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# CSE 331

# Software Design & Implementation

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Events, Listeners, and Callbacks

(Based on slides by Mike Ernst, David Notkin, Hal Perkins)

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# The limits of scaling

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What prevents us from building huge, intricate structures that work perfectly and indefinitely?

- No friction
- No gravity
- No wear-and-tear

... it's the difficulty of *understanding* them

So we split designs into sensible parts and reduce interaction among the parts

- More *cohesion* within parts
- Less *coupling* across parts



# Design exercise #1

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Write a typing-break reminder program

*Offer the hard-working user occasional reminders of the perils of Repetitive Strain Injury, and encourage the user to take a break from typing.*

Naive design:

- Make a method to display messages and offer exercises
- Make a loop to call that method from time to time

(Let's ignore multithreaded solutions for this discussion)

# TimeToStretch suggests exercises

---

```
public class TimeToStretch {
    public void run() {
        System.out.println("Stop typing!");
        suggestExercise();
    }
    public void suggestExercise() {
        ...
    }
}
```

# Timer calls run () periodically

---

```
public class Timer {
    private TimeToStretch tts = new TimeToStretch();
    public void start() {
        while (true) {
            ...
            if (enoughTimeHasPassed) {
                tts.run();
            }
            ...
        }
    }
}
```

# Main class puts it together

---

```
class Main {  
    public static void main(String[] args) {  
        Timer t = new Timer();  
        t.start();  
    }  
}
```

This program, as designed, will work...

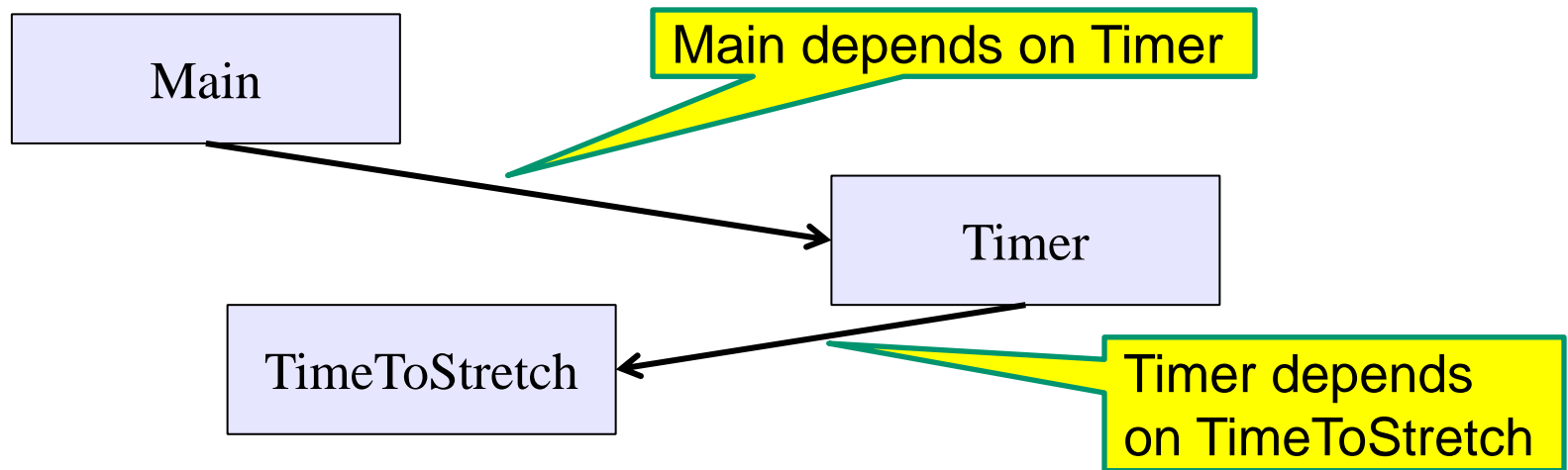
But we can do better

# Module dependency diagram (MDD)

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An arrow in a module dependency diagram (MDD) indicates “depends on” or “knows about”

- Simplistically: “any name mentioned in the source code”



What's wrong with this diagram?

- Does **Timer** really need to depend on **TimeToStretch**?
- Is **Timer** re-usable in a new context?

# Decoupling

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**Timer** needs to call the **run** method

- **Timer** does *not* need to know what the **run** method does

Weaken the dependency of **Timer** on **TimeToStretch**

- Introduce a weaker specification, in the form of an interface or abstract class

```
public abstract class TimerTask {  
    public abstract void run();  
}
```

**Timer** only needs to know that something (e.g., **TimeToStretch**) meets the **TimerTask** specification



# TimeToStretch (version 2)

---

```
public class TimeToStretch extends TimerTask {
    public void run() {
        System.out.println("Stop typing!");
        suggestExercise();
    }

    public void suggestExercise() {
        ...
    }
}
```

# Timer (version 2)

---

```
public class Timer {
    private TimerTask task;
    public Timer(TimerTask task) {
        this.task = task;
    }
    public void start() {
        while (true) {
            ...
            task.run();
        }
    }
}
```

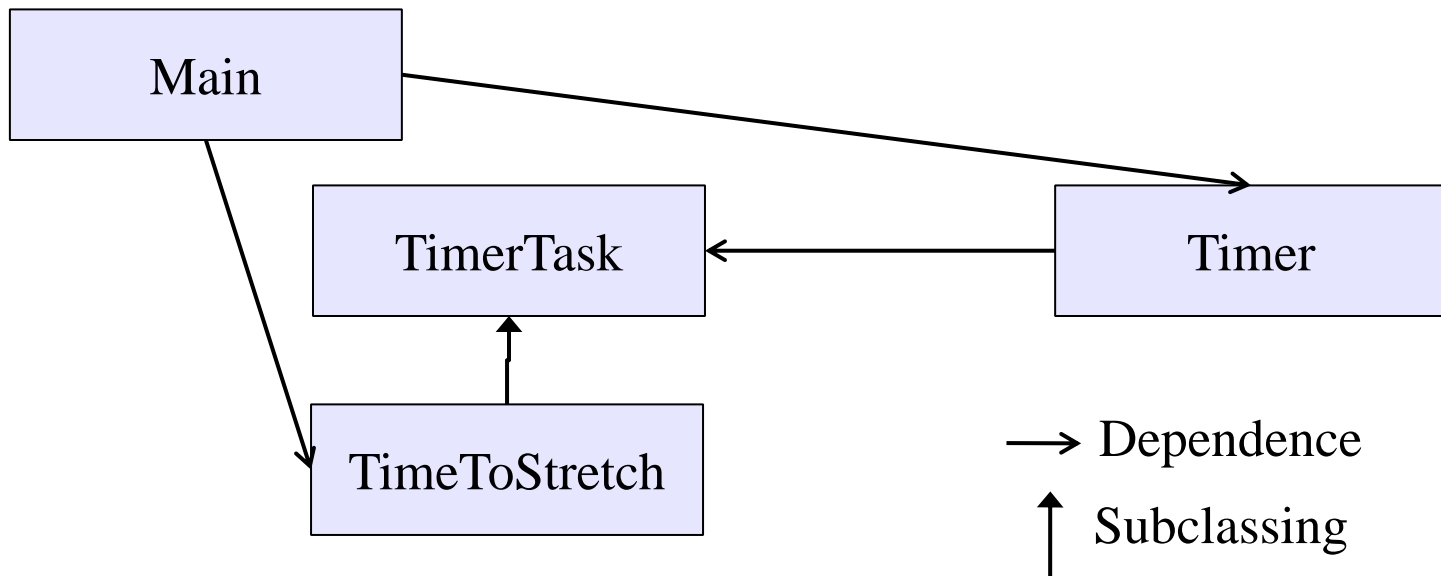
Main creates a `TimeToStretch` object and passes it to `Timer`:

```
Timer t = new Timer(new TimeToStretch());
t.start();
```

# Module dependency diagram (version 2)

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- **Timer** depends on **TimerTask**, not **TimeToStretch**
  - Unaffected by implementation details of **TimeToStretch**
  - Now **Timer** is much easier to reuse
  - **Main** depends on the constructor for **TimeToStretch**
- **Main** still depends on **Timer** (is this necessary?)



# The callback design pattern

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**TimeToStretch** creates a **Timer**, and passes in a reference to *itself* so the **Timer** can *call it back*

- This is a *callback* – a method call from a module to a client that it notifies about some condition

Use a callback to *invert a dependency*

- Inverted dependency: **TimeToStretch** depends on **Timer** (not vice versa)
  - Less obvious coding style, but more “natural” dependency
- Side benefit: **Main** does not depend on **Timer**

# Callbacks

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Callback: “Code” provided by client to be used by library

- In Java, pass an object with the “code” in a method

*Synchronous* callbacks:

- Examples: **HashMap** calls its client’s **hashCode**, **equals**
- Useful when library needs the callback result immediately

*Asynchronous* callbacks:

- Examples: GUI listeners
- *Register* to indicate interest and where to call back
- Useful when the callback should be performed later, when some interesting event occurs

# TimeToStretch (version 3)

---

```
public class TimeToStretch extends TimerTask {  
    private Timer timer;  
    public TimeToStretch() {  
        timer = new Timer(this);  
    }  
    public void start() {  
        timer.start();  
    }  
    public void run() {  
        System.out.println("Stop typing!");  
        suggestExercise();  
    }  
    ...  
}
```

Register interest  
with the timer

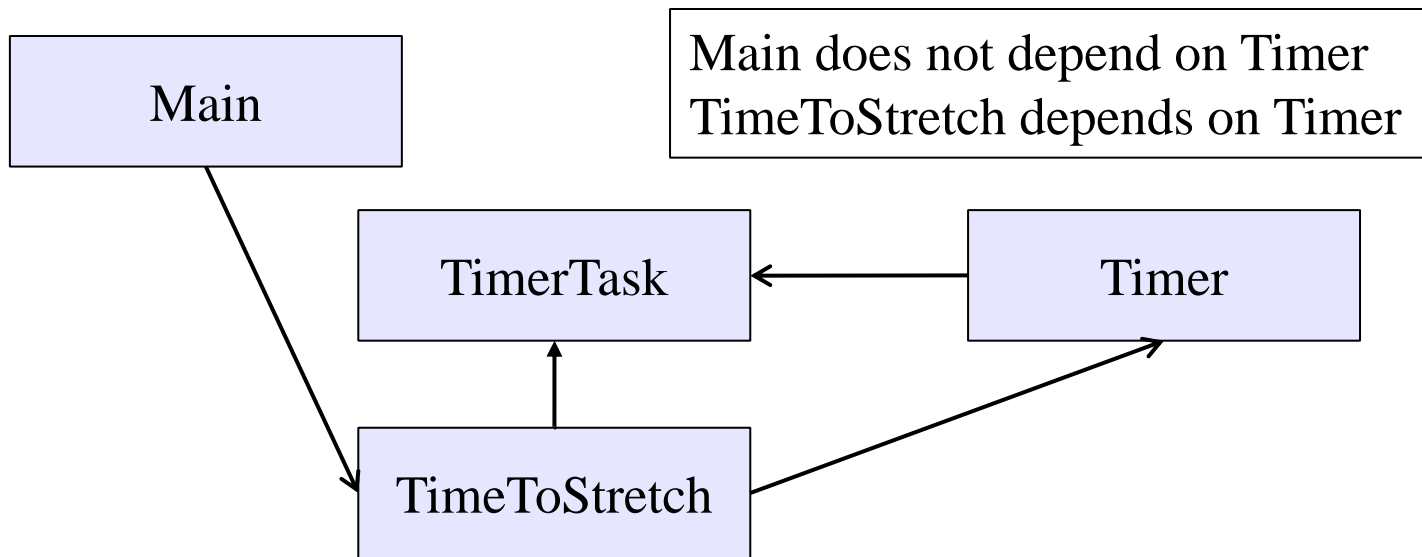
Callback entry point

# Main (version 3)

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```
TimeToStretch tts = new TimeToStretch();  
tts.start();
```

- Uses a callback in `TimeToStretch` to invert a dependency
- This MDD shows the inversion of the dependency between `Timer` and `TimeToStretch` (compare to version 1)



# Decoupling and design

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- A good design has dependences (coupling) only where it makes sense
- While you design (*before* you code), examine dependences
- Don't introduce unnecessary coupling
- Coupling is an easy temptation if you code first
  - Suppose a method needs information from another object:
  - If you hack in a way to get it:
    - The hack might be easy to write
    - It will damage the code's modularity and reusability
    - More complex code is harder to understand



# Design exercise #2

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A program to display information about stocks

- Stock tickers
- Spreadsheets
- Graphs

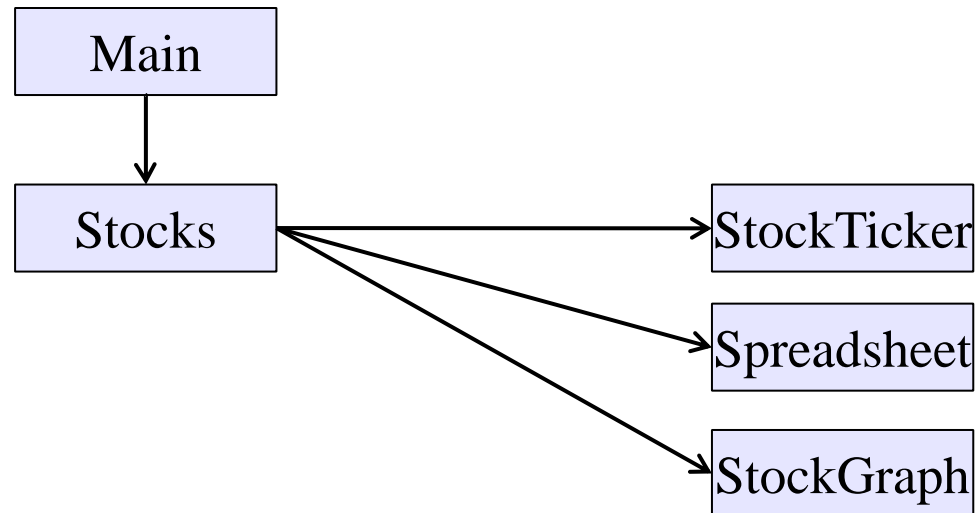
Naive design:

- Make a class to represent stock information
- That class updates all views of that information (tickers, graphs, etc.) when it changes

# Module dependency diagram

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- Main class gathers information and stores in **Stocks**
- **Stocks** class updates viewers when necessary



Problem: To add/change a viewer, must change **Stocks**

Better: insulate **Stocks** from the vagaries of the viewers

# Weaken the coupling

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What should **Stocks** class know about viewers?

- Only needs an **update** method to call with changed data
- Old way:

```
void updateViewers () {  
    ticker.update(newPrice) ;  
    spreadsheet.update(newPrice) ;  
    graph.update(newPrice) ;  
    // Edit this method to  
    // add a new viewer. ☹  
}
```

# Weaken the coupling

---

What should `Stocks` class know about viewers?

- Only needs an `update` method to call with changed data
- New way: The “observer pattern”

```
interface PriceObserver {
    void update(PriceInfo pi);
}

class Stocks {
    private List<PriceObserver> observers;
    void addObserver(PriceObserver pi) {
        observers.add(pi);
    }
    void notifyObserver(PriceInfo i) {
        for (PriceObserver obs : observers)
            obs.update(i);
    }
    ...
}
```

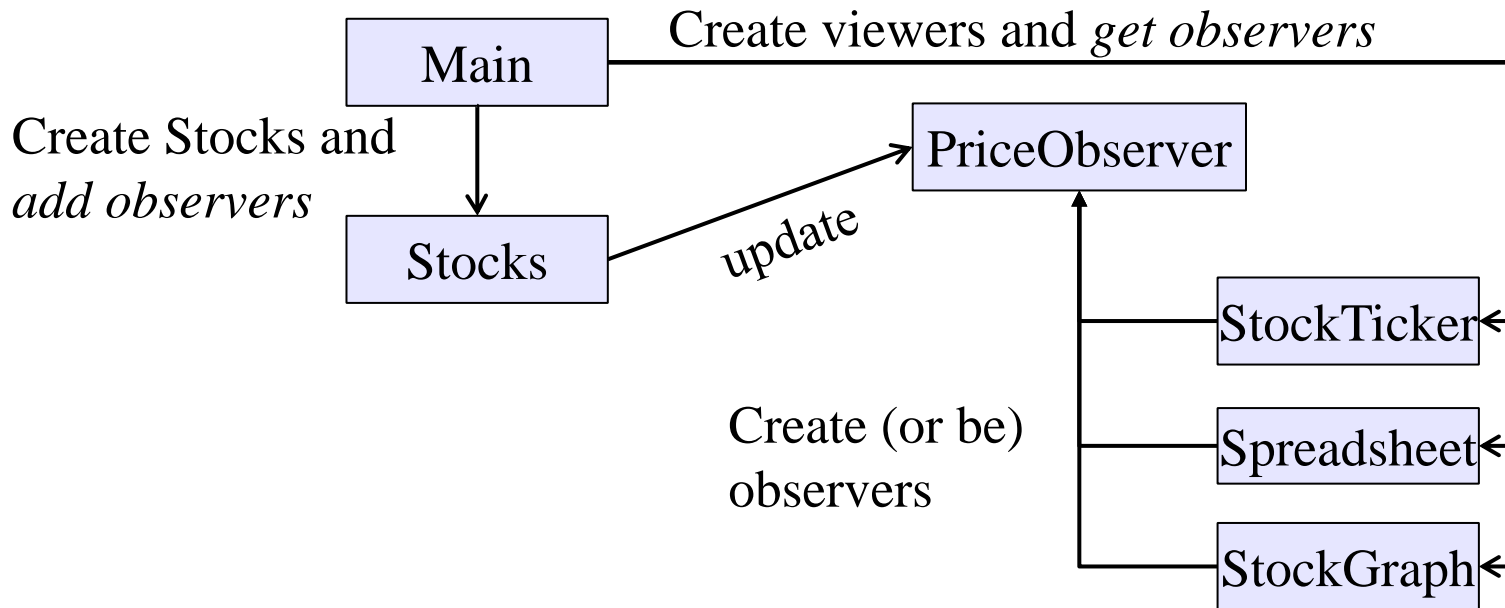
Register a  
callback

Do the callbacks

# The observer pattern

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- **Stocks** not responsible for viewer creation
- **Main** passes viewers to **Stocks** as *observers*
- **Stocks** keeps list of **PriceObservers**, notifies them of changes

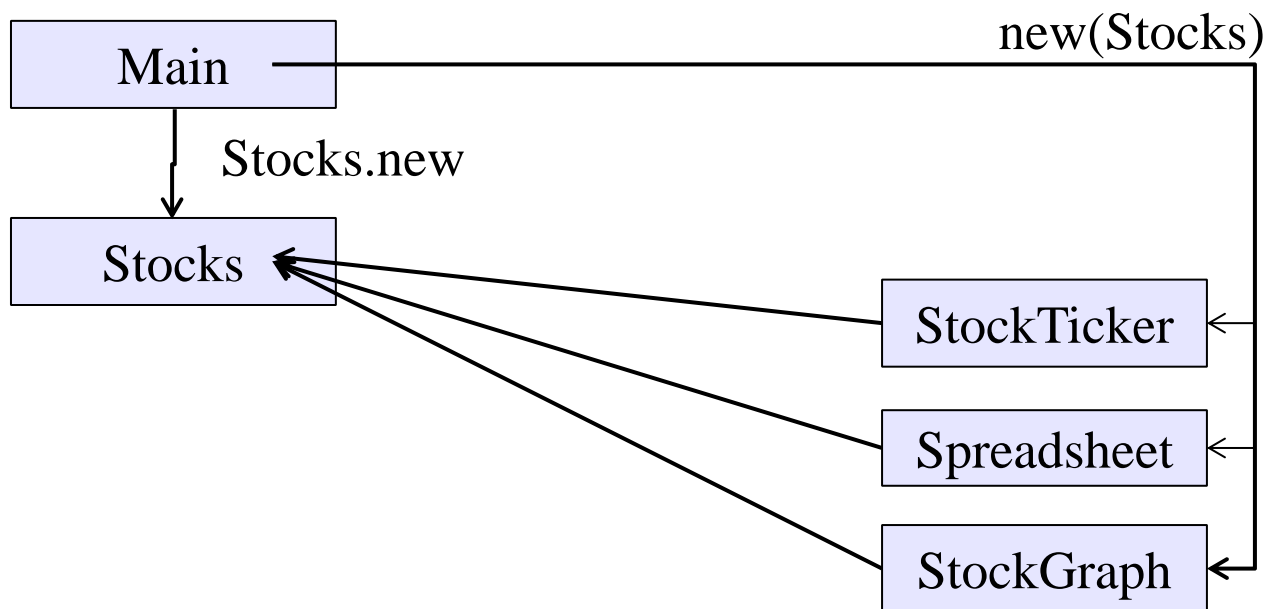


- Issue: **update** method must pass enough information to (unknown) viewers

# A different design: pull versus push

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- The Observer pattern implements *push* functionality
- A *pull* model: give viewers access to **Stocks**, let them extract the data they need



“Push” versus “pull” efficiency can depend on frequency of operations  
(Also possible to use both patterns simultaneously.)

# Another example of Observer pattern

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```
// Represents a sign-up sheet of students
public class SignupSheet extends Observable {
    private List<String> students
        = new ArrayList<String>();
    public void addStudent(String student) {
        students.add(student);
        setChanged();
        notifyObservers();
    }
    public int size() {
        return students.size();
    }
    ...
}
```

Part of the  
JDK

`SignupSheet` inherits many methods including:  
void addObserver(Observer o)  
protected void setChanged()  
void notifyObservers()

# An Observer

---

```
public class SignupObserver implements Observer {  
    // called whenever observed object changes  
    // and observers are notified  
    public void update(Observable o, Object arg) {  
        System.out.println("Signup count: "  
            + ((SignupSheet)o).size());  
    }  
}
```

Part of the JDK

Not relevant to us

cast because  
Observable is  
non-generic ☹



# Registering an observer

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```
SignupSheet s = new SignupSheet();  
s.addStudent("billg");  
// nothing visible happens  
s.addObserver(new SignupObserver());  
s.addStudent("torvalds");  
// now text appears: "Signup count: 2"
```

Java's "Listeners" (particularly in GUI classes) are examples of the Observer pattern

(Feel free to use the Java observer classes in your designs – if they are a good fit – but you don't have to use them)

# User interfaces: appearance vs. content

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It is easy to tangle up *appearance* and *content*

- Particularly when supporting direct manipulation (e.g., dragging line endpoints in a drawing program)
- Another example: program state stored in widgets in dialog boxes

Neither can be understood easily or changed easily

This destroys modularity and reusability

- Over time, it leads to bizarre hacks and huge complexity
- Code must be discarded

Callbacks, listeners, and other patterns can help