Application Class/Program Setup

For JavaFX projects, your `App` class (which we will always provide stencil code for) must extend the `javafx.application.Application` class. The `App` class, because it contains the mainline, is the entry point of the program. You must override `Application`'s `start(Stage stage)` method and set up your `Stage`, `Scene` and `PaneOragnizer` classes. Remember, the `PaneOragnizer` class is a convention we use in CS15, so you may see different design patterns in Oracle’s official Java tutorials. Regardless, we will hold you to the design standards set in CS15. As a reminder, here is our `App` class from the `ColorChanger` program in the `Graphics Part 1` lecture:
public class App extends Application {

    @Override
    public void start(Stage stage) {
        PaneOrganizer organizer = new PaneOrganizer();

        /*
        * The “200” numbers are the width and height of the
        * Scene. Feel free to change them as you wish, and
        * consider making them constants!
        */
        Scene scene = new Scene(organizer.getRoot(), 200, 200);

        stage.setScene(scene);
        stage.setTitle(“Color Changer”);
        stage.show();
    }
}

Note: You never need to instantiate a Stage manually. A Stage is automatically created and passed in when the start(Stage stage) method is called.

Debugging

When you encounter runtime exceptions in your programs, your stack trace might look like this:

Exception in Application start method
java.lang.reflect.InvocationTargetException
    at sun.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
    at sun.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:62)
    at sun.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:43)
    at java.lang.reflect.Method.invoke(Method.java:497)
    at com.sun.javafx.application.LauncherImpl.launchApplicationWithArgs(LauncherImpl.java:389)
    at com.sun.javafx.application.LauncherImpl.launchApplication(LauncherImpl.java:328)
    at sun.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
    at sun.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:62)
    at sun.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:43)
    at java.lang.reflect.Method.invoke(Method.java:497)
    at sun.launcher.LauncherHelper$FXHelper.main(LauncherHelper.java:767)
Caused by: java.lang.RuntimeException: Exception in Application start method
    at com.sun.javafx.application.LauncherImpl.launchApplication1(LauncherImpl.java:917)
    at com.sun.javafx.application.LauncherImpl.lambda$launchApplication$156(LauncherImpl.java:182)
    at java.lang.Thread.run(Thread.java:745)
Caused by: java.lang.NullPointerException
    at IsaacPacman.GameManager.<init>(GameManager.java:71)
    at IsaacPacman.RootManager.<init>(RootManager.java:26)
    at IsaacPacman.App.start(App.java:20)
Eeek!!! This stack trace is so long and un-helpful! Where do we even begin?

Let’s take a closer look - we see two lines that start with “Caused by.” These are the helpful lines! If we look at the second one:

```java
Caused by: java.lang.NullPointerException
    at IsaacPacman.GameManager.<init>(GameManager.java:71)
    at IsaacPacman.RootManager.<init>(RootManager.java:26)
    at IsaacPacman.App.start(App.java:20)
```

we see that a NullPointerException is being thrown at line 71 of GameManager.java. With this information, we can hunt down our bug and squash it!

In general, when a runtime exception is thrown, you will find the helpful “Caused by” information near the very bottom of the stack trace. It might even be a good idea to scroll down to the bottom and work your way up!

**Coordinate System**

In the world of JavaFX (and in many other graphics-related contexts), we measure screen coordinates in pixels, starting from the top-left corner of the window, like so:
Note: Negative coordinates are certainly possible! They’ll just refer to locations that are outside the bounds of the window.

Sometimes, it may be useful to store an x-y pair of pixel coordinates together. To do this, use `javafx.geometry.Point2D`. To store coordinates, we pass them into `Point2D`’s constructor. For example, if we wanted to store a `Point2D` with the x-y coordinates (345, 600), we would write:

```java
Point2D point = new Point2D(345, 600);
```

Then, to access the coordinates, we would call `point.getX()` and `point.getY()`.

Note: `Point2D` can be used for more than pixel coordinates! You can store any arbitrary x-y pair and use it as you wish. The constructor takes in doubles, so you can even store decimal values.

**Panes**

In addition to `VBox`, `HBox`, and `BorderPane`, which are detailed in the *Graphics Part 1* and *Graphics Part 2* lectures, there are numerous other `Pane` subclasses. A full list can be found [here](#) under the “Direct Known Subclasses” heading. In this guide, we will talk about a few `Pane` types that you can use to make your programs look extra-extra-pretty!

**Backgrounds**

To change a Pane’s background color, we use the `javafx.scene.layout.Background` and `javafx.scene.layout.BackgroundFill` classes. `BackgroundFill`’s constructor is of the form `BackgroundFill(Paint fill, CornerRadii radii, Insets insets)`. `javafx.scene.paint.Color` is a subclass of `Paint`, so we can pass a `Color` into the constructor (See the *Colors* section for information on how to create `Colors`). For simple Pane backgrounds, we do not need to specify `CornerRadii` and `Insets`. Thus, to create a blue `BackgroundFill`, we would write:

```java
BackgroundFill fill = new BackgroundFill(Color.BLUE,
                                         CornerRadii.EMPTY, Insets.EMPTY));
```

Don’t worry about understanding `CornerRadii` and `Insets` precisely - our example will create a background with no border.

Now, we create a `Background` using our `BackgroundFill`. We assume we have a Pane reference called `pane`, and we set pane’s background:

```java
Background background = new Background(fill);
pane.setBackground(background);
```
FlowPane

FlowPane arranges its child nodes in a straight line, one after the other. The layout is horizontal by default, but can be specified as vertical by calling `pane.setOrientation(Orientation.VERTICAL)`. When the “line” of Nodes reaches the end of the pane, it wraps around to the beginning and forms a new row or column, depending on whether the orientation is horizontal or vertical. Here, we set up a sample horizontal FlowPane:

```java
FlowPane flowPane = new FlowPane();
flowPane.setOrientation(Orientation.HORIZONTAL);  // This is the default, so this call is not strictly necessary
flowPane.getChildren().add(new Button("1"));
flowPane.getChildren().add(new Button("2"));
/* Other buttons elided */
```

We see that the rows of buttons wrap around as they reach the right side of the FlowPane.

AnchorPane

AnchorPane allows the positioning of its child Nodes relative to the edges of the AnchorPane. We simply specify the pixel distance (the “anchor”) from the edge of the pane to each Node using static methods of AnchorPane. If opposite anchors are specified (i.e. left-right or top-bottom) the Node will resize itself in that dimension to fulfill both anchor specifications. If only one anchor of a left-right or top-bottom pair is specified, the Node will maintain its default or previously specified size in that dimension. Here, we create an example AnchorPane:

```java
AnchorPane anchorPane = new AnchorPane();
```
// Button 1 will “float” in the top-left corner
Button b1 = new Button(“Button 1”);
AnchorPane.setTopAnchor(b1, 10.0);
AnchorPane.setLeftAnchor(b1, 10.0);

// Button 2 will stretch itself left-to-right
Button b2 = new Button(“Button 2”);
AnchorPane.setTopAnchor(b2, 10.0);
AnchorPane.setLeftAnchor(b2, 25.0);
AnchorPane.setRightAnchor(b2, 25.0);

/* Button 3 elided */

// Button 4 will stretch itself vertically
Button b4 = new Button(“Button 4”);
AnchorPane.setTopAnchor(b4, 35.0);
AnchorPane.setBottomAnchor(b4, 10.0);
AnchorPane.setLeftAnchor(b4, 10.0);
AnchorPane.setRightAnchor(b4, 100.0);

/* Button 5 elided */

anchorPane.getChildren().addAll(b1, b2, b3, b4, b5);

---

**GridPane**

*GridPane* allows the layout of child *Nodes* in a “grid” of rows and columns. The sizes of the rows and columns can be set as pixel measurements or, alternatively, percentages of the *GridPane*’s size. In addition, each *Node*’s alignment within its row and column can be set.

*GridPane*’s rows and columns start from 0, not 1. We do not need to specify the row-column dimensions of the *GridPane* when we instantiate it - the rows and columns are added automatically as child *Nodes* are added to the *GridPane*. To add *Nodes* to a *GridPane*, we
use the GridPane-specific method `add(Node node, int columnIndex, int rowIndex)`. Here, we create a GridPane with four columns and one row:

```java
GridPane gridPane = new GridPane();
Label label1 = new Label("Andy");
gridPane.add(label1, 0, 0); // Label added to column 0, row 0
Label label2 = new Label("van");
gridPane.add(label2, 1, 0); // Label added to column 1, row 0
Label label3 = new Label("Dam");
gridPane.add(label3, 2, 0); // Label added to column 2, row 0
Button button = new Button("Damn!");
gridPane.add(button, 3, 0); // Button added to column 3, row 0
```

Next, we set the sizes of the columns to each be 25% of the GridPane’s width using the `javafx.scene.layout.ColumnConstraints` class and a “for” loop.

```java
for (int i = 0; i < 4; i++) {
    ColumnConstraints cc = new ColumnConstraints();
    cc.setPercentWidth(25);
    gridPane.getColumnConstraints().add(cc);
}
```

The `ColumnConstraints` are applied to the columns in the order they are added. Since we add four `ColumnConstraints`, they are added to the first four columns, which are the columns we are using.

Note: The percentages do not have to all be the same; they are arbitrary. To use multiple percentage values, we would have to create the `ColumnConstraints` individually instead of in a “for” loop.

Additionally, instead of percentages, the `ColumnConstraints` width can be set to an absolute pixel dimension by passing in the desired number of pixels into the constructor (i.e. `new ColumnConstraints(50)` for a width of 50 pixels).

There is an analogous `javafx.scene.layout.RowConstraints` class for setting the heights of rows. In our example, we have only used one row. We set its height using a pixel dimension:

```java
RowConstraints rc = new RowConstraints(50);
```
gridPane.getRowConstraints().add(rc);

Finally, we set the alignment of the child Nodes within their “cells” using the static setHorizontalAlignment(Node node, HPos value) and setValignment(Node node, VPos value) methods of GridPane and a “for-each” loop. There are static CENTER, LEFT, and RIGHT constants for HPos, and static CENTER, BOTTOM, and TOP constants for VPos:

```java
for (Node child : gridPane.getChildren()) {
    GridPane.setHalignment(child, HPos.CENTER);
    GridPane.setValignment(child, VPos.CENTER);
}
```

As with the ColumnConstraints percentages, the alignments here do not have to all be the same. To use different alignment values for different children, we would have to set each child’s alignments individually instead of in a “for-each” loop.

After all of our work, here is our very pretty result!

**Buttons**

Buttons are necessary for almost any User Interface and you’re going to be implementing lots of them during your most beautiful and lovely CS15 journey.

There are a few types of buttons and they can have many differences but one thing they all have in common is that they are action producers, meaning they trigger a reaction when they are clicked/selected!

You’ll mostly be dealing with two types of buttons in CS15, the conventional button `javafx.scene.control.Button`, and the radio button `javafx.scene.control.Radio Button`.

**Button**

Let’s go over the normal Button first! The role of this button is to produce an action when clicked; very simple. You can instantiate a Button using any of the three constructors depending on how many parameters you want to enter. The first constructor will produce a Button with an empty text caption:
Button button = new Button();

The second constructor takes in a string and produces a Button with the string entered as its text:

Button button = new Button("Example");

The third constructor takes in a String and an Image and produces a button with the String entered as its text and and the Image entered. You will probably not be using this unless you decide to be creative, which of course is highly encouraged!

For this constructor, you first need to instantiate the Image:

Image icon = new Image(getClass().getResourceAsStream("icon.png"));

then produce the actual Button. (note that the above line assumes you have a .png picture of your icon in your project folder.)

Button button = new Button("Accept", new ImageView(icon));

You can always create an empty Button then use the following methods to give it text and/or an icon:

- the setText(String text) method
- the setGraphic(Node icon) method

You now know how to make a Button, but how do we make it respond to clicks? Simple, use the buttons setOnAction(EventHandler handler) which takes in a javafx.event.EventHandler as its parameter, and will execute the handle(ActionEvent event) method of the handler when clicked! The handle(ActionEvent event) method of the handler entered as a parameter will determine what happens when the button is clicked! Note that the parameter event of type ActionEvent is automatically entered by the button itself and contains information about the ActionEvent.

So suppose you have a class ButtonHandler that implements EventHandler and that already has a defined method handle(ActionEvent event) that moves a shape on your screen. If you want to make a button that moves that shape on the screen when clicked, the code would look like this:

// instantiating the button with a specific text
Button button = new Button("Move the shape!");
button.setOnAction(new ButtonHandler());
// We are basically telling the button to call the instance of our
Radio Buttons
Now let’s talk about RadioButtons; these are a little more complicated and confusing than our traditional Buttons. They have two states, selected and unselected, and they often appear in groups where only one button can be selected at once.

There are multiple constructors we can use to create instances of this class, but let’s focus on two: a normal constructor that creates a RadioButton to which you can later assign a String using the setText(String text) method, and a constructor that initially takes in the String.

Here are both constructors:

RadioButton rb1 = new RadioButton();
RadioButton rb2 = new RadioButton("example");

Your RadioButtons will probably be mutually exclusive and the way to do that is put them all in a javafx.scene.control.ToggleGroup. This will mean that when one is selected, any already selected RadioButton will be deselected, meaning there can only be one selected RadioButton in any ToggleGroup. Let’s create our ToggleGroup first:

ToggleGroup group = new ToggleGroup();

Now that we have a ToggleGroup, we can tell our previously instantiated RadioButton to belong to that ToggleGroup:

rb.setToggleGroup(group);

Let’s make more RadioButtons and add them to our group:

RadioButton rb2 = new RadioButton("example2");
RadioButton rb3 = new RadioButton("example3");
rb2.setToggleGroup(group);
rb3.setToggleGroup(group);

We can even choose if a RadioButton is selected when the program is launched:

rb.setSelected(True);
You can always know which RadioButton in a ToggleGroup is selected by calling the getSelectedToggle() method on the ToggleGroup.

The handling is the same as the normal button. One thing to keep in mind though is that when a RadioButton that belongs to a ToggleGroup is selected, that means the other Radiobuttons in the same ToggleGroup are deselected so make sure that every RadioButton handler negates/ends the actions of the previous RadioButton before executing what the selected RadioButton is supposed to do.

Labels

Labels are the backbone of any user interface, they tell the user what everything on the screen means. You’re going to be implementing a lot of them in CS15, luckily, they are easy to implement. So to create a javafx.scene.control.Label use one of the following constructors:

Label label = new Label(); // creates an empty label
Label label = new Label(“Example!!”); // creates a label with text

You can also manipulate the color and font of the Label as well as reset the text if you choose too, the following method examples might be useful. For more complex methods, refer to the Label Javadocs:

label.setText(“Any string”); // Sets the labels text to a string

// Sets the label’s font to 30pt Arial; note that we create a
// font using the font constructor Font(String font, int size)
label.setFont(new Font(“Arial”, 30));

// Sets the label’s color to the color consisting of the entered
// values of red, green and blue.
label.setTextFill(Color.rgb(20, 20, 20));

If your Label doesn’t fit where you want it to or goes horizontally without going down another line, you might consider wrapping it using the following method:

label.setWrapText(true);

You can even apply really cool effects on Label using rotation and translation methods, example:
label.setRotate(180); //rotates the label 180 degrees
//translates the label horizontally 120 pixels
label.setTranslateX(120);

**Slider**

*javax.scene.control.Slider* is an effective tool to use in JavaFX applications. It is used to display a continuous or discrete range of valid numeric choices and allows the user to interact with the control. It consists of a track and a thumb. You should be comfortable with implementing them in your CS15 projects!

Example of a Slider in Mac OS X:

![Slider Example](image)

Let’s try making one first! This is the default constructor for a Slider:

Slider(double min, double max, double value)

The constructor takes in the following three parameters:
- • **min** - minimum value of the slider, must be double
- • **max** - maximum value of the slider, must be double
- • **value** - default value of the slider, must be within the range of min to max

Example:

// This creates a slider with the minimum value of 0, maximum value // of 100 and default value of 50
Slider slider = new Slider(0, 100, 50)

The Slider has many other methods that you could incorporate to customize your Slider. Please refer to its Javadoc for more details. One method to keep in mind is the getValue() method. It returns the value (as a double) that the Slider is currently at.

In order to handle a change in the Slider, you have to create a class that implements ChangeListener (which must implement the method public void changed( . . . )). You must specify what you want your application to do when the Slider is modified in the public void changed( . . . ) method.

Then, you must remember to add the class that implements ChangeListener to the slider’s value property. By doing this, the slider’s value property will listen for changes, and it will call your changed( . . . ) method every time the slider is modified.
Here's an example in which we create a `Slider` that moves a `Rectangle` from side-to-side: (Focus on how the `SliderListener` is added and implemented; feel free to copy this code to Sublime or Eclipse and run it yourself!)

```java
//import statements elided

public class Sample extends Application {
    //main method elided
    public void start(Stage primaryStage) throws Exception {
        Slider slider = new Slider(0, 100, 50);
        Rectangle rec = new Rectangle(50, 50);
        slider.valueProperty().addListener(new SliderListener(rec));
        // Set initial x position as the slider’s value
        rec.setX(slider.getValue());
        rec.setY(50); // so that the slider and rec don’t overlap
        Pane root = new Pane();
        root.getChildren().addAll(slider, rec);
        primaryStage.setScene(new Scene(root, 300, 250));
        primaryStage.show();
    }

    private class SliderListener implements ChangeListener<Number> {
        private Rectangle _rec;

        // Constructor takes in a Rectangle as a parameter so that
        // it can change the Rectangle’s position whenever the
        // Slider’s value changes
        public SliderListener(Rectangle rec) {
            _rec = rec;
        }

        public void changed(ObservableValue<? extends Number> observable, Number oldValue, Number newValue) {
            // changes the rectangle’s x position when the slider
            // is changed
            _rec.setX(newValue.doubleValue());
        }
    }
}
```
Colors

There are three different color classes in Java 1.8 - java.awt.color, com.sun.prism.paint.color and javafx.scene.paint.Color. Make sure that you import the correct one - javafx.scene.paint.Color!

You can find the JavaFX Color Javadocs here.

Making Color in Java is very simple. There are three ways of doing so but we will only cover two for now. Here is the first way to create a Color:

Example:

Color c = Color.RED;

There are several static variables of the Color class, such as RED, BLUE, WHITE, BLACK, etc. Check out the Javadocs for more colors!

Second way of creating a Color is using the static rgb(int red, int green, int blue) method in the Color class.

The parameters red, green, and blue correspond to the red component, green component and blue component respectively, and they all have to be ints belonging to the range 0 - 255.

Example:

// This is pure red, but you get the idea! This has an implicit alpha // of 1.0. (What is alpha? Read on!)
Color c = Color.rgb(255, 0, 0)

Each Color also has an alpha value from 0.0 - 1.0 that defines the opacity of the Color. An alpha value of 0 is completely transparent, and alpha value of 1 is completely opaque.

public static Color rgb (int red, int green, int blue, double opacity);

The above method has an extra parameter of opacity, which only accepts values from 0.0 to 1.0.
Example:

```java
// This red color is 50% transparent
Color c = Color.rgb(255, 0, 0, 0.5);
```

If you are picky with your Colors, you can consult this Color Picker for specific RGB values of the Color you wish to make.

Shapes

You will make heavy use of Shapes this year, as they are needed to visually create some of the most important parts of your projects (e.g. the Doodle in Doodle Jump, and Pieces in Tetris). The JavaFX Shapes documentation is more understandable than some other Javadocs (e.g. Node Javadocs), so be sure to follow along as this section frequently refers to those Javadocs.

Types

If you look at the Direct Known Subclasses of Shape, you can see all of the different types of Shapes. You will deal frequently with Rectangles and Ellipses, and you may also work with Circles, Lines, Polygons, and Text at some point during the course.

Sizing

Shape is a subclass of Node, but it is a special kind of Node in multiple ways. Firstly, unlike Panes, Shapes do not have children Nodes. Thus, you are not able to call `shape.getChildren().add(...)`.

Additionally, Shapes are “non-resizable” Nodes. Initially, this seems confusing. Can’t I change the width and height of my Rectangle? What “non-resizable” really means is that Shapes are not resized by their parents.

The documentation of Node’s `isResizable()` method provides a good explanation of this:

```
“If this method returns false, then the parent cannot resize it during layout...
Group, Text, and all Shapes are not resizable and hence depend on the application to establish their sizing by setting appropriate properties (e.g. width/height for Rectangle, text on Text, and so on). Non-resizable Nodes may still be relocated during layout.”
```

What this means is that a Rectangle uses its width and height properties to size itself, rather than constraints determined by its parent. This is different from Buttons and Labels, which are resized by their parents. See the GridPane or AnchorPane section of this doc for an example of Labels and Buttons being resized based on constraints.
One aspect of setting Shape size that could pose some problems is the fact that size properties aren't part of the Shape superclass; rather, different specific size properties exist for each subclass. For example, Rectangles have width and height, whereas Ellipses have radiusX and radiusY. Thus, setting the size of a Rectangle would look different than setting the size of an Ellipse:

```java
Rectangle rectangle = new Rectangle();
rectangle.setHeight(10.0);
rectangle.setWidth(50.0);

Ellipse ellipse = new Ellipse();
ellipse.setRadiusX(40.0);
ellipse.setRadiusY(20.0);
```

This doesn't seem like a huge problem, but what if you want to refer to Shapes polymorphically? Let's say you have a List of Shapes, and you want to resize every Shape in your list. The following code wouldn't work because not all Shapes have setWidth() and setHeight() methods; those are specific to Rectangle.

```java
List<Shape> shapeList = new ArrayList<>();
/* code that populates list elided */
for (Shape shape : shapeList) {
    shape.setWidth(50.0);
    shape.setHeight(100.0);
}
```

If you do need a way to resize Shapes polymorphically, a couple alternatives include using a Scale transformation, or using the Shapes’ scaleX/Y properties, which Shape inherits from Node.

## Setting Location

Setting the on-screen location of Shapes is one of the least straight-forward parts of JavaFX. There are many different ways to set a Shape’s location, so here is an explanation of each of the different ways to do so. The most important thing to remember is to choose only one of the following groups of methods when setting Shape location. For example, don’t use both setLayoutX() and setTranslateX(), otherwise the behavior will not be what you expect or desire.

### Using the Shape subclass’ methods

**Description:**
Some shape subclasses have their own specific methods for setting location.
Rectangle:
javafx.scene.shape.Rectangle has setX(double y) and setY(double y) methods for setting location. These methods set the location of the upper-left corner of the Rectangle relative to the upper-left corner of its parent Node. If we had a Rectangle variable called rect that we wanted to move to (42, 85.5), we could write:

```java
rect.setX(42);
rect.setY(85.5);
```

Circle/Ellipse:
javafx.scene.shape.Circle and javafx.scene.shape.Ellipse have setCenterX(double value) and setCenterY(double value) methods for setting location. These methods set the location of the center of the shape relative to the upper-left corner of its parent Node. If we want to set a Circle or Ellipse’s location based on the upper-left corner of its bounding box instead, we can write wrapper methods:

```java
public void setLocation(Circle circle, double x, double y) {
    circle.setCenterX(x + circle.getRadius());
    circle.setCenterY(y + circle.getRadius());
}

public void setLocation(Ellipse ellipse, double x, double y) {
    ellipse.setCenterX(x + ellipse.getRadiusX());
    ellipse.setCenterY(y + ellipse.getRadiusY());
}
```

Polygon/Line:
javafx.scene.shape.Polygon and javafx.scene.shape.Line do not have subclass-specific methods for setting location.

Known Issues:
Polygon and Line do not have subclass-specific methods, so for these classes, you’ll have to use one of the other ways to set location.

The subclass-specific methods ignore the stroke (border) of the Shape, if a stroke exists. By default, a Shape’s stroke type is set to javafx.scene.shape.StrokeType.CENTERED, which means that half of the stroke width goes on the outside of the actual shape boundary, and half goes on the inside. Because the subclass-specific methods ignore the stroke, the strokes of two Shapes will overlap if the Shapes are set to adjacent locations. To avoid this, we can set a shape’s StrokeType to StrokeType.INSIDE:

```java
shape.setStrokeType(StrokeType.INSIDE);
```
Here, we have two Circles with no stroke. They are perfectly adjacent to each other.

Now, without changing the Circles’ location or size, we add a very wide stroke. We see that the Circles now appear to overlap:

If we set the Circles’ StrokeType to StrokeType.INSIDE, the Circles no longer appear to overlap:

Because the stroke is now entirely on the inside of the Circle boundary, the Circles appear smaller. However they are still the same size as the Circles without any stroke. The Circles with the default StrokeType appear larger because half of the stroke is outside of the Circle boundary. This is why the Circles appear to overlap!

**Using relocate()**

**Description:**
Each Shape inherits this method from the Node superclass. It sets the on screen location of the top left corner of the Shape’s bounding box to the coordinates passed into the method. A “bounding box” is the unrotated rectangle that surrounds a Shape and takes its graphical properties (e.g. rotation, stroke (border), size) into account. Here are some examples of bounding boxes.

Using the relocate() method differs from using the other location-setting methods in a couple important ways:

- **It includes the Stroke (border) of the Shape when positioning the Shape**
  - This is because the Shape’s stroke is included in its bounding box
- **It always sets the position based on the top left corner of the Shape’s bounding box,** whereas the other location-setting methods set the Shape’s location based on different parts of the Shape depending on the subclass
  - For example, with the other methods, Rectangles’ locations are set based on their top left corner, but Ellipses’ locations are set based on their center
relocate() adjusts the layoutX and layoutY properties of a Shape in order to set its on-screen location. However, it doesn't necessarily directly set layoutX and layoutY to the passed in x and y. This is described more in-depth in the Known Issues section.

See the setLayoutX() and setLayoutY() section for a direct comparison between using setLayoutX/Y and relocate().

**Known Issues:**
relocate() doesn’t necessarily directly set the layoutX and layoutY properties of the node with the parameters’ values, but insteads sets them relative to the Shape’s bounding box.

Why should you care about this? This could cause your program to behave unexpectedly if you want to access the location of your Shape after having used relocate(). Using getLayoutX() and getLayoutY() to obtain the location of your Shape will not necessarily return the same x and y values passed into relocate(x, y). This is because the layoutX and layoutY properties do not represent the top left corner of the Shape’s bounding box, which relocate()’s functionality is based on.

For a detailed example of this with diagrams, see the setLayoutX() and setLayoutY() section.

**Using setLayoutX() and setLayoutY()**

**Description:**
Each Shape inherits the above two methods from the Node superclass. They set the shape’s layoutX and layoutY properties, respectively.

These properties represent different things for different Shapes. For example, for Rectangles, layoutX and layoutY represent the location of the top left corner of the Rectangle. However, for Circles and Ellipses, layoutX and layoutY represent the location of the center of the Shape. Thus, be careful when using these methods, and make sure you understand that they will act differently based on the Shape.

void setLayoutX(double value) and void setLayoutY(double value).

The values passed to each of these methods are the coordinates at which we want the Shape to be located. So calling the following methods on an already instantiated Rectangle called rectangle will position rectangle at the position (25, 50) on the screen regardless of its previous position. Let’s take a look at how that’s done.

```java
Rectangle rectangle = new Rectangle(100, 100); //instantiates a new Rectangle with height and width of 100
```
rectangle.setLayoutX(25); //changes the Rectangle’s layoutX position to 25, so the position of rectangle now becomes (25,0)

rectangle.setLayoutY(50); //changes the Rectangle’s layoutY position to 50, so the new location of rectangle is (25, 50)

**Known Issues:**
A very tricky trap in JavaFX is the way `relocate()` and `setLayoutX()` interact when they are used interchangeably.

SetLayoutX/Y will set the layoutX and layoutY properties of the object to the desired coordinates. If, however, you choose to give your object a positive stroke (border), meaning that the border will be outside the object, `setLayoutX/Y` will ignore the stroke and re-position the Shape based on the top left corner of the actual Shape. This is the same issue as with using the Shape subclass’ methods, so read the Known Issues portion of that section to learn about how Strokes work.

Unlike `setLayoutX/Y`, `relocate()` includes the stroke when setting the location of the Shape, so it will set the top left corner of the entire Shape (stroke included) to the given coordinates.

To illustrate the difference between using `relocate()` and `setLayoutX/Y`, suppose we have a Rectangle that has a side length of 40 and a stroke (border) of size 20. Ignore the blue outline, the stroke we are referring to is the large yellow border of the magenta rectangle. If we call `relocate(0, 0)` on the Rectangle, the following would occur:

At this point notice that the top left corner of the entire object (including the stroke) is at location (0,0) while the layoutX and layoutY properties are both set to 10. The fact that (layoutX, layoutY) is (10, 10) means that the top left corner of the actual Shape (stroke not included) is located at (10, 10).
This shows that calling \texttt{relocate}(x, y) will not necessarily set the layoutX and layoutY properties to x and y. Using \texttt{setLayoutX}(x) and \texttt{setLayoutY}(y), however, directly sets the layoutX and layoutY properties to x and y.

Thus, calling \texttt{setLayoutX}(0) and \texttt{setLayoutY}(0) on the Rectangle instead of \texttt{relocate}(0, 0) will result in the following scenario:

Here, the layoutX and layoutY properties are actually set to 0, however, part of the Shape’s stroke is off the screen (since \texttt{setLayoutX/Y} ignores the stroke).

If you decide you want to use \texttt{setLayoutX/Y} for setting the locations of your Shapes, make sure you fully understand these issues before attempting to use these methods.

Additionally, if used exclusively, the \texttt{setLayoutX/Y} methods behave identically to \texttt{setTranslateX/Y}, so be sure to read the Known Issues portion of that section.

**Using setTranslateX() and setTranslateY()**

**Description:**
Each Shape subclass inherits the following two methods from the Node superclass. This includes Rectangle, Ellipse, Circle, Line, etc..

\texttt{setTranslateX(double value)} and \texttt{setTranslateY(double value)}

The value passed in from its parameter defines the x coordinate of the translation that is added to the Shape. For example:

\begin{verbatim}
Rectangle rect = new Rectangle(50, 50); //This creates a rectangle of width and height of 100 pixels
rect.setLayoutX(100);
rect.setLayoutY(100); //Now rectangle is located at (100, 100) (See Figure 1)
\end{verbatim}
rect.setTranslateX(50); //This moves rec 50 pixels to the right of original position, now located at (150, 100) (See Figure 2)
rect.setTranslateX(-50); //Moves rec 50 pixels to the left of original position, now located at (50, 100)

![Figure 1. Set at (100, 100)](image1) ![Figure 2. Set at (150, 100)](image2)

Note: this example is purely for pedagogical purposes. **Do not use both setLayoutX/Y and setTranslateX/Y in your project** -- you won’t ever need to and it may produce unwanted results that can be very difficult to debug. Instead, you should choose *either* setLayoutX/Y or setTranslateX/Y and use that method call for every location-setting need that you have for shapes in your project.

In general, the shape’s final translation will be computed as layoutX + translateX, where layoutX establishes the node’s stable position and translateX optionally makes dynamic adjustments to that position.

For subclasses that have location setting methods, (such as `Rectangle` and `Ellipse`), the final position would actually be layoutX + translateX + x (where x is the subclass’ location property).

**Known Issues:**
One of the main issues with using setTranslateX/Y occurs when using these methods in tandem with other location-setting methods (e.g. setX(), setLayoutX()). As shown in the description above, calling different location-setting methods on one `Shape` will result in the final on-screen location of the `Shape` differing from the location parameters passed into setTranslateX/Y.

Additionally, if used exclusively, the setTranslateX/Y methods behave identically to setLayoutX/Y, so be sure to read the Known Issues portion of that section.
Setting Colors

All subclasses of the Shape class, such as Rectangle, Circle, Ellipse and Line, have these three methods: setFill(Paint value), setStroke(Paint value) and setStrokeWidth(double value). These three methods are super important for the upcoming CS15 projects. Let’s take a look at how they work.

- setFill - fill the interior of the Shape with the Paint value that is passed in from the parameters. We usually pass in a Color, which is a subclass of the Paint class.

- setStroke - defines the color of the stroke that is drawn around the outline of the Shape. Again, we usually pass in a Color.

- setStrokeWidth - This defines the width of the border of the Shape. A value less than 0.0 will be treated as 0.0.

Example:

```java
//Instantiating variables
Rectangle rec = new Rectangle(); //The rectangle is filled with the color black, has a black outline and stroke width of 1.0 by default
rec.setFill(Color.RED); //sets rec’s fill to red
rec.setStrokeWidth(1.5); //sets rec’s stroke width to 1.5
rec.setStroke(Color.BLUE); //sets rec’s stroke to blue
```

Timelines

We use javafx.animation.Timeline to control events (animations, perhaps?) that happen at regular intervals. For this example, we will assume that we have two items that we want to move at regular intervals - a rocket ship and an alien. The catch is that we want our items to move at staggered intervals, not at the same time - we want the rocket to move, then the alien, and so on. Let's assume we have separate EventHandler<.ActionEvent> classes, RocketHandler and AlienHandler, for our two items. First, we instantiate our Timeline:

```java
Timeline timeline = new Timeline();
```

We attach EventHandler<(ActionEvent> classes to Timelines through the javafx.animation.KeyFrame class. In the KeyFrame constructor, we pass in a javafx.util.Duration object, which defines the length (in time) of the KeyFrame, and an EventHandler<(ActionEvent> object, whose handle(ActionEvent e) method will be called at the end of the KeyFrame’s duration.
The `Duration` class has static methods such as `seconds(double seconds)` and `millis(double milliseconds)` to create `Duration` objects of different lengths. Here, we create a one-second `KeyFrame` with a `RocketHandler` attached to it:

```java
KeyFrame frame1 = new KeyFrame(Duration.seconds(1),
    new RocketHandler());
```

A `Timeline` may have multiple `KeyFrames` of different lengths and with different handlers attached. We attach an `AlienHandler` to a new 50-millisecond `KeyFrame`:

```java
KeyFrame frame2 = new KeyFrame(Duration.millis(50),
    new AlienHandler());
```

Now, we add our `KeyFrames` to the `Timeline`:

```java
timeline.getKeyFrames().addAll(frame1, frame2);
// Note that if we only have one KeyFrame we can use add() instead of // addAll()
```

The `Timeline` will cycle through its `KeyFrames` one after the other. After a one-second delay, `RocketHandler`'s `handle(ActionEvent e)` method will be called, and then, after a 50-millisecond delay, `AlienHandler`'s `handle(ActionEvent e)` method will be called. The `KeyFrame` we add first in the `addAll()` method will come first in the cycle. You may find that in all but the most complicated animations, one `KeyFrame` will be sufficient - multiple `KeyFrames` are useful for events that happen sequentially, but at staggered intervals. For a `Timeline` example with only one keyframe, see the `Graphics` lecture slides.

We must tell our `Timeline` how many times to loop through its sequential list of `KeyFrames` using the `setCycleCount(int cycles)` method. We may specify any number of cycles. If we want the `Timeline` to loop continuously, we may use the built-in constant `Timeline.INDEFINITE`:

```java
timeline.setCycleCount(Timeline.INDEFINITE);
```

Finally, we must tell our `Timeline` to start:

```java
timeline.play();
```

There is also a `playFromStart()` method to reset the `Timeline` to the start of its `KeyFrame` cycle, and a `stop()` method to stop the `Timeline` and reset it to the start of its `KeyFrame` cycle.
Keyboard Input

Handlers and KeyEvents
To make programs react to keyboard input, we need an event handler that responds to javafx.scene.input.KeyEvent. We create a class that implements EventHandler<KeyEvent> - we'll call ours KeyHandler. We must write our handle(KeyEvent e) method to respond differently to different keys on the keyboard. We do this using javafx.scene.input.KeyCode. A list of KeyCode names for every key on the keyboard can be found here.

// Note that the KeyEvent will be passed in automatically when the // method is called
public void handle(KeyEvent keyEvent) {
    switch (keyEvent.getCode()) {
        case <key>:
            // Do something
            break;

        case <other key>:
            // Do something else
            break;

        // Etc. etc.

        default:
            break;
    }
}

Note that if we use a series of if-else statements to check for the different KeyCodes instead of a switch statement, we must write KeyCode.<key> instead of just <key> when we want to refer to a specific KeyCode.

Now that we have written our handle(KeyEvent keyEvent) method, we must attach our handler to the Pane that contains the elements we wish to control. We assume we have a Pane variable pane and write:

pane.addEventHandler(KeyEvent.KEY_PRESSED, new KeyHandler());
Now, when a key is pressed, the handler's `handle(KeyEvent keyEvent)` method will be called, a `KeyEvent` containing the `KeyCode` of the key pressed will be passed in, and our code will execute!

Note: There is also a `KeyEvent.KEY_RELEASED` constant, which, if passed into the `addEventHandler()` method instead of `KeyEvent.KEY_PRESSED`, will cause the `handle(KeyEvent keyEvent)` method to be called when a key is released.

**Focus Control**

JavaFX Nodes have a property called “focus.” If a Node (i.e. a Pane or a Button) is focused, the Node and its child Nodes can receive keyboard input from the user (mouse input still works on unfocused Nodes). Only one Node in an application can be focused at a time. This means that, if a Button or other GUI element accidentally becomes focused, keyboard input on a different Node (i.e. your Pane that requires keyboard input) will not work! Oh no!

In fact, this problem is quite likely to happen. We commonly use the arrow keys for program input, but in JavaFX, the arrow keys also shift the focus between Nodes. We could very well find ourselves focusing Buttons when we don’t want to! We know that a Button is focused when it has a blue glow around it:

![Button](image)

Luckily, there is a solution. The arrow keys shift the focus between Nodes because, when a `KeyEvent` is produced, it “bubbles up” through the program’s Node hierarchy and causes effects other than what we specify in our `handle(KeyEvent keyEvent)` method. We can prevent the “bubbling up” from happening by calling `keyEvent.consume()` at the very end of our `handle(KeyEvent keyEvent)` method. This “consumes” the `KeyEvent` and prevents it from moving up the Node hierarchy and shifting the focus.

The call to `consume()` will solve our problems once our intended Node actually has the focus, but a Button or other Node could still unintentionally start out with the focus when our program is first run. As it turns out, the first Node added to the root Pane receives the focus when the program begins. Therefore, we should add our Pane for which we require keyboard input to our root Pane before we add any other Nodes, especially Buttons or Panes containing Buttons!

Finally, and quite importantly, Panes are not focusable by default. Therefore, every time we instantiate a Pane for which we want to use keyboard input, we must manually set the Pane to be focusable by using the `setFocusTraversable(boolean b)` method. Additionally, although a single Pane might be the only focusable Node in our program, it is good practice to have that Pane request the program’s focus explicitly when we instantiate it. We assume that we have a Pane called `pane` and write:
```java
pane.setFocusTraversable(true);
pane.requestFocus();
```

After we take all these actions, our intended Pane will start out with the program’s focus, and our KeyEvents will be consumed before they have a chance to shift the focus away from the Pane. As a result, the program’s focus will be effectively locked to the intended Pane!