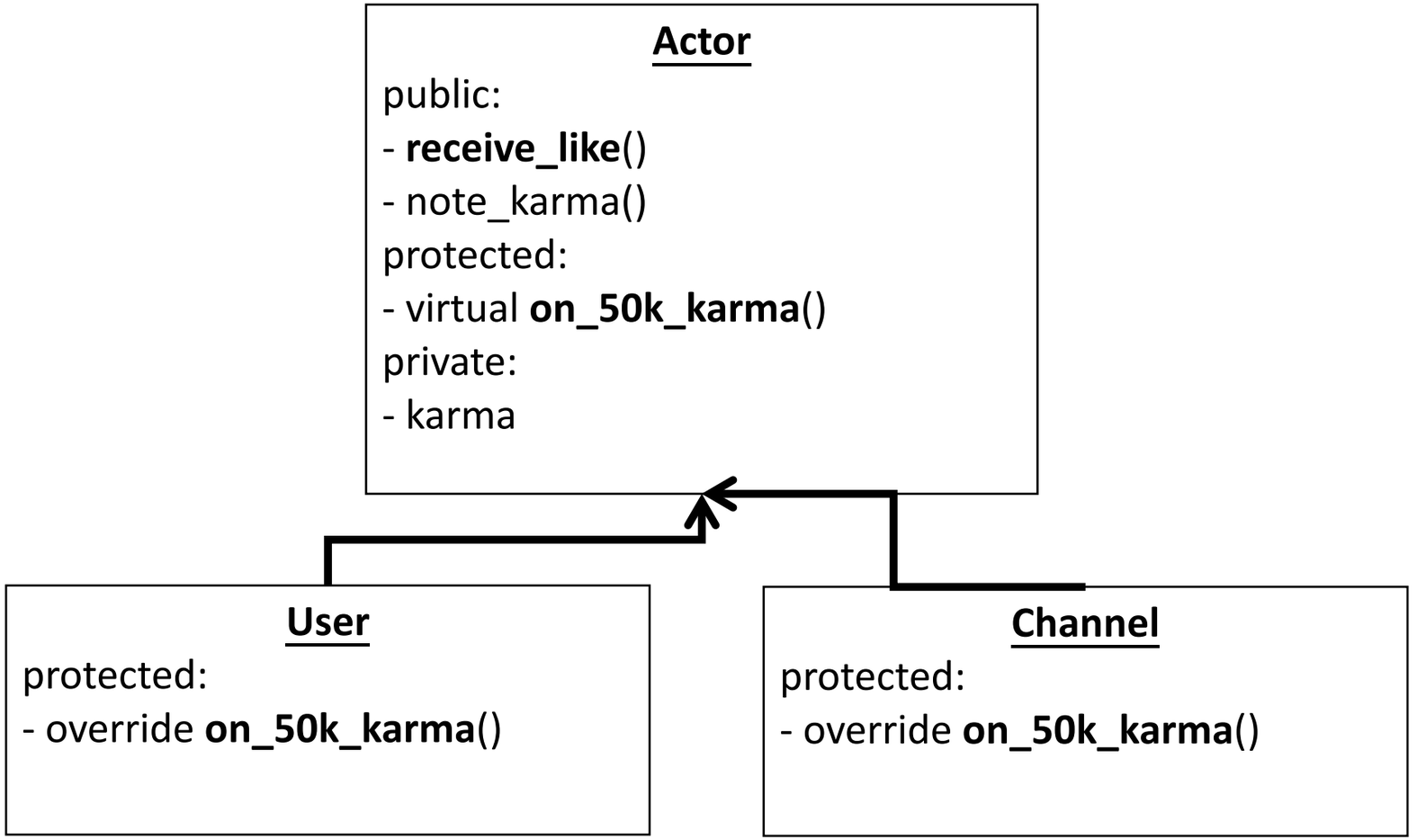
```
class User: Actor {
  public override void receive_like() {
    base.receive_like();
    if (get_karma() >= 50000)
      Console.WriteLine("Ad-free access!");
    else
      note_karma();
  }
}
```

```
class Channel: Actor {
  public override void receive_like() {
    base.receive_like();
    if (get_karma() >= 50000)
      Console.WriteLine("Channel trophy!");
    else
      note_karma();
  }
}
```

Template Method Design Pattern

- The **template method** behavioral design pattern involves a method in a superclass that operates in terms of high-level steps that are implemented by abstract helper methods provided by concrete implementations.
- Define the skeleton of an algorithm in an operation, deferring some steps to subclasses. Template method design lets subclasses redefine certain steps of that algorithm without changing the algorithm's structure.

Likes: Template Method



Likes: Template Method Implementation

```
class Actor {
  public void receive_like() {
    karma += 1;
    if (get_karma() >= 50000)
      on_50k_karma();
    else
      note_karma();
  }
  protected virtual void on_50k_karma() {}

  // Other members same as before
}
```

```
class Channel: Actor {
  protected override void on_50k_karma() {
    Console.WriteLine("Channel trophy!");
  }
}

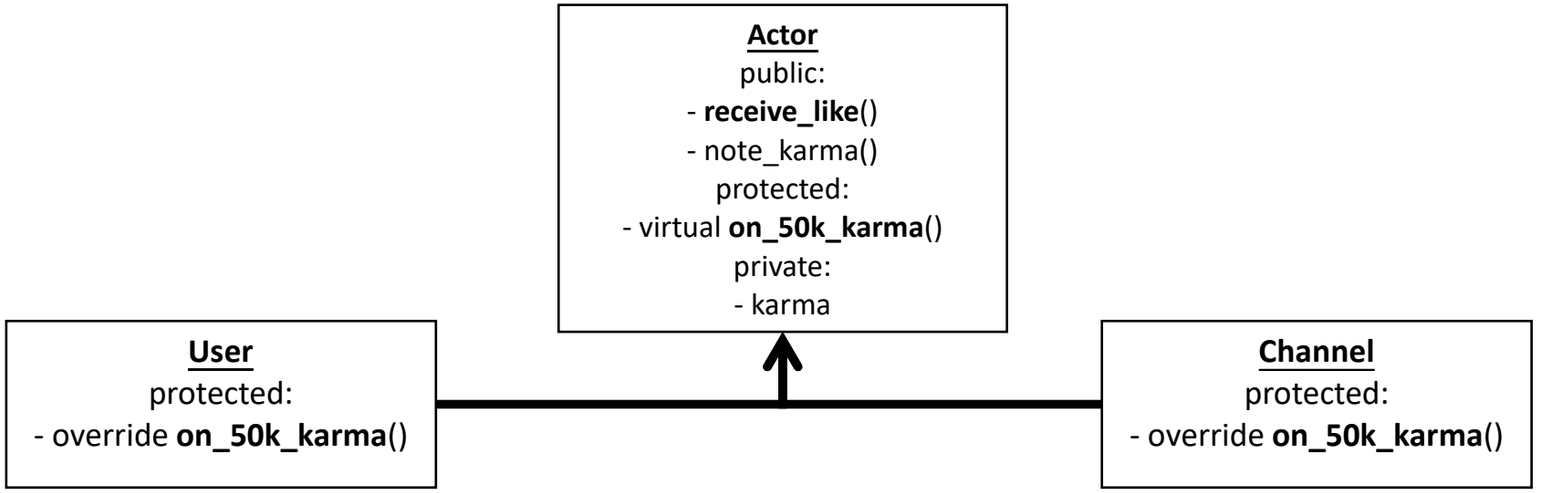
class User: Actor {
  protected override void on_death() {
    Console.WriteLine("Ad-free access!");
  }
}
```

Template Method: The “Hollywood Principle”

- In the first (anti-pattern) implementation, the derived class called the base class version of receive_like()
- In the template method implementation, the non-virtual base class receive_like() called derived class methods
- “Don't call us, we'll call you!”

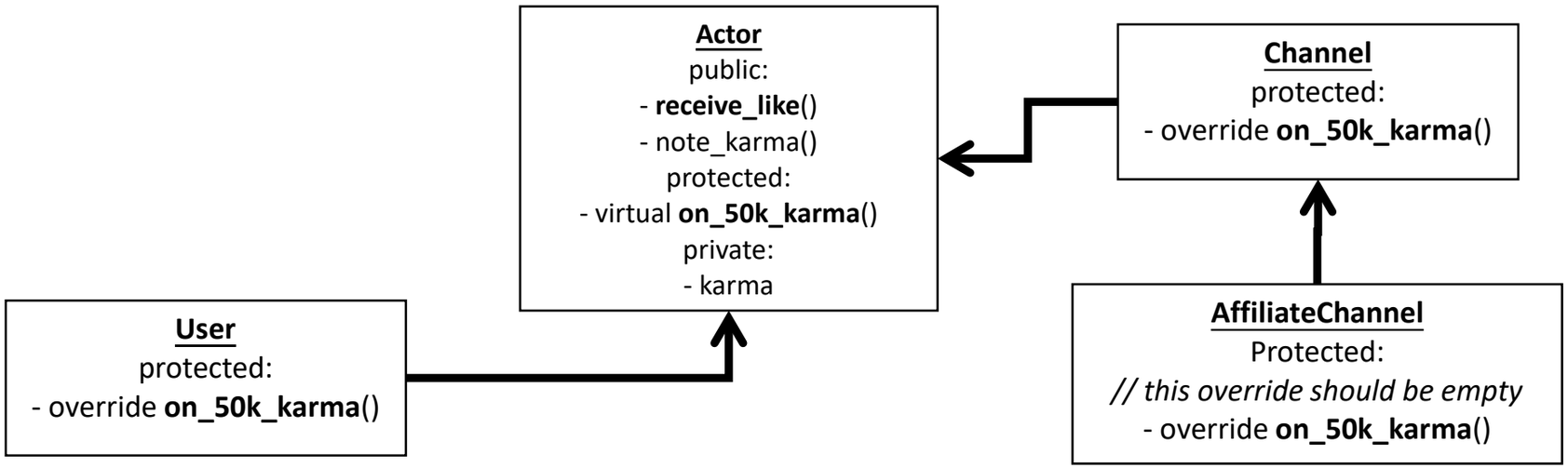
Exercise

- Suppose we want to add an AffiliateChannel to our setup. An AffiliateChannel does not receive a trophy on 50,000 karma, but instead received *nothing*.
- How would we modify our design to include this new type?



Solution

- Suppose we want to add an AffiliateChannel to our setup. An AffiliateChannel does not receive a trophy on 50,000 karma, but instead received *nothing*.
- Modify our design to include this new type.



Questions?

- Further reading from EECS 381
  - http://www.umich.edu/~eecs381/lecture/notes.html
  - See “Idioms and Design Patterns” PDFs