- Types of testing
- There are lots of different types of testing that is done on computer systems and programs, depending on the size and complexity, below are some
  - Unit testing – testing that a unit of code functions properly
  - Functional testing – testing to verify that the code functions as specified
  - Integration testing – testing that the various pieces of code function together when they are integrated together
  - Regression testing – testing to verify that the latest code updates do not break the existing code
  - Performance testing – testing to verify that the code is able to perform under various conditions – speed, stability, reliability, resources utilization
  - System testing – testing that the entire system performs correctly in the intended environment
  - Verification testing – does the code do what the requirements specify
  - Validation testing – does the code do what we want it to do
  - And many more

- Types of testing (cont)
- If you take a class in software engineering, you will become familiar with the entire software development process (below is some of it)
  - Requirements development
    - High level requirements
    - Performance requirements
    - Detailed requirements
  - Software design
    - High level design
    - Detailed design
    - Requirements mapping
    - Software development
  - Software verification
    - Develop tests for verification of requirements
    - Develop test data
- If you have a chance to take a software engineering class, I would highly recommend it

- JUnit test
- JUnit is a simple framework to write repeatable tests
  - From https://junit.org/junit4/
- JUnit 5 is the current version, https://junit.org/junit5/
  - JUnit 5 is integrated into eclipse
  - JUnit 5 tests can also be compiled & run from the command line
- JUnit uses assertions to verify that a result is what it is expected to be
- There are various assertion methods to verify
  - An array matches an expected result array
  - A String result matches the expected String result
  - An object is not null
  - Two objects are not the same
  - An object is null
  - That a list contains certain items
  - There are many more

- JUnit test (cont)
- The general idea is that once we have implemented a class, we create a JUnit test to verify that the class is functioning properly
- We are going to create a signifcant number of JUnit tests in lab 6 to test program 4
  - Some of the tests we will give you for free, and some you will implement yourself
- In lab 6 we will create tests for the following (17 tests)
  - getNumberOfEdges() & getNumberOfVertices()
  - addVertex() & addEdge()
  - toString()
  - isDirected() for various constructor calls (three of them)
  - isConnected() for the four sample graphs
  - The three types of GraphExceptions (five tests)
    - Duplicate vertices, duplicate edges, invalid edge

- JUnit test (cont)
- We will start with using JUnit5 with eclipse
- First we need to create a project, along with a class
- Since we are going to be doing this for program 4, we might as well do it for that
  - I started with a project named “program4”, and a class named “garrison_Graph”
  - I dragged and dropped Edge.java, GraphException.java, and ConnectedGraphFunctions.java into the “program4” folder that garrison_Graph.java is in
  - If you haven't done anything with program 4 yet, then get the required functions populated with no functionality for the “void” methods and returning false for the “boolean” methods, returning 0 for the “int” methods, and returning “” for the “String” methods
  - Remember to include “implements ConnectedGraphFunctions” in the class definition line

JUnit test (cont)

- Once we have the basics of the project created
- On my laptop I had to tell eclipse to use the Java 17 compiler and runtime and set the compiler compliance level to 16
  - Otherwise it did not like the Edge record
  - I did not have this problem on remote140
- Select your graph class and right/double click on it and choose “New JUnit Test Case”
- Select “New JUnit Jupiter test” (this is JUnit5)
- Get rid of the package name
- It should have filled in the name with your graph classes name with “Test” appended to it
- Select @BeforeAll and @BeforeEach
- Class under test should be your graph classes name
- If you select next it will give you a list of methods to create tests for
  - Select addVertex, addEdge, toString
  - We will add the rest manually

- JUnit test (cont)
- Select Finish and OK when asked about adding JUnit 5 to the build path
- Add "`import org.junit.jupiter.api.Assertions;`" to the list of imports (if it is not there)
- We should have something that looks like below

```
1  import static org.junit.jupiter.api.Assertions.*;
2
3  import org.junit.jupiter.api.BeforeAll;
4  import org.junit.jupiter.api.BeforeEach;
5  import org.junit.jupiter.api.Test;
6  import org.junit.jupiter.api.Assertions;
7
8  class garrison_GraphTest {
9
10     @BeforeAll
11     static void setUpBeforeClass() throws Exception {
12     }
13
14     @BeforeEach
15     void setUp() throws Exception {
16     }
17
18     @Test
19     void testAddVertex() {
20         fail("Not yet implemented"); // TODO
21     }
22
23     @Test
24     void testAddEdge() {
25         fail("Not yet implemented"); // TODO
26     }
27
28     @Test
29     void testToString() {
30         fail("Not yet implemented"); // TODO
31     }
32
33 }
```

Should be executed once prior to the tests

Should be executed prior to each test, may be named setUpBeforeEach()

- # JUnit test (cont)

- We aren't going to use @BeforeAll, but it is not hurting anything by being there
- In the @BeforeEach method, add a line to instantiate a copy of your graph class and also include a declaration statement for your graph class prior to the @BeforeAll
  - Mine looks like the below
  - If a graph object that is undirected works for a tests, then the “g = new garrison_Graph();” will have already instantiate one for each of the tests
  - The @BeforeEach method is executed before each of the tests

```
class garrison_GraphTest
{
    garrison_Graph g;

    @BeforeAll
    static void setUpBeforeClass() throws Exception
    {
    }

    @BeforeEach
    void setUp() throws Exception
    {
        g = new garrison_Graph();
    }
```

- # JUnit test (cont)

- Let's add a test for isDirected() for the zero parameter constructor
  - The graph object instantiated in the before each should work for this test, so all we need to do is check that g.isDirected() returns false
  - The assertEquals() method that compares two boolean values will work here, so we can do the following
    - Or we can use the assertFalse() method
  - Add a new @Test as below (you can add either of them)

```
// test that the zero parameter construct makes the graph undirected
@Test
void testIsDirectedForUndirectedGraph()
{
    assertEquals(false, g.isDirected());
}
```

```
// test that the zero parameter construct makes the graph undirected
@Test
void testIsDirectedForUndirectedGraph()
{
    assertFalse(g.isDirected());
}
```

- # JUnit test (cont)
- We can do similarly for the one paramter constructor
- Copy the last test, and make two new versions, one for a true test and one for a false test
- I end up with the following

```
// test that the one parameter construct makes the graph directed with true parameter
@Test
void testIsDirectedForDirectedGraph()
{
    g = new garrison_Graph(true);
    assertTrue(g.isDirected());
}

// test that the one parameter construct makes the graph undirected with false parameter
@Test
void testIsDirectedForUndirectedGraph2()
{
    g = new garrison_Graph(false);
    assertFalse(g.isDirected());
}
```

- # JUnit test (cont)

- Now we want to test our getNumberOfVertices() method
- For this test, let's add vertices for 0, 1, …, 99 with each time that we add a vertex we will check that the result of getNumberOfVertices() is correct
- For this test we will use assertArrayEquals(), to verify that the expected result to each call to getNumberOfVertices() returns the correct result
- For the test we allocate two int arrays of size 101, one will contain the expected results of getNumberOfVertices() and the other will contain the actual results of each call to getNumberOfVertices()
- The value at index 0 will be the number prior to adding any vertices, and then the value at index i, i = 1, 2, …, 100 will be the number of vertices after adding i vertices (so the value at index i is i)

- JUnit test (cont)
- Now we want to test our getNumberOfVertices() method (cont)
- Below is a copy of my code

```
// add vertices 0 - 99, verify there are the correct number of vertices
// each time one is added
@Test
void testGetNumberOfVertices()
{
    int[] getNumberOfVertices = new int[101];
    int[] expectedResultGetNumberOfVertices = new int[getNumberOfVertices.length];
    getNumberOfVertices[0] = g.getNumberOfVertices();
    expectedResultGetNumberOfVertices[0] = 0;
    for( int i = 1; i < getNumberOfVertices.length; i++ )
    {
        expectedResultGetNumberOfVertices[i] = i;
        try
        {
            g.addVertex(i-1);
            getNumberOfVertices[i] = g.getNumberOfVertices();
        }
        catch(GraphException e)
        {
        }
    }

    assertArrayEquals(getNumberOfVertices, expectedResultGetNumberOfVertices);
}
```

Add vertices 0, 1, 2, …, 100

- # JUnit test (cont)

- Now we want to test our getNumberOfEdges() method
- For this test, let's add vertices for 0, 1, …, 100 and then add edges (i, i+1) for i = 0, …, 99 with each time that we add an edge we will check that the result of getNumberOfEdges() is correct
- For this test we will use assertArrayEquals(), to verify that the expected result to each call to getNumberOfVertices() returns the correct result
- For the test we allocate two int arrays of size 101, one will contain the expected results of getNumberOfEdges() and the other will contain the actual results of each call to getNumberOfEdges()
- The value at index 0 will be the number prior to adding any edges, and then the value at index i, i = 1, 2, …, 100 will be the number of edges after adding i vertices (so the value at index i is i)

- JUnit test (cont)
- Now we want to test our getNumberOfEdges() method (cont)
- Below is a copy of my code

```
// add vertices 0 - 100, then add edges (i,i+1) i = 0, ..., 99,
// verify the number of edges is correct after each one is added
@Test
void testGetNumberOfEdges()
{
    int[] getNumberOfEdges = new int[101];
    int[] expectedResultGetNumberOfEdges = new int[getNumberOfEdges.length];
    getNumberOfEdges[0] = g.getNumberOfEdges();
    expectedResultGetNumberOfEdges[0] = 0;
    for( int i = 0; i < getNumberOfEdges.length; i++ )
    {
        try
        {
            g.addVertex(i);
        }
        catch(GraphException e)
        {
        }
    }

    for( int i = 1; i < getNumberOfEdges.length; i++ )
    {
        expectedResultGetNumberOfEdges[i] = i;
        try
        {
            g.addEdge(i-1, i);
            getNumberOfEdges[i] = g.getNumberOfEdges();

        }
        catch(GraphException e)
        {
        }
    }

    assertArrayEquals(getNumberOfEdges, expectedResultGetNumberOfEdges);
}
```

Add vertices 0, 1, 2, …, 100

Add edges (i, i+1), i = 0, 1, 2, …, 99

- # JUnit test (cont)
- Now we want to test our addVertex() method
- For this test, let's add vertices for 0, 1, …, 100 with each time that we add a vertex we will check that the result of getNumberOfVertices() is correct
- For this test we will use assertArrayEquals(), to verify that the expected result to each call to getNumberOfVertices() returns the correct result
- For the test we allocate two int arrays of size 101, one will contain the expected results of getNumberOfVertices() and the other will contain the actual results of each call to getNumberOfVertices()
- The value at index 0 will be the number prior to adding any vertices, and then the value at index i, i = 1, 2, …, 100 will be the number of vertices after adding i vertices (so the value at index i is i)
- We add two copies of each vertex, to ensure that we aren't adding duplicates
  - Note we execute getNumberOfVertices() prior to adding the duplicate vertex, since if we added the duplicate vertex prior to getNumberOfVertices(), getNumberOfVertices() would not get executed since the exception would cause the code to transfer control to the catch statement

- JUnit test (cont)
- Now we want to test our addVertex() method (cont)
- Below is what it should look like

```
// add 100 vertices twice and verify that the number of vertices
// is correct each time one is added
@Test
void testAddVertex()
{
    int[] numberOfVertices = new int[101];
    int[] expectedNumberOfVertices = new int[numberOfVertices.length];
    numberOfVertices[0] = g.getNumberOfVertices();
    expectedNumberOfVertices[0] = 0;
    for( int i = 0; i < numberOfVertices.length-1; i++ )
    {
        expectedNumberOfVertices[i+1] = i+1;
        try
        {
            g.addVertex(i);
            numberOfVertices[i+1] = g.getNumberOfVertices();
            g.addVertex(i);
        }
        catch(Exception e)
        {
        }
    }
    assertArrayEquals(numberOfVertices, expectedNumberOfVertices);
}
```

Try adding a second copy of the vertex, this should throw a GraphException and not be added

- # JUnit test (cont)

- Now we want to test our addEdge() method
- For this test, let's add vertices for 0, 1, …, 100 and edges (i, i+1) for i = 0, …, 99
- Once again, we allocate two arrays of size 101, one for the expected number of edges and one for the actual number of edges
- In this test we add two copies of each edge, to test that we are not ading duplicate edges
- We also add the duplicate edge after executing getNumberOfEdges(), for the same reason that we added the duplicate vertex after getting the number of vertices in the addVertex test

- JUnit test (cont)
- Now we want to test our addEdge() method (cont)
- Below is my code

```
// add 101 vertices and 100 edges twice and verify that the number of edges is correct
// each time an edge is added
@Test
void testAddEdge()
{
    int[] numberOfEdges = new int[101];
    int[] expectedNumberOfEdges = new int[numberOfEdges.length];
    numberOfEdges[0] = g.getNumberOfEdges();
    expectedNumberOfEdges[0] = 0;
    for( int i = 0; i < numberOfEdges.length-1; i++ )
    {
        expectedNumberOfEdges[i+1] = i+1;
        try
        {
            if( i == 0 )
            {
                g.addVertex(i);
            }
            g.addVertex(i+1);
            g.addEdge(i, i+1);
            numberOfEdges[i+1] = g.getNumberOfEdges();
            g.addEdge(i, i+1);
        }
        catch(Exception e)
        {
        }
    }

    assertArrayEquals(numberOfEdges, expectedNumberOfEdges);
}
```

Try adding a second copy of the edge, this should throw a GraphException and not be added

JUnit test (cont)

- Now we want to test that our GraphException is thrown at the appropriate times
  - When a duplicate verticex is attempted to be added
  - When a duplicate edge is attempted to be added
    - Add (u,v) twice
    - Add (u,v) and (v,u) for an undirected graph
  - When an invalid edge is added
  - And ensure that one is not thrown for a directed graph when edges (u,v) and (v,u) are added, since they are not duplicates

- JUnit test (cont)
- Testing for a GraphException for duplicate vertices
- My code is below, the "`() -> g.addVertex(0)`" is a lambda expression, which we have not discussed yet, but will later in the semester, it is telling JUnit test to apply the command "g.addVertex(0)"

```
// try to add vertex 0 twice, verify there is an exception on the second one
@Test
void testGraphExceptionForDuplicateVertex()
{
    try
    {
        g.addVertex(0);
    }
    catch(GraphException e)
    {
    }
    assertThrows(GraphException.class, () -> g.addVertex(0));
}
```

- JUnit test (cont)
- Testing for a GraphException for duplicate edges
- My code is below, here we are attempting to add the edge (0, 1) twice

```
// try to add edge (0, 1) twice, verify there is an exception on the second one
@Test
void testGraphExceptionForDuplicateEdge()
{
    try
    {
        g.addVertex(0);
        g.addVertex(1);
        g.addEdge(0, 1);
    }
    catch(GraphException e)
    {
    }
    assertThrows(GraphException.class, () -> g.addEdge(0, 1));
}
```

- JUnit test (cont)
- Testing for a GraphException for duplicate edges
- My code is below, here we are attempting to add the edge (0, 1) and then the edge (1, 0)

```
// try to add edge (1, 0) after adding edge (0, 1),
// verify there is an exception when adding (1, 0)
@Test
void testGraphExceptionForDuplicateEdge2()
{
    try
    {
        g.addVertex(0);
        g.addVertex(1);
        g.addEdge(0, 1);
    }
    catch(GraphException e)
    {
    }
    assertThrows(GraphException.class, () -> g.addEdge(1, 0));
}
```

- JUnit test (cont)
- Testing for a GraphException for an invalid edge
- My code is below, here we are attempting to add the edge (0, 1) without ever defining vertices 0 or 1

```
// try to add edge (0, 1) without adding vertices 0 & 1,
// verify there is an exception
@Test
void testGraphExceptionForInvalidEdge()
{
    assertThrows(GraphException.class, () -> g.addEdge(0, 1));
}
```

- JUnit test (cont)

- Testing for a GraphException while adding a reversed edge for a directed graph, which should not throw an exception
- My code is below, here we add edges (0, 1) and (1, 0) and verify that we have two vertices meaning that we did not throw a GraphException
  - You don't need to implement this test, the one on the next slide is "better"

Skip this test

```
// in a directed graph verify that we can add edge (0, 1) and (1, 0)
@Test
void testGraphExceptionForDuplicateEdge3()
{
    g = new garrison_Graph(true);
    try
    {
        g.addVertex(0);
        g.addVertex(1);
        g.addEdge(0, 1);
        g.addEdge(1, 0);
    }
    catch(GraphException e)
    {
    }
    assertEquals(2, g.getNumberOfEdges());
}
```

- # JUnit test (cont)
- Here's a second version of the last test
- When I originally wrote the test, I did not know there was an “assertDoesNotThrow()” assertion
- Below is a second version of the last test using “assertDoesNotThrow()”
- As you use JUnit test more you will notice that there are often multiple ways to perform the same test

```
// in a directed graph verify that we can add edge (0, 1) and (1, 0)
@Test
void testGraphExceptionForDuplicateEdge3b()
{
    g = new garrison_Graph(true);
    try
    {
        g.addVertex(0);
        g.addVertex(1);
        g.addEdge(0, 1);
        assertDoesNotThrow(() -> g.addEdge(1, 0));
    }
    catch(GraphException e)
    {
    }
}
```

- # JUnit test (cont)
- We next want to test the isConnected() method
- For this test, we have a lot that we need to do
- We need to
  - Specify a graph, that is, define the vertices & edges
  - Add the vertices and edges to the graph
- My implementation required a large amount of code, since it
  - Parses the vertices and edges from a String that defines them
  - And then adds them to the graph
- Since we have four sample graphs, the code is replicated four times
- The four sample graphs are
  - sample_directed_graph_1.txt – this one is connected
  - sample_directed_graph_2.txt – this one is not connected
  - sample_undirected_graph_1.txt – this one is connected
  - sample_undirected_graph_2.txt – this one is not connect

- # JUnit test (cont)

- Since we need access to the sample graphs within the test methods, we define them in the test class outside of the methods

- Here's how I have them defined, at the top of my test class prior to any methods

```
// sample_directed_graph_1.txt
String directedAndConnectedVertics = "{1,3,2,4,5,1,2}";
String directedAndConnectedEdges = "{(1,4),(2,1),(2,3),(3,5),(4,5),(5,2)}";

// sample_directed_graph_2.txt
String directedAndNotConnectedVertics = "{1,3,2,4,5,1,2}";
String directedAndNotConnectedEdges = "{(1,4),(2,1),(2,3),(3,5),(4,5),(0,1),(0,7),(1,7)}";

// sample_undirected_graph_1.txt
String undirectedAndConnectedVertics = "{0,1,3,2,4,5,6,7,8,9,0,2}";
String undirectedAndConnectedEdges = "{(0,5),(1,7),(2,4),(3,6),(4,9),(5,8),(6,9),(7,9),(8,9),(5,0)}";

// sample_undirected_graph_2.txt
String undirectedAndNotConnectedVertics = "{0,1,3,2,4,5,6,7,8,9,0,2}";
String undirectedAndNotConnectedEdges = "{(0,5),(1,7),(2,4),(4,9),(5,8),(6,9),(7,9),(8,9),(5,0)}";
```

- JUnit test (cont)

- Here's the code for sample_undirected_graph_1.txt

```
// test isConnected() recognizes sample_undirected_graph_1.txt is connected
@Test
void testIsConnectedUndirectedAndConnected()
{
    g = new garrison_Graph(false);
    java.util.StringTokenizer st = new java.util.StringTokenizer(undirectedAndConnectedVertics, "{},");
    while( st.hasMoreTokens() )
    {
        int newVertex = Integer.parseInt(st.nextToken());

        try
        {
            g.addVertex(newVertex);
        }
        catch(GraphException e)
        {
        }
    }

    st = new java.util.StringTokenizer(undirectedAndConnectedEdges, "{}");
    String inn = st.nextToken();
    st = new java.util.StringTokenizer(inn, "(),");
    while( st.hasMoreTokens() )
    {
        int from = Integer.parseInt(st.nextToken());
        int to = Integer.parseInt(st.nextToken());

        try
        {
            g.addEdge(from, to);
        }
        catch(GraphException e)
        {
        }
    }

    assertEquals(true, g.isConnected());
}
```

undirected graph

Parse the vertices and add them to the graph

Parse the edges and add them to the graph

• JUnit test (cont)

- Here's the code for sample_undirected_graph_2.txt

```
// test isConnected() recognizes sample_undirected_graph_2.txt is not connected
@Test
void testIsConnectedUndirectedAndNotConnected()
{
    g = new garrison_Graph(false);
    java.util.StringTokenizer st = new java.util.StringTokenizer(undirectedAndNotConnectedVertics, "{},");
    while( st.hasMoreTokens() )
    {
        int newVertex = Integer.parseInt(st.nextToken());

        try
        {
            g.addVertex(newVertex);
        }
        catch(GraphException e)
        {
        }
    }

    st = new java.util.StringTokenizer(undirectedAndNotConnectedEdges, "{}");
    String inn = st.nextToken();
    st = new java.util.StringTokenizer(inn, "(),");
    while( st.hasMoreTokens() )
    {
        int from = Integer.parseInt(st.nextToken());
        int to = Integer.parseInt(st.nextToken());

        try
        {
            g.addEdge(from, to);
        }
        catch(GraphException e)
        {
        }
    }

    assertEquals(false, g.isConnected());
}
```

undirected graph

Parse the vertices and add them to the graph

Parse the edges and add them to the graph

- JUnit test (cont)

- Here's the code for sample_directed_graph_1.txt

```
// test isConnected() recognizes sample_directed_graph_1.txt is connected
@Test
void testIsConnecteDirectedAndConnected()
{
    g = new garrison_Graph(true);
    java.util.StringTokenizer st = new java.util.StringTokenizer(directedAndConnectedVertics, "{},");
    while( st.hasMoreTokens() )
    {
        int newVertex = Integer.parseInt(st.nextToken());

        try
        {
            g.addVertex(newVertex);
        }
        catch(GraphException e)
        {
        }
    }

    st = new java.util.StringTokenizer(directedAndConnectedEdges, "{}");
    String inn = st.nextToken();
    st = new java.util.StringTokenizer(inn, "(),");
    while( st.hasMoreTokens() )
    {
        int from = Integer.parseInt(st.nextToken());
        int to = Integer.parseInt(st.nextToken());

        try
        {
            g.addEdge(from, to);
        }
        catch(GraphException e)
        {
        }
    }

    assertEquals(true, g.isConnected());
}
```

directed graph

Parse the vertices and add them to the graph

Parse the edges and add them to the graph

- JUnit test (cont)
- Here's the code for sample_directed_graph_2.txt

```
// test isConnected() recognizes sample_directed_graph_2.txt is not connected
@Test
void testIsConnecteDirectedAndNotConnected()
{
    g = new garrison_Graph(true);
    java.util.StringTokenizer st = new java.util.StringTokenizer(directedAndNotConnectedVertics, "{},");
    while( st.hasMoreTokens() )
    {
        int newVertex = Integer.parseInt(st.nextToken());

        try
        {
            g.addVertex(newVertex);
        }
        catch(GraphException e)
        {
        }
    }

    st = new java.util.StringTokenizer(directedAndNotConnectedEdges, "{}");
    String inn = st.nextToken();
    st = new java.util.StringTokenizer(inn, "(),");
    while( st.hasMoreTokens() )
    {
        int from = Integer.parseInt(st.nextToken());
        int to = Integer.parseInt(st.nextToken());

        try
        {
            g.addEdge(from, to);
        }
        catch(GraphException e)
        {
        }
    }

    assertEquals(false, g.isConnected());
}
```

directed graph

Parse the vertices and add them to the graph

Parse the edges and add them to the graph

JUnit test (cont)

- And finally, for the toString() test, we create an undirected graph with vertices 0, 1, …, 9 and edges (0,1), (1,2), …, (8,9) and then compare the output of the toString() method with the expected result
- Below is my code

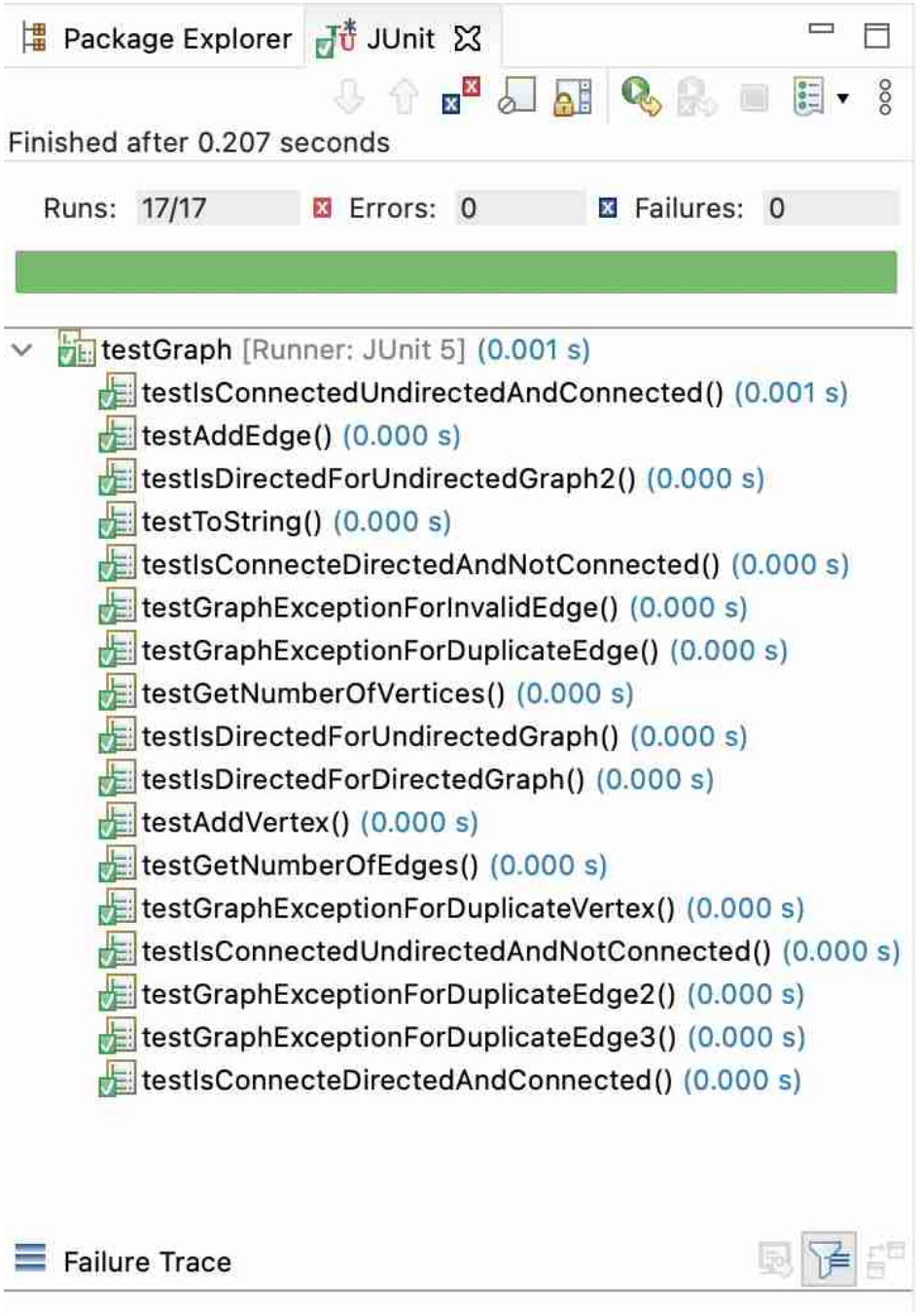
```
// add vertices 0 - 9, and edges (i,i+1), i = 0, ..., 8
// verify toString() comes out correct
@Test
void testToString()
{
    String expectedToString = "G = (V, E)\n";
    expectedToString = expectedToString + "V = {0,1,2,3,4,5,6,7,8,9}\n";
    expectedToString = expectedToString + "E = {(0,1),(1,2),(2,3),(3,4),(4,5),(5,6),(6,7),(7,8),(8,9)}";

    for( int i = 0; i < 10; i++ )
    {
        try
        {
            g.addVertex(i);
        }
        catch(GraphException e)
        {
        }
    }

    for( int i = 0; i < 9; i++ )
    {
        try
        {
            g.addEdge(i, i+1);
        }
        catch(GraphException e)
        {
        }
    }

    assertEquals(expectedToString, g.toString());
}
```

Add vertices 0, 1, …, 9

Add edges (0, 1), (1, 2), …, (8, 9)

- JUnit test (cont)
- To run the JUnit tests
  - Right click on the test program
  - Select run as
  - Select JUnit test
  - A JUnit panel should show up on the tab that Package Explorer is on
  - It should list the number of tests run, how many errors there were, and how many failures there were
    - The next slide shows the JUnit panel
- The first time I tried to run the tests on remote140, I got a popup window saying "The input type of the launch configuration does not exits"
  - I clicked OK
  - I then selected "Run all tests in the selected project, package or source folder:"
    - It filled in "program4"
    - And then I clicked run and it executed the tests

- JUnit test (cont)
- Here's what the JUnit view looks like in eclipse for my implementation



JUnit test (cont)

- You can also compile and execute JUnit5 tests from the commandline
- With JUnit4 the files that are included with eclipse are all you need to compile and execute tests from the commandline
- With JUnit5 I was able to compile using the files that came with eclipse, but I couldn't figure out how to get it to run from the commandline
- But you can download “junit-platform-console-standalone-1.8.2.jar” which has everything you need to compile and execute test from the commandline
- My testing file is named testGraph.java, and is in the same folder as ConnectedGraphFunctions.java, GraphException.java, garrison_Graph.java, and Edge.java
- To compile I executed
  - “javac -classpath junit-platform-console-standalone-1.8.2.jar:. testGraph.java”
- To run the tests I executed
  - “java -jar junit-platform-console-standalone-1.8.2.jar --class-path . --select-class testGraph”

- JUnit test (cont)
- Here's the output after running from the commandline

```
Thanks for using JUnit! Support its development at https://junit.org/sponsoring

╷
├─ JUnit Jupiter ✔
│  └─ testGraph ✔
│     ├─ testIsConnectedUndirectedAndConnected() ✔
│     ├─ testAddEdge() ✔
│     ├─ testIsDirectedForUndirectedGraph2() ✔
│     ├─ testToString() ✔
│     ├─ testIsConnecteDirectedAndNotConnected() ✔
│     ├─ testGraphExceptionForInvalidEdge() ✔
│     ├─ testGraphExceptionForDuplicateEdge() ✔
│     ├─ testGetNumberOfVertices() ✔
│     ├─ testIsDirectedForUndirectedGraph() ✔
│     ├─ testIsDirectedForDirectedGraph() ✔
│     ├─ testAddVertex() ✔
│     ├─ testGetNumberOfEdges() ✔
│     ├─ testGraphExceptionForDuplicateVertex() ✔
│     ├─ testIsConnectedUndirectedAndNotConnected() ✔
│     ├─ testGraphExceptionForDuplicateEdge2() ✔
│     ├─ testGraphExceptionForDuplicateEdge3() ✔
│     └─ testIsConnecteDirectedAndConnected() ✔
└─ JUnit Vintage ✔

Test run finished after 86 ms
[         3 containers found      ]
[         0 containers skipped    ]
[         3 containers started    ]
[         0 containers aborted    ]
[         3 containers successful ]
[         0 containers failed     ]
[        17 tests found           ]
[         0 tests skipped         ]
[        17 tests started         ]
[         0 tests aborted         ]
[        17 tests successful      ]
[         0 tests failed          ]
```