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## Chapter 0: Introduction

Constellation is a graph-based data analysis application enabling data access, federation and manipulation capabilities across large and complex data sets. While it provides significant capability out of the box, it has been designed with extensibility and modularity in mind. There are two prominent ways of extending Constellation, namely through its **views** or by creating **plugins**. Views appear as windows in the application and provide visualisation of and interaction with the graph. Plugins perform operations on the graph. In addition, there are several other ways that Constellation can be customised, including defining new attributes or even your own custom graph.

This guide will introduce you to the most common ways to customise Constellation in order to solve domain-specific problems. Each chapter will introduce a new concept interspersed with a series of practical exercises. These exercises will build on each other to form a complete solution to a hypothetical scenario.

### Assumed Knowledge

In order to effectively extend Constellation, you should have knowledge in the following areas:

- Familiarity with using Constellation for data analysis.
- Experience with Java and preferably JavaFX.
- Familiarity with representing data as a graph.
- Basic experience with NetBeans development.

### Document Conventions

Throughout this training document we will use the following conventions:

**TIP:** This is a tip. Tips describe features or concepts that are nice to know but not crucial for a good understanding of the rest of the material.

**This is an important fact.** Important facts describe features or concepts that are crucial to successful Constellation development.

```
1 This is a code block. Code blocks contain valid Java code that will be
2 needed to complete the development tasks in this document. In general,
3 you can complete the development tasks by copy-and-pasting these code
4 blocks into the skeleton classes contained in the exercises module.
```

## Required Files

Clone the **Constellation** and **Constellation Training** repositories.

The constellation repository contains the source code to build the Constellation application which we will be developing against. The Constellation Training repository contains source code for all exercises covered in this tutorial along with solutions.

## The Scenario

Our scenario takes place as a pandemic sweeps across the globe. We will use Constellation to track the spread of a multitude of deadly diseases in order to identify strategies to curb the various outbreaks. To aid in this mission, we have three data sets at our disposal:

- *Cities*: a table of cities along with their populations and geographic coordinates.
- *Flights*: a table of flight paths between cities along with flight information.
- *Outbreaks*: a table holding the current infection levels for each infected city.

There are two modules provided with this training: ‘exercises’ and ‘solutions’. You will be creating a NetBeans module suite for each, based on the provided Constellation platform. The exercises module provides skeleton code for you to work from throughout this tutorial, whilst the solutions module provides a completed version of all functionality.

The cities, flights and outbreaks data sets can be found in the provided modules under the `release/modules/ext/` folder. You will need to look at this directly for the first exercise; after that it will be accessed through code.

## Exercise 0.1: Exploring the Data

Gaining familiarity with your data is a helpful first step before approaching the problem as a Constellation development task. We will import our datasets using the **Delimited File Importer** in Constellation in order to explore the data and determine how to best represent it as a graph.

1. Import the Cities table into your graph, with each row representing a node. Attributes such as ‘Geo.Latitude’ and ‘Geo.Longitude’ will already exist in the schema, while attributes such as ‘Population’ will need to be created. As each node will represent a city, you should use the city name as the primary key by mapping it to the ‘Identifier’ attribute.
2. Import the Flights table into your graph, with each row representing a transaction. These transactions will represent flights between cities, and so should connect existing city nodes on your graph. You should use the departure city as the source node ‘Identifier’ and the arrival city as the destination node ‘Identifier’.
3. Import the Outbreaks table into your graph, enriching existing nodes with new attribute information in each row.

Now that you have a representation of the data as a graph, try answering the following questions:

- How many diseases exist?
- What is the most infected city?
- What is the average number of flights out of each city?

## Chapter 1: Development Environment

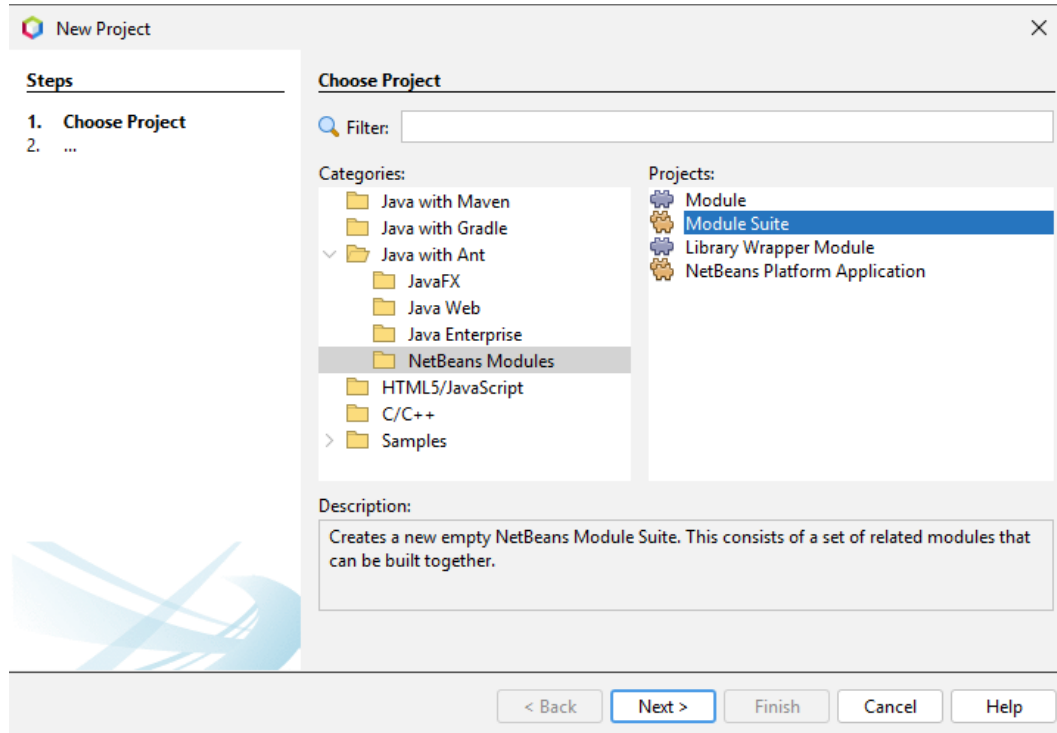
Constellation is built in Java 21 on top of the NetBeans platform, taking advantage of its module and windowing systems, among others. For information on how to install and configure Java 21 or NetBeans, refer to instructions on the Azul and Apache Netbeans websites.

## Exercise 1.1: Setting up your Development Environment

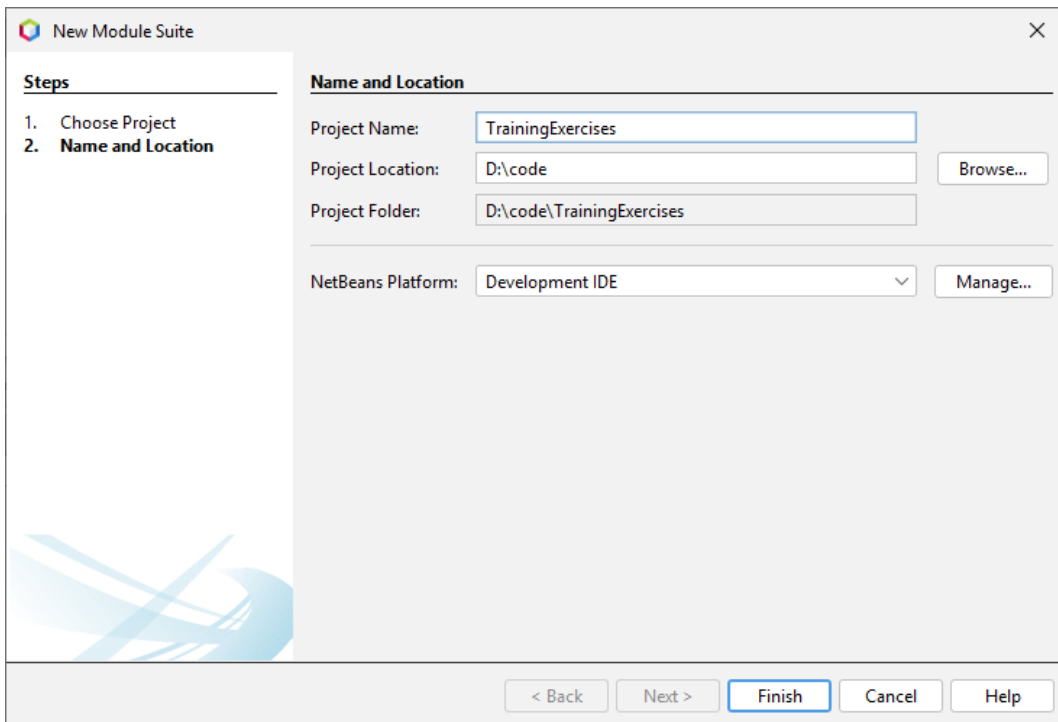
### 1.1.1: Creating a Module Suite

NetBeans allows related code to be grouped into **modules**, which can be added or removed from a NetBeans platform as required. These modules are stored in and managed by a **module suite**.

1. Click on *File > New Project*, then select *Module Suite* under the *NetBeans Modules* sub-category of *Java with Ant*. Click *Next*.



2. Enter 'TrainingExercises' as the project name for your module suite. Specify a convenient project location of your choice.

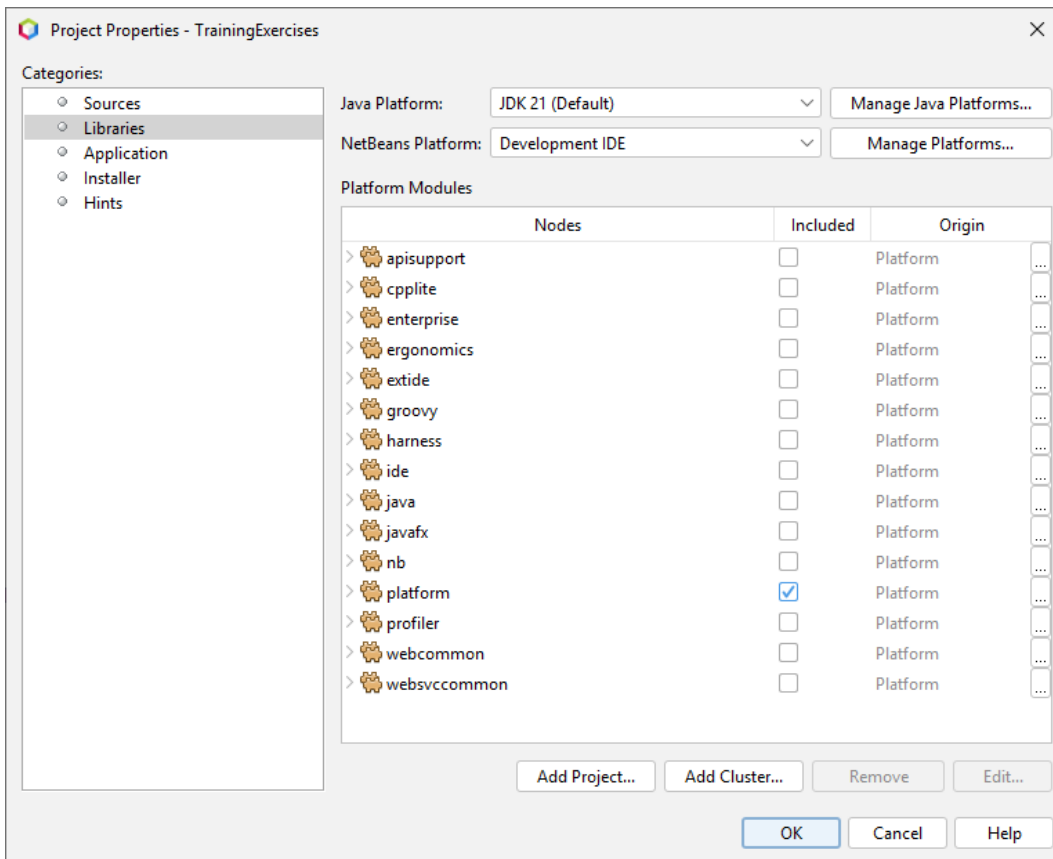


3. Click Finish.

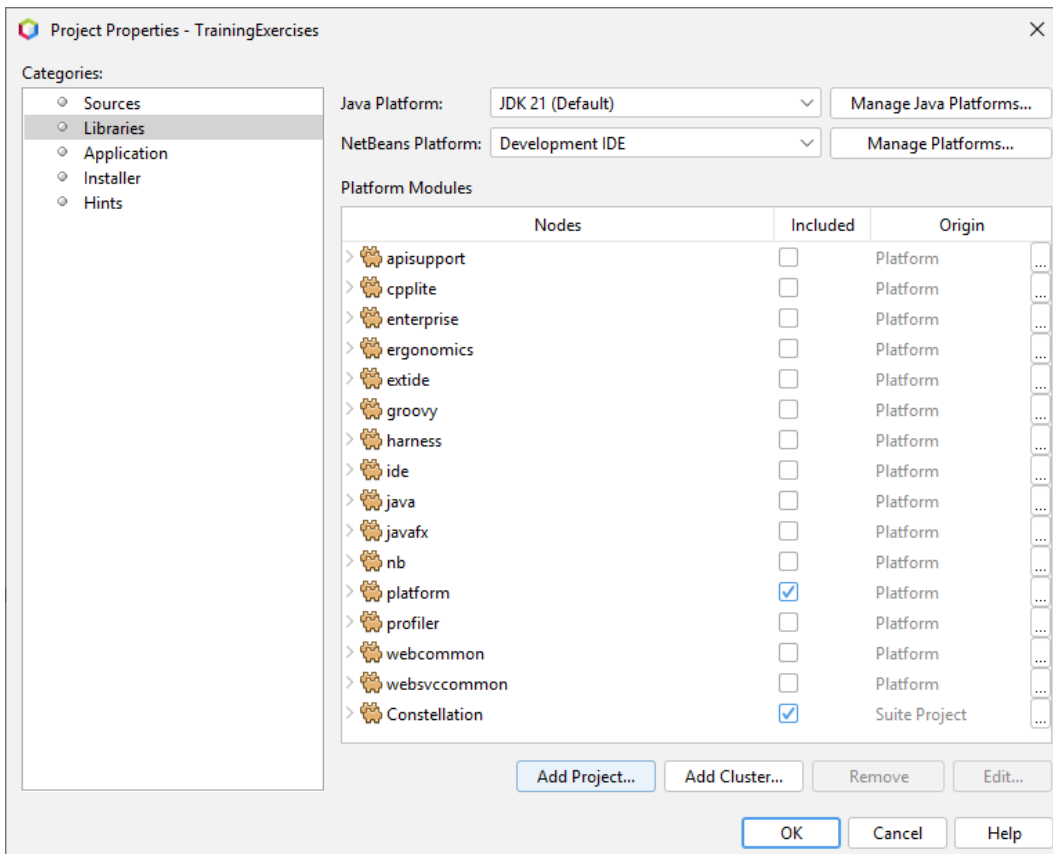
### 1.1.2: Configuring a Module Suite

You can configure a module suite by right clicking it and choosing *Properties*. Let's add Constellation as a module dependency to our newly created Training module.

1. Within the properties window, select *Libraries*.
2. Deselect all modules except platform.



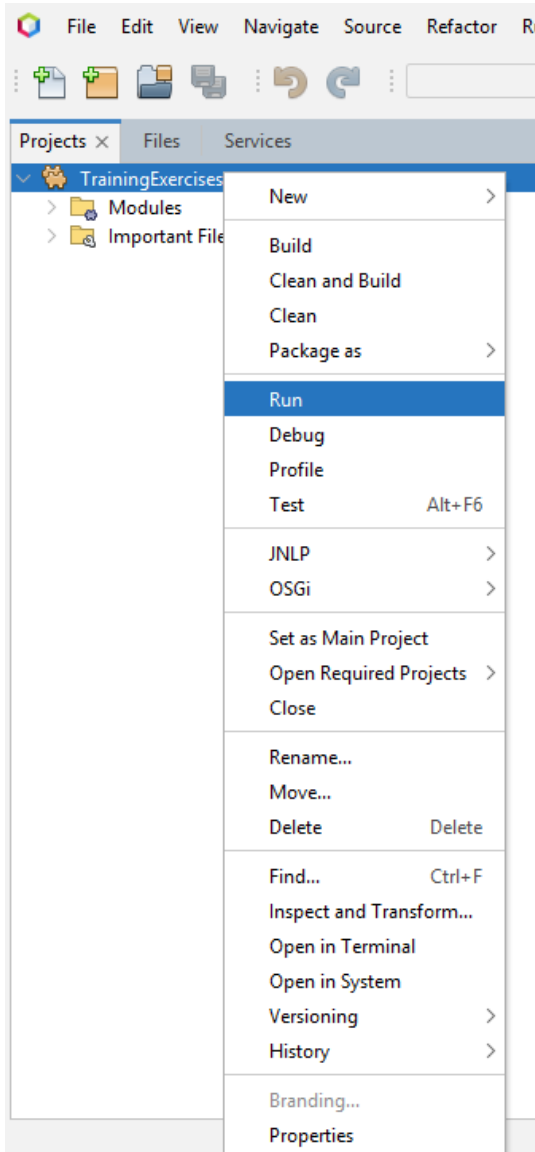
3. Select *Add Project* and browse to the Constellation module suite.



4. Click *OK*, to finalise configuration of your module suite.

### 1.1.3: Running a Project

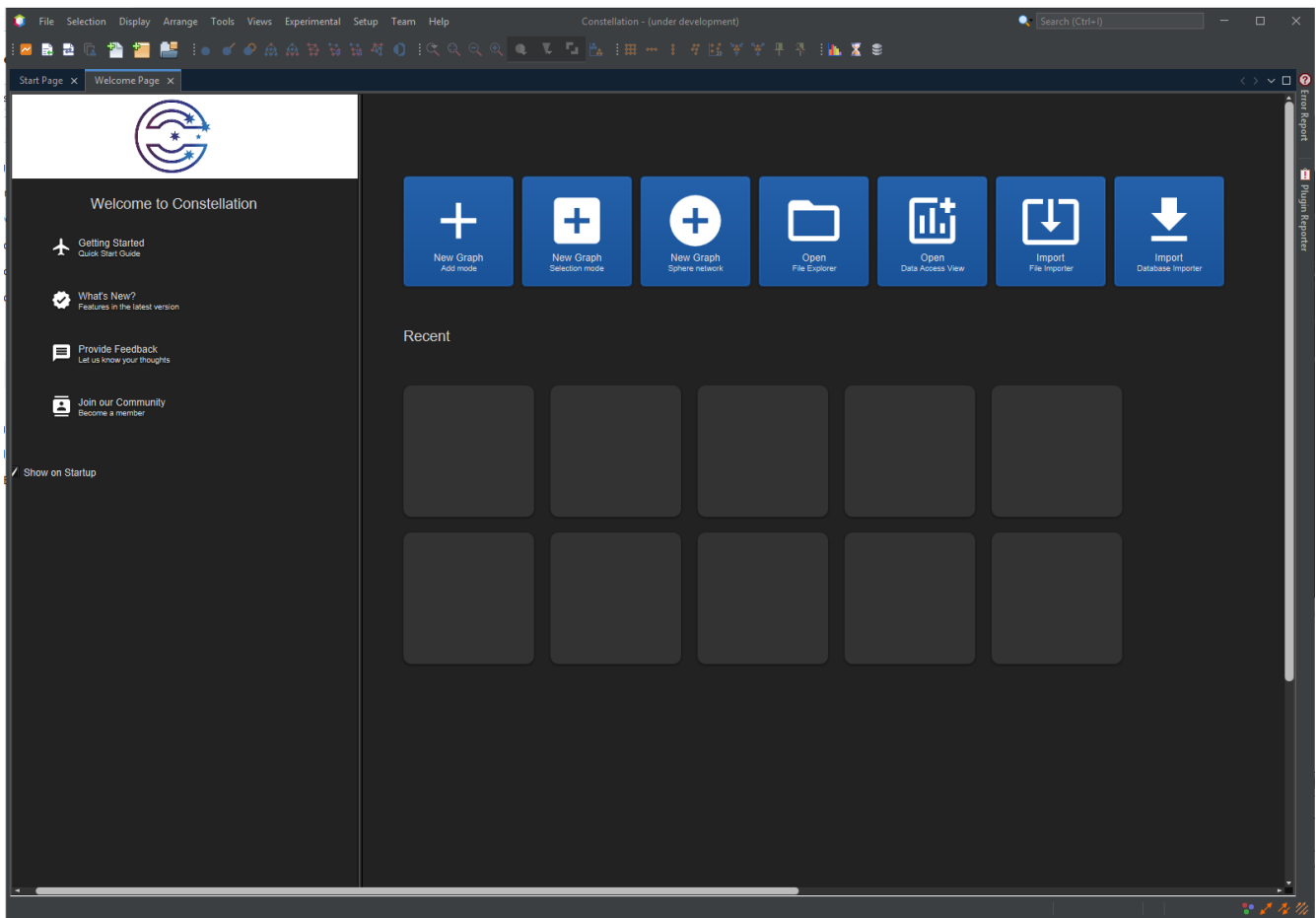
Verify that Constellation runs by right clicking on your new module suite and selecting *Run*.



**TIP:** Pressing the F6 key is a shortcut for running your main project. When you have multiple projects open, you can specify the main project by right-clicking on it and selecting “Set as Main Project”. This simply means that NetBeans can make assumptions about what to clean, build, or run when you don’t specify otherwise.

Once Constellation has finished loading, you should be presented with the Constellation Welcome Page.

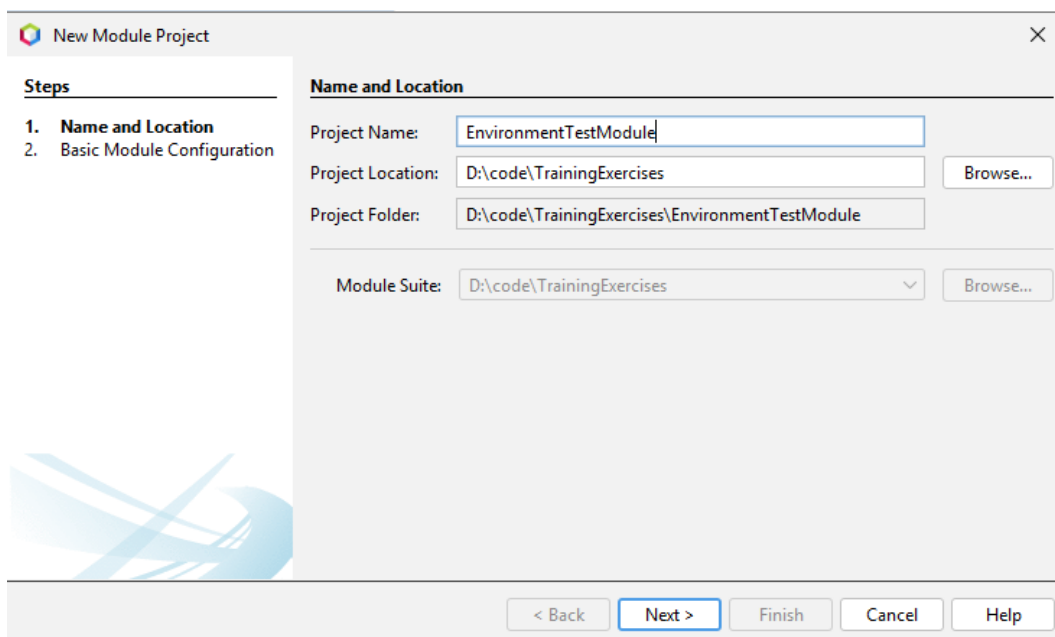




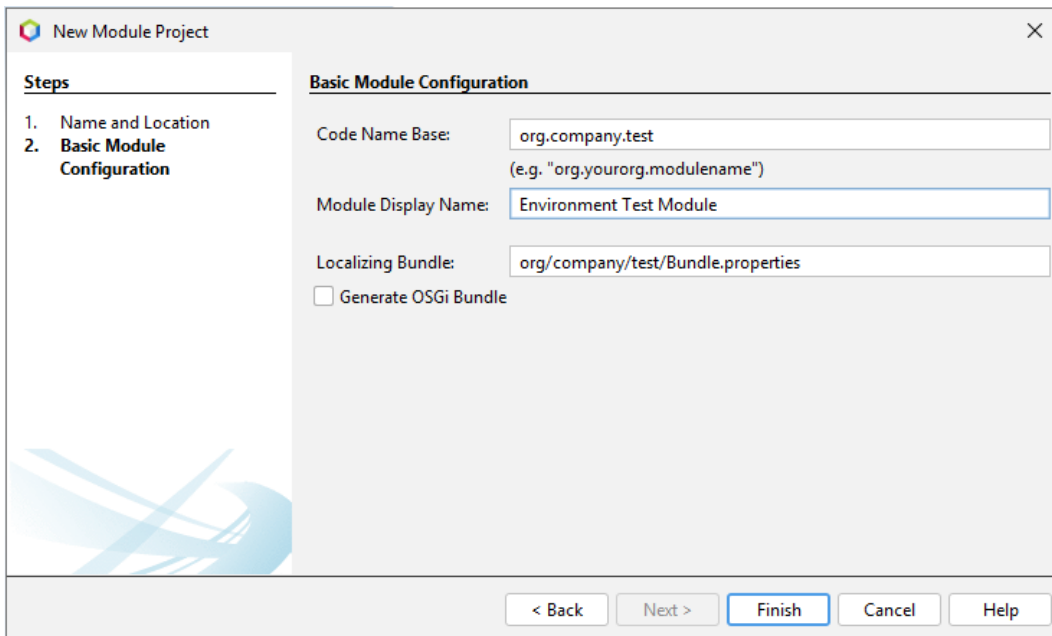
#### 1.1.4: Creating a Module

In order to start writing code, we first need a module to store it in.

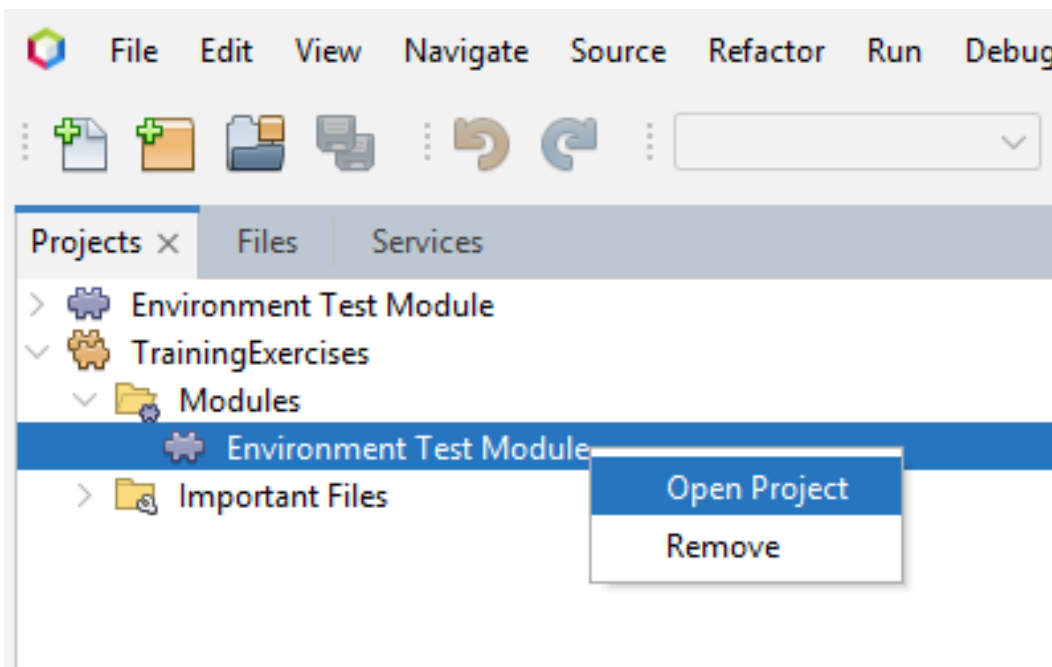
1. Expand your module suite, right click on *Modules* and select the *Add New...* option.
2. Enter *EnvironmentTestModule* as the project name for your module, then click *Next*.



3. Enter “org.company.test” as code name base and module display name and “Environment Test Module” for your module display name, then click **Finish**.



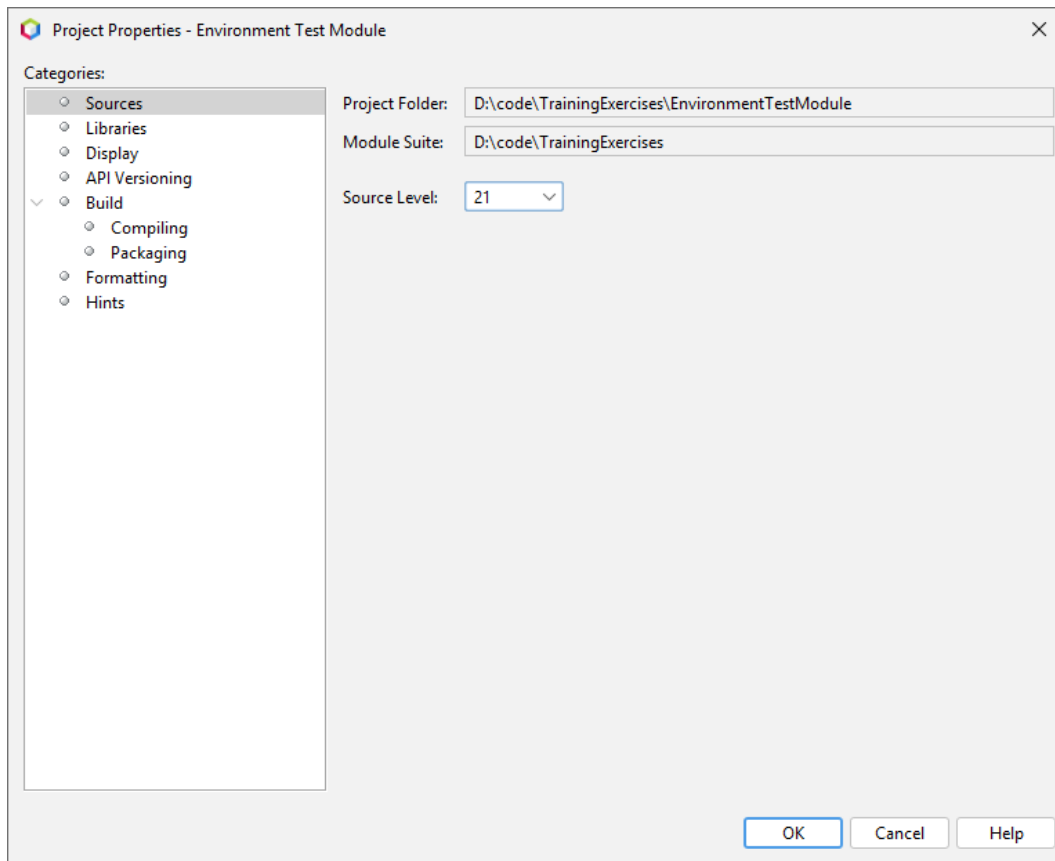
4. You should now see your new module in the *Modules* directory of your module suite. To open your new module, right click it and select *Open Project*.



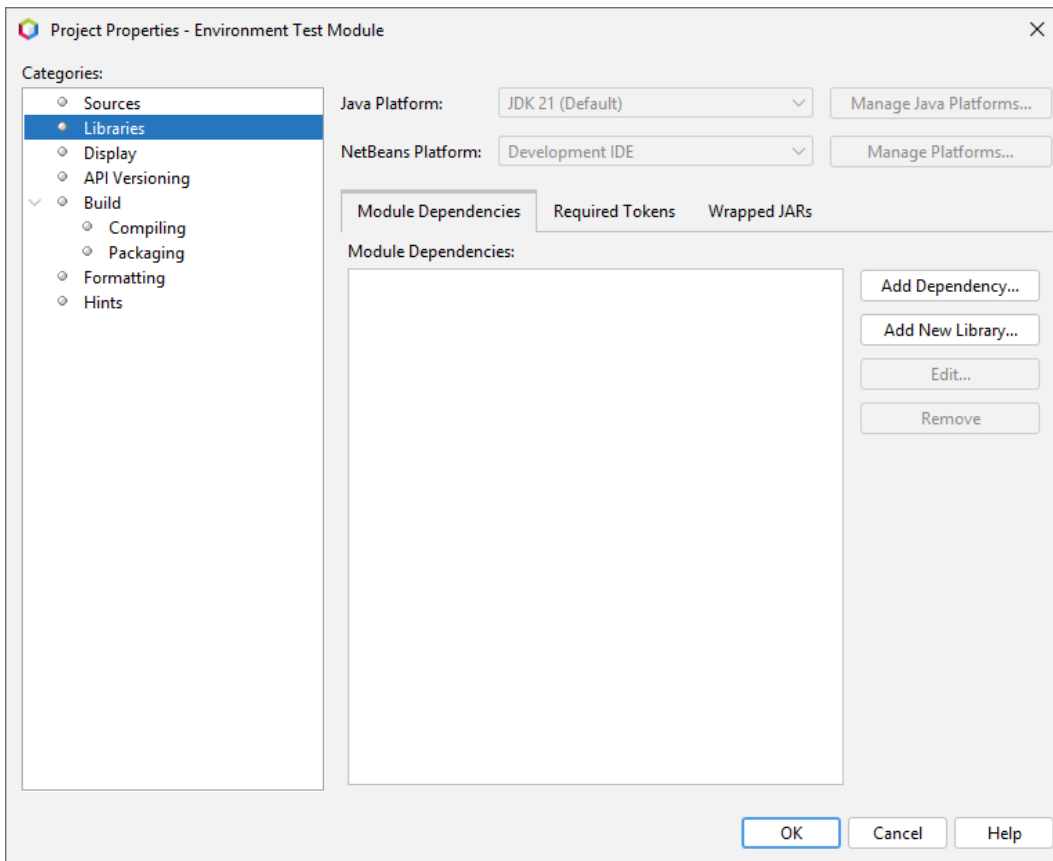
### 1.1.5: Configuring a Module

Similar to a module suite, you can configure a module by right clicking an open module and selecting *Properties*.

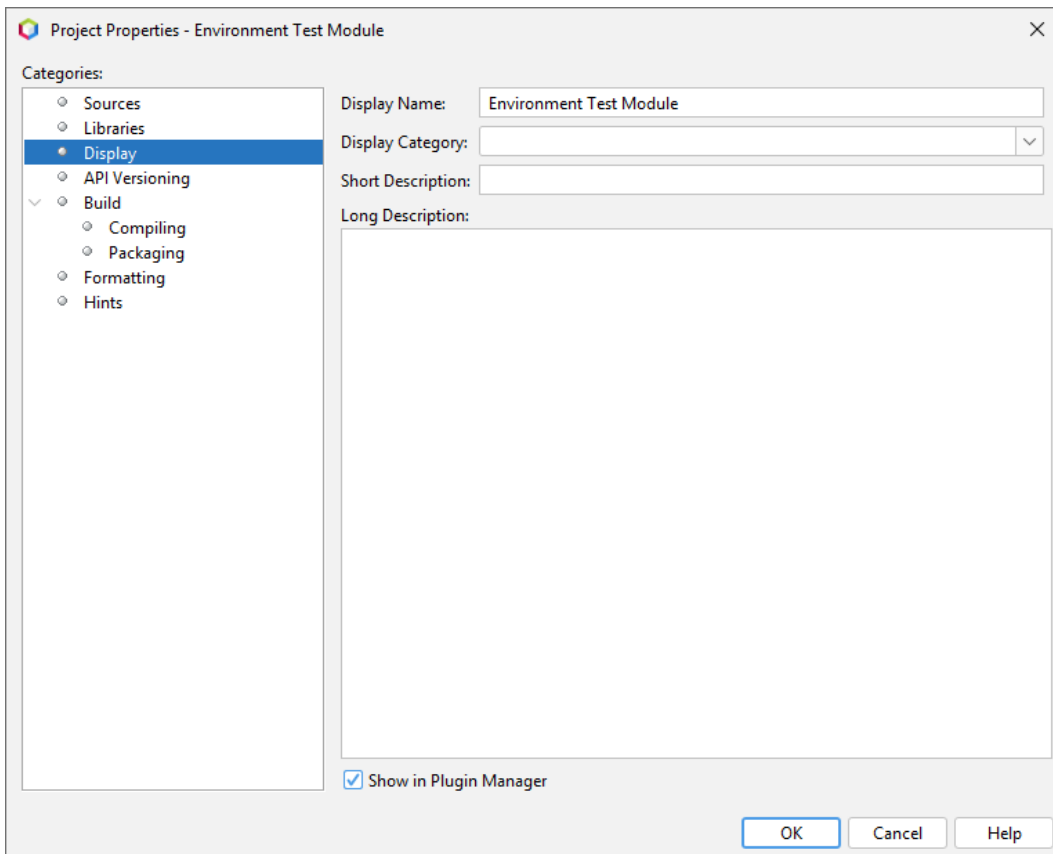
1. Since we are working in Java 21, it is always a good idea to ensure that your module is Java 21 compliant. This can be achieved by clicking *Sources* and setting the *Source Level* to 21.



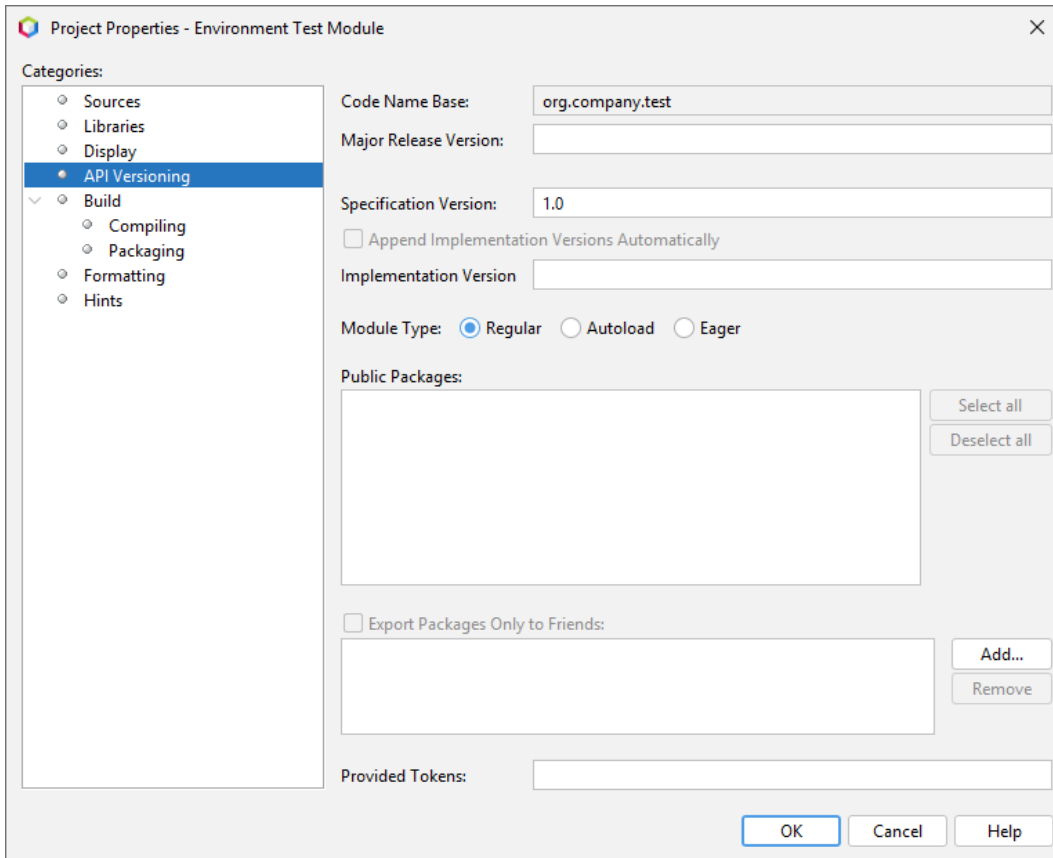
2. You can also add or remove dependencies for your module under the *Libraries* category. At this stage we have no required dependencies but we will visit this page later in the section.



3. You can give your module a name, category and description under the *Display* category.



4. Finally, once you have some code in your module, you can manage whether packages are public or private to other modules under the *API Versioning* category. You can also increment the version number of your module here.

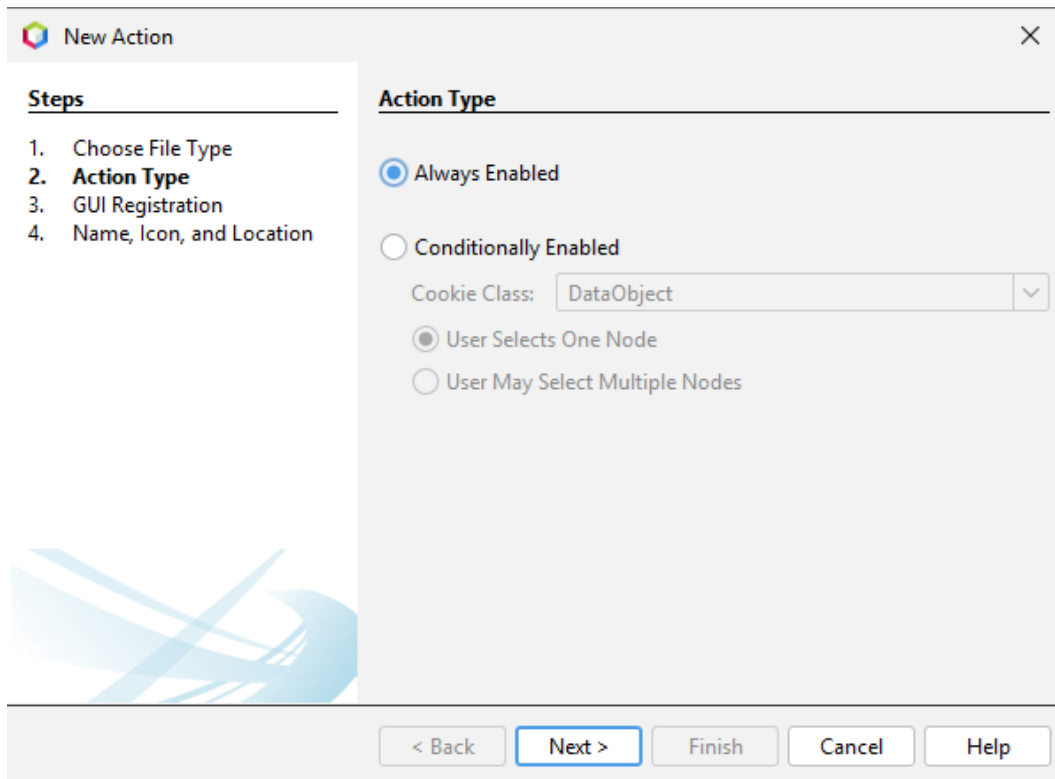


5. Click *OK* to finalise configuration of your module.

### 1.1.6: Testing your Environment

To make sure your environment is configured correctly, let's try adding some code to it and observing the output.

1. Right click on the root package your module (in the *Source Packages* directory) and select the *New > Action...* option.
2. Leave the action type as Always Enabled and click Next.



**New Action**

**Steps**

1. Choose File Type
- 2. Action Type**
3. GUI Registration
4. Name, Icon, and Location

**Action Type**

☒ Always Enabled

☐ Conditionally Enabled

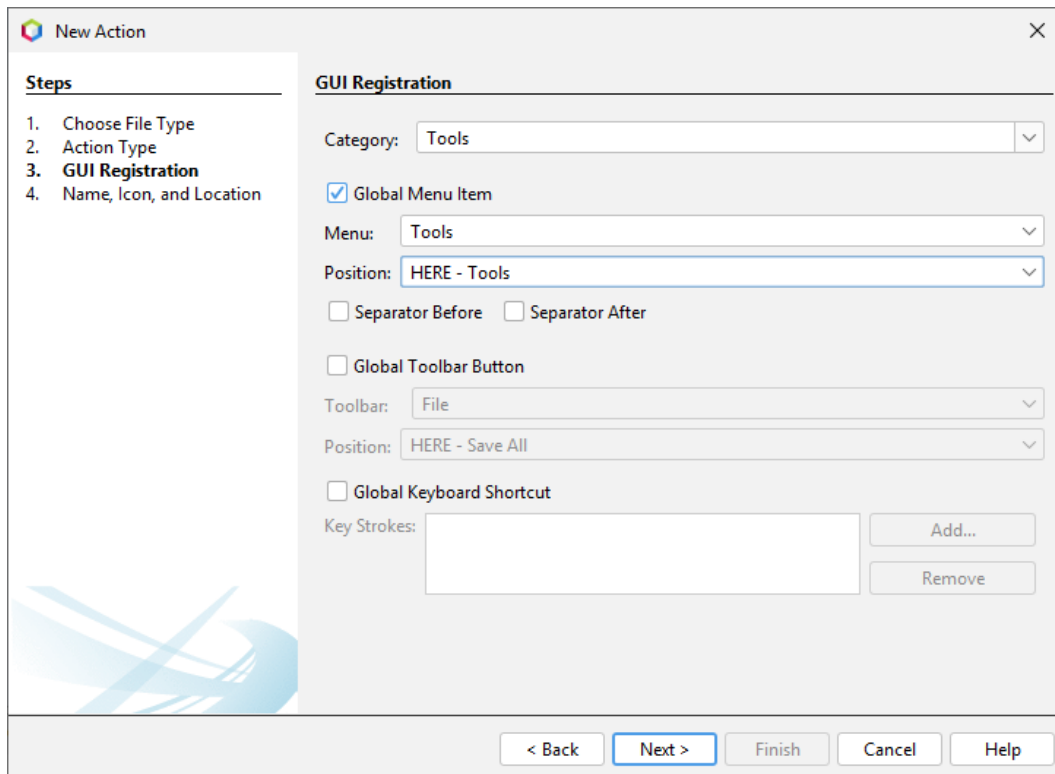
Cookie Class:

☒ User Selects One Node

☐ User May Select Multiple Nodes

< Back   **Next >**   Finish   Cancel   Help

3. Set the *Category*, *Menu* and *Position* as shown below and then click *Next*.



**New Action**

**Steps**

1. Choose File Type
2. Action Type
- 3. GUI Registration**
4. Name, Icon, and Location

**GUI Registration**

Category:

☒ Global Menu Item

Menu:

Position:

☐ Separator Before   ☐ Separator After

☐ Global Toolbar Button

Toolbar:

Position:

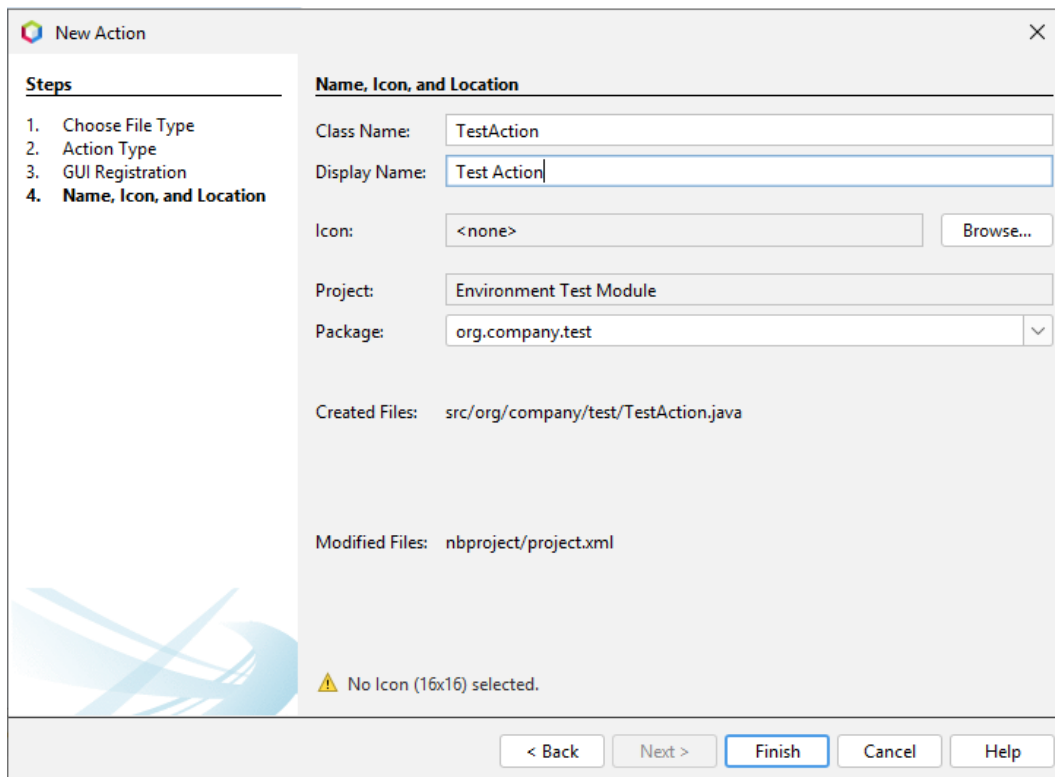
☐ Global Keyboard Shortcut

Key Strokes:

Add...   Remove

< Back   **Next >**   Finish   Cancel   Help

4. Set the *Class Name* and *Display Name* as shown below and then click *Finish*.



5. This will create a class called **TestAction**. Paste the following code inside this class:

```
1 @Override
2 public void actionPerformed(final ActionEvent e) {
3     System.out.println("Your Environment is Configured Correctly!");
4 }
```

6. Run your project, and find the action you just created (remember you can search for it using the quick search bar) and run it. Observe the message printed to the NetBeans console.

**TIP:** Here are some useful NetBeans shortcuts:

Auto-complete (Ctrl+Space): Standard auto-complete as found in most IDEs.

Fix Imports (Ctrl+Shift+I): This will add import statements for classes that you have used in your code. An efficient way to work through this tutorial is to copy and paste the code snippets from the document into your IDE. If you take this approach, fixing the imports will be required to make the code compile.

Auto-format (Alt+Shift+F): The most efficient way to work through this tutorial is to copy-paste the code blocks from the document to the exercise classes. Use can use auto-format to fix the formatting of these code blocks.

Insert Code (Alt+Insert): Netbeans provides a number of useful shortcuts for implementing common code patterns such as constructors, getter and setter methods, and equals and hashCode methods.

Copy Code (Ctrl + Shift + Up, Ctrl + Shift + Down): Copies the selected block of code (or single line if there is no selection) to the line above or below.

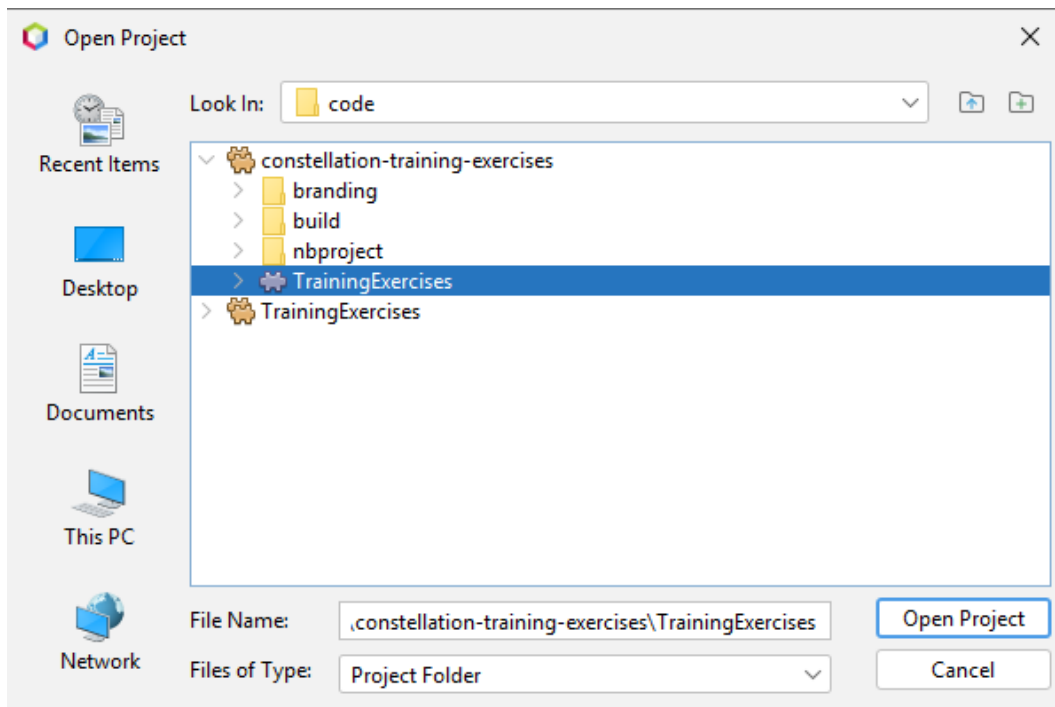
Move Code (Alt + Shift + Up, Alt + Shift + Down): Moves the selected block of code (or single line if there is no selection) to the line above or below.

Comment (Ctrl + /): Comment or uncomment the selected block of code (or single line if there is no selection).

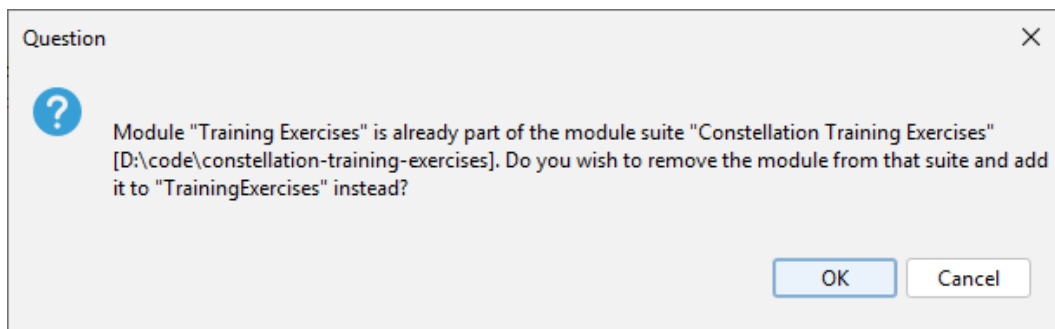
NetBeans will also provide useful hints in the margins which can be clicked for further options. These include automatic code generation and import resolution.

### 1.1.7: Import the Training Module

Right click on the *Modules* directory inside your module suite and select *Add Existing...* Browse to the TrainingExercises module as displayed below and click *Open Project*.



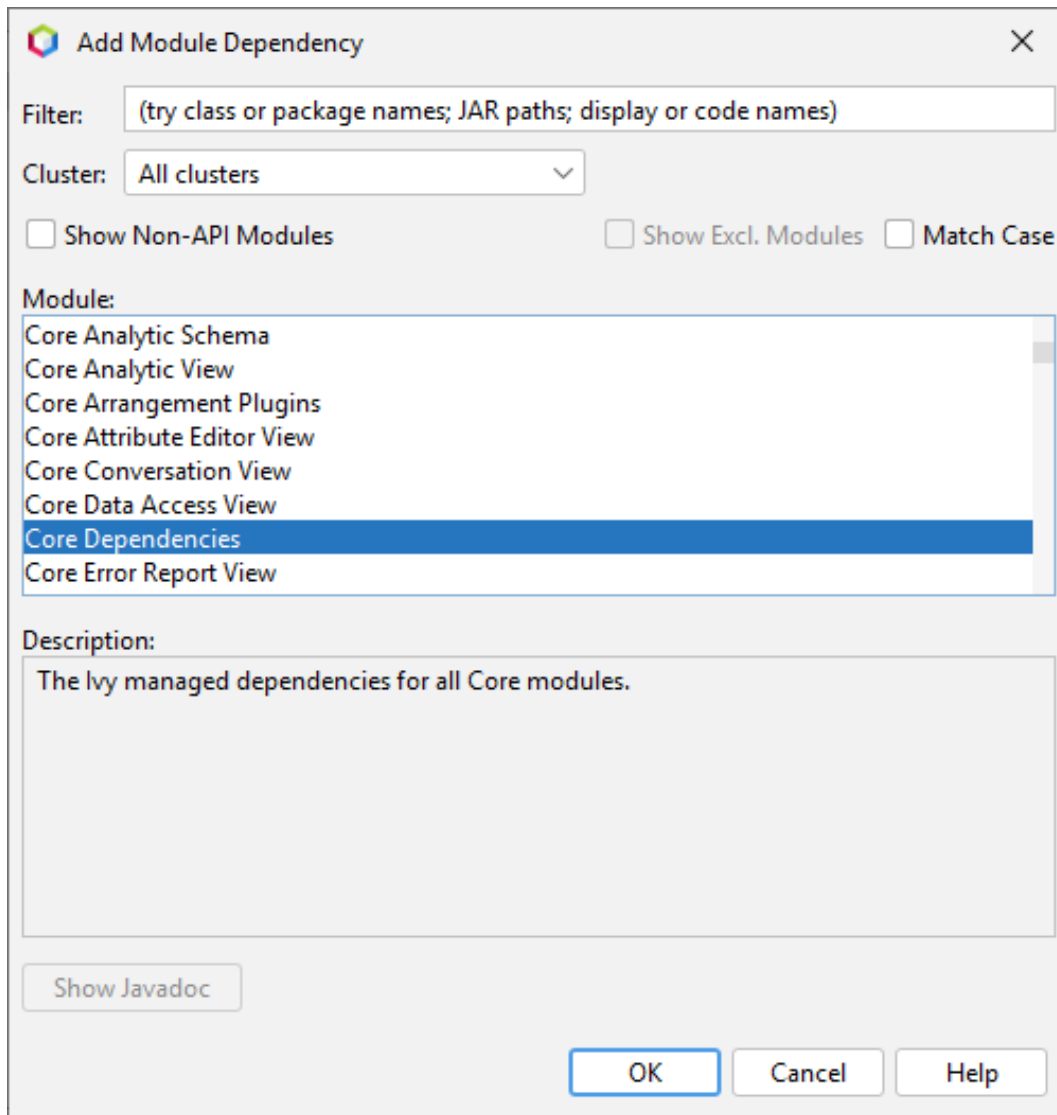
As the module you are importing currently belongs to another module suite, NetBeans will warn you that it will be removed from its existing module suite:



Click *OK* to confirm.

To ensure you have access to the classes provided by Constellation, we should add all of its modules as dependencies. Recall from **1.1.5** that this can be achieved by clicking *Add Dependency...* under the *Libraries* category within your module's properties.





Select all modules beginning with “Core” (you can hold the shift key to select a range) and click *OK* to add them as dependencies of your module.

**TIP:** You can follow the same process of creating and configuring a module suite described in this chapter for the training solutions.

## Chapter 2: Data Access

While importing data with the Delimited File Importer is appropriate in many circumstances, it has a number of restrictions that make it inflexible for certain data formats:

1. There is only a small, finite set of delimited file types that the importer accepts. While there is a mechanism by which new file formats can be programmatically added, only those that can be intuitively translated to a tabular form are suitable. Some file formats have no tabular interpretation.
2. In addition to requiring data in a tabular form, the Delimited File Importer imports each row as an independent record. Many data sets have rows/records that depend on each other, meaning the Delimited File Importer will not interpret these relationships to a graph.
3. The Delimited File Importer provides a fixed number of transforms that can be performed on your data as it is ingested. While these transforms provide for most common datasets, there are many situations where the provided transforms are inadequate. While new transforms can be added programmatically, there are

limitations as to the functions that these transforms can perform.

4. Using the Delimited File Importer can often be a time-consuming task, requiring the user to manually specify attribute mappings as well as several other options. While a successful attribute mapping can be saved as a template for future use, the process is still more time-consuming than is ideal in situations where the same file format needs to be imported into Constellation repeatedly.

In situations where the file format is more complex, the transforms required are more specialised, or the file format needs to be imported repeatedly, Constellation provides for the development of a specialised plugin that performs a custom import quickly and efficiently. This chapter will take you through the process of implementing such a plugin to directly import all infected cities and display them on the graph with their relevant attributes.

While any plugin in Constellation can add data to the graph, the Data Access View provides a framework to streamline this process. It adds a number of benefits that make running data access plugins more powerful than running them as standalone plugins, such as:

1. The Data Access View allows multiple data access plugins to be run concurrently, dramatically reducing the time spent waiting for these plugins to perform their queries.
2. The Data Access View allows multiple data access “steps” to be performed in sequence, allowing subsequent plugins to query based on the results of previously finished plugins.
3. Many data access plugins require similar parameter values, such as a time range, to be provided by the user. The Data Access View collects identical parameters from each plugin and only requires the user to specify the values once.
4. The Data Access View provides a consistent user interface for each plugin, making the user experience more intuitive and relieving the plugin developer of having to build a custom user interface for their plugin.

In this chapter, we will be implementing a new “Import Infected Cities” plugin as a Data Access Plugin to take advantage of the above features, and directly import all cities that have at least one outbreak associated with them.

## Plugin Templates

Plugins are designed to be very flexible and place very few restrictions on what the plugin writer can do while the plugin is running. As a consequence, this also means that the plugin writer has a number of responsibilities to ensure that the plugin runs constructively. These include:

1. **Graph Locking:** Constellation provides re-entrant read and write locks on its graph structures to allow multiple plugins to run concurrently without corrupting the graph data. As a result, a plugin writer is responsible for ensuring the correct read/write locks are acquired before performing operations on the graph. Equally importantly, the plugin writer must ensure that each lock is released once it is no longer required.
2. **User Feedback:** Constellation provides a plugin with the means to provide feedback to the user as the plugin runs, such as marking the target graph as busy, updating a progress bar as a long-running operation progresses, and providing status messages. A compliant plugin will provide this feedback in a consistent and helpful way.
3. **Error handling:** Constellation provides a number of consistent ways in which to alert the user to errors that occur while the plugin is running, including the ability to distinguish between programming errors (bugs) and expected errors (such as network connection failures). It is important that the plugin writer handle each error in an appropriate way in order to provide the best user feedback and leave the application in a consistent state.

**To prevent the risk of dead-locking the application, plugin writers MUST ensure that they do not request a write lock on the Event Dispatch Thread (EDT).**

Writing a generic plugin can require a considerable amount of work. It involves a significant amount of boiler-plate code, and increases the potential for numerous programming errors.

Plugin templates provide starting points for plugins with different lifecycles. We will look at these in more detail in Chapter 6. In this chapter, we will focus on plugins that run from the Data Access View, which are required to follow a lifecycle that ensures they can run concurrently with other data access plugins and still produce valid results. The lifecycle of these plugins consists of three stages:

1. **Read stage:** In this stage the plugin holds a read lock on the graph and must gather all necessary information from the graph that it will need later to perform the query stage of its execution. In general, this will include

gathering the important details of all selected nodes/transactions of the graph as this is usually what specifies the basis for any resulting data base query that will follow. Importantly, the plugin should not need to revisit the graph in later stages to gather more information as, by these later stages, the graph may have been edited by a concurrently running plugin. It is also important that this stage is completed quickly as other plugins may be waiting on this stage to finish before beginning subsequent stages.

2. **Query stage:** During this stage, the plugin has no lock on the graph and so can perform long running tasks that can be completed independently of the graph and only relying on information gained during the read stage. This stage typically involves performing a database query or other long-running calculation.
3. **Edit stage:** During this stage the plugin acquires a write lock on the graph and make any changes required to present its results. As a write lock is required for this stage, it is important that the edit happens as quickly as possible so that other plugins can have a chance to also add their results. It is also important that the plugin be robust to the possibility that other plugins may have edited the graph since this plugin was in the read stage.

To ease the development of plugins that adhere to this lifecycle, the **SimpleQueryPlugin** provides most of the base functionality, requiring the plugin writer to override three methods to define the plugin's behaviour in each of the three plugin lifecycle stages. Extending **SimpleQueryPlugin** makes the process of creating a data access plugin much easier.

Additionally, it turns out that many data access plugins have very similar requirements for their read and edit stages. From the read stage, they only require a list of the selected nodes/transactions on the graph, as well as any associated attributes for these elements. Correspondingly, the only function of the edit stage is to take a list of new nodes/transactions produced in the query stage and add them to the graph. To take advantage of this pattern, the **RecordStoreQueryPlugin** extends **SimpleQueryPlugin** to provide standard implementations for the read and edit stages, requiring the plugin writer to specify only the query stage. We will use the **RecordStoreQueryPlugin** to simplify the creation of our "Import Infected Cities" plugin.

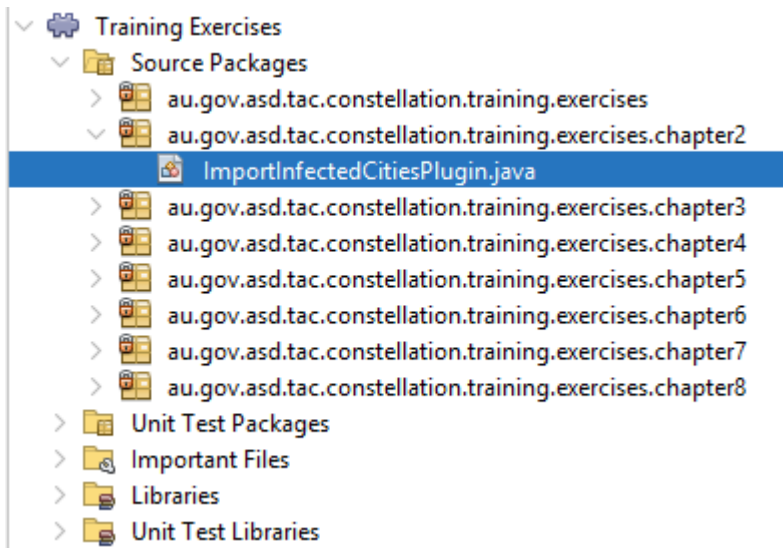
## Record Store

In order to provide a **RecordStoreQueryPlugin** with the selected graph elements needed to perform its query stage, and also to accept a resulting list of elements to add to the graph in the edit stage, the plugin utilises an important and widely-used data structure called a **RecordStore**. A **RecordStore** provides an abstract representation of a tabular dataset, with named columns and ordered rows, similar to a CSV file or spread sheet. Each row represents a node and/or transaction in the graph and each column represents an attribute associated with these elements. There is a standard column naming convention that allows columns to specify which element they apply to. In the query stage, the **RecordStorePlugin** creates a new **RecordStore**, making a new row for each element it needs to pass to the plugin's query stage. The role of the query stage is simply to read information from this provided **RecordStore**, use this information to perform a query or calculation, and produce a new **RecordStore** containing the results intended for addition to the graph. The **RecordStoreQueryPlugin** will then use the edit stage to add these new elements to the graph.

**TIP:** A **RecordStore** stores column values exclusively as **Strings**. It is important to remember that, even though there are methods that allow you to set column values to any **Object**, this is just a convenience feature and all **Object** values are immediately converted to Strings by their **Object.toString()** method. null values remain as null.

## Exercise 2.1: Import Infected Cities Plugin

In this exercise we will go through the necessary steps to create a fully working data access plugin in Constellation. To begin, find and open the **ImportInfectedCitiesPlugin** skeleton class in the chapter2 package of the Training Exercises module.



### 2.1.1: Create a plugin

To represent a plugin in Constellation, your class must either implement the `Plugin` interface or extend one of the many plugin template classes. In this case we are extending **RecordStoreQueryPlugin** as a convenient way to create a plugin compliant with the Data Access View. Make your class extend **RecordStoreQueryPlugin** and use the NetBeans hint “Implement all abstract methods” to implement the required `query(...)` method.

```
1 public class ImportInfectedCitiesPlugin extends RecordStoreQueryPlugin {
2
3     @Override
4     protected RecordStore query(final RecordStore query, final PluginInteraction interaction,
5                               final PluginParameters parameters) throws InterruptedException, PluginException {
6         ...
7     }
8 }
```

### 2.1.2: Register your plugin

Constellation maintains a global registry of all plugins in the application. To register your plugin, you need to include a **@ServiceProvider** annotation registering your class as implementing the **Plugin** interface. Service providers are an inbuilt NetBeans feature that allows classes to register themselves for lookup at runtime. Constellation uses this framework extensively to provide most of its extension mechanisms.

```
1 @ServiceProvider(service = Plugin.class)
2 public class ImportInfectedCitiesPlugin extends RecordStoreQueryPlugin {
```

**TIP:** The **ServiceProvider** annotation registers a class as providing an implementation of another class. Any registered classes can later be looked up on request using the NetBeans Lookup API. In the case above, the **ImportInfectedCitiesPlugin** class is being registered as a **Plugin** so that the **PluginRegistry** class can locate it for later use. Note that altering **ServiceProvider** annotations will require a clean and build before changes will take effect.

As well as registering your plugin with Constellation, by convention each plugin is also added as a static constant to a registry class in the default package of its module. These registry classes are made public and provide a convenient way for other developers to find your plugin. Open the **PandemicPluginRegistry** class from the default package of the exercise module and add:

```
1 public static final String IMPORT_INFECTED_CITIES = ImportInfectedCitiesPlugin.class.getName();
```

We will discuss how these registry classes are used in Chapter 4 when we need to instantiate and execute another plugin from our plugin.

### 2.1.3: Include your plugin in the Data Access View

Back in our plugin, there is an extra step required to include it in the Data Access View. Your plugin should implement the **DataAccessPlugin** interface (NetBeans will again help you implement the required methods) and should include another **@ServiceProvider** annotation registering it as implementing the **DataAccessPlugin** interface

```
1 @ServiceProviders({
2     @ServiceProvider(service = DataAccessPlugin.class),
3     @ServiceProvider(service = Plugin.class)
4 })
5
6 public class ImportInfectedCitiesPlugin extends RecordStoreQueryPlugin implements
    DataAccessPlugin {
```

### 2.1.4: Specify the type and position of your plugin in the Data Access

View:

Plugins displayed in the Data Access View are grouped into various sections that all perform related tasks. You can specify which group your plugin appears in by implementing the **getType()** method in your plugin class. This is one of the methods NetBeans has inserted for you as part of the **DataAccessPlugin** interface. Implement it as shown below to specify you want your plugin to appear in the experimental group. Note that the type needs to be a registered type name from an implementation of **DataAccessPluginType**.

```
1 @Override
2 public String getType() {
3     return DataAccessPluginCoreType.EXPERIMENTAL;
4 }
```

Within a section, plugins are ordered based on their requested position. You can specify this position by implementing another method from the **DataAccessPlugin** interface:

```
1 @Override
2 public int getPosition() {
3     return 0;
4 }
```

Higher positions appear after lower positions. A position of 0 requests your plugin to appear first in the section.

### 2.1.5: Give your plugin a name:

Each plugin in Constellation has a human readable name that is displayed in the user interface. You can specify the name of your plugin by overriding the **getName()** method from the **AbstractPlugin** class:

```
1 @Override
2 public String getName() {
3     return "Import Infected Cities";
4 }
```

However, Constellation provides a shortcut for this by specifying an **@NbBundle** message with a key identical to the class name. Delete your implementation of **getName()** and replace it with an **@NbBundle** annotation on your class:

```
1 @ServiceProviders({
2     @ServiceProvider(service = DataAccessPlugin.class),
3     @ServiceProvider(service = Plugin.class)
4 })
5
6 @NbBundle.Messages("ImportInfectedCitiesPlugin=Import Infected Cities")
```

```

7
8 public class ImportInfectedCitiesPlugin extends RecordStoreQueryPlugin implements
    DataAccessPlugin {

```

Finally, remove the **UnsupportedOperationException** from the body of your query method and replace it with code to print out a message when the plugin is run. At this stage we return an empty record store so nothing will be added to the graph.

```

1 @Override
2 protected RecordStore query(final RecordStore query, final PluginInteraction interaction,
3     final PluginParameters parameters) throws InterruptedException, PluginException {
4     System.out.println("Testing Infected Cities Plugin");
5     return new GraphRecordStore();
6 }

```

If you compile and run Constellation at this stage, you should see your plugin appear in the Data Access View as expected:

1. Your plugin should appear in the EXPERIMENTAL section of the data access view.
2. Your plugin should appear at or near the top of the EXPERIMENTAL section based on your specified position of 0.
3. Your plugin should be displayed with the name you specified in the **@NbBundle** annotation.

Run your plugin on an empty graph to see your message appear in the console.

### 2.1.6: Adding Graph Elements to the Graph

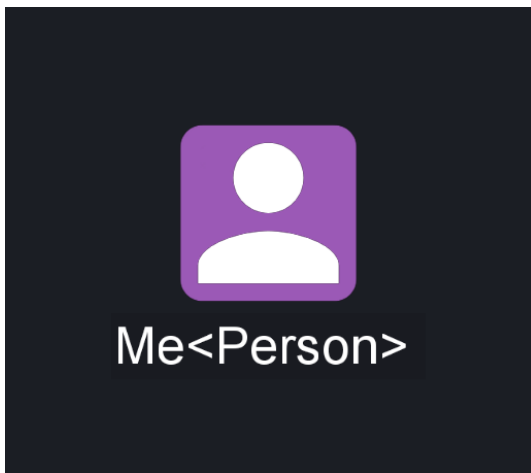
Adding nodes and transactions to the graph involves adding data to the **RecordStore** instance returned from our query method. To begin with, we will add a single node to the graph.

```

1 @Override
2 protected RecordStore query(final RecordStore query, final PluginInteraction interaction,
3     final PluginParameters parameters) throws InterruptedException, PluginException {
4     final RecordStore result = new GraphRecordStore();
5     result.add();
6     result.set(GraphRecordStoreUtilities.SOURCE + VisualConcept.VertexAttribute.IDENTIFIER,
7         "Me");
8     result.set(GraphRecordStoreUtilities.SOURCE + AnalyticConcept.VertexAttribute.TYPE,
9         AnalyticConcept.VertexType.PERSON);
10    return result;

```

If you compile and run Constellation again, your plugin will now add a single node to the graph. You should see that Constellation has assisted you by setting icon and colour values for the node based on the type you specified.



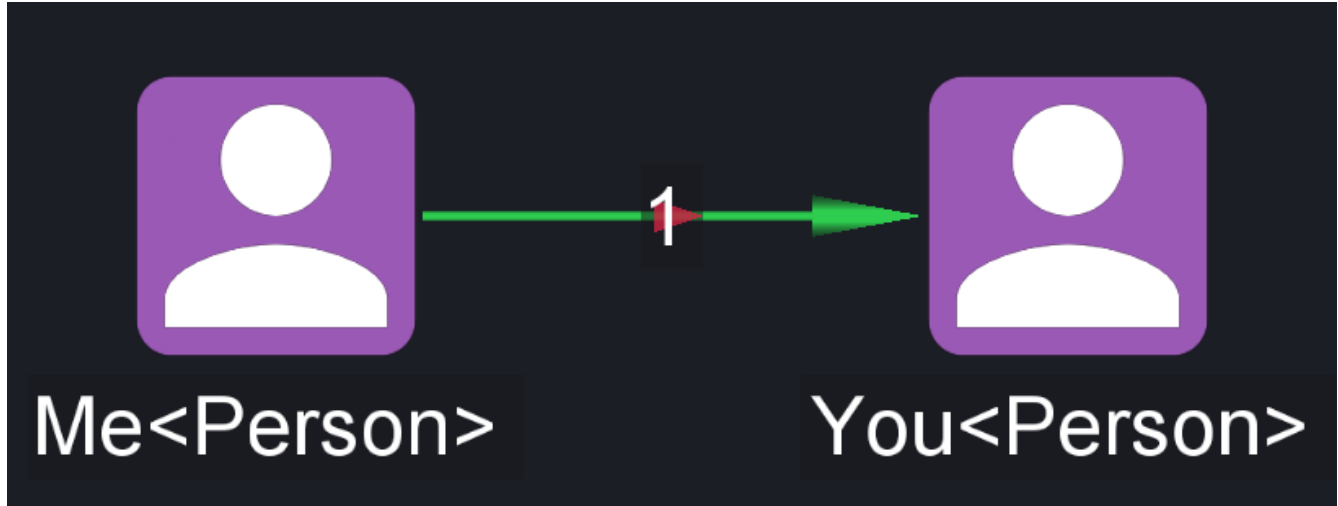
Looking at the code, the query method performs three main tasks:

1. Firstly, it creates a new **GraphRecordStore** object, an instance of **RecordStore** designed to interact with graphs. This data structure will hold the nodes and transactions that will be added to the graph.
2. Next, **RecordStore.add()** is called to create a new row. Each row in a record store is capable of holding a transaction, as well as its source and destination nodes. However, if some elements are omitted, the remaining elements will still be added to the graph. We will make use of this behaviour by only specifying a source node.
3. Finally, a series of **RecordStore.set(key,value)** calls are made to add column values to our new row. The **RecordStore** will automatically create new columns as they are needed and each key value adheres to a format that tells the **RecordStore** what type of element the column relates to. In this case, the column name begins with **GraphRecordStoreUtilities.SOURCE** which indicates that this column belongs to the source node. Other prefixes that can be used are **GraphRecordStore.DESTINATION** to specify a destination node attribute, or **GraphRecordStore.TRANSACTION** to specify a transaction attribute. A transaction will only be created if both source and destination node attributes are specified explaining why, in this case, only a single node has been added to the graph. The remaining part of the key specifies the actual attribute that the column refers to in the graph, and for this we use well known attributes from the **VisualConcept** and **AnalyticConcept**. Schemas and concepts will be discussed further in Chapter 3.

As mentioned above, to add a transaction to the graph all that is needed is to specify both source and destination node attributes (and optionally transaction attributes) in a single row of the RecordStore:

```
1 @Override
2 protected RecordStore query(final RecordStore query, final PluginInteraction interaction,
3     final PluginParameters parameters) throws InterruptedException, PluginException {
4     final RecordStore result = new GraphRecordStore();
5     result.add();
6     result.set(GraphRecordStoreUtilities.SOURCE + VisualConcept.VertexAttribute.IDENTIFIER,
7         "Me");
8     result.set(GraphRecordStoreUtilities.SOURCE + AnalyticConcept.VertexAttribute.TYPE,
9         AnalyticConcept.VertexType.PERSON);
10    result.set(GraphRecordStoreUtilities.DESTINATION +
11        VisualConcept.VertexAttribute.IDENTIFIER, "You");
12    result.set(GraphRecordStoreUtilities.DESTINATION + AnalyticConcept.VertexAttribute.TYPE,
13        AnalyticConcept.VertexType.PERSON);
14    result.set(GraphRecordStoreUtilities.TRANSACTION +
15        AnalyticConcept.TransactionAttribute.TYPE,
16        AnalyticConcept.TransactionType.COMMUNICATION);
17    return result;
18 }
```

Running Constellation again will now demonstrate that the plugin will add a new transaction to the graph, as well as the source and destination nodes for that transaction. Again, the schema has provided assistance by setting an appropriate transaction colour based on the specified transaction type.



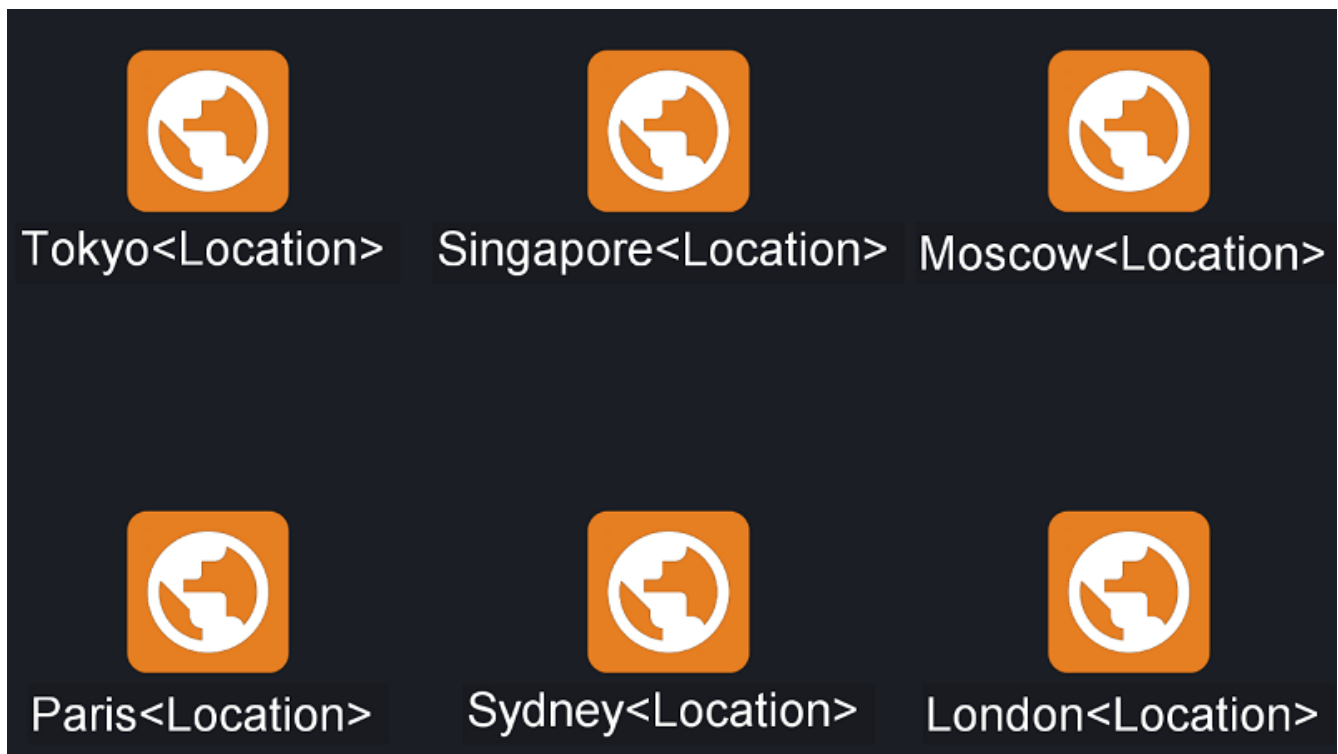
Finally, we will modify our query method to perform the task we originally intended: to import all cities from our data set that have at least one outbreak. To help us with this, and future data access tasks, this training comes with a helper class, **OutbreakUtilities**, which will perform the data access queries we required.

**TIP:** The **OutbreakUtilities** class has many useful methods that will be used throughout this training document to simplify our development.

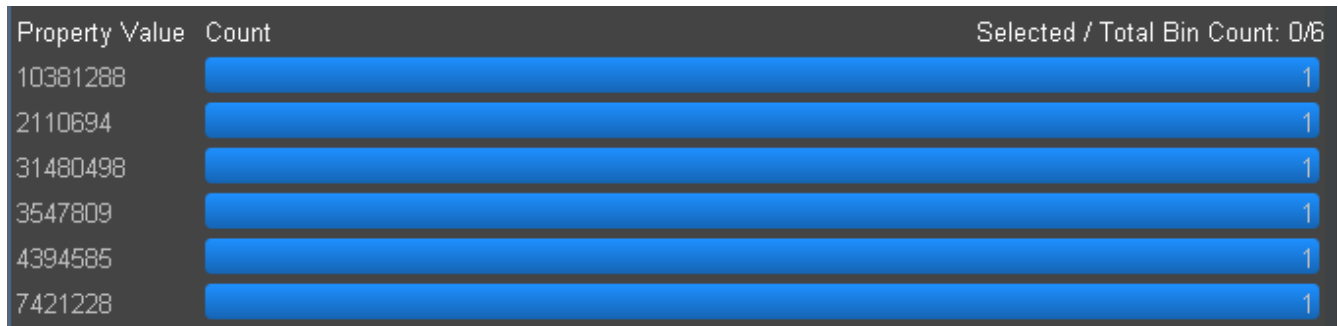
```
1 @Override
2 protected RecordStore query(final RecordStore query, final PluginInteraction interaction,
3     final PluginParameters parameters) throws InterruptedException, PluginException {
4     final RecordStore result = new GraphRecordStore();
5     for (final OutbreakUtilities.City city : OutbreakUtilities.getInfectedCities()) {
6         result.add();
7         result.set(GraphRecordStoreUtilities.SOURCE +
8             VisualConcept.VertexAttribute.IDENTIFIER, city.getName());
9         result.set(GraphRecordStoreUtilities.SOURCE + AnalyticConcept.VertexAttribute.TYPE,
10             AnalyticConcept.VertexType.LOCATION);
11         result.set(GraphRecordStoreUtilities.SOURCE + "Population", city.getPopulation());
12         result.set(GraphRecordStoreUtilities.SOURCE + SpatialConcept.VertexAttribute.LATITUDE,
13             city.getLatitude());
14         result.set(GraphRecordStoreUtilities.SOURCE + SpatialConcept.VertexAttribute.LONGITUDE, city.getLongitude());
15         result.set(GraphRecordStoreUtilities.SOURCE + "Outbreak", city.getOutbreak());
16     }
17     return result;
18 }
```

Running your plugin now will import all infected cities into Constellation, with a result similar to:





While the data is now successfully importing, one problem arises when you attempt to histogram the city populations in order to find the cities with the largest populations:



Notice that the populations are not sorting correctly as integers, but rather as strings. This occurs because, unless directed otherwise, new attributes created by a **RecordStore** are created as string attributes. This can be corrected by appending a type to the end of a column key (“<” + type + “>”) when specifying **RecordStore** column values:

```
1 result.set(GraphRecordStoreUtilities.SOURCE + "Population" + "<" +
    IntegerAttributeDescription.ATTRIBUTE_NAME + ">",
2     city.getPopulation());
```

Running the plugin again will show that the population attribute now sorts correctly as it has been added to the graph as an integer attribute.

As the process of adding a city to a **RecordStore** is such a common task, **OutbreakUtilities** provides another convenience method that will do this for us. This allows us to simplify our query method:

```
1 @Override
2 protected RecordStore query(final RecordStore query, final PluginInteraction interaction,
3     final PluginParameters parameters) throws InterruptedException, PluginException {
4     final RecordStore result = new GraphRecordStore();
5     for (final OutbreakUtilities.City city : OutbreakUtilities.getInfectedCities()) {
6         result.add();
7         OutbreakUtilities.addCityToRecord(city, result, GraphRecordStoreUtilities.SOURCE);
```

```

8     }
9     return result;
10 }

```

## Chapter 3: Schemas

One advantage to using a graph to represent data it can provide visual cues to highlight features of the data. You may have noticed this when you built your graph in the last exercise, with each node being given an icon and a background colour automatically to help identify them as representing people or locations. A Constellation graph is able to make changes like these on its own by following a set of rules defined by a developer; we call this set of rules a **schema**. Every graph in Constellation will have a schema associated with it which defines the **attributes** and **types** a graph considers important, as well as the ways in which these attributes and types should interact with the graph. Constellation is then able to use the rules in this schema to make changes automatically in response to a user modifying a graph.

### Exercise 3.1: Pandemic Schema

We are now going to create our own schema to allow us more control over how our pandemic data is represented in a Constellation graph. This will help make analysis of the pandemic a bit easier later on. Start by opening the **PandemicSchemaFactory** skeleton class from the ‘chapter3’ package in the ‘TrainingExercises’ module.

#### 3.1.1: Building a Schema Factory

To create a new schema, we first need a **SchemaFactory**, which is responsible for creating **Schema** classes, and so it needs to define several parameters used for schema construction. Ensure **PandemicSchemaFactory** is registered as a **SchemaFactory** class, and that it extends **AnalyticSchemaFactory**.

```

1 @ServiceProvider(service = SchemaFactory.class)
2 public class PandemicSchemaFactory extends AnalyticSchemaFactory {
3     ...
4 }

```

A schema should always be assigned a name. This name will be saved into Constellation graph files so that the schema can be recalled on load, and so it is important to remember that changing this name will break any previously saved graphs which use this schema. Give **PandemicSchemaFactory** a unique name.

```

1 public static final String NAME =
2     "au.gov.asd.tac.constellation.training.schema.PandemicSchemaFactory";
3
4 @Override
5 public String getName() {
6     return NAME;
7 }

```

It is also required to give a schema a label and a description, whose values will be displayed to the user within Constellation. Give **PandemicSchemaFactory** a label and description.

```

1 @Override
2 public String getLabel() {
3     return "Pandemic Graph";
4 }
5
6 @Override
7 public String getDescription() {
8     return "This graph provides support for analysing a pandemic - for training purposes";
9 }

```

The position of a schema will determine where it sits within the ‘New Graph’ menu in Constellation. Lower positions are considered more important by Constellation, and the schema with the lowest position will become the default graph type. Give **PandemicSchemaFactory** a position which will ensure it is the default schema factory.

```
1 @ServiceProvider(service = SchemaFactory.class, position = 0)
2 public class PandemicSchemaFactory extends AnalyticSchemaFactory {
3     ...
4 }
```

There are other attributes we could specify here, such as the key attributes created schemas or the default labels for the graph, but for this example we’ll simply inherit the behaviour of the super class. Run Constellation and observe that a ‘Pandemic Graph’ option exists in the File menu under ‘New Graph’. Currently creating a new graph with this schema factory will cause an exception because we haven’t defined the schema itself yet. You may notice it inherits its icon from the Analytic Schema; later on we will show you how to modify this.

### 3.1.2: Registering Schema Concepts

Now it’s time to start defining what our schema is all about by registering attributes and types to it. This is done by grouping attributes and types into related concepts using the **SchemaConcept** class, and registering these concepts to our schema. Let’s start by registering some existing schema concepts to **PandemicSchemaFactory**.

- **The Constellation Views Concept:** defines attributes used by views in Constellation; this should be registered to all schemas.
- **The Visual Concept:** allows our schema awareness of colours, icons and other visual attributes
- **The Analytic Concept:** enables us to effectively analyse our data as a graph by providing knowledge of types and other relevant attributes.

```
1 @Override
2 public Set<Class<? extends SchemaConcept>> getRegisteredConcepts() {
3     final Set<Class<? extends SchemaConcept>> registeredConcepts = new HashSet<>();
4     registeredConcepts.add(ConstellationViewsConcept.class);
5     registeredConcepts.add(VisualConcept.class);
6     registeredConcepts.add>AnalyticConcept.class);
7     return Collections.unmodifiableSet(registeredConcepts);
8 }
```

### 3.1.3: Building a Schema

There’s just one thing left to do now; we need to define the schema this factory will create, which is done using the **Schema** class. Try creating a pandemic schema class (which should extend as **AnalyticSchema**) as an inner class within **PandemicSchemaFactory**.

```
1 protected class PandemicSchema extends AnalyticSchema {
2     public PandemicSchema(final SchemaFactory factory) {
3         super(factory);
4     }
5 }
```

To complete this step, you must also tell the schema factory that the pandemic schema is the schema it should be building.

```
1 @Override
2 public Schema createSchema() {
3     return new PandemicSchema(this);
4 }
```

Try running Constellation and creating a Pandemic Graph. This graph should successfully open.

A schema gives us the opportunity to perform smart operations at certain points within the lifecycle of a graph. For example, we can fully specify the behaviour of the graph when it is opened, or when a node is added to it. Try implementing the **completeVertex** method in the **PandemicSchema** class to update the type of ‘Location’ vertices to ‘City’ vertices. You can test this behaviour out by launching CONSTELLATION and running the ‘Import Infected Cities’ plugin from the previous chapter.

```
1 @Override
2 public void completeVertex(final GraphWriteMethods graph, final int vertex) {
3     final int typeAttributeId = AnalyticConcept.VertexAttribute.TYPE.get(graph);
4     final SchemaVertexType vertexType = graph.getObjectValue(typeAttributeId, vertex);
5     if (AnalyticConcept.VertexType.LOCATION.equals(vertexType)) {
6         graph.setStringValue(typeAttributeId, vertex, "City");
7     }
8     super.completeVertex(graph, vertex);
9 }
```

## Schema Attributes

Every feature in Constellation relies on attributes. Fundamentally you need attributes to store and categorise data within a graph, but they are also required for almost all of Constellation’s views and plugins to operate. We saw how easy it is to create new attributes using a record store in the previous chapter, but attributes created this way cannot easily be used for functionality outside of the plugin in which they are created. Registering **schema attributes** to your schema ensures that will always be available to any graph using your schema. This also provides you the opportunity to customise the attribute, including specifying a name and description for the attribute and whether or not to add it to the graph up front. Schema attributes will be coloured grey within the Attribute Editor.

## Exercise 3.2: Outbreak Attribute, Part 1

Since the focus of our scenario is on tracking the spread of various diseases, it would be beneficial for us to allow full control over the way we manage data related to these diseases. To achieve this we will build an ‘Outbreak’ attribute and register it to our schema.

### 3.2.1: Building a Schema Concept

A schema attribute should always be associated with a schema concept, so let’s build a ‘pandemic concept’. This concept will need to be registered as a **SchemaConcept** class, and given a name as well as a set of parent concepts. It is worth noting that when we register a concept to a schema, all of its children will also be registered. Open and complete the **PandemicConcept** class now, assigning **AnalyticConcept** as its parent.

```
1 @ServiceProvider(service = SchemaConcept.class)
2 public class PandemicConcept extends SchemaConcept {
3     @Override
4     public String getName() {
5         return "Pandemic";
6     }
7
8     @Override
9     public Set<Class<? extends SchemaConcept>> getParents() {
10         final Set<Class<? extends SchemaConcept>> parentSet = new HashSet<>();
11         parentSet.add>AnalyticConcept.class);
12         return Collections.unmodifiableSet(parentSet);
13     }
14 }
```

### 3.2.2: Building a Schema Attribute

Schema attributes can be built using the builder pattern available to the **SchemaAttribute** class, making it easy to see what aspects of an attribute can be modified. Note that once a schema attribute has been built it is immutable.

Build an outbreak schema attribute in the **PandemicConcept** class, setting its type to ‘string’ for now. Note that we have placed our schema attribute within the static inner class **VertexAttribute**. This is not required but is a convenient way to group attributes and types for ease of use later.

```
1 public static class VertexAttribute {
2     ...
3     public static final SchemaAttribute OUTBREAK = new
4         SchemaAttribute.Builder(GraphElementType.VERTEX,
5             StringAttributeDescription.ATTRIBUTE_NAME, "Outbreak")
6         .setDescription("An outbreak consisting of one or more diseases and their influence")
7         .create()
8         .build();
9 }
```

You also need to build a population schema attribute. Take some time to look over the properties which can be set using the schema attribute builder.

### 3.2.3: Registering Schema Attributes

Once you have one or more schema attributes, you should register them with your concept by overriding the **getSchemaAttributes** method. Register your outbreak schema attribute to the **PandemicConcept** class.

```
1 @Override
2 public Collection<SchemaAttribute> getSchemaAttributes() {
3     final List<SchemaAttribute> schemaAttributes = new ArrayList<>();
4     ...
5     schemaAttributes.add(VertexAttribute.OUTBREAK);
6     return Collections.unmodifiableCollection(schemaAttributes);
7 }
```

Once your concept is complete, don’t forget that you will need to register it to a schema before you will be able to make use of it within Constellation. In this example, since we set the parent concept of our pandemic concept to the analytic concept, and have registered the analytic concept with our pandemic schema, the pandemic concept will be included automatically. Observe your new attribute in action by launching Constellation and observing your new attribute in the Attribute Editor.

## Exercise 3.3: Outbreak Attribute, Part 2

It is often useful to store more complex Java objects on the graph, allowing more specialised functionality. Since our outbreak attribute is holding information about a set of diseases and the population affected by each, it would make more sense to store this data in a Map, and to provide helpful methods for manipulating the data. For this exercise we will be making use of the ‘Outbreak’ class we have provided.

### 3.3.1: Defining a New Attribute Type

In order to use the ‘Outbreak’ object as a Constellation attribute, we need to describe how it fits into the attribute framework; this is done using the **AttributeDescription** class. An attribute description defines how this object should be written to and retrieved from memory. Since our attribute will be managing an object (as opposed to a primitive type), we can make use of the simplified **AbstractObjectAttributeDescription** class, which severely decreases the number of operations we have to define. Open and examine the **OutbreakAttributeDescription** class.

```
1 @ServiceProvider(service = AttributeDescription.class)
2 public class OutbreakAttributeDescription extends AbstractObjectAttributeDescription {
3     public static final String ATTRIBUTE_NAME = "outbreak";
4     public static final Class<?> NATIVE_CLASS = Outbreak.class;
5     public static final Outbreak DEFAULT_VALUE = null;
6     public OutbreakAttributeDescription() {
7         super(ATTRIBUTE_NAME, NATIVE_CLASS, DEFAULT_VALUE);
8     }
9 }
```

```

8     }
9 }

```

An attribute description will typically store and manage an array of attribute values where each index within the array will represent an element on the graph with the equivalent id. For our **OutbreakAttributeDescription** class, this will be an array of **Outbreak** objects which is actually defined in the super class as `data[]`. While we still have the option to override any of the methods for managing this array defined by an attribute description, the only functionality we are required to define using this simplified sub-class is how to store and retrieve this object as a string value. The **Outbreak** class contains **toString** and **valueOf** methods for converting to and from a string, so have a go at using these to complete the attribute description.

```

1 @Override
2 public void setString(final int id, final String value) {
3     data[id] = Outbreak.valueOf(value);
4 }
5
6 @Override
7 public String getString(final int id) {
8     return data[id] == null ? null : data[id].toString();
9 }

```

Now we should go back to the **PandemicConcept** class and redefine the existing outbreak schema attribute as an outbreak type attribute instead of a string type attribute.

```

1 public static class VertexAttribute {
2     ...
3     public static final SchemaAttribute OUTBREAK = new
4         SchemaAttribute.Builder(GraphElementType.VERTEX,
5             OutbreakAttributeDescription.ATTRIBUTE_NAME, "Outbreak")
6             .setDescription("An outbreak consisting of one or more diseases and their influence")
7             .create()
8             .build();
9 }

```

Now if you run Constellation, right click on your Outbreak attribute in the Attribute Editor and choose *Modify Attribute*, you should see its type set as “outbreak”. You might also notice that you cannot edit this attribute; we’ll address this later.

### 3.3.2: Defining Attribute IO

Since this is a brand new attribute type, we will also need to define how to save and load any data of this type to disk; this is done using the **AbstractGraphIOProvider** class. Before we do this, try opening and saving a Pandemic Graph in Constellation, and observing how the outbreak information is lost. Now open and complete the **OutbreakIOProvider** class.

```

1 @ServiceProvider(service = AbstractGraphIOProvider.class)
2 public class OutbreakIOProvider extends AbstractGraphIOProvider {
3
4     @Override
5     public String getName() {
6         return OutbreakAttributeDescription.ATTRIBUTE_NAME;
7     }
8 }

```

Constellation .star files store the graph as compressed JSON, so our IO provider should define how to write ‘Outbreak’ attributes in the JSON format, and how to read the resulting JSON data back into an ‘Outbreak’ attribute type.

```

1 @Override

```

```

2 public void readObject(final int attributeId, final int elementId, final JsonNode jnode, final
    GraphWriteMethods graph,
3     final Map<Integer, Integer> vertexMap, final Map<Integer, Integer> transactionMap,
4     final GraphByteReader byteReader, final ImmutableObjectCache cache) throws IOException
    {
5     final String attributeValue = jnode.isNull() ? null : jnode.textValue();
6     graph.setStringValue(attributeId, elementId, attributeValue);
7 }
8
9 @Override
10 public void writeObject(final Attribute attribute, final int elementId, final JsonGenerator
    jsonGenerator,
11     final GraphReadMethods graph, final GraphByteWriter byteWriter, final boolean verbose)
    throws IOException {
12     if (verbose || !graph.isDefaultValue(attribute.getId(), elementId)) {
13         final String attributeValue = graph.getStringValue(attribute.getId(), elementId);
14         if (attributeValue == null) {
15             jsonGenerator.writeNullField(attribute.getName());
16         } else {
17             jsonGenerator.writeStringField(attribute.getName(), attributeValue);
18         }
19     }
20 }

```

Try opening and saving a Pandemic Graph in Constellation again and observe that it no longer fails.

## Schema Types

The final function we want our schema to assist users with is understanding the types of data that the schema deals with. Similar to attributes, types can be used in special ways by views or plugins within Constellation, so it is a good idea to register them to a schema if we want this ability.

## Exercise 3.4: City and Flight Types

For our scenario, we have decided that the best way to visualise the spread of disease is to connect cities by the flights connecting them. This means we should create a 'city' node type and a 'flight' transaction type and register these types to our schema. This is where **schema types** come into play.

### 3.4.1: Building a Schema Type

A vertex type can be created using a builder on the **SchemaVertexType** class, making it easy to see what aspects of a vertex type can be modified. Note that once a type has been built, it is immutable. Let's go ahead and build a 'city' vertex type for **PandemicConcept**.

```

1 public static class VertexType {
2     public static final SchemaVertexType CITY = new SchemaVertexType.Builder("City")
3         .setDescription("A node representing a city, eg. Canberra, Australia.")
4         .setColor(ConstellationColor.CLOUDS)
5         .setForegroundIcon>AnalyticIconProvider.GLOBE)
6         .setBackgroundIcon(IconManager.getIcon("Flat Square"))
7         .build();
8 }

```

Creating a transaction type involves a very similar process. Let's go ahead and build a 'flight' transaction type for **PandemicConcept**.

```

1 public static class TransactionType {
2     public static final SchemaTransactionType FLIGHT = new
        SchemaTransactionType.Builder("Flight")

```



```

3     .setDescription("A flight route connecting two locations.")
4     .setColor(ConstellationColor.BANANA)
5     .build();
6 }

```

Take some time to look over the properties which can be set using the vertex type and transaction type builders.

### 3.4.2: Registering Schema Types

In order for our schema to make use of these types, we will need to register them to **PandemicConcept**.

```

1 @Override
2 public List<SchemaVertexType> getSchemaVertexTypes() {
3     final List<SchemaVertexType> schemaVertexTypes = new ArrayList<>();
4     schemaVertexTypes.add(VertexType.CITY);
5     return Collections.unmodifiableList(schemaVertexTypes);
6 }
7
8 @Override
9 public List<SchemaTransactionType> getSchemaTransactionTypes() {
10    final List<SchemaTransactionType> schemaTransactionTypes = new ArrayList<>();
11    schemaTransactionTypes.add(TransactionType.FLIGHT);
12    return Collections.unmodifiableList(schemaTransactionTypes);
13 }

```

Now if you run Constellation and run the ‘Import Infected Cities’ plugin again, your City nodes should have the icons and colour we specified.

## Exercise 3.5: Biohazard Icon

It’s likely that if you go to the effort of creating your own schema, you will also want some icons to differentiate it from the others. Adding built-in icons to Constellation is just as simple as adding attributes or types, so let’s try adding an icon now.

### 3.5.1: Building an Icon Provider

Before we build an icon, we should create an **IconProvider**. Open **PandemicIconProvider**; it should look something like this:

```

1 @ServiceProvider(service = ConstellationIconProvider.class)
2 public class PandemicIconProvider implements IconProvider {
3     ...
4 }

```

### 3.5.2: Building a Constellation Icon

Now we can add an icon to this icon provider using the builder on the **ConstellationIcon** class. This builder will require you to define the icon using an implementation of the **IconData** class. In this example we will use the **FileIconData** to load a PNG file from the codebase, but it is worth noting that several other **IconData** implementations exist for loading icons in different ways.

```

1 public static final ConstellationIcon BIOHAZARD = new ConstellationIcon.Builder("Biohazard",
2     new FileIconData("modules/ext/biohazard.png", "au.gov.asd.tac.Constellation.training"))
3     .addCategory("Training")
4     .build();
5
6 @Override
7 public List<ConstellationIcon> getIcons() {
8     final List<ConstellationIcon> pandemicIcons = new ArrayList<>();

```



```

9     pandemicIcons.add(BIOHAZARD);
10    return Collections.unmodifiableList(pandemicIcons);
11 }

```

**TIP:** The **FileIconData** class makes use of NetBeans **InstalledFileLocator** service internally. This allows you to safely look-up a file resource with reference to a module, which can be extremely useful as NetBeans will often move files during a build.

### 3.5.3: Setting an Icon

Finally, we should set this icon wherever we wish to use it; in this case we will use it to represent our pandemic schema. Override the **getIconSymbol** method on **PandemiSchemaFactory** to achieve this.

```

1 @Override
2 public ConstellationIcon getIconSymbol() {
3     return PandemicIconProvider.BIOHAZARD;
4 }

```

Try creating a new icon yourselves and adding it to the ‘City’ schema type. This will involve building a new **ConstellationIcon**, and setting it as the icon for the ‘City’ vertex type you created earlier.

Now that we have our own schema designed around the pandemic scenario, try running the ‘Import Infected Cities’ plugin again and observe the results.

## Chapter 4: Advanced Data Access

In Chapter 2, we implemented a fully functional Data Access Plugin that imported all the cities that are currently experiencing an outbreak. However, there are several additional aspects of a plugin’s execution that we left out:

1. **Plugin parameters:** in most cases, a plugin will require configuration from the user before it executes, such as time ranges. Plugin parameters provide a simple way for plugins to request common configuration values from the user such as strings, numbers, times and dates, with various entry methods such as text boxes and choice boxes.
2. **Plugin interaction:** during its execution, a plugin has the option to interact with the user, either by providing feedback or requesting additional input.
3. **Error handling:** if something goes wrong while a plugin is running, Constellation provides simple mechanisms to alert the user, and modifications made by the plugin as it is rolled-back.
4. **Interruption:** Constellation provides a consistent mechanism that allows the user to cancel a plugin’s execution and roll-back any changes the plugin has made.
5. **Plugin Registry:** Constellation’s global registry of all plugins in the application that enables a plugin to find and execute other plugins during its execution.
6. **Logging:** Constellation provides inbuilt logging that records the execution of each plugin, including start/stop times and any parameters that have been passed to the plugin. The logging framework can be extended to send the logging events to custom destinations. This will be further explored in Chapter 8.

In this chapter, we will implement two new plugins that will make use of each of these features. The first will use plugin parameters to allow the user to import a custom list of cities while the second will allow the user to find flights connecting the selected cities on their graph, adding the new flights and connecting cities to their graph.

### Exercise 4.1: Import Custom Cities Plugin

The Import Custom Cities Plugin will behave similarly to the Import Infected Cities we developed in Chapter 2, except that it will allow the user to choose which cities to import. To do this, we will add a parameter to our plugin providing a text box in which the user can enter the cities they are interested in, one on each line. To ease development, we will begin with a skeleton class in the chapter4 package of the Training Exercises module. Within this package, locate and open the **ImportCustomCitiesPlugin** class, noting that many of the steps you performed

in Chapter 2 have been already included. Add this plugin to the **PandemicPluginRegistry** following the same method as shown in Chapter 2 for the **ImportInfectedCitiesPlugin**. Note that the service provider annotations have been commented out to prevent the plugin from being loaded in Constellation before now. These should be uncommented.

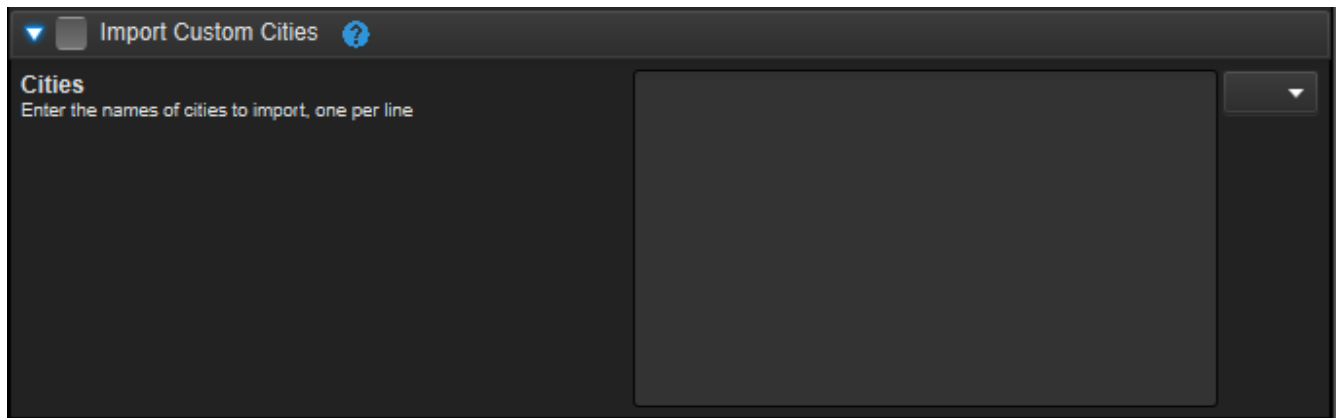
#### 4.1.1: Adding a Parameter

To add parameters to a plugin, you will need to implement the **createParameters()** method on your **Plugin** class. Do this now, adding the following code to your class:

```
1 private static final String CITIES_PARAMETER_ID =
    PluginParameter.buildId(ImportCustomCitiesPlugin.class, "cities");
2
3 @Override
4 public PluginParameters createParameters() {
5     final PluginParameters parameters = new PluginParameters();
6
7     final PluginParameter<StringParameterValue> citiesParameter =
        StringParameterType.build(CITIES_PARAMETER_ID);
8     citiesParameter.setName("Cities");
9     citiesParameter.setDescription("Enter the names of cities to import, one per line");
10    StringParameterType.setLines(citiesParameter, 10);
11    parameters.addParameter(citiesParameter);
12
13    return parameters;
14 }
```

This method adds a single string parameter to our plugin, specifying that the value should be edited in a text box with 10 lines. We also specify a label and brief description that will be displayed to the user. Notice that some configuration of plugin parameters is not performed on the parameter itself, but rather through static methods on the **PluginParameterType**. Note also that each parameter is created with an ID value that should be unique within the application and will be used later to get the parameter when the plugin is running. By convention, we ensure uniqueness by prefixing the ID with the class name. There are many other parameter types such as **BooleanParameterType**, **IntegerParameterType** and **DateTimeRangeParameterType**. Consult the Constellation Javadoc on usage of these types.

If you compile and run Constellation now, you will see the Import Custom Cities plugin alongside the Import Infected Cities plugin in the Data Access View. Expanding the plugin's parameter pane will reveal our cities parameter which can be filled in:



You can now enter in city names but running the plugin will cause no effect because we have not modified our query method to use the values entered into our new parameter.

#### 4.1.2: Modify the query method to use the user entered city names

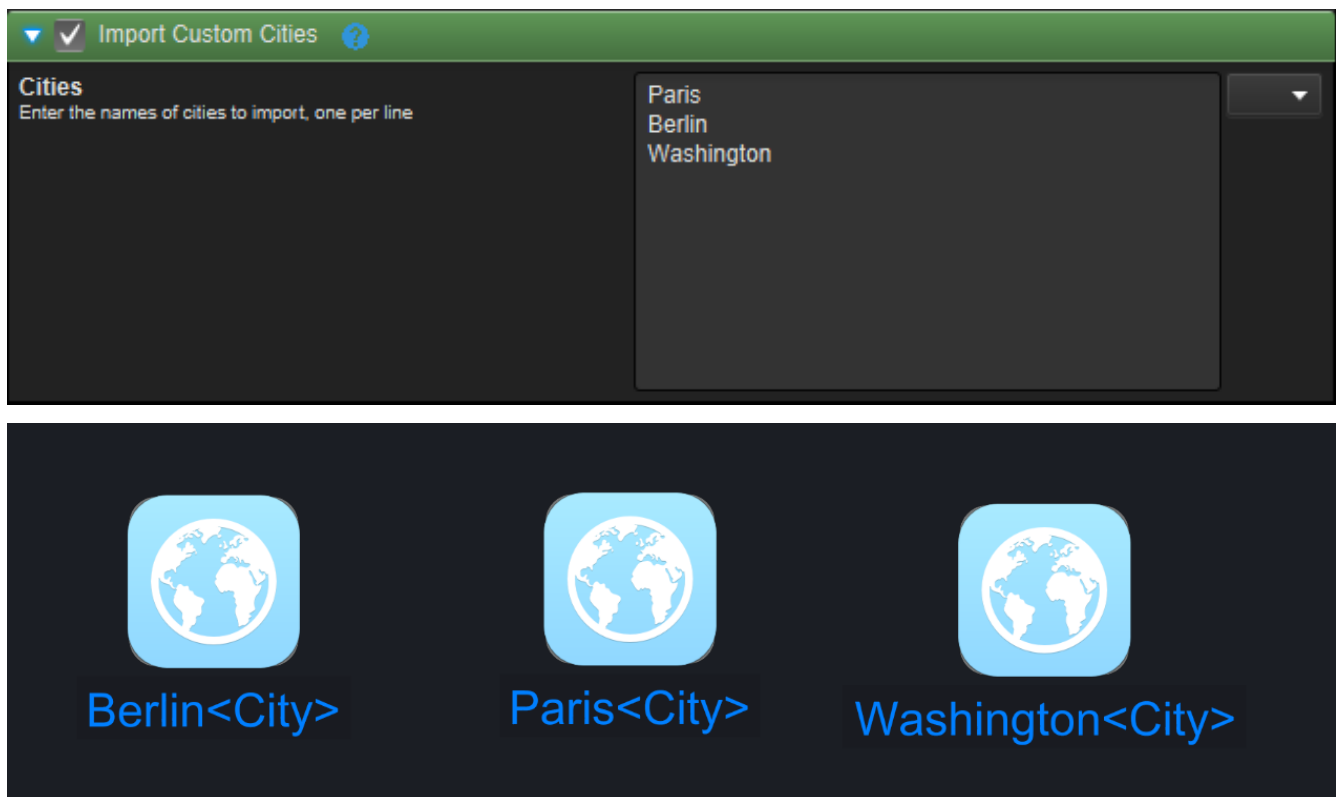
```

1 @Override
2 protected RecordStore query(final RecordStore query, final PluginInteraction interaction,
3     final PluginParameters parameters) throws InterruptedException, PluginException {
4     final RecordStore result = new GraphRecordStore();
5
6     final String citiesString = parameters.getStringValue(CITIES_PARAMETER_ID);
7     final String[] cityNames = citiesString.split("\n", -1);
8
9     for (final String cityName : cityNames) {
10         final OutbreakUtilities.City city = OutbreakUtilities.getCity(cityName);
11         result.add();
12         OutbreakUtilities.addCityToRecord(city, result, GraphRecordStoreUtilities.SOURCE);
13     }
14     return result;
15 }

```

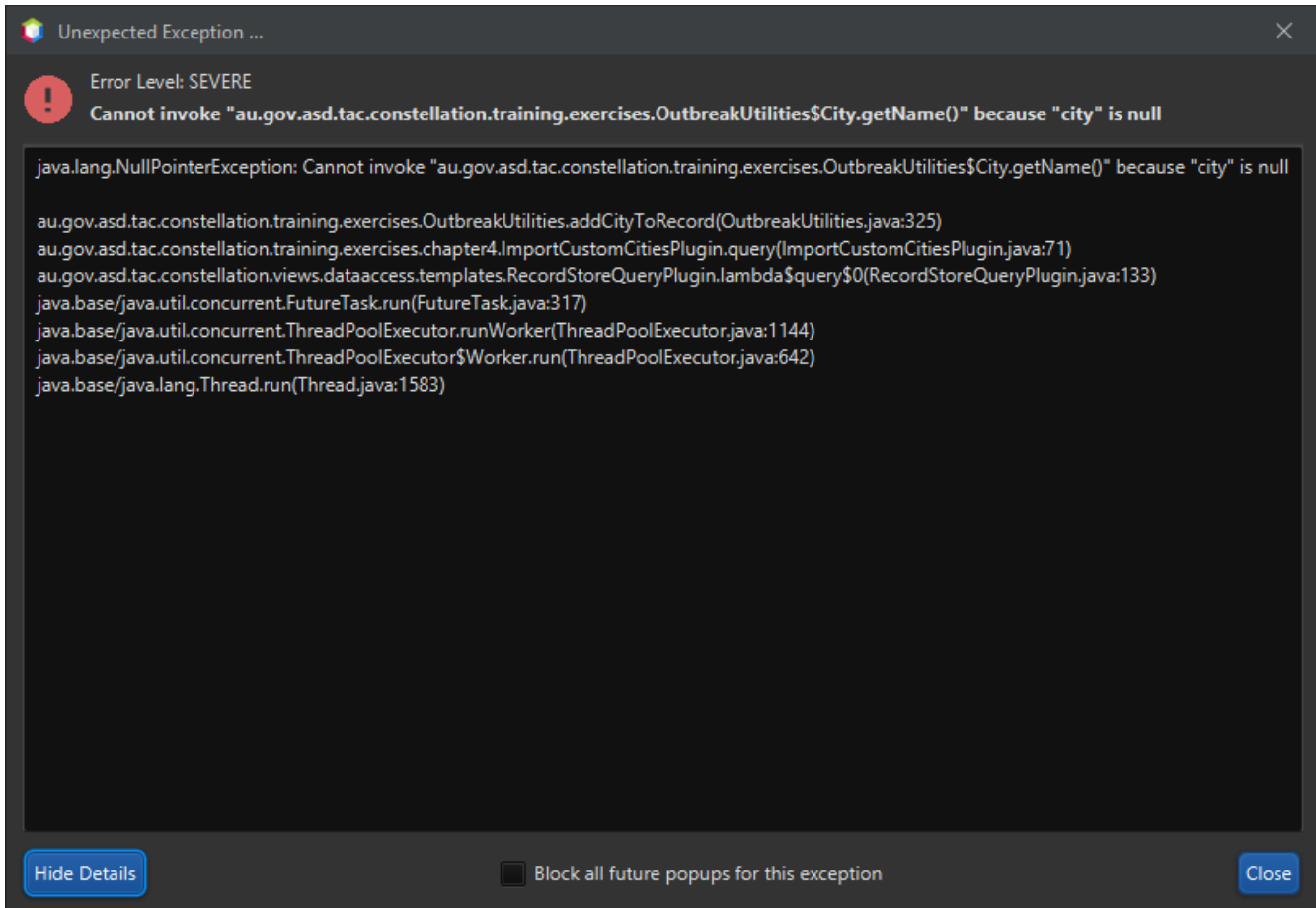
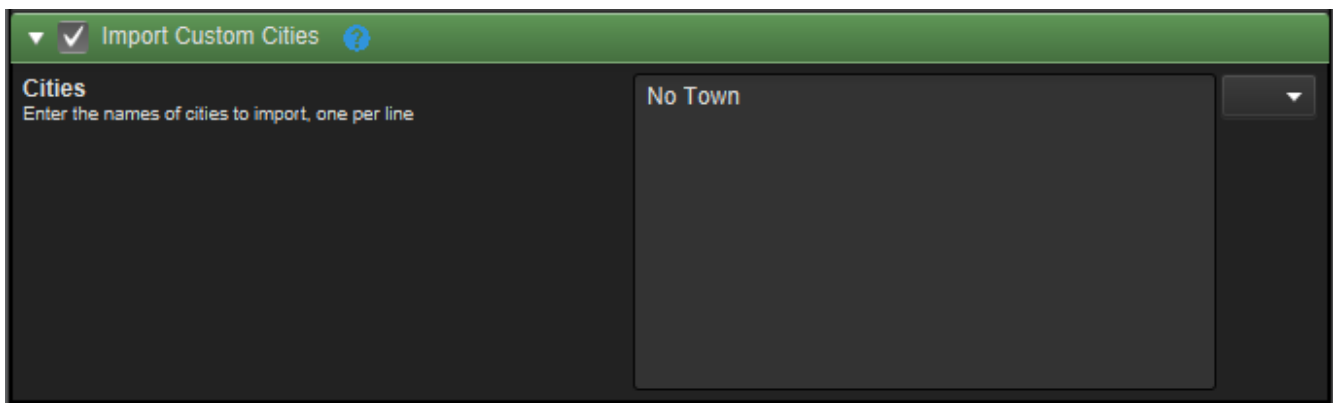
The query method now retrieves the user entered string from its parameter using the parameter ID as a key, splits the string on newline characters to get the individual city names and uses another access helper method to get the attributes for that city. The remaining code is similar to the previous plugin.

Compile and run Constellation to demonstrate that the plugin now adds the correct city nodes to the graph based on the user input.



#### 4.1.3: Handling Errors

What happens if the user enters a city name that is not in our dataset? We have implemented the helper function to return null which will cause a **NullPointerException** to be thrown. Luckily, Constellation will handle exceptions thrown from a plugin by rolling back any changes the plugin has made and presenting the exception stack trace in a dialog:



While this works and will protect the data integrity of the graph, Constellation provides a more elegant way of handling errors by using the **PluginException** class. Add a null check to your query method:

```
1 for (final String cityName : cityNames) {
2     final OutbreakUtilities.City city = OutbreakUtilities.getCity(cityName);
3     if (city == null) {
4         throw new PluginException(PluginNotificationLevel.WARNING, "Unknown City: " +
5             cityName);
6     }
7     ...
8 }
```

Throwing a **PluginException** from your plugin allows you to customise the way in which Constellation responds to the error. Depending on the **PluginNotificationLevel** specified, Constellation will respond in different ways:

1. *FATAL, ERROR*: A dialog box is displayed describing the error
2. *WARNING*: A notification bubble is displayed describing the error
3. *INFO*: A status message is displayed describing the error
4. *DEBUG*: The user is not informed and a line is sent to the default log.

Attempting to add a missing city will now display a notification in the bottom right corner of the Constellation window. Try setting different notification levels and see what effect that has on the user experience.

## 4.2: Chain Cities Plugin

The second plugin we will implement in this chapter is the **ChainCitiesPlugin** which will find all flights into or out of the selected cities in your graph and add them as new transactions, along with their source and destination cities, if they do not already exist in the graph. Again, we will begin with a skeleton class that already implements the basics to give ourselves a head start. Open the **ChainCitiesPlugin** class in the Chapter 4 package of the Training Exercises to begin. As always, remember to add this plugin to the **PandemicPluginRegistry** and uncomment the service provider annotations.

During the read stage, a **RecordStoreQueryPlugin** collects relevant selected graph elements from the graph and adds them to a **RecordStore**, along with all known attributes for each element. This **RecordStore** is passed to the query method through the query **RecordStore** in its parameters. By default, all selected nodes are included but other options can be specified by overriding the `getRecordStoreType()` method. For instance, all selected transactions could be returned by:

```
1 @Override
2 public String getRecordStoreType() {
3     return GraphRecordStoreUtilities.TRANSACTION;
4 }
```

We will not override this method as we need the default behaviour.

### 4.2.1: Read the query RecordStore

Our plugin will get the currently selected nodes from the graph by using the default behaviour of the **RecordStoreQueryPlugin** and reading the rows of the query **RecordStore**. To begin with, modify our query method to print the name of each city to the console.

```
1 @Override
2 protected RecordStore query(final RecordStore query, final PluginInteraction interaction,
3     final PluginParameters parameters) throws InterruptedException, PluginException {
4     final RecordStore result = new GraphRecordStore();
5     query.reset();
6     while (query.next()) {
7         final String cityName = query.get(GraphRecordStoreUtilities.SOURCE +
8             VisualConcept.VertexAttribute.IDENTIFIER);
9         System.out.println(cityName);
10    }
11    return result;
12 }
```

A **RecordStore** has an inbuilt row pointer that makes accessing its rows in order more convenient, so the first thing the new query method does is reset the pointer to just before the first record. This allows an elegant iteration over all the records as shown. At each row, the identifier attribute is read and printed to standard out. If you build and run Constellation at this point, the plugin will print all selected city names to the console.

### 4.2.2: Adding Flights

The next step is to perform a query for each selected city and add the resulting flights to the graph:

```

1 @Override
2 protected RecordStore query(final RecordStore query, final PluginInteraction interaction,
3     final PluginParameters parameters) throws InterruptedException, PluginException {
4     final RecordStore result = new GraphRecordStore();
5     query.reset();
6
7     while (query.next()) {
8         final String cityName = query.get(GraphRecordStoreUtilities.SOURCE +
9             VisualConcept.VertexAttribute.IDENTIFIER);
10        for (final OutbreakUtilities.Flight flight : OutbreakUtilities.getFlights(cityName)) {
11            final City source = flight.getSource();
12            final City destination = flight.getDestination();
13            result.add();
14
15            OutbreakUtilities.addCityToRecord(source, result,
16                GraphRecordStoreUtilities.SOURCE);
17            result.set(GraphRecordStoreUtilities.TRANSACTION +
18                TemporalConcept.TransactionAttribute.DATETIME,
19                flight.getDepartureTime());
20            OutbreakUtilities.addCityToRecord(destination, result,
21                GraphRecordStoreUtilities.DESTINATION);
22        }
23    }
24    return result;
25 }

```

By now you should find the new code familiar as it follows the same pattern we used in Chapter 2 to add transactions to the graph. As each city is read from the query **RecordStore**, we use another convenience method in the **OutbreakUtilities** class to find all flights leaving or departing that city. With that information, we add a new row to the result **RecordStore**, including the departing city as the source node, the destination city as the destination node, and the flight itself as the transaction between them. Notice how we did not need to de-duplicate the city nodes as Constellation will do this for us based on the schema's attribute keys.

As with cities, adding flights to a **RecordStore** is such a common occurrence that **OutbreakUtilities** provides a convenience method for this also:

```

1 ...
2 for (final OutbreakUtilities.Flight flight : OutbreakUtilities.getFlights(cityName)) {
3     result.add();
4     OutbreakUtilities.addFlightToRecord(flight, result);
5 }
6 ...

```

Note: The above code replaces the **entire** for loop from previous code snippet.

#### 4.2.3: Add Plugin Interaction

Constellation provides mechanisms by which the plugin can provide real-time progress and feedback to the user as it executes. In this section, we will use these mechanisms to provide a simple progress bar display along with a status message that will update as each city is processed.

```

1 Modify your ChainCitiesPlugin.query() method:
2 ...
3
4 final RecordStore result = new GraphRecordStore();
5 int currentStep = 0;
6 query.reset();
7
8 while (query.next()) {

```

```

9     final String cityName = query.get(GraphRecordStoreUtilities.SOURCE +
    VisualConcept.VertexAttribute.IDENTIFIER);
10     interaction.setProgress(currentStep++, query.size(), "Processing: " + cityName, true);
11 ...

```

As we process each city, we call `setProgress(...)` on the provided **PluginInteraction** object. This allows us to both pass a progress value in the form of current step and total steps, as well as a simple status message.

**TIP:** Constellation provides an inbuilt mechanism that will interrupt the execution of a plugin and revert any changes that plugin has made to the graph. A plugin can request that this happens by throwing an **InterruptedException** at any time in its execution. In addition, Constellation can request a plugin cancels its execution by setting the interrupt flag on its thread. It is the responsibility of the plugin to periodically check this flag, especially during long-running tasks, and throw an **InterruptedException** if it finds that this flag is set. As it is also good practice to provide progress updates to the user during these long running tasks, the `setProgress(...)` method will check the interrupt flag and throw the required exception for you, preventing the need to check the flag manually. This means, that by regularly updating the plugins progress as shown above, the plugin is automatically cancellable. This check is enabled by specifying `true` as the last parameter to `setProgress(...)`.

Build and run Constellation and observe the progress bar and status message in the bottom left corner as the plugin runs.

#### 4.2.4: Datetime Range Parameters

Many data access plugins limit their queries to user defined time ranges and the **ChainCitiesPlugin** should be no exception. To do this, we need to add a datetime range parameter to our plugin by implementing the `createParameters()` method, similar to our **ImportCustomCitiesPlugin**:

```

1 @Override
2 public PluginParameters createParameters() {
3     final PluginParameters parameters = new PluginParameters();
4
5     final PluginParameter<DateTimeRangeParameterType.DateTimeRangeParameterValue> datetime
6         = CoreGlobalParameters.DATETIME_RANGE_PARAMETER;
7     parameters.addParameter(datetime);
8     return parameters;
9 }

```

A significant difference this time is that we have used a globally defined parameter (with its own globally defined parameter ID), instead of creating our own as we did in the **ImportCustomCitiesPlugin**. Previously, we wanted to make our parameter ID unique so that it did not clash with other parameters in the application. In this case, we want to match the parameter ID of other data access plugins that specify a datetime range parameter. This will allow the Data Access View to present this parameter only once instead of making the users enter in the same values multiple times.

Run Constellation now and see that the datetime range parameter has not appeared under our plugin's heading. However, our plugin will have access to the parameter displayed at the top of the Data Access View.

There is nothing wrong with specifying a unique ID for your own datetime range parameters. This will cause your plugin to create its own parameter in the user interface and will allow your users to specify a datetime range independently of the main value. However, in most cases, the behaviour we have created here is preferred.

Finally, we need to make use of the datetime range in our query method. For this we use another **OutbreakUtilities** helper method that accepts a start and end time and only returns flights where the departure time falls within this range. Add the following to the top of our existing query method:

```

1 final DateTimeRange datetimeRange =
    parameters.getDateTimeRangeValue(CoreGlobalParameters.DATETIME_RANGE_PARAMETER_ID);
2 final long startTime = datetimeRange.getZonedStartEnd()[0].toInstant().toEpochMilli();
3 final long endTime = datetimeRange.getZonedStartEnd()[1].toInstant().toEpochMilli();
4

```



```

5 Now adjust our call to getFlights(...) to use the version that that
6 takes a time range:
7
8 for (final OutbreakUtilities.Flight flight : OutbreakUtilities.getFlights(cityName, startTime,
    endTime)) {

```

Running your plugin now will show that the datetime range entered in the global Data Access View parameters will be used to filter the flights that are returned.

#### 4.2.5: Plugin Registry

Constellation keeps a registry of every plugin available in the application. By querying the registry, you can find out which plugins are available and access various properties of each plugin including its name, description and the parameters it requires. You are also able to create an instance of a plugin and run it. In the current iteration of our **ChainCitiesPlugin**, we add new nodes and transaction to the graph with no attention to the layout of our expanded graph. In this section, we will make use of the plugin registry to run a layout algorithm on the newly added content.

While it may be tempting to simply add code to the end of our query method that will cause an arrangement to occur, recall that the query method is only responsible for adding the new content to a **RecordStore** and not for actually adding that content to the graph. This process is handled by the **RecordStoreQueryPlugin** parent class and does not occur until the edit method is run. If the arrangement was to occur in the query method, the new content would not be included.

**RecordStoreQueryPlugin** implements the **edit(...)** method from **SimpleQueryPlugin** in order to add content to the graph. This means that we can also add functionality at this time by doing the same:

```

1 @Override
2 protected void edit(final GraphWriteMethods wg, final PluginInteraction interaction,
3     final PluginParameters parameters) throws InterruptedException, PluginException {
4     super.edit(wg, interaction, parameters);
5
6     final Plugin deselectAllPlugin =
7         PluginRegistry.get(VisualGraphPluginRegistry.DESELECT_ALL);
8     final Plugin treesPlugin = PluginRegistry.get(ArrangementPluginRegistry.TREES);
9     final Plugin resetPlugin = PluginRegistry.get(InteractiveGraphPluginRegistry.RESET_VIEW);
10
11     PluginExecution.withPlugin(deselectAllPlugin).executeNow(wg);
12     PluginExecution.withPlugin(treesPlugin).executeNow(wg);
13     PluginExecution.withPlugin(resetPlugin).executeNow(wg);
14 }

```

The new implementation of **edit(...)** performs 3 tasks:

1. Firstly, it calls its parent's implementation which will cause the new content to be added to the graph.
2. Secondly, it queries the **PluginRegistry** for the tree arrangement plugin. By convention, each module that contributes plugins to Constellation provides a registry class that contains static plugin names for each plugin they provide. Look at the documentation for **ArrangementRegistry** to see how this is done. By including a **@ServiceProvider** annotation on your plugin class, your plugin is also included in the registry and can be run by other plugins.
3. Finally, the plugin is run on the current thread, using the write lock that has already been granted to our plugin. There are several modes in which a plugin can be run, including those that run the plugin on the current thread (**executeNow(...)**) or on another thread (**executeLater(...)**). There are also options that allow you to pass through an existing graph lock, or allow the called plugin to gain its own lock. These options will be explored in more detail in Chapter 6.

In situations like this, where a plugin is to be called with no options, **PluginExecution** provides a more convenient syntax that looks up the plugin and executes it in one line:



```
1 PluginExecution.withPlugin(ArrangementPluginRegistry.TREES).executeNow(wg);
```

## Chapter 5: Analytic Plugins

In the previous chapter we explored some of the extra features of data access plugins, that are concerned with reading data from and writing to the graph using a **RecordStore**. This pattern works well for data access plugins, but to perform analytics on your data it is a bit limiting. In this chapter we will look at using the graph API directly, examine some different plugin templates, study methods of executing plugins within plugins, and write a NetBeans **Action** that allows a plugin to be run from Constellation's menu (rather than the data access view).

**TIP:** For the remainder of this tutorial, when testing plugins and other extensions, it is recommended to use the graph we produced by running Import Custom cities, followed by Chain Cities. Please run these plugins and save the graph.

### The Graph API

Until now we have been reading from and writing to the graph indirectly. Constellation also has a rich API to interact directly with the graph. The API makes a clear distinction between reading and writing for the purposes of locking and integrity of the graph

Two interfaces, **GraphReadMethods** and **GraphWriteMethods**, provide all the standard operations for interacting with a graph. **GraphWriteMethods** extends **GraphReadMethods** so that anything you can do while reading, you can also do while writing. Objects implementing these interfaces are given to you in the **SimpleReadPlugin** and **SimpleEditPlugin**, respectively.

Graph elements are stored on the graph using an integer ID. This ID is constant and unique to that graph and element type, so long as the element remains on the graph. No guarantees can be made about the ID of a vertex that was removed (whether or not it will be reused or by which vertex).

To iterate through all the IDs of vertices on the graph, for example, we could use the following loop (assuming we have a **GraphReadMethods** or **GraphWriteMethods** called graph):

```
1 for (int vertexPosition = 0; vertexPosition < graph.getVertexCount(); vertexPosition++) {
2     final int vertexId = graph.getVertex(vertexPosition);
3 }
```

This example is for vertices but similar code works for other graph elements. Graph element IDs are used by the rest of the API, so with these IDs we could now answer a question such as ‘what is the highest degree (number of neighbours) of a vertex in the graph?’

```
1 int maxDegree = 0;
2 for (int vertexPosition = 0; vertexPosition < graph.getVertexCount(); vertexPosition++) {
3     final int vertexId = graph.getVertex(vertexPosition);
4     final int degree = graph.getVertexNeighbourCount(vertexId);
5
6     if (degree > maxDegree) {
7         maxDegree = degree;
8     }
9 }
```

In the above code, maxDegree will hold the maximum degree at the end of the loop. The method **getVertexNeighbourCount()** is answering a question about the graph structure. We could also use vertexId to perform an attribute based operation, such as setting the vertex's population, but for this we also need the ID of the population attribute on the graph. We can get this from the attribute itself in the relevant **SchemaConcept**.

```
1 final int populationAttributeId = PandemicConcept.VertexAttribute.POPULATION.get(graph);
2 final int population = graph.getIntValue(populationAttributeId, vertexId);
3 graph.setIntValue(populationAttributeId, vertexId, population + 1000);
```

The above code sets the value of the population attribute for the node with ID vertexId to 1000 more than its previous value. Note that we use `getIntValue()` and `setIntValue()` because we know that population is an integer attribute. There are analogous operations for getting and setting other primitive values, and strings. When none of these apply, `setObjectValue()` and `getObjectValue()` should be used.

There is a lot more to the graph API, but that covers the basics. We will continue to use it as we write plugins in this chapter, but you should refer to the JavaDoc should you wish to know more. When using the graph API, be mindful of the following:

- Always remember to use the ID of graph elements when getting/setting attributes or structural properties. Don't expect them to ever be in the same order when iterating.
- Never add or remove graph elements whilst iterating through that element on the graph. This will mess up the IDs. Instead, store a list of things to add/remove and do it after the loop.
- Attribute values should be immutable. Remember this when implementing your own types of attributes. This means when you set an attribute value on the graph you will often be making a new object.
- Whenever you try and get the ID of an attribute, if it doesn't exist on the graph, the value `GraphConstants.NOT_FOUND` will be returned. This is an integer (-1107) that is easy to distinguish from other legitimate IDs, hence should you see this value in debug or an `ArrayIndexOutOfBoundsException`, you will know what the problem is.

### Simple Plugin Templates

In chapter 2, the concept of plugin templates was introduced, and it was explained that the templates represent a lifecycle of interacting with the graph, and handle the locking, logging and parameter handling throughout that lifecycle. You wrote a `RecordStoreQueryPlugin` template in that chapter, a fairly high level template tailor made to read and query data using Constellation's `RecordStore` format. For interacting with the graph at a more rudimentary level, a number of 'simple' plugin templates exist:

- **SimpleReadPlugin** – A plugin template for reading from the graph. Manages a read lock on the graph.
- **SimpleEditPlugin** – A plugin template for writing to the graph. Manages a write lock on the graph. Note that write locks also allow reading from the graph.
- **SimpleQueryPlugin** – A Plugin template with the same lifecycle as `RecordStoreQueryPlugin`, but data format agnostic – no data is passed between the stages of the lifecycle. For performing queries where you need to use your own custom data structures.
- **SimplePlugin** – Performs no locking, allows a single `execute()` method to be overwritten. Usually you should use `SimpleReadPlugin` or `SimpleEditPlugin` in preference to this template, unless you need control over graph locking, or need a plugin that doesn't read or write to the graph at all.

The most commonly used of the above four is the `SimpleEditPlugin`, which we will be using to implement analytics in this chapter.

## Exercise 5.1: Percentage of population afflicted plugin

In this exercise we will write a `SimpleEditPlugin` to calculate the percentage of the population afflicted with a given disease for each city on the graph. Open `PercentageAfflictedPlugin` from chapter 5 of the exercises module.

### 5.1.1: Create the parameters

We need a parameter to allow the user to enter the disease that they wish to analyse. This could be a string parameter, but a drop-down list of diseases would be even nicer. We can build such a parameter using `SingleChoiceParameterType`. Add the following code to the `createParameters()` method to achieve this:

```
1 final PluginParameters parameters = new PluginParameters();
2 final PluginParameter diseaseParameter = SingleChoiceParameterType.build(DISEASE_PARAMETER_ID);
3 diseaseParameter.setName(DISEASE_PARAMETER_LABEL);
4 parameters.addParameter(diseaseParameter);
5 return parameters;
```

### 5.1.2: Updating the parameters

You might notice that in the above code we don't set the options for the diseases. In previous plugins we have done all parameter configuration the `createParameters()` method. However we would like our drop-down to be populated with a list of diseases currently on the graph, and to do this we need reference to the graph. Luckily we can implement the method to do this – it is run after parameter creation, but before the parameters are presented to the user.

```
1 @Override
2 public void updateParameters(final Graph graph, final PluginParameters parameters) {
3
4     final Set<String> diseases = new HashSet<>();
5     final ReadableGraph readableGraph = graph.getReadableGraph();
6     try {
7         ...
8     } finally {
9         readableGraph.release();
10    }
11    SingleChoiceParameterType.setOptions((PluginParameter<SingleChoiceParameterType.SingleChoiceParameterV
12    parameters.getParameters().get(DISEASE_PARAMETER_ID), new ArrayList<>(diseases));
13 }
```

So this is the skeleton of the method, but we haven't actually pulled the diseases from the graph yet. You might notice that the graph parameter is of type **Graph**. This is different to the read/write methods objects we are used to seeing. A **Graph** object in and of itself has no access to the graph, but it does allow us to obtain a lock on the graph to do either reading or writing. This is the purpose of the method `getReadableGraph()`, which gives us a read lock on the graph.

**ReadableGraph** implements **GraphReadMethods**, so we have access to all the usual methods. However because we have control of the lock, we must remember to release it after we are finished with the graph. Inside the try block in the above code, loop over the vertices in the graph, retrieving each outbreak attribute value using `getObjectValue()`. Add the diseases from each outbreak to the set diseases.

All operations on a **ReadableGraph** must be called in a try block, with `readableGraph.release()` being called in the corresponding finally block. There is a corresponding **WritableGraph** object, which must also be operated on in a try block, with `writableGraph.commit()` being called in the finally. Until now, the plugin framework has been handling this work behind the scenes.

### 5.1.3: Setting up the attributes

We now need to perform the plugin logic inside the `edit` method. There are a number of things we need – the disease name the user chose, and the attribute IDs of type (to determine if nodes are cities), population and outbreak. The following code retrieves all this information from the graph and the parameters.

```
1 final String diseaseName = parameters.getStringValue(DISEASE_PARAMETER_ID);
2 final int outbreakAttributeId = PandemicConcept.VertexAttribute.OUTBREAK.get(graph);
3 final int typeAttributeId = AnalyticConcept.VertexAttribute.TYPE.get(graph);
4 final int populationAttributeId = PandemicConcept.VertexAttribute.POPULATION.get(graph);
```

**TIP:** The `get()` method used above is a shortcut for retrieving the attribute ID of a **SchemaAttribute** object from the given graph. This method will return the error code **GraphConstants.NOT\_FOUND** if the attribute does not exist on the graph. If you wish to retrieve the attribute id of an attribute which you expect might not exist on your graph, you can instead use the `ensure()` method, which will check if an attribute exists, and if not create it before returning the attribute ID.

We also need to create a new attribute to fill with the percentages of people afflicted with the given disease in each city. This is done with `addAttribute()` from **GraphWriteMethods**, which takes a **GraphElementType** representing the element you want the attribute for, the type name of the attribute, the name of the attribute, a description, and a default value. It will return the ID of the newly added attribute.

```

1 final String percentageAfflictedAttributeName = "percentage afflicted with " + diseaseName;
2
3 final int percentageAfflictedAttributeId = graph.addAttribute(GraphElementType.VERTEX,
4     FloatAttributeDescription.ATTRIBUTE_NAME, percentageAfflictedAttributeName,
5     percentageAfflictedAttributeName, 0,
6     null);

```

#### 5.1.4: Performing the calculations

We now have everything we need to actually perform our calculations and store the values on the newly created attribute. This part involves a simple iteration over vertices on the graph, retrieval of relevant attributes, and setting of the new attribute for nodes that are cities and have the disease of interest. We add the following code to complete the `edit` method.

```

1 for (int vertexPosition = 0; vertexPosition < graph.getVertexCount(); vertexPosition++) {
2     final int vertexId = graph.getVertex(vertexPosition);
3
4     if (graph.getObjectValue(typeAttributeId,
5         vertexId).equals(PandemicConcept.VertexType.CITY)) {
6         final Outbreak outbreak = graph.getObjectValue(outbreakAttributeId, vertexId);
7         if (outbreak != null && outbreak.getDiseases().contains(diseaseName)) {
8             final float population = graph.getIntValue(populationAttributeId, vertexId);
9             final float percentageAfflicted = (100f *
10                 outbreak.getAffectedPopulation(diseaseName)) / population;
11             graph.setFloatValue(percentageAfflictedAttributeId, vertexId, percentageAfflicted);
12         }
13     }
14 }

```

#### 5.1.5: Making an action

Now we need to add the plugin to Constellation's menu. To do this, we create a **SimplePluginAction** corresponding to the plugin. Open **PercentageAfflictedAction** from chapter 5 of the exercises module.

This class is very lightweight as the framework does a lot for us. The annotations presently at the top of this class constitute boilerplate code for a NetBeans **Action**. The **SimplePluginAction** class (which extends **Action**) automatically takes the parameters for a plugin, wraps them in a JavaFX dialog box, and exposes the plugin from the menu.

There are only two things we need to do in our action; describe which plugin we want to run, and describe where we want it to appear in the menu. To achieve the first, change the call to the super constructor so that its second argument is the class name of our plugin, and the third is true to indicate that we want to run the plugin interactively (prompt the user for parameters). Now might be a good time to add the class name to the registry so that we can access it nicely. The constructor should end up looking like this:

```

1 public PercentageAfflictedAction(final GraphNode context) {
2     super(context, PandemicPluginRegistry.PERCENTAGE_AFFLICTED, true);
3 }

```

Secondly, we need to tell the action where in the menu we would like it to appear. This is done through annotations. Add the following to the top of the class:

```

1 @ActionReferences({
2     @ActionReference(path = "Menu/Tools", position = 0),
3     @ActionReference(path = "Shortcuts", name = "C-P")
4 })

```

The first **@ActionReference** annotation gives the menu location (the syntax being menu/submenu/submenu... for as many levels as you like) and the position of the action within that menu (0 being at the top). The second **@ActionReference** annotation adds a shortcut "Control+P" to run the action. This is optional of course.

Now that we have everything set up, try running the plugin from the tools menu in Constellation. Examine the created attribute in histogram to see what its values look like across the graph.

### 5.1.6: Visualising the results of the plugin

We can visualise the results of this plugin by examining the attribute we created, for example, in the histogram. However it might be nice to directly visualise the percentages on the graph. To do this we can set one of the Constellation attributes that controls the visual appearance of nodes.

Try setting the ‘node radius’ attribute (which you can find in **VisualConcept**) to be based on the percentage afflicted for each city. This attribute controls the physical size of the nodes on the graph. Note that you might want to apply some scaling and clamp the values between 1 (the default size) and 10 to prevent nodes from becoming too big or small.

## Exercise 5.2: Spreading the Disease

In this exercise you will follow a similar pattern to the previous exercise, but the implementation details are left up to you. The goal is to create a plugin that ‘spreads’ diseases across the graph.

The increase in diseases at a node should be based on the current outbreak status of the node, and the incoming flights from other infected cities. When the plugin is run, it should ask the user for the number of days over which to spread the disease. The way you model this is up to you – keep it simple though, the point is not to have a mathematically sound representation of how infections spread! Feel free to take shortcuts, like assuming that the flights on the graph represent exactly one day’s worth of air travel.

We will be using this plugin in chapter 7, so should you get stuck, or not wish to spend too much time on implementing it, a complete solution is available in the training solutions module.

### 5.2.1: Create a plugin with parameters

Open **SpreadInfectionPlugin** from chapter 5 of the exercises module. Like the other plugin we wrote in this chapter, this is a **SimpleEditPlugin**. Implement the **createParameters()** method to return a **PluginParameters** containing a single integer parameter with the number of days to spread the infection for.

### 5.2.2: Implement the plugin logic

Implement the **edit()** method in the plugin. This is where you will need to iterate over all vertices in the graph, and for each vertex iterate over all neighbours to propagate diseases both internally and based on flight routes. Some patterns that might help you with these iterations are as follows:

To iterate over the neighbours of a vertex with ID `vertexId`, you can

```
1 for (int vertexNeighbourPosition = 0; vertexNeighbourPosition <
    graph.getVertexNeighbourCount(vertexId);
2     vertexNeighbourPosition++) {
3     final int neighbourId = graph.getVertexNeighbour(vertexId, vertexNeighbourPosition);
4     ...
5 }
```

To iterate over the transactions between two neighbouring nodes `vertexId` and `neighbourId`, you can

```
1 final int neighbourLink = graph.getLink(vertexId, neighbourId);
2 for (int neighbourTransactionPosition = 0; neighbourTransactionPosition <
    graph.getLinkTransactionCount(neighbourLink);
3     neighbourTransactionPosition++) {
4     final int transactionId = graph.getLinkTransaction(neighbourLink,
        neighbourTransactionPosition);
5     ...
6 }
```

Finally, to test whether the vertex with ID `vertexId` is the destination node of the transaction with ID `transactionId` you can

```
graph.getTransactionDestinationVertex(transactionId) == vertexId;
```

### 5.2.3: Create the action

Open **SpreadInfectionAction** from chapter 5 of the exercises module. Call the correct plugin inside the constructor and add the relevant annotation to make it show up in the tools menu beneath the Percentage Afflicted action.

## Exercise 5.3: Arranging by Geographic Coordinates

For the final exercise in this chapter we will be trying something a little different – arranging nodes on the graph. While this might seem like a fairly low level operation, it can be implemented as a **SimpleEditPlugin** simply by modifying the ‘x’, ‘y’ and ‘z’ attributes on the graph. Open **PandemicArrangementPlugin** from chapter 5 of the exercises module.

### 5.3.1: Setting up the arrangement

The class in the exercises module already has all the relevant annotations and makes use of the plugin interaction framework. The first thing we need to do in the `edit()` method is retrieve all the attributes of interest. ‘x’ and ‘y’ belong to **VisualConcept**, which contains all the attributes relating to the display of a graph (e.g. color, selected, icon etc.).

```
1 final int latitudeAttributeId = SpatialConcept.VertexAttribute.LATITUDE.get(writableGraph);
2 final int longitudeAttributeId = SpatialConcept.VertexAttribute.LONGITUDE.get(writableGraph);
3 final int yAttributeId = VisualConcept.VertexAttribute.Y.get(writableGraph);
4 final int xAttributeId = VisualConcept.VertexAttribute.X.get(writableGraph);
5
6 if (latitudeAttributeId == GraphConstants.NOT_FOUND || longitudeAttributeId ==
    GraphConstants.NOT_FOUND) {
7     throw new PluginException(PluginNotificationLevel.ERROR, "Required attributes
        'Geo.Latitude' or 'Geo.Longitude'"
8         + "do not exist on this graph!");
9 }
```

### 5.3.2: The logic of the arrangement

Now that we have the relevant attributes, we need to iterate over all vertices in the graph, setting the values of their ‘x’ and ‘y’ attributes based on their latitude and longitude attributes.

```
1 final int vertexCount = writableGraph.getVertexCount();
2 for (int vertexPosition = 0; vertexPosition < vertexCount; vertexPosition++) {
3     interaction.setProgress(vertexPosition, vertexCount, "Arranging by Geographic
        Coordinates...", true);
4     final int vertexId = writableGraph.getVertex(vertexPosition);
5     final float vertexLatitude = writableGraph.getFloatValue(latitudeAttributeId, vertexId);
6     final float vertexLongitude = writableGraph.getFloatValue(longitudeAttributeId, vertexId);
7
8     writableGraph.setFloatValue(yAttributeId, vertexId, vertexLatitude);
9     writableGraph.setFloatValue(xAttributeId, vertexId, vertexLongitude);
10 }
```

### 5.3.3: Register the plugin

Register the plugin as **PandemicPluginRegistry.ARRANGE\_BY\_GEOGRAPHIC\_COORDINATES**.

### 5.3.4: Creating the action

We have finished implementing the arrangement itself. Open **PandemicArrangementAction** from chapter 5 of the exercises module. Note that this class extends **AbstractAction**, rather than **SimplePluginAction**. The reason for this will become clear in a minute. In an **AbstractAction**, we need to set the **GraphNode** as shown in the constructor, and then directly run the content of our action in the **actionPerformed()** method. Note that this method is an override of a method from Java's **ActionListener** interface. This means that we are free to do anything here rather than running a single Constellation plugin.

In this case, because it would be nice to run the arrangement, and then immediately afterwards run the 'Reset View' plugin. This plugin resets the view so that we can immediately appreciate the results of the arrangement. To do this we use the **PluginExecutor** class. This works similarly to the **PluginExecution** class, but allows us to run several plugins, one after the other, using the same lock on the graph. We won't go into it in any more detail than that – see the API docs for more information. Add the following code to the **actionPerformed()** method to complete our arrangement:

```
1 PluginExecutor.startWith(PandemicPluginRegistry.ARRANGE_BY_GEOGRAPHIC_COORDINATES)
2   .followedBy(InteractiveGraphPluginRegistry.RESET_VIEW)
3   .executeWriteLater(context.getGraph());
```

Using the graph you saved earlier, run your new plugin from the Arrange menu, noting that each city node will move to its latitude-longitude location on the screen.

## Chapter 6: Extending Views

Now that we have plugins to import and query the infection status of cities, and to perform analysis on this data, the next thing we might want to do is extend Constellation's inbuilt views in order to visualise this data in an enlightening manner to help analysts control outbreaks.

### Attribute Interactions

Extensions of **AbstractAttributeInteraction<T>** provide extra information about how to present attribute values to the user for a given type of attribute. This is in contrast to the attribute description classes which define the internal representation of attribute values.

### Exercise 6.1: Creating an Attribute Interaction

Now we are going to revisit the Outbreak attribute that was created for the Pandemic Schema in Chapter 3, and change Constellation so that this attribute can be modified in the Attribute Editor. Open **OutbreakAttributeInteraction** from Chapter 6 of the exercises module.

#### 6.1.1: Understand the available methods

**getDataType()** returns the name of the attribute type. This should be the *ATTRIBUTE\_NAME* constant from the relevant attribute description.

**getValueType()** returns the Class object that is the Java type of the attribute values. This should always match the type parameter *<T>* of the attribute interaction.

**getDisplayText(Object attrVal)** is a method called by the Attribute Editor, the Table View and the Histogram (among other views) to get a displayable string for an attribute value. This differs from calling **getStringValue** directly on the graph, which represents attribute values uniquely as strings, but not necessarily in a user-friendly manner. Indeed, **getDisplayText** is permitted to return the same string for different attribute values (useful for complex objects where you only want to present a summary of them to the user).

**getDisplayText** should always return null whenever the attribute value is null – its representation should be independent from the attribute type. Views have a standard way of presenting null values for any attribute, usually with the string 'No Value'.

**getDisplayNodes(Object attrVal, double width, double height)** is a similar method that returns a list of JavaFX nodes that visually represent the attribute value (conforming to the width and height parameters). This is used for



attribute types such as Color and Icon. It is worth knowing about, but doesn't make much sense to use for Outbreak attributes. The default implementation always returns an empty list.

There are many other useful methods in the **AttributeInteraction** class which we will implement as needed.

### 6.1.2: Implement custom display text for an Outbreak

Implement **getDisplayText** so that it returns the **toString** representation of an Outbreak object when its outbreakData map is non-empty, otherwise the string "Clear of Infection". Uncomment the service provider at the top of the class.

Observe the effect of this change by looking at the outbreak of a node not affected by any diseases, in either the attribute editor or the histogram. The string "Clear of Infection" should be displayed.

#### Attribute Editor

The Attribute Editor provides a simple mechanism for users to view and edit attributes on the graph. The Attribute Editor uses JavaFX panels called 'Editors' to allow the users to input new values. These editors are type specific – Constellation contains one for each inbuilt attribute type. Many of the attributes we are using for this scenario use inbuilt types. For example, 'Geo.Latitude' is a FloatOrNull type attribute. However, the attribute 'Outbreak' has its own eponymous type. Currently there is no way to edit this attribute through the attribute editor – you will notice that its edit button is disabled.

At this point you might be wondering why users would manually alter individual values on their graph rather than retrieve them through a file import or a plugin. Imagine that someone on the team of infection control analysts is charged with keeping the data up-to-date as new reports of infection come in. We would certainly prefer to re-query the whole dataset through our plugin, but perhaps the central repository of data is only updated weekly. Hence the aforementioned team member sometimes needs to make manual updates to the 'Outbreak Status' attribute of various city nodes.

## Exercise 6.2: Editing Outbreak objects as Strings

The simplest way to enable editing of Outbreak values is to allow them to be edited as Strings. The advantage of this method is that you don't need to write a JavaFX editor, but on the downside users may find the editing process a little more obscure. To achieve this, we need to implement some more methods in **OutbreakAttributeInteraction**.

### 6.2.1: Specify the preferred edit type

Firstly we need to implement the **getPreferredEditTypes()** method:

```
return Arrays.asList(StringAttributeDescription.ATTRIBUTE_NAME);
```

This method will come into effect where no specific 'Outbreak' editor exists, giving the attribute editor the option to fall back to the 'String' editor instead. Multiple types can be listed; the first one with a registered editor will be chosen. Note that we could choose a different attribute description here if it made sense, however String is usually the sensible choice.

### 6.2.2: Translate between the native type and the edit type

Next we need to tell the attribute editor how to go from an Outbreak to a String value, and vice versa, when editing. The attribute interaction does this by providing **AttributeValueTranslator** objects; functional interfaces that convert from one type of object to another.

In **toEditTranslator**(String dataType) we need to add the following code to return a translator from Outbreak to String (used when the user requests to edit the attribute value):

```
1 ...
2 if (dataType.equals(StringAttributeDescription.ATTRIBUTE_NAME)) {
3     return v -> {
4         return v == null ? null : ((Outbreak) v).toString();
5     };
6 }
7 ...
```



In `fromEditTranslator(String dataType)` we need to add the following code to return a translator from String to Outbreak (used when the user commits an edit to the attribute value):

```
1 ...
2 if (dataType.equals(StringAttributeDescription.ATTRIBUTE_NAME)) {
3     return v -> {
4         return v == null ? null : Outbreak.valueOf((String) v);
5     };
6 }
7 ...
```

We need to check the `dataType` parameter to determine which translator to return in each of these parameters. This is because we could have an attribute interaction which facilitates values being edited as multiple types. If none of the types we are interested in match, we should always return a call to `super` (which will return an appropriate Identity operation translator).

### 6.2.3: Validating edits

The logic of the two translators above is quite simple – `toString()` to convert from an Outbreak to a String, and `Outbreak.valueOf()` to convert from a String to an Outbreak. In the latter case, you might wonder what happens if a user enters a String which does not describe a valid Outbreak object. Presently, when they press ‘ok’ in the String editor, `Outbreak.valueOf()` will be called and throw an `IllegalArgumentException`. To prevent this, there is a method we can override to disable the ‘ok’ button and display an error message when the current value is invalid.

The `fromEditValidator(String dataType)` method should return a `ValueValidator`; that is a functional interface that processes a value to determine validity for the attribute type being edited. They should return null when the value is valid, otherwise a String containing an appropriate error message. Just like the translator methods, this method needs to check its `dataType` parameter and return a call to `super` at the end if no types of interest match.

Implement `fromEditValidator` so that it returns a validator for String values that returns the message “Invalid String for Outbreak” whenever `Outbreak.valueOf()` would throw an `IllegalArgumentException`.

```
1 @Override
2 public ValueValidator fromEditValidator(final String dataType) {
3     if (dataType.equals(StringAttributeDescription.ATTRIBUTE_NAME)) {
4         return v -> {
5             try {
6                 Outbreak.valueOf((String) v);
7                 return null;
8             } catch (IllegalArgumentException ex) {
9                 return "Invalid String for Outbreak";
10            }
11        };
12    }
13    return super.fromEditValidator(dataType);
14 }
```

### Editor Factories

The more involved method for exposing the editing of ‘Outbreak’ type attributes is to write an editor specifically for the attribute type. `AttributeValueEditorFactory<V>` classes allow custom user interfaces to be created and used to edit attribute values of a given type. This will be easier for users than requiring them to enter strings which correctly represent the desired outbreak value. Open `OutbreakEditorFactory` from Chapter 6 of the exercises module.

The type parameter `<V>` of the editor factory should match the Java type of the attribute values that they will be used to edit. Factories contain an `AbstractEditor<V>` implementation as an inner class (the type parameter is shared). This is where most of the work gets done.

The factory itself contains two methods. `createEditor` should return a new instance of the encapsulated `AbstractEditor`, passing all parameters through as supplied. The type of `initialValue` and the type parameter for

validator need to match <V>. The constructor for the **AbstractEditor** should call the super constructor, again passing all parameters through. **getAttributeType()** should return the name of the attribute type, which as usual is the *ATTRIBUTE\_NAME* constant from the relevant attribute description.

### Exercise 6.3: Creating an Editor Factory for Outbreak objects

Observe that as well as the boilerplate code for the factory, much of the **OutbreakEditor** has been implemented as this particular editor requires some fiddly JavaFX. For this exercise, follow along to try and gain an understanding of the function of each of the methods in **OutbreakEditor**.

#### 6.3.1: Creating the Editor Controls

**createEditorControls()** returns a JavaFX Node that contains the controls needed to edit the attribute value. For a String, this would just be a **TextField**. For this editor, we have a dynamic list of **DiseaseEntry** objects each which contain two **TextField** objects; one for the disease name and one for the number of people infected with that disease.

All the controls that the user interacts with should be instance variables as other methods will need to access them. It is typical to place all your controls into some type of JavaFX pane (even if there is only one) and return that pane from this method. Of course you can also create labels, nested panes etc. inside this pane to assist with the formatting of the editor; these can be local variables.

**Note** that the constructor for an **AbstractEditor** should only ever call super; all GUI elements must be initialised upon declaration or inside **createEditorControls**.

#### 6.3.2: Getting the value from the controls

**getValueFromControls()** returns the attribute value that is represented by the current value of the controls. In other words, this is returning the value of the attribute that the user set. If the current configuration of the controls doesn't represent a valid value, this method should throw a *ControlsInvalidException* with a single string argument explaining why. This will be captured by the framework to disable the 'ok' button and display the error message in red.

In this editor, we get the disease name and number of people infected from each **DiseaseEntry** and use this to populate the outbreak data map for a new Outbreak object. If one of the **DiseaseEntry** objects has a non-integer value for its number of people infected, we throw a *ControlsInvalidException* indicating this.

#### 6.3.3: Setting the value on the controls

**updateControlsWithValue(V value)** needs to configure the controls based on the supplied attribute value. This is used to display the current value of the attribute to the user when they first click edit.

In this editor we remove each **DiseaseEntry** from the pane and then add new ones corresponding to the data from the supplied Outbreak value.

#### 6.3.4: Ensuring the editor updates

Inside **createEditorControls** we also need to add a JavaFX **ChangeListener** to the relevant properties of each control (e.g. the *textProperty* of a **TextField**). This change listener simply needs to call **update()**, a method implemented in **AbstractEditor** that coordinates validation, translation, and the retrieval of the current value from the controls. Note that in most cases it is sufficient (and desirable) for all updates to the GUI to be performed inside **updateControlsWithValue**. You may perform some updates inside a **ChangeListener** on a GUI element, but you should still call **update()** at the end of the listener.

In this editor **update()** is called for the two **TextField** objects and the remove button for each **DiseaseEntry**. Note that this is done inside the **DiseaseEntry** constructor since these are dynamically created and so the **createEditorControls** method doesn't know about them.

### 6.3.5: Adding the ability to set null values

Observe that in `getValueFromControls` if the list of `DiseaseEntry` objects is empty, an `Outbreak` object with an empty `outbreakData` map is returned. This indicates that a city is ‘Clear of Infection’, which is different to a null value indicating a lack of information. The editor currently has no way of setting null. Add a checkbox to the bottom of the editor that explicitly sets the value to null. This will require following the process of steps 6.3.1 through to 6.3.4

### Histogram

Extending the attribute editor was good for viewing and editing single values of the ‘Outbreak’ attribute. Some forms of analysis might require that we analyse the distribution of values of this attribute across the graph. Perhaps analysts would like to rank cities by the total number of infected people across all diseases so as to triage the disease control efforts. Alternatively, ranking cities by the number of people affected by a single disease might provide clues as to the conditions under which that specific disease prospers. These are both perfect cases for the histogram.

The histogram works by ‘binning’ attribute values into ‘bins’. Each bin has a label, and a number giving the total number of attribute values falling into that bin. Bins are also comparable. By default, the histogram will use the `compareTo()` and `equals()` methods of the native type of an attribute in order to place them into bins and sort those bins. Like many other views, it will use the relevant attribute interaction’s `getDisplayText` method to label the bins. If the native type of the attribute does not implement `Comparable`, then the histogram will sort based on `hashCode()`, which whilst rarely useful will ensure against failure.

## Exercise 6.4: Sorting Outbreak in the Histogram

If you look at the ‘Outbreak’ attribute in the histogram now, you will notice that the labels are as expected but that the sorting seems random. This is because it is sorting by `hashCode()` as `Outbreak` doesn’t implement `Comparable`.

### 6.4.1: Implement Comparable for Outbreak

Open the `Outbreak` class. Observe that there is a commented out method for `compareTo()`. Uncomment this method and make `Outbreak` implement `Comparable`. This sorting compares outbreak statuses firstly by the number infected by their most virulent disease, then by the next most virulent disease, and so on. Run the application again and observe the new behaviour in histogram.

### 6.4.2: Sorting objects that aren’t Comparable

If the native type of an attribute value is not `Comparable`, but you want it to sort in the histogram in a manner other than using `hashCode()`, you can override `createComparator()` in the relevant attribute interaction. This method should return a `Comparator` which compares attribute values of the given type. This is useful when it is not possible or does not make sense that the native type of an attribute implements `Comparable` itself, or when you want the default method of sorting to differ from the type’s natural ordering. Note that if the object does not implement `Comparable` and you override `createComparator`, then you also need to override `isComparable` in the attribute interaction to return true.

Try overriding `isComparable` in `OutbreakAttributeInteraction` so that it returns false. Observe that `Outbreak` objects go back to sorting by `hashCode()`. Remove this override and instead try overriding `createComparator` so that it returns the number of distinct diseases in the `Outbreak`. Observe that `Outbreak` objects now sort by the number of distinct diseases they contain.

### Histogram Bin Formatters

Now that you have made `Outbreak` objects comparable, you can observe the ‘Outbreak’ attribute in a more meaningful way in the histogram. We could now go on to change the `Comparator` in the attribute interaction, or `Outbreak`’s implementation of `Comparable`, so that `Outbreaks` are sorted by the total number of people infected. Apart from the fact that with this approach we can only have one manner of sorting, it would also mean that each `Outbreak` shows up as a single entry in the histogram with its full string label. What we really want is not only to sort by the total number of people infected, but to group `Outbreaks` by this number and label the resulting groups with that number. In order to do this we need to create a `BinFormatter`.

## Exercise 6.5: Creating the ‘Total Infections’ Bin Formatter

Open **TotalInfectionsFormatter** from chapter 6 of the exercises module. A formatter takes the default bins for a given attribute, and returns new bins instead. This is done by the **createBin** method. These new bins perform a function on the original bins to compute the desired grouping and labelling. In this exercise the new bins are described by the **TotalInfectionsBin** inner class.

### 6.5.1: Setting up the Formatter

In the constructor for the **TotalInfectionsFormatter**, we need to make a call to the super constructor with two arguments; the name and position of the formatter in the histogram’s drop-down list.

```
1 public TotalInfectionsFormatter() {  
2     super("Total People Infected ", 1);  
3 }
```

In the **appliesToBin**(final Bin bin) method we need to check whether this formatter is appropriate for a given default bin. This gets called by the histogram to see whether the formatter should appear in the drop-down list. In this case we need to check that the bin is an **AttributeBin** which is binning Outbreak attributes. The following statement achieves this:

```
1 return bin instanceof AttributeBin && ((AttributeBin) bin).getAttributeType()  
2     .equals(OutbreakAttributeDescription.ATTRIBUTE_NAME);
```

Note that **AttributeBin** is the default bin type for all attributes whose native types are objects. Attributes whose native types are primitives have their own specific Bins (**IntBin**, **FloatBin**, etc.)

### 6.5.2: Setting up the custom bin

The **TotalInfectionsBin** class is our custom bin which will take values from the default bin for the Outbreak attribute and process them to provide the custom grouping and labelling that we desire. Note that it extends **IntBin**. This is because the key that we will be grouping by, the total number of infected people, is an integer. If key is not a primitive, you should choose to extend **ObjectBin** here.

### 6.5.3: Setting the key for the bin

**setKey**(final GraphReadMethods graph, final int attribute, final int element) is called for each graph element to set the key for that element. This key will define the binning and sorting of the attribute values. There are two bits of code that need to be added to this method.

The first thing we need to do is to make sure the key is set correctly in the default bin by calling

```
1 bin.setKey(graph, attribute, element);
```

Now bin.key will be the Outbreak attribute value corresponding to the graph current element. We now need to set the key for this bin to be the total number of infected people in this Outbreak.

```
1 key = bin.getKeyAsObject() == null ? -1  
2     : ((Outbreak) bin.getKeyAsObject()).getNumberOfDiseases() == 0 ? 0  
3     : ((Outbreak) bin.getKeyAsObject()).getOutbreakData().values().stream().reduce((x, y) -> {  
4         return x + y;  
5     }).get();
```

Note that we set -1 for null because the key for this bin must be a primitive int.

### 6.5.4: Setting the label for the bin

All that remains is to set the label for each bin. This should always be done in **prepareForPresentation**() as this method is called after the bins have been created and grouped. In this case we simply set the label to be the number of people infected, first checking the null case.

```
label = bin.key == null ? null : String.valueOf(key);
```

So we now have a formatter to rank cities by the total number of infected people in the histogram. Run Constellation to see this new sorting take effect.

To rank cities by the number of people infected by a given disease, there needs to be some way of allowing the user to choose which disease they are interested in. Of course you could use a separate formatter for each disease, but this is rather clumsy.

## Exercise 6.6: Creating the ‘Number Infected with Disease’ Bin

Formatter

Open **SpecifiedDiseaseFormatter** from chapter 6 of the exercises module. Much of this class looks the same as the previous formatter – these bits were left in so you don’t need to rewrite them.

### 6.6.1: Add PluginParameters to the formatter

Inside a **BinFormatter** we can implement the **createParameters()** method to return a **PluginParameters** object. Notice that in the **createBin()** method you have access to the **PluginParameters** object that the user has populated, so you can use it to customise the construction of the bin. To see an example of what the parameters looks like graphically, look at the ‘Custom Format’ formatter for a temporal type attribute.

We implement **createParameters** to return a **PluginParameters** object with a single String parameter for the disease name.

```
1 @Override
2 public PluginParameters createParameters() {
3     final PluginParameters parameters = new PluginParameters();
4
5     final PluginParameter diseaseNameParam =
6         StringParameterType.build(DISEASE_NAME_PARAMETER_ID);
7     diseaseNameParam.setName(DISEASE_NAME_PARAMETER_LABEL);
8     parameters.addParameter(diseaseNameParam);
9
10    return parameters;
11 }
```

### 6.6.2: Use the parameters in the construction of the bin

Currently the **SpecifiedDiseaseBin** inside the formatter has no field telling it which disease to look at. Add such a field and set it in the constructor. After doing this we will need to pass the parameter value entered by the user through to the bin’s constructor. We do this by changing **createBin** to:

```
1 return new SpecifiedDiseaseBin((AttributeBin) bin,
    parameters.getStringValue(DISEASE_NAME_PARAMETER));
```

### 6.6.3: Set the key and label for the bin

Just like before we now need to set the key and label of this bin. The key will need to look up the specified disease in the outbreak map and take the number of people infected with it. In the case that the map doesn’t contain that disease, the key should be set to 0. We should handle null values as before. The label should read “X people infected with Y”, where X is the number infected and Y is the name of the disease. Implement the relevant code to achieve this in **setKey** and **prepareForPresentation**. Run Constellation and choose the formatter we just made from histogram to see this new sorting take effect.

## Quality Control View

Imagine as an analyst that after ranking cities by population infected from ebola (by using the appropriate histogram bin formatter), you noticed that three particularly heavily infected cities were all in the one part of Africa. This seems like a promising place to start infection control, but before jumping to conclusions, it is important to check the integrity of the data. Perhaps there was an error in reporting in this area and these values are far too big. One

simple sanity check would be to ensure that the number of people infected with a single disease in any city was always less than that city's population. Writing custom rules for the quality control view allows you to automatically flag nodes where data may be missing, corrupt or otherwise substandard, such as in this example.

## Exercise 6.7: Writing a Quality Control Rule

Open `OutbreakExceedsPopulationRule` from chapter 6 of the exercises module

### 6.7.1: Setting the rule's properties

Firstly we have to return String values from `getName()` and `getDescription()`. These can be anything you like – they are presented to the user in the QC View to name and describe the rule.

Secondly, from `getQuality(final int vertex)`, we need to return an integer score between 1 and 100 indicating the severity of the data integrity issue for a node flagged with the rule, where higher values indicate a more severe issue. The levels of severity are represented numerically and using colour in the QC View. Return 50 from this method for now, indicating a moderately severe issue.

### 6.7.2: Implement the rule's logic

`executeRule(final GraphReadMethods graph, final int vertex)` takes a vertex ID and is expected to run the rule against this vertex (with reference to the graph if necessary) and return true if the rule matches the node, otherwise false. To implement this rule we first need to gather all the relevant attribute values from the graph – the type of the node, the node's Outbreak and the node's population.

```
1 final int typeAttr = AnalyticConcept.VertexAttribute.TYPE.get(graph);
2 final int outbreakAttr = PandemicConcept.VertexAttribute.OUTBREAK.get(graph);
3 final int populationAttr = PandemicConcept.VertexAttribute.POPULATION.get(graph);
4
5 final SchemaVertexType type = graph.getObjectValue(typeAttr, vertex);
6 final Outbreak outbreak = graph.getObjectValue(outbreakAttr, vertex);
7 final int population = graph.getIntValue(populationAttr, vertex);
8
9 Now we want to check, if the node is a city node, whether any disease in
10 the outbreak for this vertex has a number of people infected that
11 exceeds the population of the city:
12
13 if (type.equals(PandemicConcept.VertexType.CITY) && outbreak != null) {
14     for (final int numInfected : outbreak.getOutbreakData().values()) {
15         if (numInfected > population) {
16             return true;
17         }
18     }
19 }
20 return false;
```

Note that it might be a good idea for to wrap the above code block in a check to see if the attributes we are retrieving actually exist, returning false if they don't:

```
1 if (typeAttr != GraphConstants.NOT_FOUND && outbreakAttr != GraphConstants.NOT_FOUND
2     && populationAttr != GraphConstants.NOT_FOUND) {
3     ...
4 }
```

### 6.7.3: Per-vertex quality scores

It is worth noting that the `getQuality` method takes a vertex ID as a parameter, meaning that a single rule can indicate different levels of severity for different nodes. As it does not have reference to the graph, these severity levels should be populated in a map inside the `executeRule` method for later retrieval.

Inside **executeRule**, populate a map that sets the score of a node to be based on the amount by which the most prevalent disease exceeds the population, with a minimum of 50 when it is equal, and a maximum of 100 when it is double. Return this score from **getQuality**.

## Chapter 7: Creating Views

Once you have a collection of conceptually related plugins, you may want to develop an interface to present them to users in a cohesive manner. This is exactly the purpose of Views in Constellation. All views make use of NetBeans' Top Component framework, which handles aspects such as windowing and layout automatically. On top of this, Constellation views can be provided the ability to listen to a graph and react to any changes as appropriate. At the lowest level this is achieved using **modification counters** accessed via the graph API which increment whenever the graph is changed. There are various counters available including a counter for each attribute on the graph which will increment whenever that particular attribute is modified in any way, a graph structure counter which will increment whenever the graph is modified in such a way that it's overall structure changes, and a global counter which will increment whenever any aspect of the graph changes.

### Exercise 7.1: PANDEMIC View

We have developed a number of plugins to build and manage information about the pandemic we are analysing. Let's construct a basic view to easily allow us to simulate the spread of the outbreak, and summarise the results in a meaningful way.

#### 7.1.1: Creating a Top Component

We should start by creating a **TopComponent** class. You should refer to the NetBeans documentation for details on how to do this and what options are available. For this exercise you can make use of the provided **PandemicViewTopComponent** class.

```
1 @ConvertAsProperties(...)
2 @TopComponent.Description(...)
3 @TopComponent.Registration(...)
4 @ActionID(...)
5 @ActionReferences({
6     @ActionReference(path = "Menu/Views", position = 2100),
7     @ActionReference(path = "Shortcuts", name = "CS-Z")})
8 @TopComponent.OpenActionRegistration(...)
9 @Messages(...)
10 public final class PandemicViewTopComponent extends TopComponent {
11     public PandemicViewTopComponent() {
12         setName(Bundle.CTL_PandemicViewTopComponent());
13         setToolTipText(Bundle.HINT_PandemicViewTopComponent());
14         initComponents();
15         setLayout(new BorderLayout());
16         setPreferredSize(new Dimension(500, 500));
17     }
```

#### 7.1.2: Creating a Pane

Now we should create a pane to display using the top component. For this exercise, we will make a JavaFX **BorderPane**, however for your own views you can choose to use any JavaFX or Swing pane.

```
1 public class PandemicViewPane extends BorderPane {
2     public PandemicViewPane() {
3         setPadding(new Insets(5));
4     }
5 }
```

So we don't get bogged down in GUI code, let's keep things simple – we'll define a **TextArea** to write output to, and a **Button** to run the 'spread infection' plugin. Note that we will call this plugin using the plugin registry we previously created.

```

1 private final TextArea summary;
2 private final FlowPane options;
3 public PandemicViewPane() {
4     ...
5
6     summary = new TextArea();
7     setCenter(summary);
8     final Button infectButton = new Button("Spread Infection");
9     infectButton.setOnAction(event -> {
10         PluginExecution.withPlugin(PandemicPluginRegistry.SPREAD_INFECTION)
11             .executeLater(GraphManager.getDefault().getActiveGraph());
12     });
13
14     options = new FlowPane();
15     options.setAlignment(Pos.CENTER_RIGHT);
16     options.getChildren().add(infectButton);
17     setBottom(options);
18 }

```

We will now add a **refresh** method to our pane which simply updates the pane with the list of all outbreaks on the graph ordered by the number of unique diseases within that outbreak.

```

1 private final AbstractAttributeInteraction interaction = AbstractAttributeInteraction
2     .getInteraction(OutbreakAttributeDescription.ATTRIBUTE_NAME);
3 ...
4 public final void refresh(final GraphReadMethods graph) {
5     Platform.runLater(() -> {
6         final ProgressIndicator progress = new ProgressIndicator();
7         progress.setMaxSize(50, 50);
8         setCenter(progress);
9
10        final Map<Outbreak, String> outbreaks = new TreeMap<>(Comparator.reverseOrder());
11        if (graph != null) {
12            final int outbreakAttributeId =
13                PandemicConcept.VertexAttribute.OUTBREAK.get(graph);
14            final int identifierAttributeId =
15                VisualConcept.VertexAttribute.IDENTIFIER.get(graph);
16            final int vertexCount = graph.getVertexCount();
17
18            for (int vertexPosition = 0; vertexPosition < vertexCount; vertexPosition++) {
19                final int vertexId = graph.getVertex(vertexPosition);
20                final String identifier = graph.getStringValue(identifierAttributeId,
21                    vertexId);
22                final Outbreak outbreak = graph.getObjectValue(outbreakAttributeId, vertexId);
23
24                if (outbreak != null && !outbreak.getOutbreakData().isEmpty()) {
25                    outbreaks.put(outbreak, identifier);
26                }
27            }
28
29            final StringBuilder summaryText = new StringBuilder("Outbreak Summary:\n\n");
30
31            for (final Map.Entry<Outbreak, String> outbreak : outbreaks.entrySet()) {

```



```

30         summaryText.append(outbreak.getValue())
31         .append(": ")
32         .append(interaction.getDisplayText(outbreak.getKey()))
33         .append("\n\n");
34     }
35
36     summary.setText(summaryText.toString());
37     setCenter(summary);
38 });
39 }

```

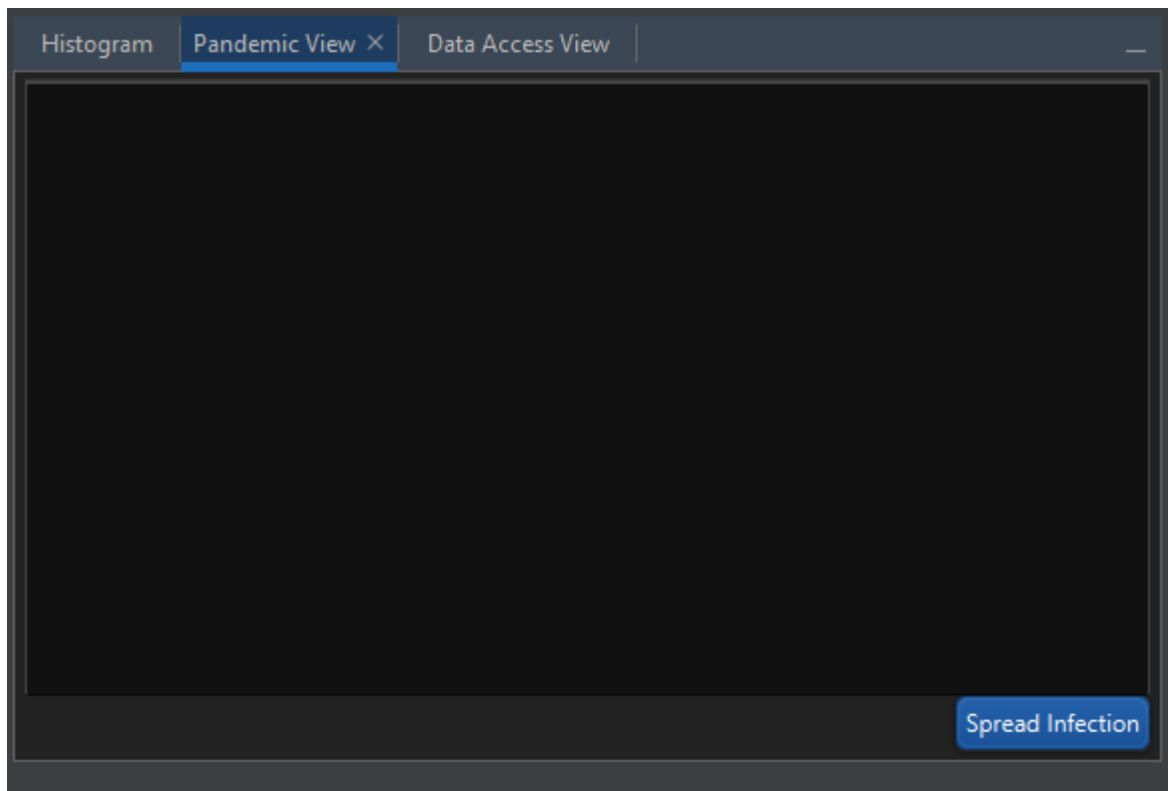
Now let's insert our pane into the top component. Note that since NetBeans top components use swing by default, we will need to ensure that our pane is constructed on the JavaFX thread explicitly using the **Platform.runLater** command.

```

1 private JFXPanel container;
2 private PandemicViewPane pandemicPane;
3 public PandemicViewTopComponent() {
4     ...
5     container = new JFXPanel();
6     Platform.setImplicitExit(false);
7     Platform.runLater(() -> {
8         pandemicPane = new PandemicViewPane();
9         container.setScene(new Scene(pandemicPane));
10        container.getScene().getStylesheets().add(JavafxStyleManager.getMainStyleSheet());
11        add(container, BorderLayout.CENTER);
12    });
13 }

```

Try running Constellation now and opening your new view. Note that the text field will be empty as we have not told it what to display yet.



### 7.1.3: Listening to the Graph

We know our view will need the ability to listen to the graph, so that we can react to changes in the outbreak data we are storing there. This is achieved using the **GraphManagerListener** and **GraphChangeListener** classes, which will provide you with the chance to react as the graph changes.

```
1 public final class PandemicViewTopComponent extends TopComponent implements
    GraphManagerListener, GraphChangeListener {
2     ...
3     @Override
4     public void newActiveGraph(final Graph graph) {
5         ...
6     }
7
8     @Override
9     public void graphOpened(final Graph graph) {
10        ...
11    }
12
13    @Override
14    public void graphClosed(final Graph graph) {
15        ...
16    }
17
18    @Override
19    public void graphChanged(final GraphChangeEvent event) {
20        ...
21    }
22 }
```

Next up we need to define what happens when we detect a change. To do this, we will use the **graphChanged** method to see if the change affected the outbreak attribute, and update our view if necessary.

```
1 private long outbreakModificationCounter = 0;
2 private Graph currentGraph = null;
3
4 @Override
5 public void graphChanged(final GraphChangeEvent event) {
6     final ReadableGraph readableGraph = currentGraph.getReadableGraph();
7     try {
8         final int outbreakAttributeId =
9             PandemicConcept.VertexAttribute.OUTBREAK.get(readableGraph);
10        final long currentOutbreakModificationCounter =
11            readableGraph.getValueModificationCounter(outbreakAttributeId);
12
13        if (currentOutbreakModificationCounter > outbreakModificationCounter) {
14            outbreakModificationCounter = currentOutbreakModificationCounter;
15            pandemicPane.refresh(readableGraph);
16        }
17    } finally {
18        readableGraph.release();
19    }
20 }
```

In order for this system to work, we need to keep track of the current active graph in order to listen to it. We also need to track the value for the modification counter for the outbreak attribute. We can handle all of this using the **newActiveGraph** method.

```
1 @Override
```

```

2 public void newActiveGraph(final Graph graph) {
3     if (currentGraph != graph) {
4         if (currentGraph != null) {
5             currentGraph.removeChangeListener(this);
6             currentGraph = null;
7         }
8
9         if (graph != null) {
10            currentGraph = graph;
11            currentGraph.addChangeListener(this);
12            final ReadableGraph readableGraph = currentGraph.getReadableGraph();
13            try {
14                final int outbreakAttributeId =
15                    PandemicConcept.VertexAttribute.OUTBREAK.get(readableGraph);
16                outbreakModificationCounter =
17                    readableGraph.getValueModificationCounter(outbreakAttributeId);
18            } finally {
19                readableGraph.release();
20            }
21        }
22    }
23 }

```

Remove any code from the **graphOpened** and **graphClosed** methods as we don't wish to perform any operation for these events.

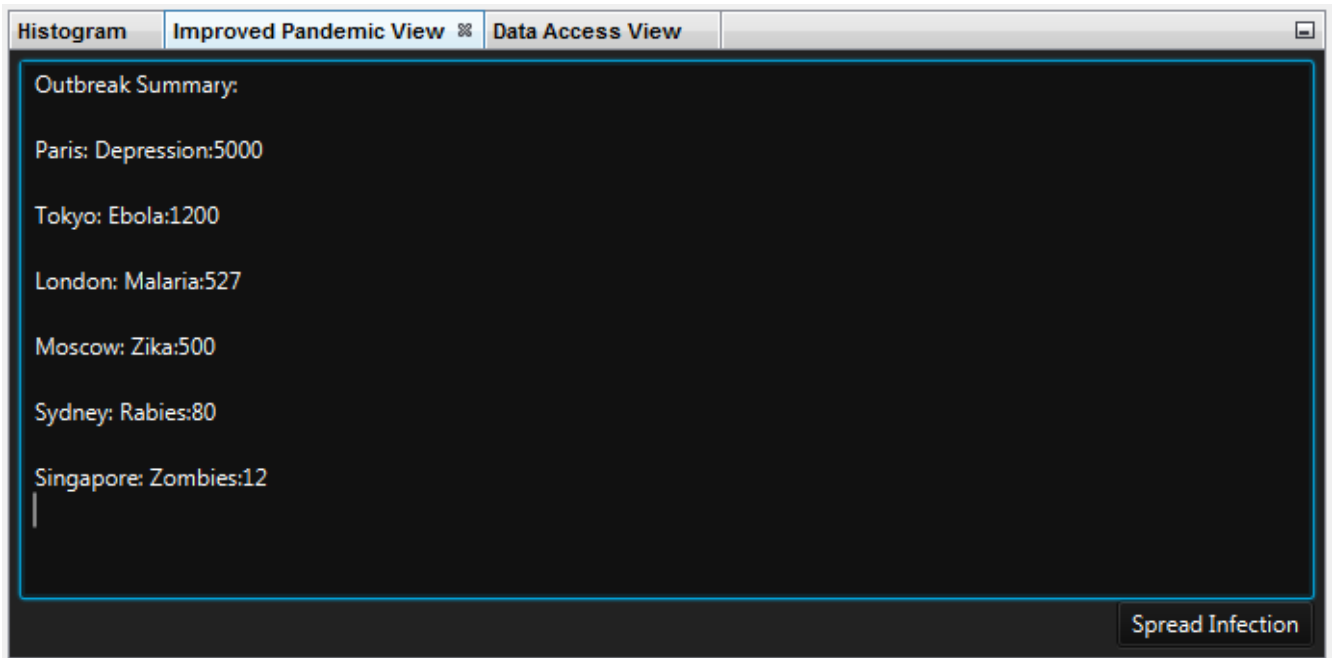
Finally, we should register our top component to **GraphManager** as a listener.

```

1 public PandemicViewTopComponent() {
2     ...
3     GraphManager.getDefault().addGraphManagerListener(PandemicViewTopComponent.this);
4 }
5
6 @Override
7 public void componentOpened() {
8     GraphManager.getDefault().addGraphManagerListener(this);
9     newActiveGraph(GraphManager.getDefault().getActiveGraph());
10 }
11
12 @Override
13 public void componentClosed() {
14     GraphManager.getDefault().removeGraphManagerListener(this);
15 }

```

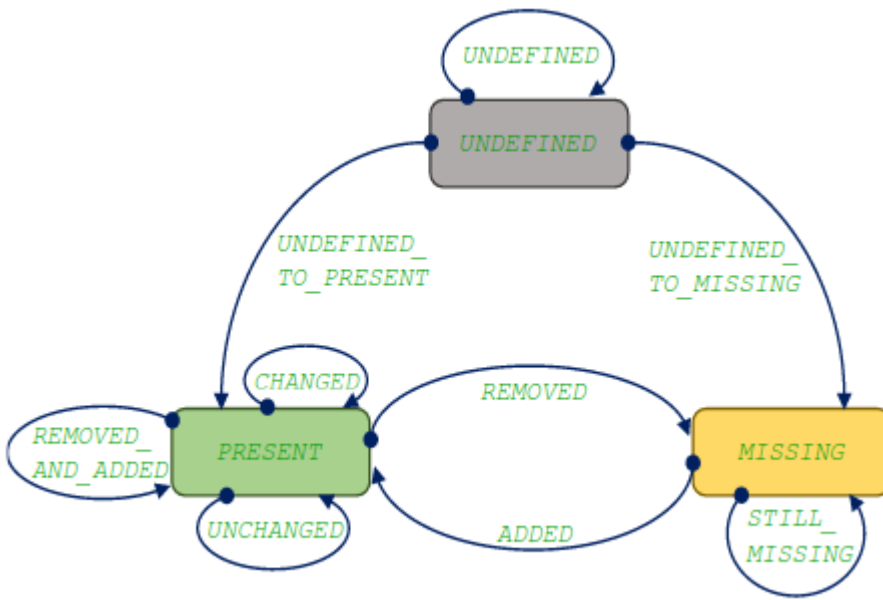
Observe the behaviour of your new Pandemic view within Constellation. Note that the text field will initially be empty and will only update when the 'Outbreak' attribute is changed, either by running the 'Spread Infection' plugin, or by manually editing the 'Outbreak' attribute.



### Simplified Graph Listening Framework

While monitoring and responding to the various modification counters on a graph is immensely flexible, it can also quite quickly become overwhelming for more complex views. For this reason, Constellation also provides a higher level framework which simplifies the interaction between a view and the graph. This framework abstracts away from the idea of counters on the graph, instead asking you to concentrate more on how your view should behave.

- A **monitor** defines which part of the graph you wish to listen to, such as an attribute or the structure of the graph itself.
- A **listener** defines what action to take when a change occurs.
- A **transition filter** defines the types of changes you care about. These changes are defined by transitions between states, and are defined as follows:



Once you have defined these concepts, they can all be managed using a **monitor manager**.

## Exercise 7.2: Improved PANDEMIC view

Let's simplify our view from the previous exercise using the simplified listening framework. We again start by creating a **TopComponent** class and a pane to display within our top component (although we can re-use the pane we created in the previous exercise here).

```
1 @ConvertAsProperties(...)
2 @TopComponent.Description(...)
3 @TopComponent.Registration(...)
4 @ActionID(...)
5 @ActionReferences(...)
6 @TopComponent.OpenActionRegistration(...)
7 @Messages(...)
8 public final class ImprovedPandemicViewTopComponent extends TopComponent {
9     private JFXPanel container;
10    private PandemicViewPane pandemicPane;
11    public ImprovedPandemicViewTopComponent () {
12        setName(...);
13        setToolTipText(...);
14        initComponents();
15        setLayout(new BorderLayout());
16        setPreferredSize(new Dimension(500, 500));
17        container = new JFXPanel();
18        Platform.setImplicitExit(false);
19        Platform.runLater(() -> {
20            pandemicPane = new PandemicViewPane();
21            container.setScene(new Scene(pandemicPane));
22            container.getScene().getStylesheets().add(JavafxStyleManager.getMainStyleSheet());
23            add(container, BorderLayout.CENTER);
24        });
25    }
26    ...
27 }
```

### 7.2.1: Creating a Monitor Manager

Now we will create a **MonitorManager** to manage all the graph listening for us. This class can be initialised with an optional counter indicating how many times you expect the class to be started, which is often useful if you could be starting it from more than one thread. Since we could be initialising our monitor manager from either the swing thread of the top component or the JavaFX thread of our pane, we will initialise it with a counter of 2.

```
1 private final MonitorManager manager;
2 public ImprovedPandemicViewTopComponent() {
3     ...
4     manager = new MonitorManager(2);
5 }
```

### 7.2.2: Creating a Monitor

We can then define the behaviour of our listener, starting with the monitor. Since we are only interested in changes in the value of the outbreak attribute, we should create an **AttributeValueMonitor** class.

```
1 private final AttributeValueMonitor outbreakMonitor;
2 public ImprovedPandemicViewTopComponent() {
3     ...
4     outbreakMonitor = new
5     AttributeValueMonitor(PandemicConcept.VertexAttribute.OUTBREAK);
6 }
```

### 7.2.3: Creating a Listener

Lastly we need to define the behaviour of our listener when a change occurs. This is done using the **MonitorListener** class.

```
1 private final MonitorListener listener;
2 public ImprovedPandemicViewTopComponent() {
3     ...
4     listener = (monitorManager, monitor, graph, newGraph, updateCount) -> {
5         pandemicPane.refresh(graph);
6     };
7 }
```

### 7.2.4: Creating a Transition Filter

The next thing to define is our transition filter which is done using the **MonitorTransitionFilter** class. This class simply needs to be constructed with a list of **MonitorTransition** states you wish to respond to.

```
1 private final MonitorTransitionFilter transitionFilter;
2 public ImprovedPandemicViewTopComponent() {
3     ...
4     transitionFilter = new MonitorTransitionFilter(MonitorTransition.UNDEFINED_TO_PRESENT,
5         MonitorTransition.CHANGED,
6         MonitorTransition.ADDED, MonitorTransition.REMOVED_AND_ADDED
7 );
8 }
```

### 7.2.5: Registering a Monitor

Now it's just a matter of registering our monitor, transition filter, and monitor listener to our monitor manager, and starting it. Note that we are starting the monitor manager when the view is opened and stopping it when the view is closed to prevent unnecessary operations from being handled when the user is not using the view.

```
1 public ImprovedPandemicViewTopComponent() {
2     ...
3     manager.addMonitorListener(listener, transitionFilter, outbreakMonitor);
4     Platform.runLater(() -> {
5         ...
6         manager.start();
7     });
8 }
9
10 @Override
11 public void componentOpened() {
12     manager.start();
13 }
14
15 @Override
16 public void componentClosed() {
17     manager.stop();
18 }
```

Launch Constellation and observe that this simplified view has the same behaviour as our previous view.

## Generic View Framework

There is one more level of abstraction available to help simplify creating a view in Constellation. The generic view framework is built on the assumption that there is a large amount of overlap between the graph listening behaviour of views in Constellation – things like responding to selection is almost always required for example. Creating a

view using this framework is simply a matter extending one of the **AbstractTopComponent** classes instead of the Netbeans **TopComponent** class.

- The **ListeningTopComponent** takes care of all the standard graph listening patterns that all views require, and provides a simplified interface for adding new listening behaviours.
- The **SwingTopComponent** builds on the **ListeningTopComponent**, providing a simplified interface for adding and managing Swing GUI elements.
- The **JavaFxTopComponent** builds on the **ListeningTopComponent**, providing a simplified interface for adding and managing JavaFX GUI elements.

Using the generic view framework additionally has the advantage of standardised behaviour across views – that is, if there is an issue with your view, then it is likely an issue for all other views using the framework.

## Exercise 7.3: Generic PANDEMIC view

We will now simplify our view further by making use of the generic view framework.

### 7.3.1: Creating a Generic Top Component

To create a view using the generic top component framework, you should start by creating a regular Netbeans top component, and then change it to extend a class within the framework.

```
1 @ConvertAsProperties(...)
2 @TopComponent.Description(...)
3 @TopComponent.Registration(...)
4 @ActionID(...)
5 @ActionReferences(...)
6 @TopComponent.OpenActionRegistration(...)
7 @Messages(...)
8 public final class GenericPandemicViewTopComponent extends JavaFxTopComponent {
9     public GenericPandemicViewTopComponent() {
10         setName(...);
11         setToolTipText(...);
12         initComponents();
13     }
14     ...
15 }
```

### 7.3.2: Adding Content

From here you'll need to implement a few abstract methods (these will change depending on which top component type you choose). For the **JavaFxTopComponent** top component, we will need to specify some JavaFX content to display and optionally a stylesheet to use. We should also initialise the content, which tells the framework to fit it into the top component in a standardised way.

```
1 private PandemicViewPane pandemicPane;
2 public GenericPandemicViewTopComponent() {
3     ...
4     pandemicPane = new PandemicViewPane();
5     initContent();
6 }
7
8 @Override
9 protected PandemicViewPane createContent() {
10     return pandemicPane;
11 }
12
13 @Override
```

```

14 protected String createStyle() {
15     return null;
16 }

```

### 7.3.3: Adding Listeners

Next we should add our listeners. The framework provides a range of methods for adding various types of listeners – refer to the javadoc for more information on what’s available. In our case, we need to listen to the outbreak attribute, so we will make use of the **addAttributeChangeListener()** method, which asks us to map an attribute to a handler.

```

1 private PandemicViewPane pandemicPane;
2 public GenericPandemicViewTopComponent () {
3     ...
4     addAttributeChangeListener(PandemicConcept.VertexAttribute.OUTBREAK, graph -> {
5         final ReadableGraph readableGraph = graph.getReadableGraph();
6         try {
7             pandemicPane.refresh(readableGraph);
8         } finally {
9             readableGraph.release();
10        }
11    });
12 }

```

### 7.3.4: Handling Changes

Finally, we can optionally add handlers for when the state of the view or graph changes (such as when the view is opened or the active graph is changed). Once again the framework provides a range of methods allowing you to account for these sorts of cases – refer to the javadoc for more information on what’s available. In our case, we will override the **handleComponentOpened()** method in order to have the view update immediately by calling **manualUpdate()** to manually fire our outbreak attribute change handler.

```

1 @Override
2 public void handleComponentOpened() {
3     manualUpdate();
4 }

```

Once again, launch Constellation and observe that this generic view has the same behaviour as our two previous views.

And that’s it! We’ve now created a view capable of assisting our analysis, and responding to changes in the graph in around 100 lines of code.

## Chapter 8: User Interaction

We have now covered all that Constellation has to offer in terms of creating and extending features for data analysis. The final touch is knowing how to advertise these creations to your users, and how to monitor their use.

### Exercise 8.1: What’s New

When you first launch Constellation, by default, you will be presented with the **Tutorial Page**. This page acts as a hybrid ‘welcome screen’ and ‘getting started’ document. The pane on the right of the Tutorial Page contains a reverse chronological list of changes and updates which have occurred over the last month known as the What’s New section. As a developer, you can add to this section as you please.



### 8.1.1: Building a What's New Provider

Before we can add our own 'what's new' entries, we need to build a **WhatsNewProvider** class, which Constellation will use to locate them. This class simply needs to define the location of the file containing your 'what's new' entries and the section (or category) these entries belong to.

```
1 @ServiceProvider(service = WhatsNewProvider.class)
2 public class PandemicWhatsNewProvider extends WhatsNewProvider {
3
4     @Override
5     public String getResource() {
6         return "whatsnew.txt";
7     }
8
9     @Override
10    public String getSection() {
11        return "Pandemic";
12    }
13 }
```

### 8.1.2: Adding What's New Entries

'What's new' entries are stored as formatted strings in a text document within the Constellation code base. Let's open up the 'whatsnew.txt' file now and take a look at its format.

The string format for a 'what's new' entry must begin with a line of the form:

**== <date formatted as yyyy-MM-dd> <title of what's new entry>**

This can then be followed by any text, noting that HTML formatting is respected.

The first example 'what's new' entry is of particular interest as it demonstrates how to create a **sticky post**. This is simply achieved by setting the date of the entry to any date after the year 3000. You'll notice there is also an example of how to link to internal help documentation.

Try adding some of your own 'what's new' entries to the 'whatsnew.txt' file and observe how they are rendered in Constellation. Notice the coloured badges that appear beside the title of each entry indicating the module that entry belongs to and whether or not it is a recent entry.

## Exercise 8.2: Help

Constellation makes use of NetBeans' built-in **help framework** for providing help documentation. We are not going to go into too much detail on how this works, but to get you started let's jump into an example.

### 8.2.1: Writing a Help Page

Help pages in Constellation are simply HTML documents. Open 'import-custom-cities.html' and take a look at its format.

Other than linking to 'constellation.css' for some basic formatting, this is just a very simple HTML document. Feel free to add any text you wish to it now to see how it looks within Constellation.

### 8.2.2: Hooking into the Help Framework

NetBeans uses a series of xml files to find and organise help documents. Let's go through those now.

- **pandemic-hs.xml**: This is the *helpset* document, which defines a collection of help documents. This document allows us to name our help set, and link it to various other organisational documents required by the help framework.
- **pandemic-toc.xml**: This is the *table of contents* document, which allows us to specify headings, groupings and order for our set of help documents.

- **pandemic-idx.xml**: This is the *index* document, which allows us to specify unique id's for looking up help documents.
- **pandemic-map**: This is the *mapping* document, which allows us to map our indexes to the actual HTML help documents.

You won't need to make any changes here, so try launching Constellation and finding the 'Import Custom Cities' help page.

### Exercise 8.3: Logging

By default, Constellation will not perform any logging for you, but there is an extensible **logging framework** available for any developer to implement. This framework will create log entries at the following points in Constellation's lifecycle:

- When Constellation is launched
- When a plugin begins execution
- During a plugins' execution
- When a plugin throws an exception
- When a plugin finishes execution
- When Constellation is closed

The logging framework allows for any number of **log consumers** to collect and forward information at any of these points.

#### 8.3.1: Building a Logger

To register a new log consumer, you simply need to create a **ConstellationLogger** class. This will provide you with a number of methods to implement:

- **applicationStart** and **applicationStop** allow you to create a log when Constellation is launched or closed. These are called automatically by Constellation.
- **pluginStart** and **pluginStop** allow you to create a log when Constellation begins or ends execution of a plugin. These are called automatically by Constellation's plugin framework.
- **pluginError** allows you to create a log when an exception is thrown by a plugin in Constellation. This is called automatically by Constellation's plugin framework.
- **pluginInfo** and **pluginProperties** allow you to create a log when a plugin submits some information. These methods are generally implemented in a way specific to an individual plugin and are usually used to facilitate the logging of intermediate plugin information.

To make things a little simpler, there also exists the **DefaultConstellationLogger** class, which implements all of the above methods but takes no action for any of them. By extending this class you can choose to only submit logs for the specific lifecycle points which interest you. Try creating your own log consumer now which simply prints to the console for the **applicationStart**, **applicationStop**, **pluginStart** and **pluginStop** methods.

#### 8.3.2: Using the Delegating Logger

If you wish to have multiple log consumers (say, one which prints to console and one which stores logs in a database) you can make use of the **DelegatingConstellationLogger** class to allow all your log consumers the opportunity to create logs. This class is simply a **ConstellationLogger** class itself, which looks up all other log consumers and asks them all to create a log.

To use the **DelegatingConstellationLogger** class, you simply need to ensure it is the default log consumer. The default log consumer is decided by comparing the position of all registered log consumers (which is optionally specified in the **ServiceProvider** annotation). The **DelegatingConstellationLogger** has a position of 0, so as long as all your log consumers have a position higher than this, it will be the default log consumer.

Try creating a second log consumer which simply prints different messages than your first log consumer. Don't set a position attribute on either of your log consumers (which will give them a default position of `Integer.MAX_VALUE`) to ensure the **DelegatingConstellationLogger** is active. Launch Constellation and observe the output.

It is worth noting that using multiple loggers can result in a performance penalty. To prevent this, it is recommended that you do not perform any long running operations inside the methods provided by **ConstellationLogger**. This can be worked around by queuing any long running operations and performing them later.

### 8.3.3: Logging a Plugin

In this section, we will use our new log consumer to accept logs from a plugin. Start by opening the **ChainCities-Plugin** class from Chapter 4. We will update this to provide more information about the execution of our Chain Cities plugin. Add the following code to the query method, directly before the return statement:

```
1 ...
2 ConstellationLogger.getDefault().pluginInfo(this, "Successfully queried " + query.size() + "
   cities.");
3 final Properties loggingProperties = new Properties();
4 loggingProperties.setProperty("ResultCount", String.valueOf(result.size()));
5 ConstellationLogger.getDefault().pluginProperties(this, loggingProperties);
6 ...
```

The code above first submits a simple information string to the logging system stating how many cities have been queried. Note that there is only one value recorded for plugin info. Subsequent calls to this method during a single plugin execution will over-write previous calls. The subsequent code creates a Java properties object with a key-value pair recording the number of flights we added to the graph. The properties object is then passed to the logging system as the plugin properties object. Again, while the properties object can hold as many key-value pairs as required, only a single plugin properties object is recorded for each plugin execution. Subsequent calls will over-write any previous calls.

Note that in this case we are logging using the **pluginProperties** method, which our current log consumers do not handle. Try overriding this method in one of your log consumers to print all properties to the console, and then run this plugin and observe the behaviour.

### 8.3.4: Logging to a file

The logging framework enables logging with plugins which is useful but sometimes you just want to log to a file. NetBeans has preconfigured routing to write to `var/log/messages.log` relative to the `-userdir` passed in when you use `java.util.logging.Logger`. Therefore the recommended approach to log would be to use `Logger` opposed to `System.out.println`.

```
1 ...
2 private static final Logger LOGGER = Logger.getLogger(OutbreakUtilities.class.getName());
3 ...
4 LOGGER.log(Level.INFO, "Flights: {0}", flightCount);
```

By default the lowest level of logging is “info”. To be able to log “fine”, “finer” and “finest” you have to pass that as an argument when launching Constellation like so:

```
constellation64.exe -J-Dau.gov.asd.tac.constellation.training.solutions.OutbreakUtilities.level=FINE
```

## Chapter 9: Extras

We have now added a huge number of features to Constellation in order to fully enable analysis of a pandemic. However, this guide has not yet covered all of the ways in which Constellation can be extended. This chapter will explore some other ways Constellation can be built upon. Please refer to the Training Solutions module suite for source code and other resources related to this chapter.

### Conversation View

The Conversation View allows you to view any data you might define as content (text, images, audio, video, etc.) in a chronological flow, as if a conversation was occurring. By default, it will render any text which appears in the ‘Content’ transaction attribute, but you can add your own **ConversationContributionProvider** classes to add new types of content to the conversation.

A valid conversation contribution requires 2 things – a check that the graph is relevant to this conversation contribution, and the logic for building the contribution. The contribution that is built should be a **ConversationContribution** object.

```

1 @ServiceProvider(service = ConversationContributionProvider.class)
2
3 public class IconContributionProvider extends ConversationContributionProvider {
4     private final SchemaAttribute iconAttribute =
5         VisualConcept.VertexAttribute.FOREGROUND_ICON;
6     private final SchemaAttribute flightAttribute = VisualConcept.TransactionAttribute.AIRLINE;
7
8     public IconContributionProvider() {
9         super("Icons", Integer.MAX_VALUE);
10    }
11
12    @Override
13    public boolean isCompatibleWithGraph(final GraphReadMethods graph) {
14        return iconAttribute.get(graph) != GraphConstants.NOT_FOUND
15            && flightAttribute.get(graph) != GraphConstants.NOT_FOUND;
16    }
17
18    @Override
19    public ConversationContribution createContribution(final GraphReadMethods graph, final
20        ConversationMessage message) {
21        final int iconAttributeId = iconAttribute.get(graph);
22        final int senderId = message.getSender();
23        final ConstellationIcon senderIcon = graph.getObjectValue(iconAttributeId, senderId);
24
25        final int flightAttributeId = flightAttribute.get(graph);
26        final int transactionId = message.getTransaction();
27        final String flight = graph.getStringValue(flightAttributeId, transactionId);
28
29        return new IconContribution(message, senderIcon, flight);
30    }
31
32    private class IconContribution extends ConversationContribution {
33        private final ConstellationIcon icon;
34        private final String flight;
35
36        public IconContribution(final ConversationMessage message, final ConstellationIcon
37            icon, final String flight) {
38            super(IconContributionProvider.this, message);
39            this.icon = icon;
40            this.flight = flight;
41        }
42
43        @Override
44        protected Region createContent(final TooltipPane tips) {
45            final VBox content = new VBox();
46            final ImageView iconImage = new ImageView(icon.buildImage());
47            final SelectableLabel iconLabel = new SelectableLabel(flight, true, null, tips,
48                null);
49            content.getChildren().addAll(iconImage, iconLabel);
50        }
51    }
52
53    }
54
55    }

```

```

46         return content;
47     }
48
49     @Override
50     public String toString() {
51         return "Icon Contribution";
52     }
53 }
54 }

```

## Map View

The Map View provides a geospatial view of the data in a graph. It comes complete with a basic set of base maps, tools and exporters, but these can be easily added to.

New base maps can be made available to the Map View by registering a **MapProvider** class. Given a coordinate (x, y), this class simply needs to return a tile image to place there, either from a local or network source. Below is an example of retrieving tiles from a local database.

```

1 @ServiceProvider(service = MapProvider.class)
2 public class BlackAndWhiteMapProvider extends MapProvider {
3
4     @Override
5     public String getName() {
6         return "Black & White";
7     }
8
9     @Override
10    public int zoomLevels() {
11        return 6;
12    }
13
14    @Override
15    public String getZoomString(final Coordinate coordinate) {
16        final float gridSize = PApplet.pow(2, coordinate.zoom);
17        final float negativeRow = gridSize - coordinate.row - 1;
18        return (int) coordinate.zoom + "/" + (int) coordinate.column + "/" + (int) negativeRow;
19    }
20
21    @Override
22    public PImage getTile(final Coordinate coordinate) {
23        final File blackAndWhiteMap =
24            ConstellationInstalledFileLocator.locate("modules/ext/Black&White.mbtiles",
25                "au.gov.asd.tac.constellation.training.solutions", false,
26                BlackAndWhiteMapProvider.class.getProtectionDomain());
27        final String connection = String.format("jdbc:sqlite:%s",
28            blackAndWhiteMap.getAbsolutePath());
29
30        final int zoom = (int) coordinate.zoom;
31        final float gridSize = PApplet.pow(2, coordinate.zoom);
32        final float negativeRow = gridSize - coordinate.row - 1;
33        final int row = (int) negativeRow;
34        final int column = (int) coordinate.column;
35        return MBTilesLoaderUtils.getMBTile(column, row, zoom, connection);
36    }
37
38    @Override
39    public String[] getTileUrls(final Coordinate coordinate) {

```

```

38         return null;
39     }
40 }

```

New tools can be overlaid on the Map View by registering a **MapOverlay** class. An overlay is built on top of the Processing framework, which provides a high level API for rendering on your graphics card, and simply asks you to define what to draw on screen and how to handle mouse and keyboard events.

```

1 @ServiceProvider(service = MapOverlay.class)
2 public class MousePositionOverlay extends MapOverlay {
3     private boolean mousePressed = false;
4
5     @Override
6     public float getName() {
7         return "Mouse Position Overlay";
8     }
9
10    @Override
11    public float getX() {
12        return renderer.getX() + renderer.getWidth() - 10 - width;
13    }
14
15    @Override
16    public float getY() {
17        return renderer.getY() + renderer.getHeight() - 10 - height;
18    }
19
20    @Override
21    public void overlay() {
22        renderer.noStroke();
23        renderer.fill(mousePressed ? HIGHLIGHT_COLOR : BACKGROUND_COLOR);
24        renderer.rect(x, y, width, height);
25        float yOffset = y + margin;
26        final String mouseX = String.valueOf(renderer.mouseX) + "px";
27        final String mouseY = String.valueOf(renderer.mouseY) + "px";
28        drawLabel("Mouse", x + 60, yOffset);
29        drawValue(mouseX, x + 60, yOffset, valueBoxMediumWidth, false, false);
30        drawValue(mouseY, x + 60 + valueBoxMediumWidth + padding, yOffset,
31            valueBoxMediumWidth, false, false);
32    }
33
34    @Override
35    public void mouseMoved(final MouseEvent event) {
36    }
37
38    @Override
39    public void mouseClicked(final MouseEvent event) {
40    }
41
42    @Override
43    public void mousePressed(final MouseEvent event) {
44        mousePressed = true;
45    }
46
47    @Override
48    public void mouseDragged(final MouseEvent event) {
49    }

```

```

50
51     @Override
52     public void mouseReleased(final MouseEvent event) {
53         mousePressed = false;
54     }
55
56     @Override
57     public void mouseWheel(final MouseEvent event) {
58     }
59
60     @Override
61     public void keyPressed(final KeyEvent event) {
62     }
63 }

```

New exporters can be added to the Map View by registering a **MapExporter** class. For convenience, you can also choose use the **AbstractGeoExportPlugin** class, which implements **MapExporter** but takes care of all the logic surrounding extracting geo data from the graph

```

1 @ServiceProviders({
2     @ServiceProvider(service = MapExporter.class),
3     @ServiceProvider(service = Plugin.class)
4 })
5 @NbBundle.Messages("TextGeoExporter=Export to Text")
6 @PluginInfo(pluginType = PluginType.EXPORT, tags = {"EXPORT"})
7 public class TextGeoExporter extends AbstractGeoExportPlugin {
8
9     @Override
10    protected FileChooser.ExtensionFilter getExportType() {
11        return new FileChooser.ExtensionFilter("TEXT", "*.txt");
12    }
13
14    @Override
15    protected void exportGeo(final PluginParameters parameters, final String uuid, final
        Map<String, String> shapes,
16        final Map<String, Map<String, Object>> attributes, final File output) throws
        IOException {
17        for (final String id : shapes.keySet()) {
18            final String shape = shapes.get(id);
19            try (final FileWriter writer = new FileWriter(output)) {
20                writer.write(String.format("%s=%s\n", id, shape));
21            }
22        }
23    }
24
25    @Override
26    public String getDisplayName() {
27        return "Text";
28    }
29
30    @Override
31    public String getPluginReference() {
32        return this.getClass().getName();
33    }
34 }

```

Analytic View

The Analytic View provides a way to calculate and visualise analytic results from a graph as well as have those results interact with that graph. It comes pre-packaged with a wide range of analytic plugins, and of course you can also add your own.

An analytic plugin is defined by writing an **AnalyticPlugin** class. You can also use one of the higher-level analytic plugin classes:

- A **ScoringAnalyticPlugin** assigns scores to graph elements based on a specified attribute after running a specified plugin.
- A **MultiScoringAnalyticPlugin** assigns multiple scores to graph elements based on a specified attribute after running a specified plugin.
- A **ClusterAnalyticPlugin** assigns cluster numbers to both nodes and transactions based on a set of specified attributes after running a specified plugin.
- A **GraphAnalyticPlugin** records whole-of-graph scores based on a set of specified attributes after running a specified plugin.

```

1 @ServiceProviders({
2     @ServiceProvider(service = Plugin.class),
3     @ServiceProvider(service = AnalyticPlugin.class)
4 })
5 @NbBundle.Messages("OutbreakCountAnalytic=Outbreak Count Analytic")
6 @PluginInfo(tags = {"ANALYTIC"})
7 @AnalyticInfo(analyticCategory = "Count")
8 public class OutbreakCountAnalytic extends AnalyticPlugin<ScoreResult> {
9
10     protected ScoreResult result;
11
12     @Override
13     public Set<SchemaAttribute> getPrerequisiteAttributes() {
14         final Set<SchemaAttribute> attributes = new HashSet<>();
15         attributes.add(PandemicConcept.VertexAttribute.OUTBREAK);
16         return attributes;
17     }
18
19     @Override
20     protected final void edit(final GraphWriteMethods graph, final PluginInteraction
        interaction,
21         final PluginParameters parameters) throws InterruptedException, PluginException {
22         result = new ScoreResult();
23
24         final int identifierAttributeId = VisualConcept.VertexAttribute.IDENTIFIER.get(graph);
25         final int outbreakAttributeId = PandemicConcept.VertexAttribute.OUTBREAK.get(graph);
26         final int outbreakCountAttributeId =
            PandemicConcept.VertexAttribute.OUTBREAK_COUNT.ensure(graph);
27
28         PluginExecution.withPlugin(PandemicPluginRegistry.SPREAD_INFECTION).executeNow(graph);
29
30         final int vertexCount = graph.getVertexCount();
31         for (int vertexPosition = 0; vertexPosition < vertexCount; vertexPosition++) {
32             final int vertexId = graph.getVertex(vertexPosition);
33             final Outbreak vertexOutbreak = graph.getObjectValue(outbreakAttributeId,
                vertexId);
34             if (vertexOutbreak != null) {
35                 final String identifier = graph.getStringValue(identifierAttributeId,
                    vertexId);
36                 final float score = vertexOutbreak.getNumberOfDiseases();

```



```

37         final boolean isNull = score == (int)
            graph.getAttributeDefaultValue(outbreakCountAttributeId);
38         result.add(new ScoreResult.ElementScore(GraphElementType.VERTEX, vertexId,
            identifier, isNull, score));
39     }
40 }
41 }
42
43 @Override
44 public Set getAnalyticAttributes(final PluginParameters parameters) {
45     final Set<SchemaAttribute> attributes = new HashSet<>();
46     attributes.add(PandemicConcept.VertexAttribute.OUTBREAK_COUNT);
47     return attributes;
48 }
49
50 @Override
51 public ScoreResult getResults() {
52     return result;
53 }
54
55 @Override
56 public Class<? extends AnalyticResult> getResultType() {
57     return ScoreResult.class;
58 }
59 }

```

Each analytic plugin must specify an **AnalyticResult** which determines the type of output the analytic produces. For example, the **ScoringAnalyticPlugin** uses a **ScoreResult** which records a score against a graph element, whereas the **GraphAnalyticPlugin** uses a **GraphResult** which records a score against a graph.

The results of analytic plugins can be aggregated together using an **AnalyticAggregator** class. This allows you to build more complex analytics by combining the results of simpler analytics. An analytic aggregator is valid for your analytic if it supports the same result type as your analytic.

Once you have one or more analytic plugins, you can create an **AnalyticQuestionDescription** class to represent a question you might ask of the graph. This class asks you to define the analytic plugins which will answer your question, values for the parameters of those plugins, and the method for aggregating the results in order to create a pre-set analytic for users to run. Note that the analytic plugins specified must use the same result type in order for them to be aggregated.

```

1 @ServiceProvider(service = AnalyticQuestionDescription.class)
2 public class HowManyOutbreaksQuestion implements AnalyticQuestionDescription {
3
4     @Override
5     public String getName() {
6         return "How many outbreaks?";
7     }
8
9     @Override
10    public String getDescription() {
11        return "Counts the number of outbreaks per city";
12    }
13
14    @Override
15    public List<Class<? extends AnalyticPlugin<ScoreResult>>> getPluginClasses() {
16        return Arrays.asList(OutbreakCountAnalytic.class);
17    }
18 }

```

```

19  @Override
20  public Class<? extends AnalyticAggregator<ScoreResult>> getAggregatorType() {
21      return SumScoreAggregator.class;
22  }
23
24  @Override
25  public Class<? extends AnalyticResult> getResultType() {
26      return ScoreResult.class;
27  }
28
29  @Override
30  public void initialiseParameters(final AnalyticPlugin plugin, final PluginParameters
    parameters) {
31  }
32 }

```

When an analytic plugin or question is run in the Analytic View, the result can be displayed within the Analytic View using an **InternalVisualisation** class or within the graph using a **GraphVisualisation** class. The Analytic View is able to automatically pick appropriate visualisations based on the result type of the analytic run by using the **InternalVisualisationTranslator** and **GraphVisualisationTranslator** classes, which define the logic for translating a result type to a visualisation.

### Schema View

The Schema View provides information about or related to the schema of the current graph. By default, the Schema View reveals information about attributes, vertex types, transaction types and plugins, but of course you can add more information using a **SchemaViewNodeProvider** class.

```

1  @ServiceProvider(service = SchemaViewNodeProvider.class)
2  public class PandemicNodeProvider implements SchemaViewNodeProvider {
3      private static final String INFO = "<Information about pandemics goes here>";
4
5      @Override
6      public void setContent(final Tab tab) {
7          final VBox node = new VBox();
8          final Label pandemicInfo = new Label(INFO);
9          node.getChildren().add(pandemicInfo);
10
11          Platform.runLater(() -> {
12              tab.setContent(node);
13          });
14      }
15
16      @Override
17      public void discardNode() {
18      }
19
20      @Override
21      public String getText() {
22          return "Pandemic Info";
23      }
24 }

```

## Chapter 10: Useful Links

Some useful reference links that one should be across are as follows:

- <http://wiki.netbeans.org/FaqIndex>

- <http://wiki.netbeans.org/NetBeansDeveloperFAQ>
- <http://wiki.netbeans.org/NetBeansUserFAQ>
- <https://netbeans.org/community/releases/82/relnotes.html>
- <https://netbeans.org/community/releases/81/relnotes.html>