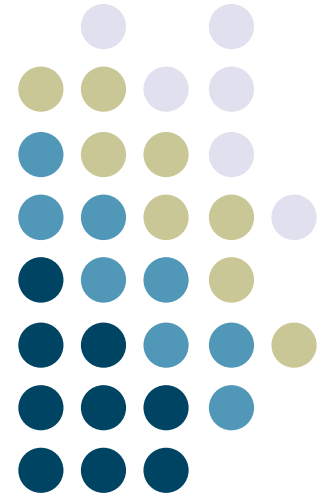
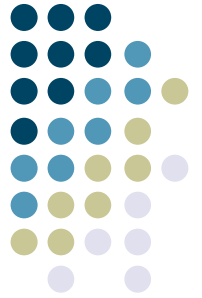


UI Software Organization



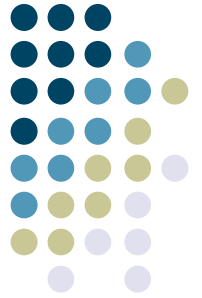
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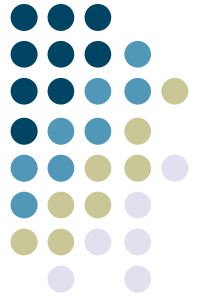
The user interface

- From previous class:
 - Generally want to think of the “UI” as only one component of the system
 - Deals with the user
 - Separate from the “functional core” (AKA, the “app”)



Separation of Concerns

- There are good software engineering reasons to do this
 - Keep UI code separate from app code
 - Isolate changes
 - More modular implementation
 - Different expertise needed
 - Don't want to iterate the whole thing

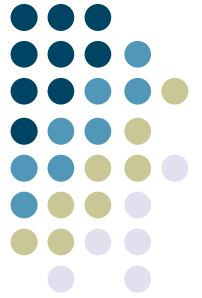


In practice, very hard to do...

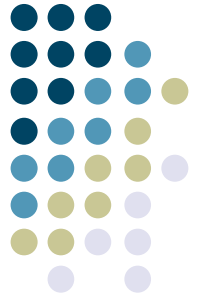
- More and more interactive programs are tightly coupled to the UI
 - Programs structured around UI concepts/flow
 - UI structure “sneaks into” application
- Not always bad...
 - Tight coupling can offer better feedback/performance

Separation of concerns is a central theme of UI organization

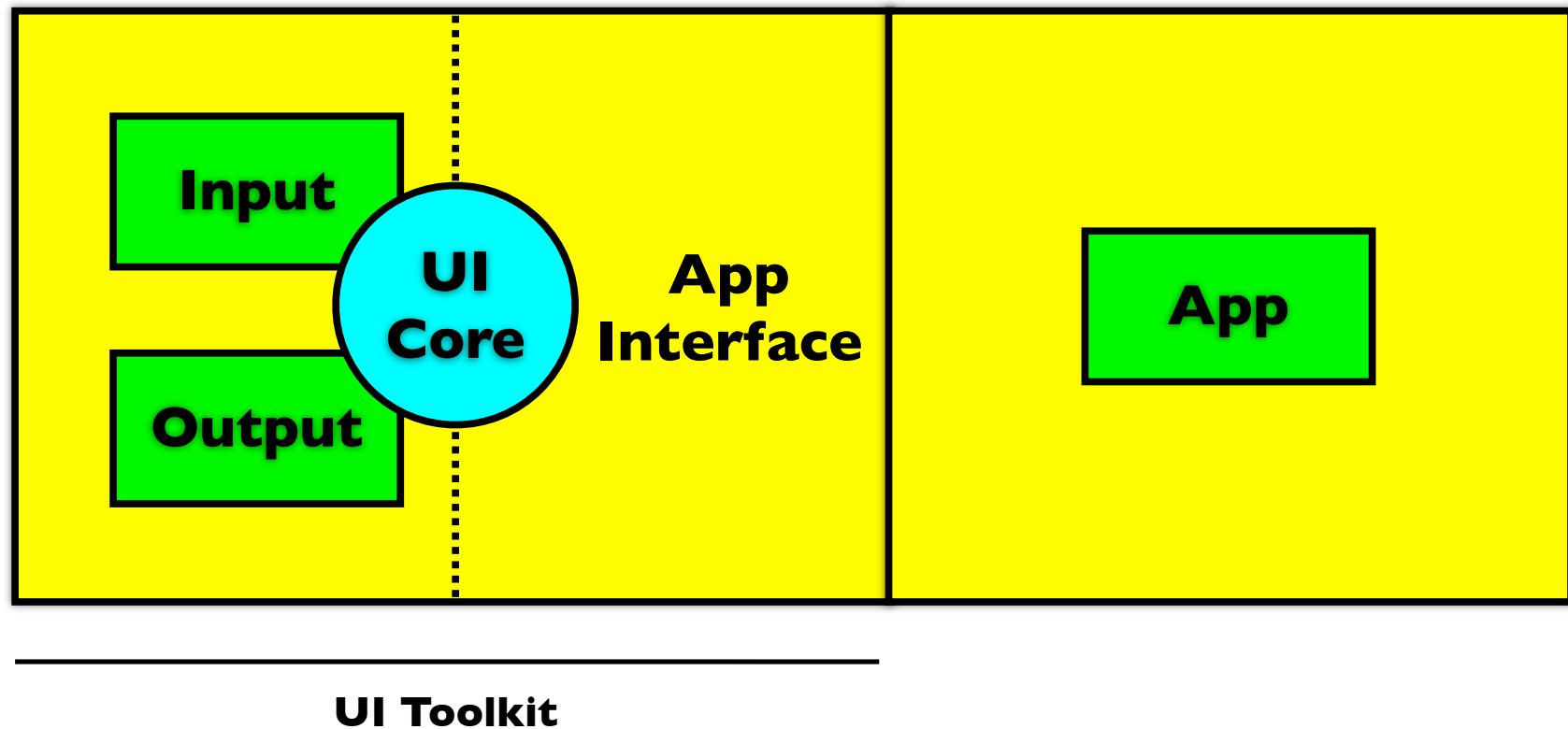
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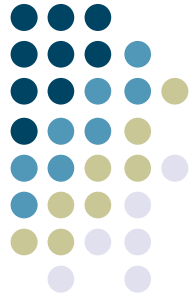


- A continual challenge
- A continual tension and tradeoff
- Real separation of UI from application is almost a lost cause

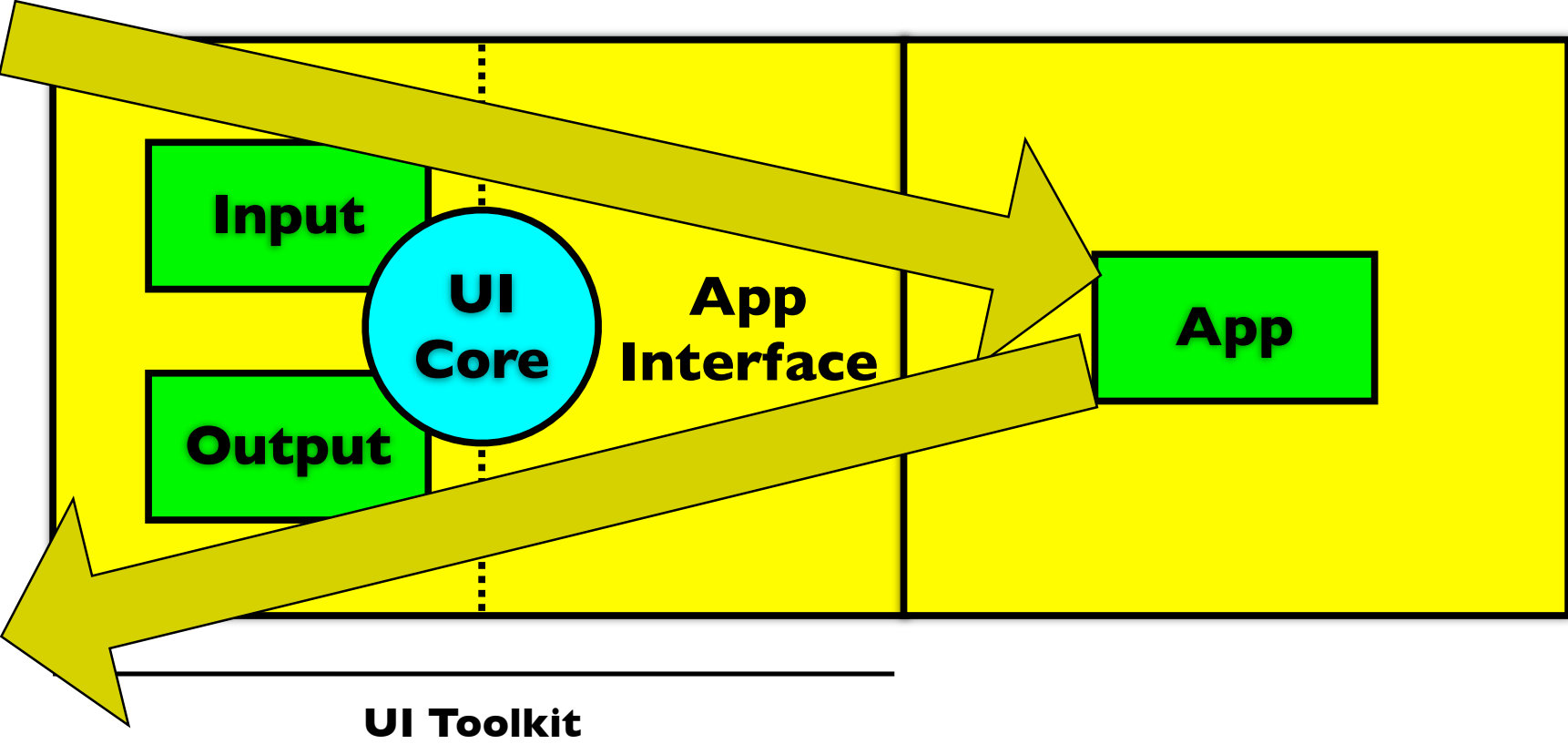


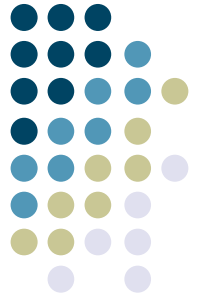
Conceptual Overview of the UI





Basic UI Flow



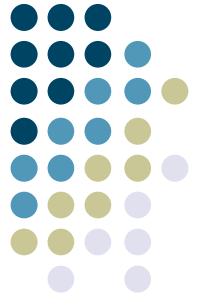


How would you architect this?

- Tempting to architect systems around these boxes
 - One module for input, one for output, etc.
 - Has been tried (“Seeheim model”)
 - Didn’t work well

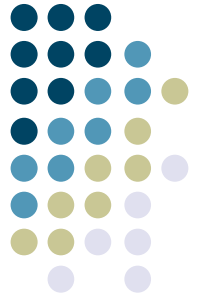
Why “Big Box” architectures don’t work well

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- Modern (“direct manipulation”) interfaces tend to be collections of quasi-independent agents
 - Each **interactor** (“object of interest” on the screen) is separable
 - Example: an on-screen button
 - Produces “button-like” output
 - Acts on input in a “button-like” way
 - Etc.

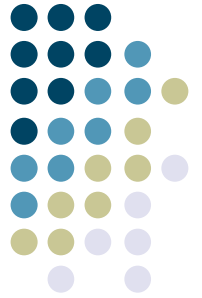
Leads to object-based architectures



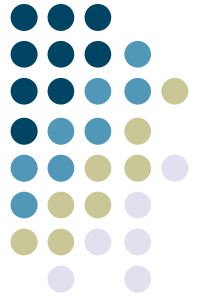
- Each on-screen interactor corresponds to an object instance
 - Common methods for
 - Drawing output (button-like appearance)
 - Handling input (what happens when I click)
- Classes are organized into a subclassing hierarchy
 - Typically a top-level “Component” or “Widget” class that describes basic interactor capabilities
 - Leaf-node classes for the things you actually see on the screen (buttons, scrollbars, etc.)
 - Intermediate classes for common behaviors (text or mouse processing)
- Objects are organized hierarchically at runtime
 - Normally reflecting spatial containment relationships
 - NOTE: different than class hierarchy created at development time
- **Interactor trees**

Challenge: maintaining separation of concerns

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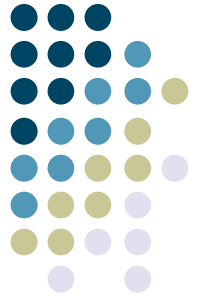


- Trick is coming up with a separation that works quickly, simply, and extensibly
 - Even a single button may be hopelessly complex (pluggable looks-and-feels anyone?)
 - Needs to be extensible to new interactors
 - What's the right factoring for all this stuff?
- Will see some strategies later
- Basically: common O-O patterns to manage complexity



UI Toolkits

- System to provide development-time and runtime support for UIs
 - Core functionality
 - Input & output handling
 - Connecting to the application
- Also: specific interaction techniques
 - Library of interactors
 - Look and feel (sometimes pluggable)

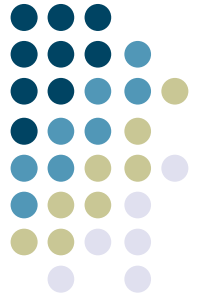


Categories of users

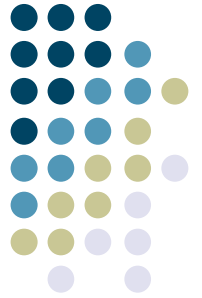
- Consumer
 - End-user, albeit indirectly
- Programmers
 - Interface designer
 - Application builder
 - Toolkit implementer/maintainer
 - Interactor writer
 - Tool builder
 - Expert end-user (through scripting)

Toolkit functionality in detail (Roadmap of topics)

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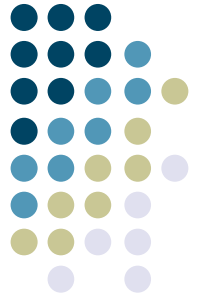


- Core functions
 - Hierarchy management
 - Create, maintain, tear down tree of interactor objects
 - Geometry management
 - Dealing with coordinate systems
 - On-screen bounds of interactors
 - Interactor status/information management
 - Is this interactor visible? Is it active?



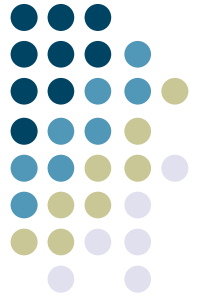
Toolkit functionality in detail

- Output
 - Layout
 - Establishing the size and position of each object
 - Both initially, and after a resize
 - (Re)drawing
 - Damage management
 - Knowing what needs to be redrawn
 - Localization and customization
 - We won't talk much about this...



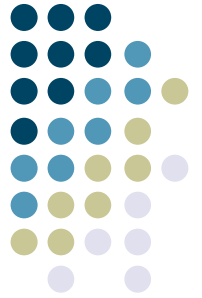
Toolkit functionality in detail

- Input
 - Picking
 - Figuring out what interactors are “under” a given screen point
 - Event dispatch, translation, handling
 - This is where a lot of the work goes



Toolkit functionality in detail

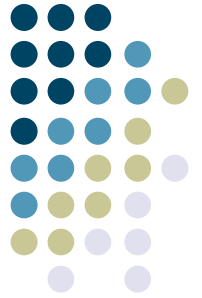
- Application interface
 - How the UI system connects with application code
 - Callbacks
 - Command objects
 - Undo models
 - ...



Example: Java Swing

- All functions of interactors encapsulated in base class
 - `javax.swing.JComponent`
 - All objects on-screen inherit from this class
- Terminology:
 - interactor, widget, component, control, ...

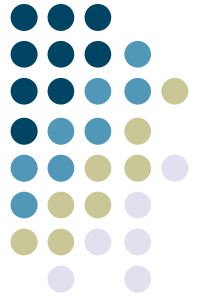
Standard object-oriented approach



- Base class (or interface) defines the set of things that every interactor must do
 - e.g., `public void paintComponent(Graphics g);`
- Subclasses provide specific specialized implementations
 - Do the right drawing, input, etc., to be a button vs. a slider vs. ...

JComponent API defines methods

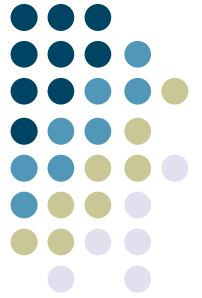
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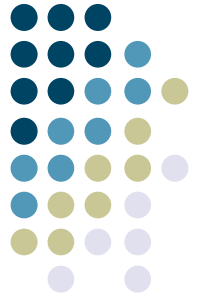
- Hierarchy management
- Geometry management
- Object status management
- Layout
- (Re)drawing
- Damage management
- Picking

In subclasses and other parts of the toolkit:

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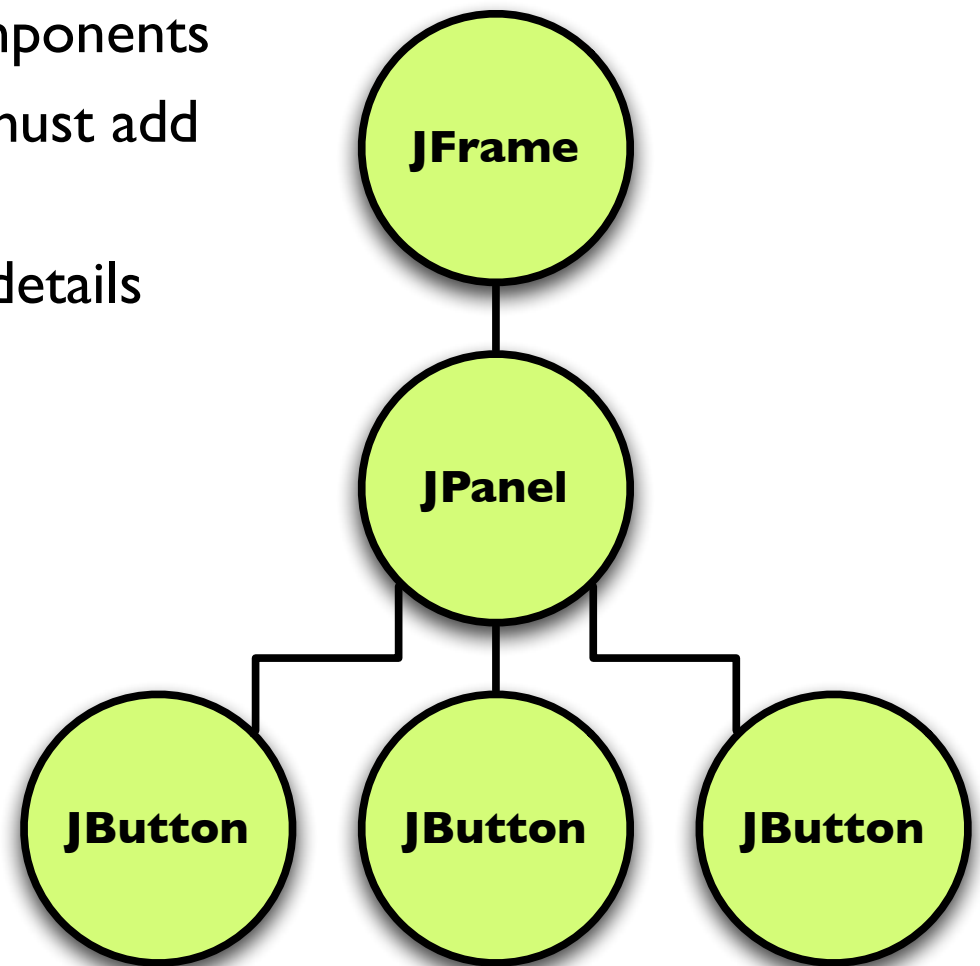


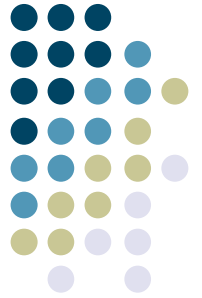
- Input dispatch and handling
- Application interface
- Pluggable looks and feels
- Undo support
- Accessibility



Hierarchy Management

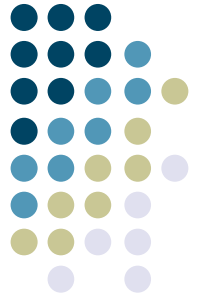
- Swing interfaces are trees of components
- To make something appear, you must add it to the tree
- Swing takes care of many of the details from there
 - Screen redraw
 - Input dispatch





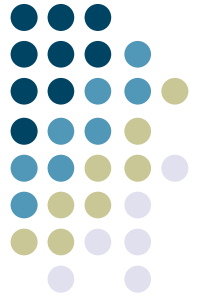
Hierarchy Management

- Lots of methods for manipulating the tree
 - `add()`, `remove()`, `removeAll()`, `getComponents()`, `getComponentCount()`, `isAncestorOf()`, ...
- Common mistake
 - If nothing shows up on the screen, make sure you've added it!



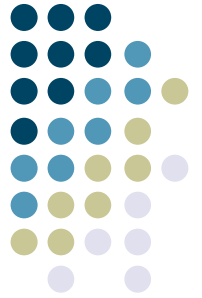
Geometry Management

- Every component maintains its own geometry:
 - Bounding box: `getX()`, `getY()`, `getWidth()`, `getHeight()`
 - X,Y are relative to parent
 - i.e., 0,0 is at parent's top left corner
 - Other operations: `setSize()`, `setLocation()`, `setBounds()`, `getSize()`, `getLocation()`, `getBounds()`
 - All drawing happens within that box
 - System clips to bounding box
 - Including output of children!
 - Drawing is relative to top-left corner
 - Each component has its own coordinate system



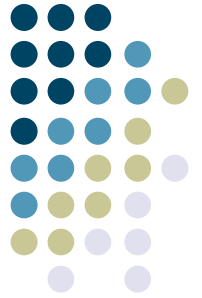
Object Status

- Each component maintains information about its “state”
 - isEnabled(), setEnabled()
 - isVisible(), setVisible()
- Lots of other methods of lesser importance



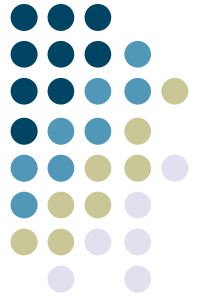
Each component handles:

- Layout (we'll talk about this later...)
- Drawing
 - Each component knows how to (re)create its appearance based on its current state
 - Responsible for painting three items, in order:
 1. Component
 2. Borders
 3. Children
 - `paintComponent()`, `paintBorder()`, `paintChildren()`
 - **These are the only places to draw on the screen!!!**
 - Automatically called by `JComponent`'s `paint()` method, which is itself called by the Swing `RepaintManager` (figures out "damaged" regions)



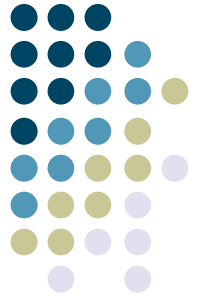
Damage Management

- Damage: areas of a component that need to be redrawn
 - Sometimes: computed automatically by Swing RepaintManager
 - e.g., if another window is dragged over your component, or your component is resized
 - Other times: you need to flag damage yourself to tell the system that something in your internal state has changes and your on-screen image may not be correct
 - e.g., your component needs to change the color of a displayed label
- Managing damage yourself:
 - `repaint(Rectangle r)`
 - Puts the indicated rectangle on the RepaintManager's queue of regions to be redrawn
- Terminology: *damage* is not a Swing term; generic



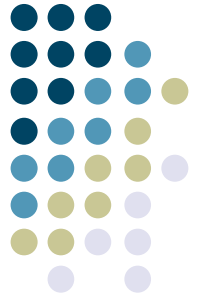
Picking

- Determine if a point is “inside” a component
 - `contains(int x, int y)`
 - Is the point inside the bounding box of this component (uses local coordinate system of component)
- Terminology: likewise, *picking* is not a Swing term



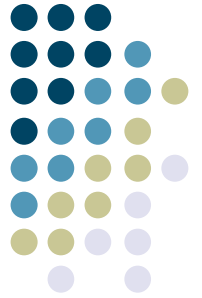
Other stuff

- Input (we'll talk about this later...)
- Application interface
 - Glue between component and application functionality
 - Not directly in component, but there is a convention for how to associate your functionality with a component
 - *Callbacks*: you register code with a component to say “call this code when something happens”
- Terminology: Swing uses the term *listener* for a piece of application code that will be called back in response to something happening
 - The code “listens for” something happening



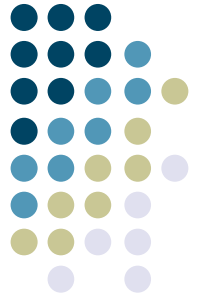
Listeners

- Any given component may have multiple situations in which it invokes a listener
 - Button pressed, list scrolled, list item selected
 - Different *types of listeners* representing different *types of things happening*
- Therefore, each component has a list of *listeners* for each situation
- Standardized names for accessing these lists
 - `addPropertyChangeListener()`, `getPropertyChangeListeners()`, `removePropertyChangeListener()`
 - `addActionListener()`, `getActionListeners()`, `removeActionListener()`



More on listeners

- There is generally a separate interface for each type of listener
 - `PropertyChangeListener`
 - `ActionListener`
- Your code must implement the appropriate listener interface *and* be registered with the list of appropriate list of listeners on the appropriate component
 - Example: button press causes listeners on the button's `ActionListener` list to be called
 - Define your code so that it implements `ActionListener`
 - Register it with the button using `addActionListener()`



Events

- Most listener interfaces define methods that take an *event object* that describes what just happened
- Separate classes of events for each listener interface
 - ActionListener: ActionEvent
 - MouseListener: MouseEvent
- Passed as a parameter containing details of what happened
 - e.g., MouseListener: mouse coordinates, whether it was pressed, released, etc.