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Cryptography for Java Developers runs in central London on:

- Wednesday 26 June 2013
- Saturday 29 June 2013

Cryptography for C Developers runs in central London on:

- Wednesday 10 July 2013
- Saturday 13 July 2013

To register for these courses, please:

- Follow the link at www.cogentlogic.com/London or
- Call freephone: 08000 438 478

- 1 Introduction to Cryptography
- 2 Cryptographic Service Providers
- 3 Symmetric Key Cryptography
- 4 Symmetric Key Cryptography for Android and iOS
- 5 Asymmetric Key Cryptography
- 6 Digital Signatures
- 7 Authenticated Encryption
- 8 Digital Certificates
- 9 PKI
- 10 Key Stores and Trust Stores
- 11 SSL and TLS (JSSE)
- 12 Accessing LDAP Servers with JNDI
- 13 Certificate Revocation Lists and OCSP
- 14 Privilege Management Infrastructure

- Android Training Courses
  - *Developing Mobile Applications with Android* is for Java programmers wishing to get up to speed on Android development.
  - *Software Development with Java* is for programmers wishing acquire a thorough grounding in Java.
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  - *Developing Mobile Applications with iOS* is for Objective-C programmers wishing to get up to speed on iOS development.
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  - *Developing Web Applications with Ruby on Rails* is for Ruby programmers wishing to get up to speed on Rails development.

  - *Software Development with Ruby* is for programmers wishing acquire a thorough grounding in Ruby.

Java Native Interface with Eclipse and Android

Jeff Lawson

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Java Native Interface with Eclipse and Android

What Is JNI and Why Use It?

Jeff Lawson

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What Is JNI?

- The *Java Native Interface* is a technology that enables Java developers to call C and C++ software from Java programs
- Asynchronous calls are possible with C/C++ calling back into Java
- JNI has been part of the Java platform since 1997

Why Use JNI?

- JNI is useful for:
  - Calling C/C++ libraries that off functions not available in Java, e.g. telephony, sound, graphics (images, 2D/3D animation, physics)
  - Calling platform-native code, e.g. Windows Registries
  - Re-using an existing corporate/organisation code base in C/C++
  - Improving the performance of compute-bound Java code
  - Incorporating Java solutions (JVM) into C/C++ projects

What is the Process for Using JNI?

- To make use of JNI we simply:
  - Write C/C++ code intended to be called from Java; this is often purpose-built Java-access code, e.g.
  - In Java, declare and call native methods that call into C/C++, e.g.
  - Compile the C/C++ code into a library, e.g.
  - Load the library into the Java program at runtime, e.g.
  - Compile and run the Java program

JNI Documentation

- The official source for JNI documentation is:

  `docs.oracle.com/javase/7/docs/technotes/guides/jni/`

- The book The Java Native Interface *Programmer's Guide and Specification* is available in print and as a free web download that Sun used to provide but Oracle seem not to, so search for it online!

Java Native Interface with Eclipse and Android

Compiling C/C++ Programs

Jeff Lawson

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Compiling C/C++

- C and C++ source code typically comprises:
  - One or more implementation file(s), with file name extensions `.c` and `.cpp`, respectively
  - Associated header file(s) with `.h` file name extension
- The collection of source code files must be:
  - Compiled into object code
  - Linked with zero or more libraries into a final library or executable
- JNI Java code calls into one or more libraries:
  .o files on Unixes (Linux and Mac OS X), .dll files on Windows
- Tool collections, like a compiler plus a linker are known as a *toolchain*

GNU Compiler Collection

- *GNU C Compiler* (GCC) was originally developed by Richard Stallman for use with the GNU Project, a free Unix-like operating system

- GCC has since grown to support C++, Obj-C, Java and more; it is now known as the *GNU Compiler Collection* and is available from:

  `gcc.gnu.org`

- GCC is available for:

  - Mac OS X as an optional Xcode component, *Command Line Tools*
  - Linux with `up2date`, `yum` or `apt-get`, as applicable to the distro
  - Windows with MinGW (not Cygwin because it targets Cygwin)

GCC on Mac OS X

- To install GCC on Mac OS X through Xcode:
  - Xcode menu, Preferences..., Downloads tab, Components tab
  - Select Command Line Tools and click the Install button

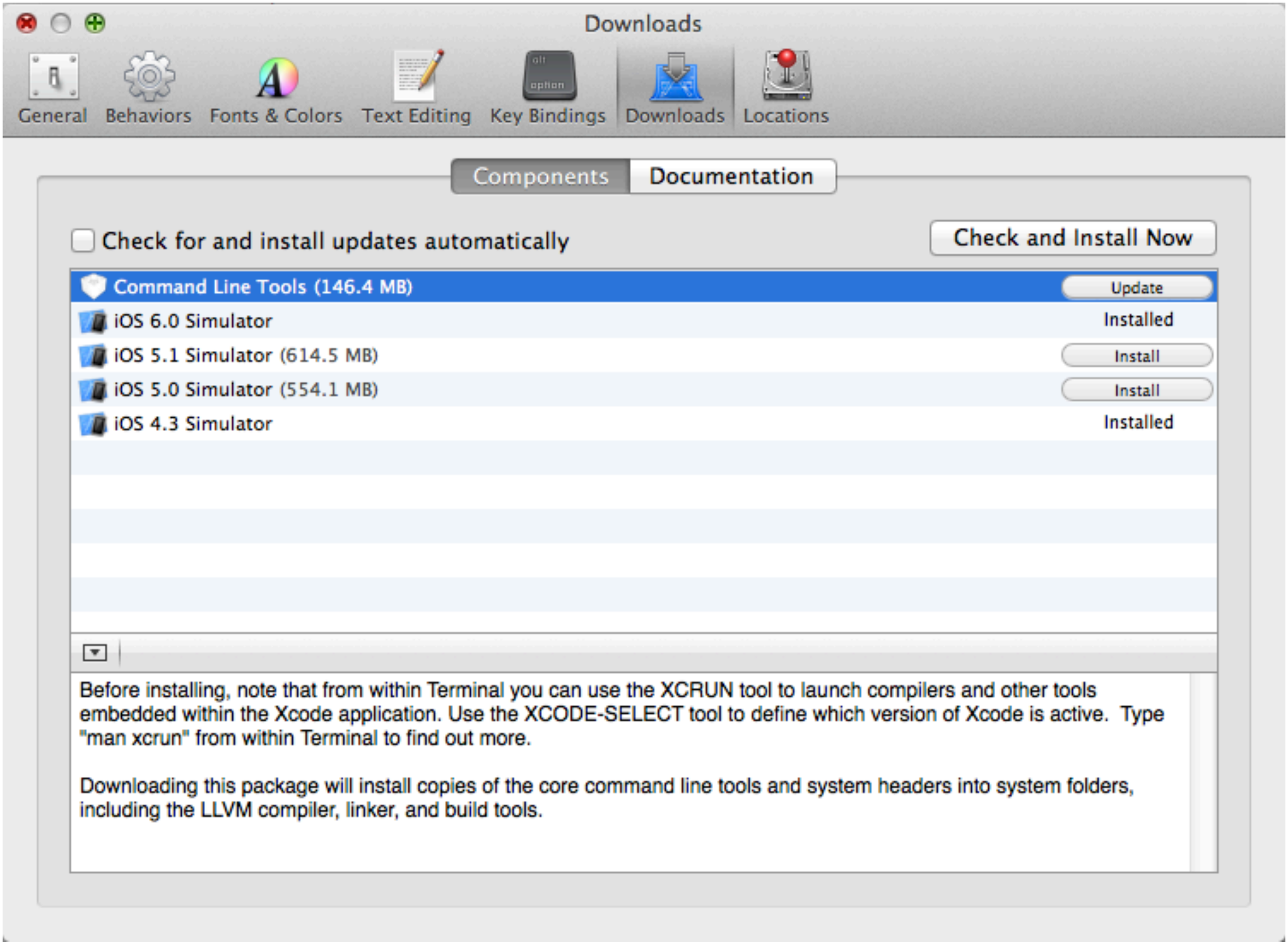
...

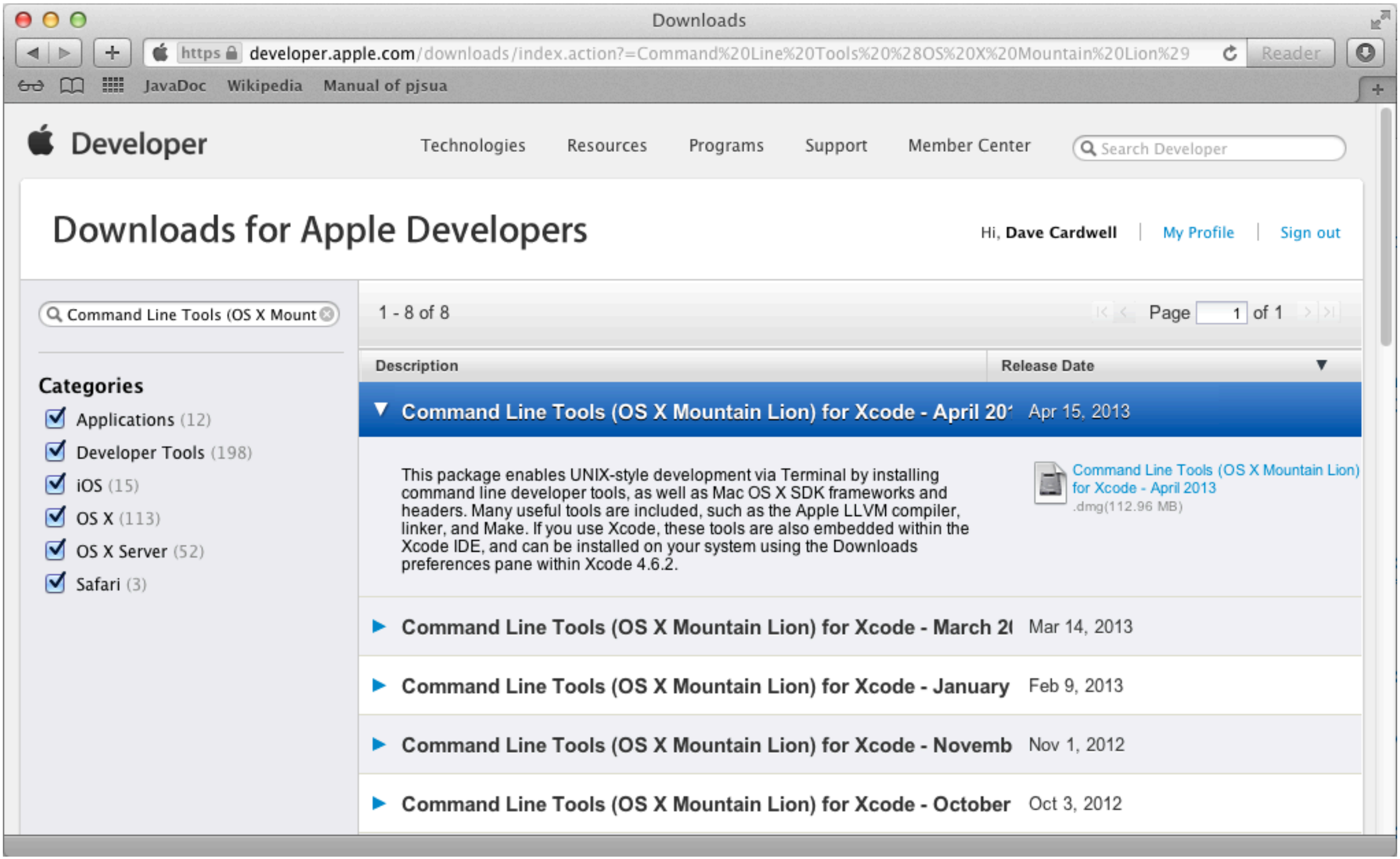
...

- To Install GCC on Mac OS X without Xcode, download the Command Line Tools from:

```
developer.apple.com/downloads/index.action?=
    Command%20Line%20Tools%20%28OS%20X%20Mountain%20Lion%29
```

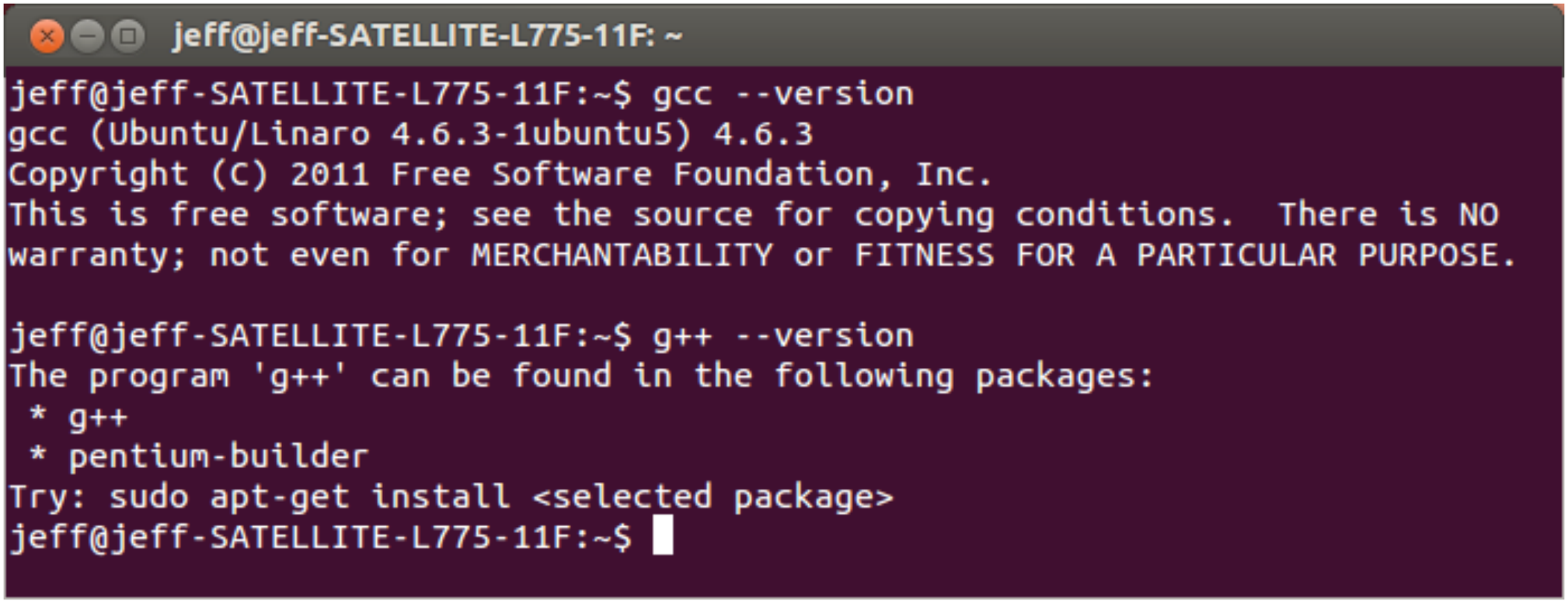
...





GCC on Linux

- First, check for the presence of GCC by entering `gcc --version` then, if GCC is absent, install it
- To install GCC on Red Hat Enterprise, enter `up2date gcc`
- For CentOS / Fedora Core, enter `yum install gcc`
- For Debian / Ubuntu, enter `sudo apt-get install gcc`
- Similarly, for the C++ compiler:
    - Check for the C++ compiler by entering `g++ --version`
    - If necessary, install, e.g. `sudo apt-get install g++`



```
jeff@jeff-SATELLITE-L775-11F: ~
jeff@jeff-SATELLITE-L775-11F:~$ sudo apt-get install g++
[sudo] password for jeff:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following extra packages will be installed:
  g++-4.6 libstdc++6-4.6-dev
Suggested packages:
  g++-multilib g++-4.6-multilib gcc-4.6-doc libstdc++6-4.6-dbg libstdc++6-4.6-doc
The following NEW packages will be installed
  g++ g++-4.6 libstdc++6-4.6-dev
0 upgraded, 3 newly installed, 0 to remove and 208 not upgraded.
Need to get 8,615 kB of archives.
After this operation, 25.4 MB of additional disk space will be used.
Do you want to continue [Y/n]? Y
Get:1 http://gb.archive.ubuntu.com/ubuntu/ precise/main libstdc++6-4.6-dev amd64 4.6.3-1ubuntu5 [1,66
0 kB]
Get:2 http://gb.archive.ubuntu.com/ubuntu/ precise/main g++-4.6 amd64 4.6.3-1ubuntu5 [6,954 kB]
Get:3 http://gb.archive.ubuntu.com/ubuntu/ precise/main g++ amd64 4:4.6.3-1ubuntu5 [1,442 B]
Fetched 8,615 kB in 10s (828 kB/s)
Selecting previously unselected package libstdc++6-4.6-dev.
(Reading database ... 142534 files and directories currently installed.)
Unpacking libstdc++6-4.6-dev (from .../libstdc++6-4.6-dev_4.6.3-1ubuntu5_amd64.deb) ...
Selecting previously unselected package g++-4.6.
Unpacking g++-4.6 (from .../g++-4.6_4.6.3-1ubuntu5_amd64.deb) ...
Selecting previously unselected package g++.
Unpacking g++ (from .../g++_4%3a4.6.3-1ubuntu5_amd64.deb) ...
Processing triggers for man-db ...
Setting up g++-4.6 (4.6.3-1ubuntu5) ...
Setting up g++ (4:4.6.3-1ubuntu5) ...
update-alternatives: using /usr/bin/g++ to provide /usr/bin/c++ (c++) in auto mode.
Setting up libstdc++6-4.6-dev (4.6.3-1ubuntu5) ...
jeff@jeff-SATELLITE-L775-11F:~$
```

GCC on Windows

- To install GCC on Windows, use Minimalist GNU for Windows (MinGW) from `www.mingw.org`

- Download the installer from:
  `sourceforge.net/projects/mingw/files/Installer/mingw-get-inst/`

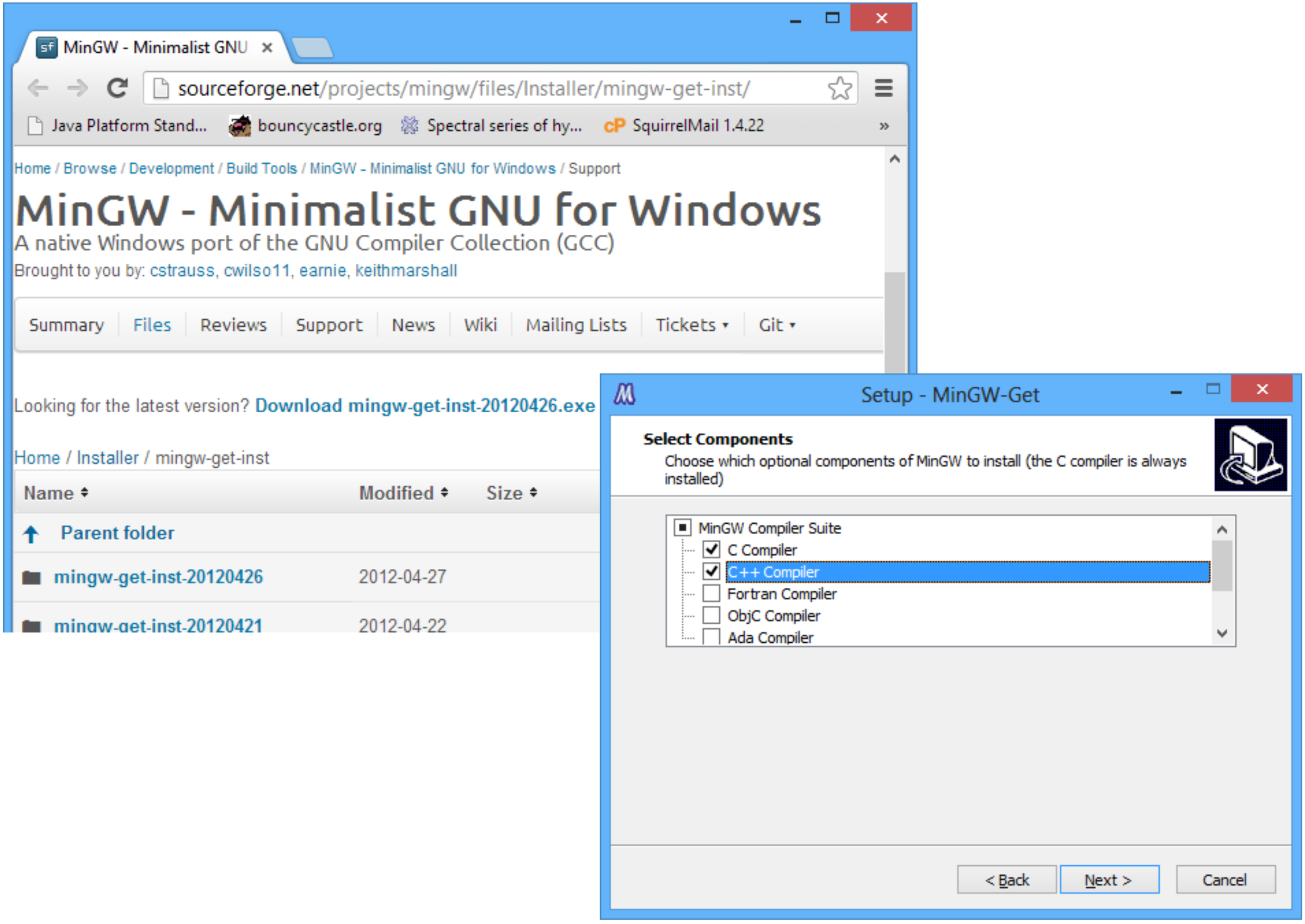
  e.g. `mingw-get-inst-20120426.exe`

- The C++ compiler is not installed by default, so select it (there is no need to install MSYS)

- Several components will downloaded from through a shell script

- Manually add `C:\MinGW\bin` to the PATH environment variable

For 64-bit support, see:
`mingw-w64.sourceforge.net`



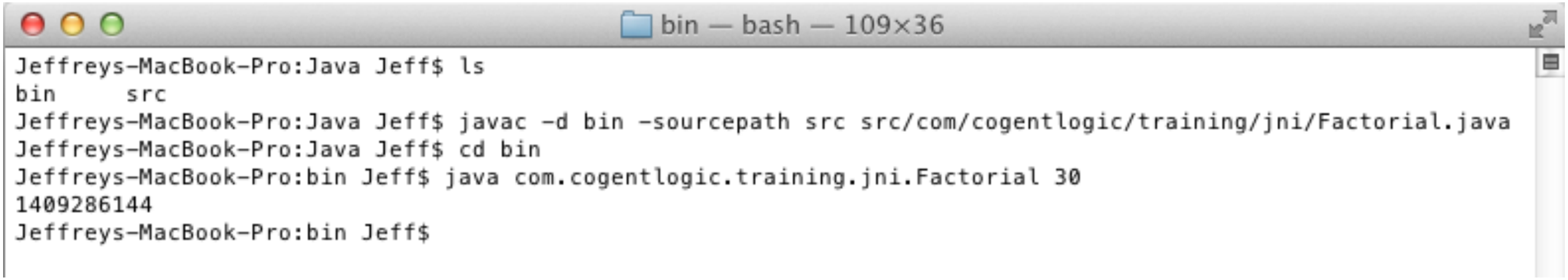
Sample Java Program

- Let's look at compilation and execution of a simple Java program

```
package com.cogentlogic.training.jni;

public class Factorial
{
  public static int evaluate(int n)
  {
     return n == 1 ? 1 : n * evaluate(n - 1);
  }

  public static void main(String[] args)
  {
     if (args.length == 1)
        System.out.println(Factorial.evaluate(
                                   Integer.parseInt(args[0])));
  }
}
```

- We compile and execute the Java program in the usual way:

```
javac -d bin -sourcepath src
      src/com/cogentlogic/training/jni/Factorial.java

java com.cogentlogic.training.jni.Factorial 30
```



Sample C Program

- Here is an equivalent program in C:

```
#include "Factorial.h"
#include <stdio.h>        // printf
#include <stdlib.h>       // atoi

int factorial(int n)
{
  return n == 1 ? 1 : n * factorial(n - 1);
}

int main(int argc, const char **argv)
{
  // Should be two arguments: the command and the parameter
  if (argc != 2)
     return -1;
  int nFactorial = factorial(atoi(argv[1]));
  printf("%d\n", nFactorial);
  return 0;
}
```

- We typically need a C header file:

```
#ifndef FACTORIAL_H_
#define FACTORIAL_H_

int factorial(int n);

#endif /* FACTORIAL_H_ */
```

- To compile the C source code `Factorial.c` in to the object code file `Factorial.o`:

```
gcc -o Factorial.o Factorial.c
```

- To execute the C program on Mac/Linux:

```
./Factorial.o 30
```

- To execute the C program on Windows:

```
.\Factorial.o 30
```

(or `Factorial.o 30`)

Sample C++ Program

- Here an equivalent program in C++:

```
#include "Factorial.h"
#include <stdlib.h>      // atoi
#include <iostream>      // std::cout, etc.

Factorial::Factorial()
{
}

Factorial::~Factorial()
{
}

int Factorial::evaluate(int n)
{
  return n == 1 ? 1 : n * evaluate(n - 1);
}
```

- (C++ code continued):

```
int main(int argc, const char **argv)
{
  // Should be two arguments: the command and the parameter
  if (argc != 2)
     return -1;

  Factorial* factorial = new Factorial();
  int nFactorial = factorial->evaluate(atoi(argv[1]));

  std::cout << nFactorial << std::endl;

  return 0;
}
```

- We typically need a header file:

```
#ifndef FACTORIAL_H_
#define FACTORIAL_H_

class Factorial
{
public:
  Factorial();
  virtual ~Factorial();
  int evaluate(int n);
};

#endif /* FACTORIAL_H_ */
```

- To compile the C++ source code `Factorial.cpp` in to the object code file `Factorial.o`:

```
g++ -o Factorial.o Factorial.cpp
```

- To execute the C++ program:

```
./Factorial.o 30
```

Java Native Interface with Eclipse and Android

Writing C Functions and C++ Methods Callable from Java

Jeff Lawson

Contents

- JNI Code
- Calling C from Java
- Calling C++ from Java

JNI Code

- Java Native Interface documentation can be found at:

  `docs.oracle.com/javase/7/docs/technotes/guides/jni`

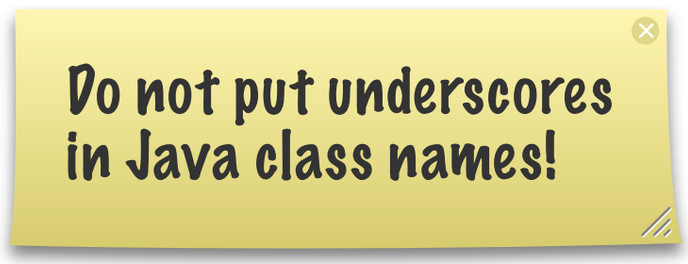
- JNI requires C and C++ functions to be named as follows:

  `Java_<package_name>_<Java_class_name>_<function_name>`

  where `<package_name>` contains underscores in place of periods

- For example, for a Java class called `Test` in the package `test.greet` needing to make a call to a native method it knows as `greeting`, the C/C++ function is named:

  `Java_test_greet_Test_greeting`



- C++ functions must be exposed with C linkage using `extern "C"`

Calling C from Java

- Sample C header file: (*MathsC.h*)

```
#ifndef MATHSC_H_
#define MATHSC_H_

#include <jni.h>

JNIEXPORT jint JNICALL
    Java_com_cogentlogic_training_jni_Maths1_fibonacci(JNIEnv*,
                                                       jobject,
                                                       jint);

#endif  // MATHSC_H_
```

- Sample C implementation file: (*MathsC.c*):

```
#include "MathsC.h"

int fib(int n)
{
  // F0 = 0;  F1 = 1
  // Fn = Fn-1 + Fn-2   for n > 1
  return n <= 1 ? n : fib(n - 1) + fib(n - 2);
}

JNIEXPORT jint JNICALL
  Java_com_cogentlogic_training_jni_Maths1_fibonacci(JNIEnv* penv,
                                                     jobject obj,
                                                     jint n)
{
  return fib(n);
}
```

- This code needs to be compiled then linked as a library

- The Java code loads the library and calls its native method(s), e.g. (*Maths1.java*)

```
package com.cogentlogic.training.jni;

public class Maths1
{
  static
  {
     System.loadLibrary("MathsC");
  }

  public native int fibonacci(int n);

  public static void main(String[] args)
  {
     if (args.length == 1)
     {
        Maths1 maths1 = new Maths1();
        System.out.println("" +
                  maths1.fibonacci(Integer.parseInt(args[0])));
     }
  }
}
```

- To compile `MathC.c` on Mac OS X:

```
gcc -I/System/Library/Frameworks/JavaVM.framework/Headers
    -o MathsC.o -c MathsC.c
```

`-c` means 'compile only'
The `-I` option specifies the location of `jni.h`

- To link `MathC.o` on Mac OS X:

```
gcc -shared -o libMathsC.jnilib MathsC.o
```

The generated library must be named `lib<name>.jnilib` where `<name>` is referenced by the Java code

- To run *Maths1.java* on Mac OS X, compile the class:

```
javac -d bin -sourcepath src
      src/com/cogentlogic/training/jni/Maths1.java
```

then enter:

```
java com.cogentlogic.training.jni.Maths1 30
```

- To compile and link `MathC.c` on Linux (tested on ubuntu 12.04 LTS):

```
gcc -fPIC -I/usr/lib/jvm/java-7-oracle/include
          -I/usr/lib/jvm/java-7-oracle/include/linux
          -o libMathsC.so -shared MathsC.c
```

  x86-64 architectures require Position Independent Code for shared libraries, hence, the use of `-fPIC`

- To run *Maths1.java* on Linux, compile the class:

```
javac -d bin -sourcepath src
      src/com/cogentlogic/training/jni/Maths1.java
```

  then enter:

```
java -Djava.library.path=./ com.cogentlogic.training.jni.Maths1 30
```

- To compile and link `MathC.c` on Windows (32- and 64-bit) using 32-bit GCC and 32-bit Java*:

```
gcc -Wall -D_JNI_IMPLEMENTATION_ -Wl,--kill-at
    -I"C:/Program Files (x86)/Java/jdk1.7.0_21/include"
    -I"C:/Program Files (x86)/Java/jdk1.7.0_21/include/win32"
    -shared -o MathsC.dll MathsC.c
```

  x86-64 architectures require `-m64`

- To run *Maths1.java* on Windows, compile the class:

```
"C:\Program Files (x86)\Java\jdk1.7.0_21\bin\javac" -d bin
   -sourcepath src src/com/cogentlogic/training/jni/Maths1.java
```

  then enter:

```
"C:\Program Files (x86)\Java\jdk1.7.0_21\bin\java"
                          com.cogentlogic.training.jni.Maths1 30
```

* From `java.sun.com`, download Windows 32-bit JDK as the version *Windows x86,* e.g. `jdk-7u21-windows-i586.exe`

Calling C++ from Java

- Sample C header file: (*MathsCPP.h*)

```
#include <jni.h>

class MathsCPP
{
public:
    int fib(int n);
};

#ifdef __cplusplus
extern "C" {
#endif

JNIEXPORT jint JNICALL
  Java_com_cogentlogic_training_jni_Maths2_fibonacci(JNIEnv*,
                                                     jobject, jint);

#ifdef __cplusplus
}
#endif
```

```
#ifndef MATHSCPP_H_
omitted for lack of space
```

- Sample C++ implementation file: (*MathsCPP.cpp*):

```
#include "MathsCPP.h"

int MathsCPP::fib(int n)
                  {return n <= 1 ? n : fib(n - 1) + fib(n - 2);}

#ifdef __cplusplus
extern "C" {
#endif

JNIEXPORT jint JNICALL
 Java_com_cogentlogic_training_jni_Maths2_fibonacci(JNIEnv* penv,
                                                    jobject obj, jint n)
{
  MathsCPP* mathsCPP = new MathsCPP();
  int nFib = mathsCPP->fib(n);
  delete mathsCPP;
  return nFib;
}

#ifdef __cplusplus
}
#endif
```

- The Java code loads the library and calls its native method(s), e.g. (*Maths2.java*)

```
package com.cogentlogic.training.jni;

public class Maths2
{
   static
   {
      System.loadLibrary("MathsCPP");
   }

   public native int fibonacci(int n);

   public static void main(String[] args)
   {
      if (args.length == 1)
      {
         Maths2 maths2 = new Maths2();
         System.out.println("" +
                  maths2.fibonacci(Integer.parseInt(args[0])));
      }
   }
}
```

- To compile `MathCPP.cpp` on Mac OS X:

```
g++ -I/System/Library/Frameworks/JavaVM.framework/Headers
    -o MathsCPP.o -c MathsCPP.cpp
```

`-c` means 'compile only'
The `-I` option specifies the location of `jni.h`

- To link `MathCPP.o` on Mac OS X:

```
g++ -shared -o libMathsCPP.jnilib MathsCPP.o
```

The generated library must be named `lib<name>.jnilib` where `<name>` is referenced by the Java code

- To run *Maths2.java* on Mac OS X, compile the class:

```
javac -d bin -sourcepath src
      src/com/cogentlogic/training/jni/Maths2.java
```

then enter:

```
java com.cogentlogic.training.jni.Maths2 30
```

Java Native Interface with Eclipse and Android

Compiling C/C++ Programs with Eclipse

Jeff Lawson

Contents

Adding C/C++ to Eclipse

- Various Eclipse packages are available from:

  `www.eclipse.org/downloads/`

- You can choose a package that supports both Java and C/C++

- To add C/C++ support to a Java-based version of Eclipse:

  - Select `Install New Software...` from the `Help` menu

  - Select the releases software site,
    e.g. `Juno - http://download.eclipse.org/releases/juno`

  - Select `C/C++ Development Tools` under `Programming Languages`

  - Click the `Next >` button twice, accept the license then click `Finish`

Install

Available Software

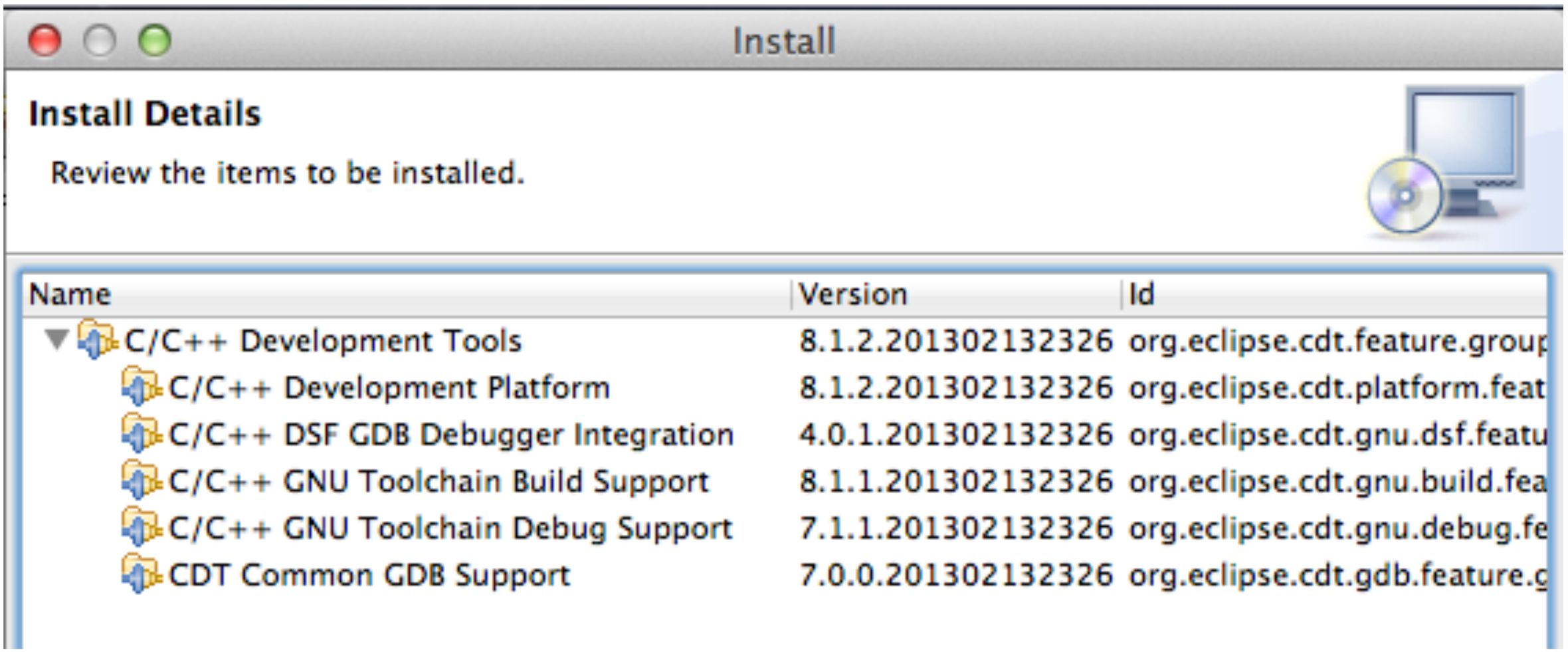
Check the items that you wish to install.

Work with: Juno - http://download.eclipse.org/releases/juno — Add...

Find more software by working with the "Available Software Sites" preferences.

type filter text

Name	Version
Modeling	
Programming Languages	
Autotools support for CDT	3.0.1.201302132326
C/C++ Call Graph Visualization	1.1.0.201302051708
C/C++ Development Tools	8.1.2.201302132326
C/C++ Development Tools SDK	8.1.2.201302132326
C/C++ Library API Documentation Hover Help	1.0.0.201302051708
C/C++ Unit Testing Support	7.0.0.201302132326
CDT Visual C++ Support	1.0.0.201302132326

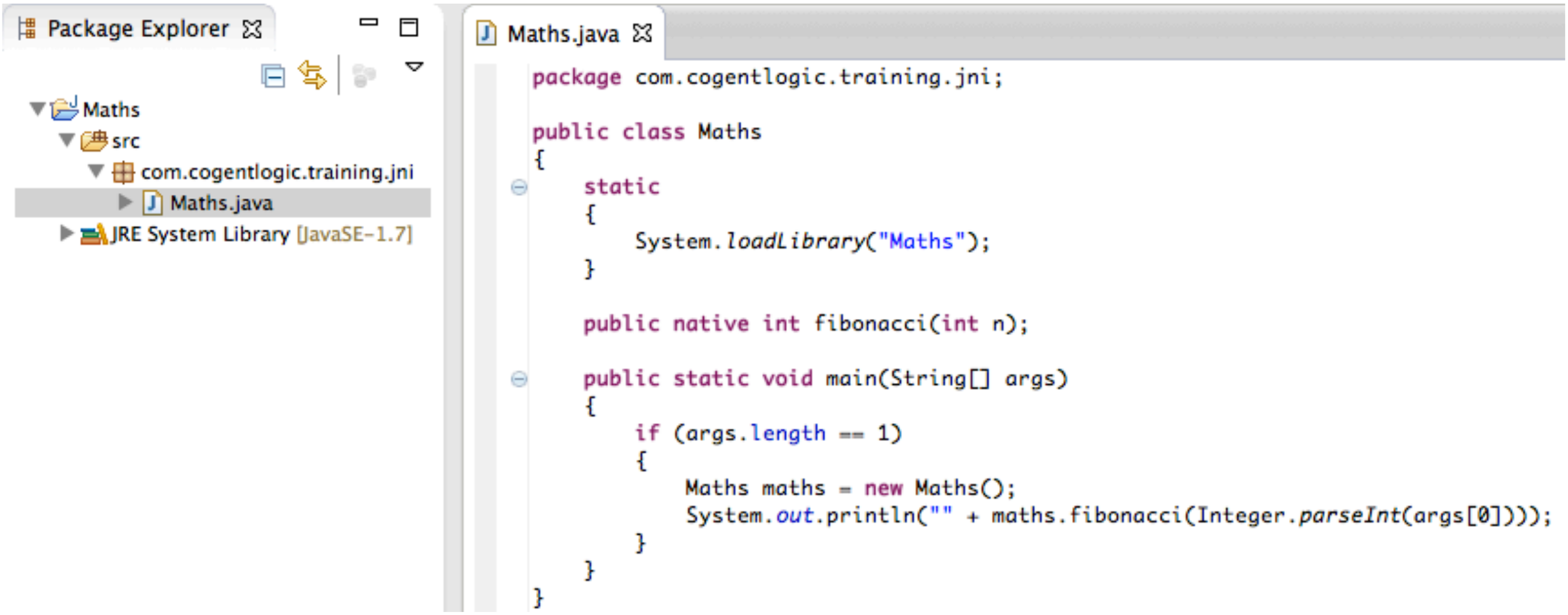


- Finally, from the `Window` menu select `Open Perspective` followed by `Other...`
- Select the `C/C++` perspective

Java and C/C++ with Eclipse

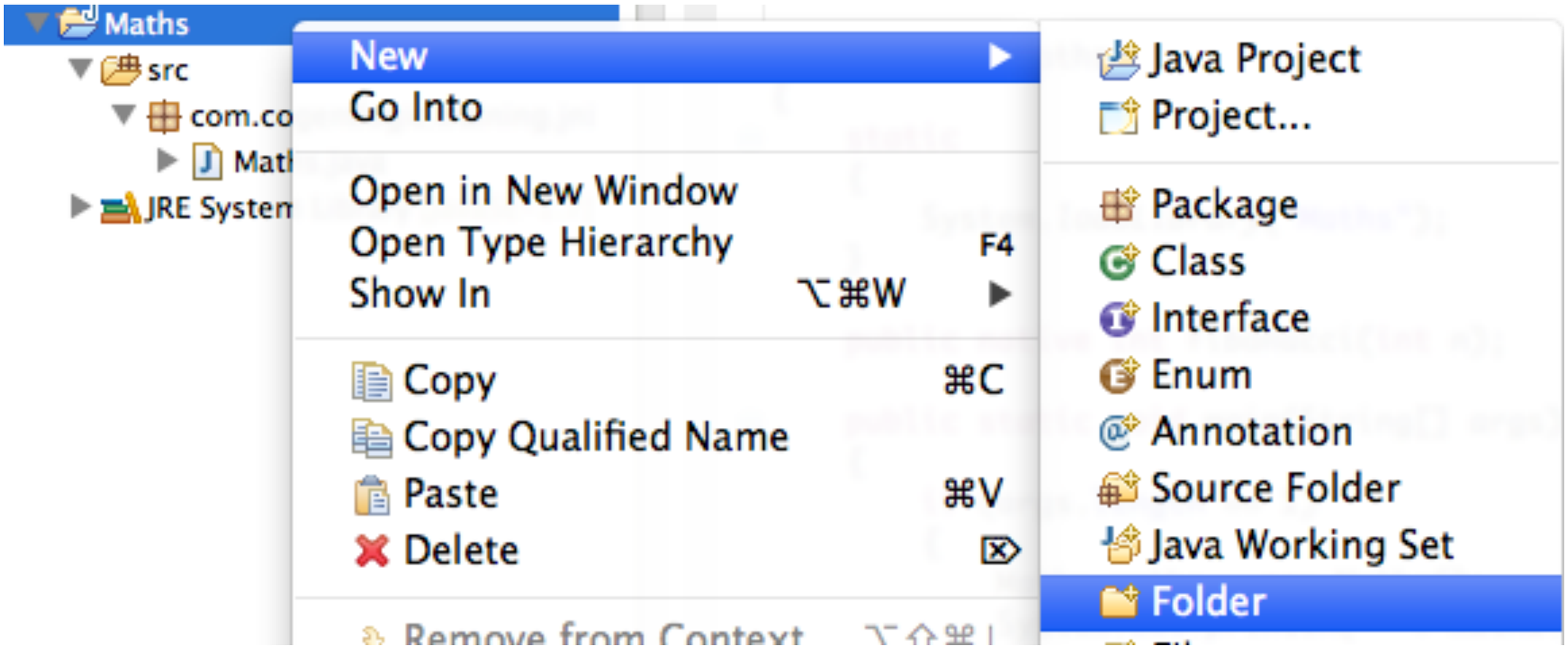
- You can create separate Java and C/C++ projects and import the C/C++ library into the Java project
- You will most likely want to use a combination Java/C/C++ project!
- The general procedure is:
  - Create a Java project with Java source code
  - Add C/C++ source code in its own folder, e.g. `jni`
  - Convert the project to a mixed Java and C/C++ project
  - Configure settings to have Java load the C/C++ library
- The following procedure applies to Mac OS X...

- Here a Java project has been created and a class has been added:

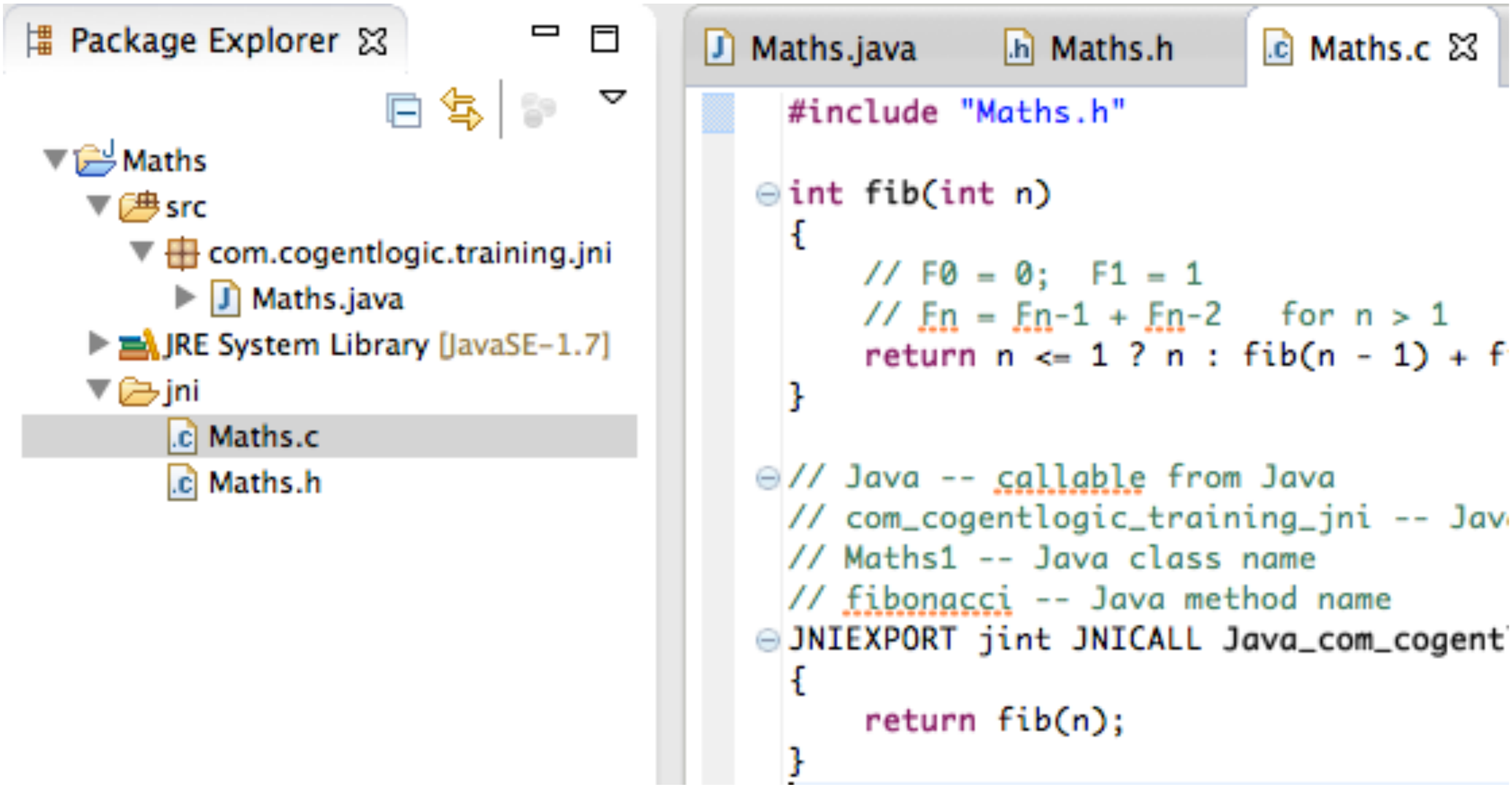


- The `Maths` class is similar to `Maths1` seen earlier
- The library will be called `Maths`, similar to `MathsC` seen earlier

- Create a folder to hold the C/C++ code, here called `jni`:

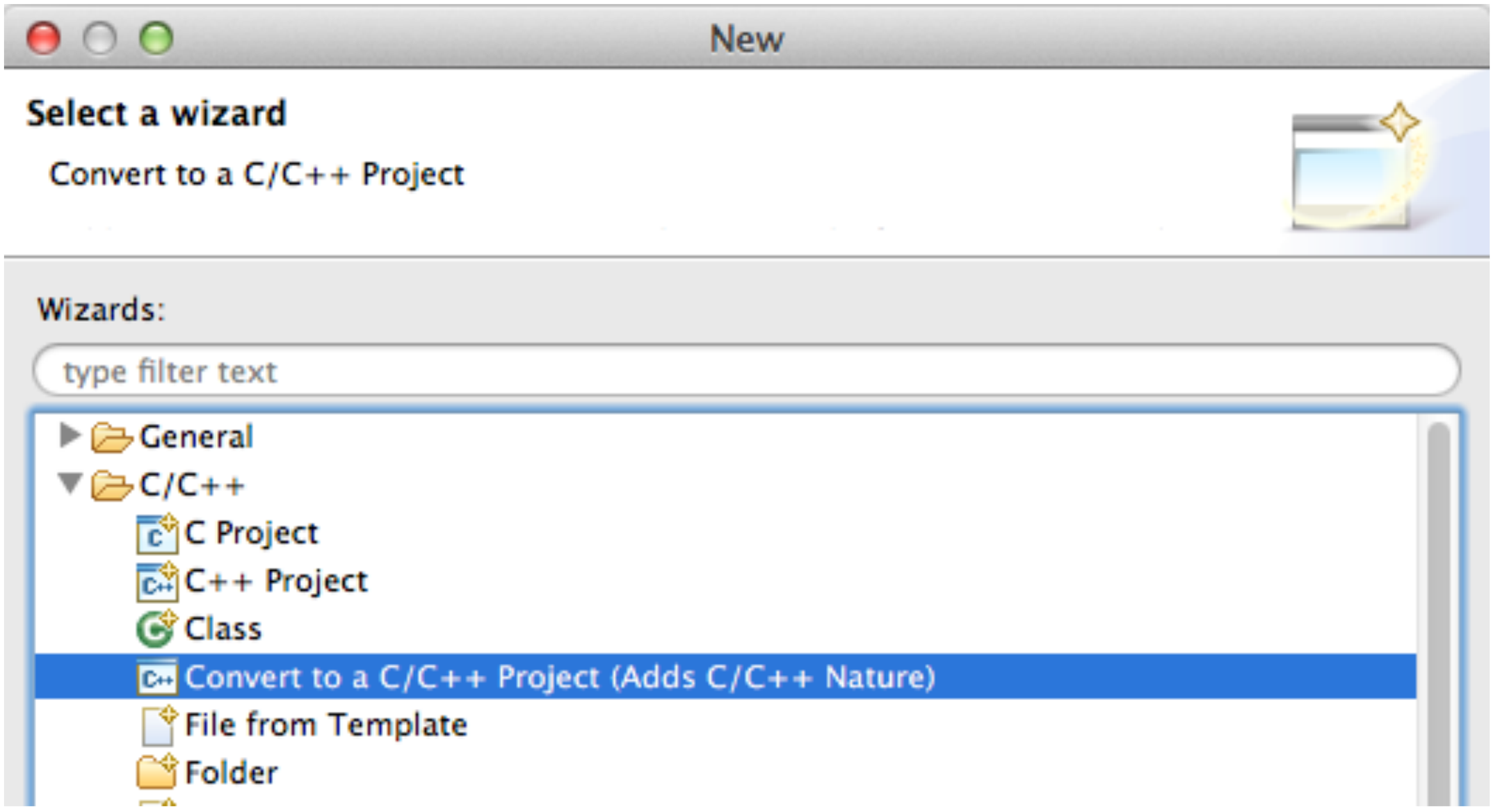


- Add a C header file and a C or C++ implementation file:

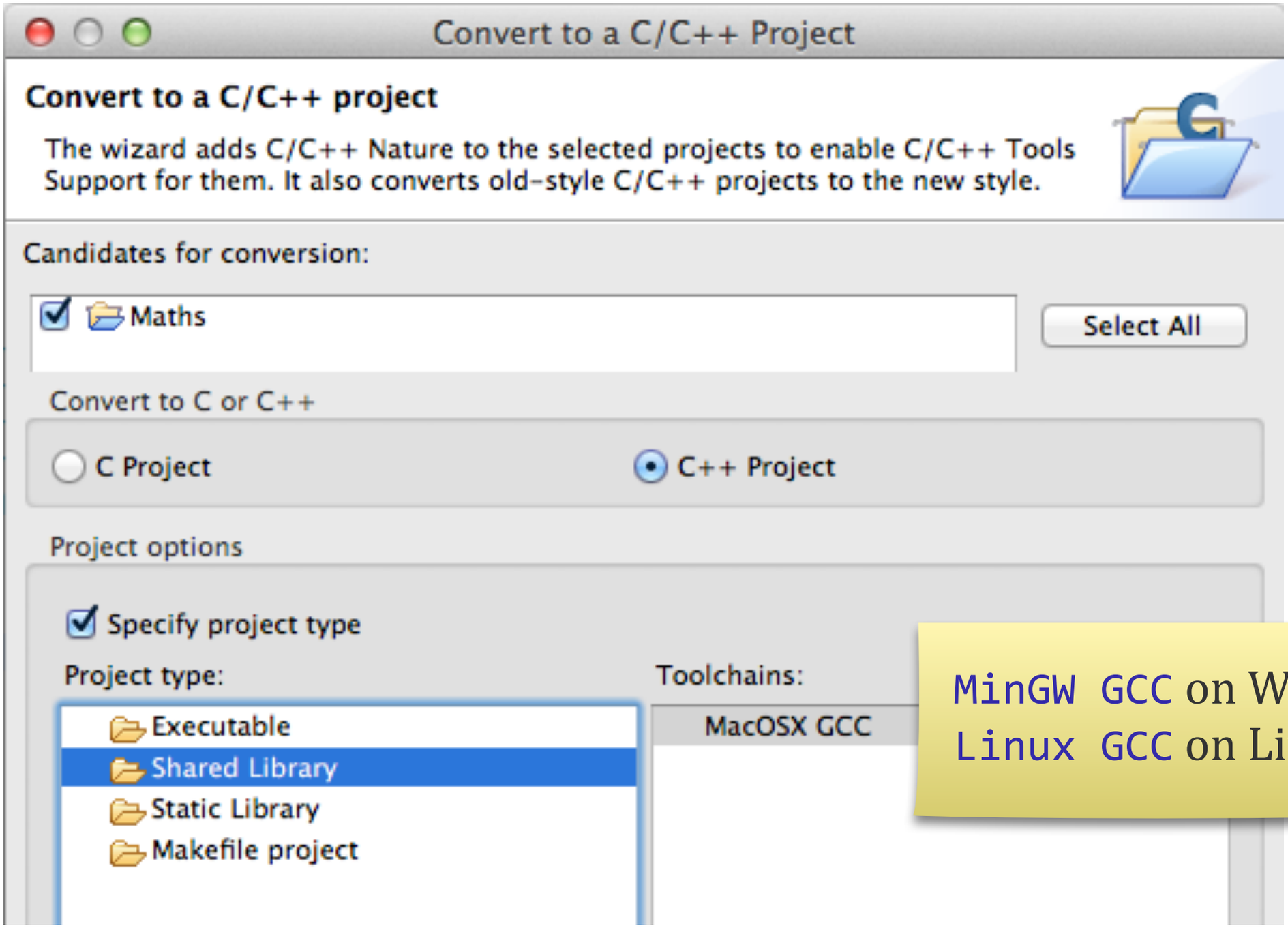


- These files are pretty much the same as `MathsC.h` and `MathsC.c` seen earlier

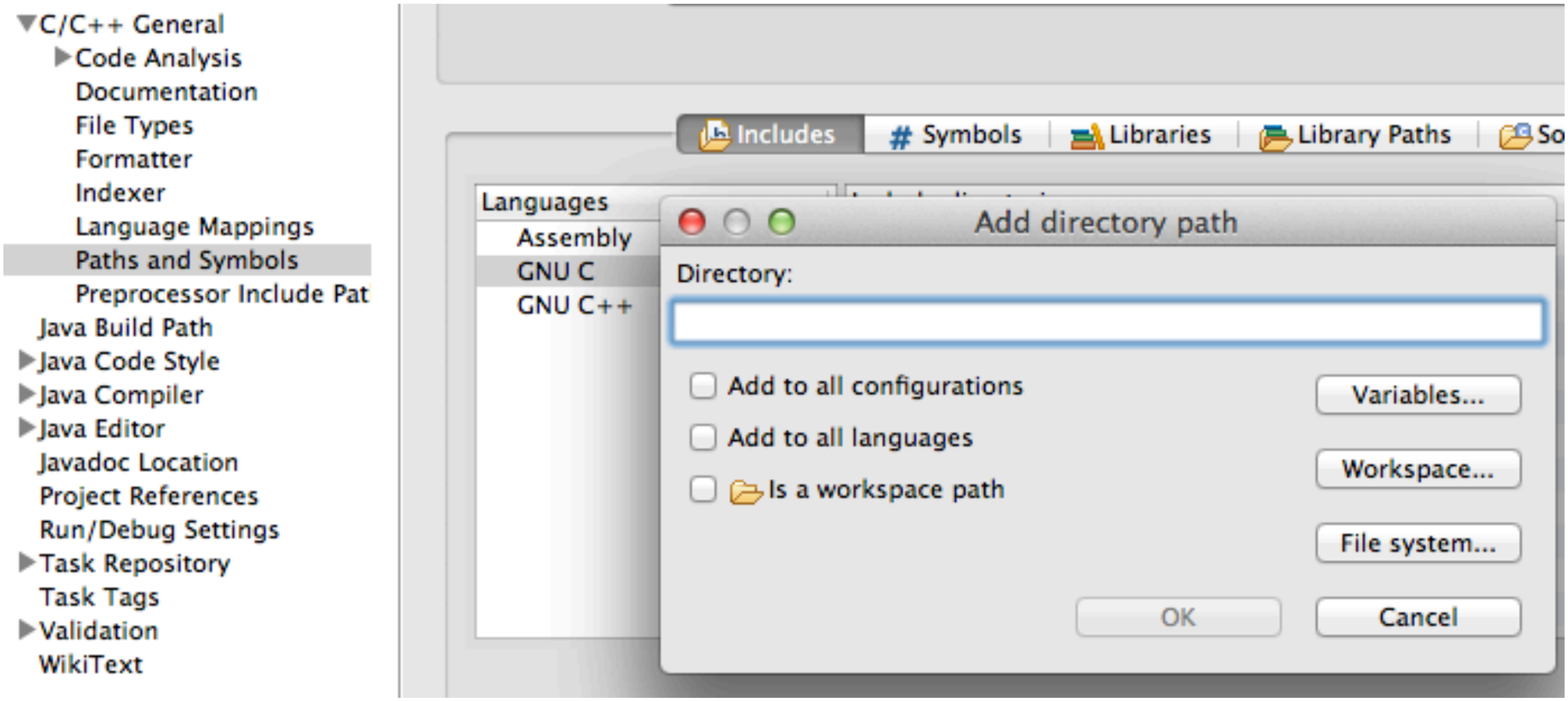
- Convert the project
  - From the `File` menu, select `New` the `Other...`
  - Under `C/C++`, select `Convert to a C/C++ Project`



- Click the `Next >` button
- Select `Shared Library` then click the `Finish` button



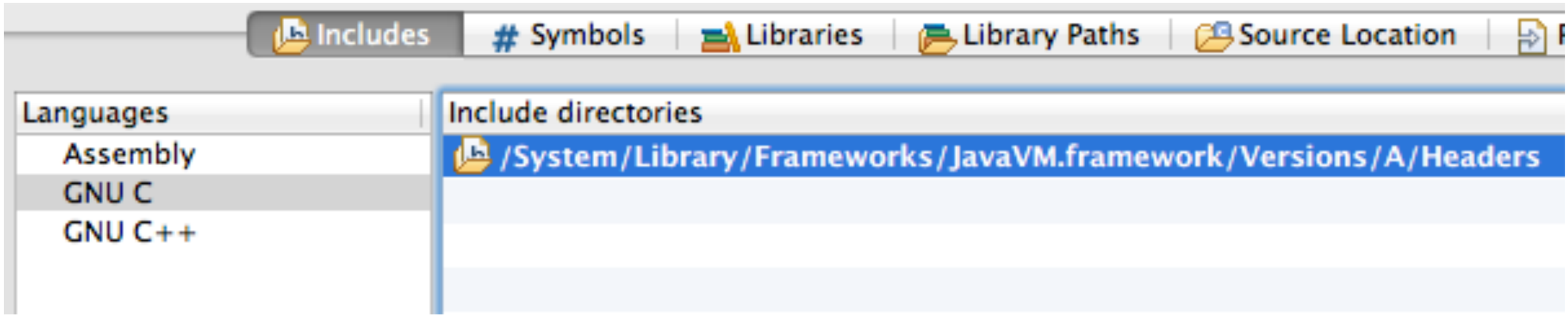
- The project will have C/C++ build errors because we have not specified the JNI header files path
- In the project's `Properties`, `C/C++ General`, select `Paths and Symbols`
- On the `Includes tab`, select GNU C and click the `Add...` button



- Click the `Filesystem...` button and navigate to the JNI header files path, e.g. for Mac OS X, `/System/Library/Frameworks/JavaVM.framework/Headers`

- Click the `OK` button followed by the `Apply` button

- Accept the offer to rebuild the project then click the next `OK` button

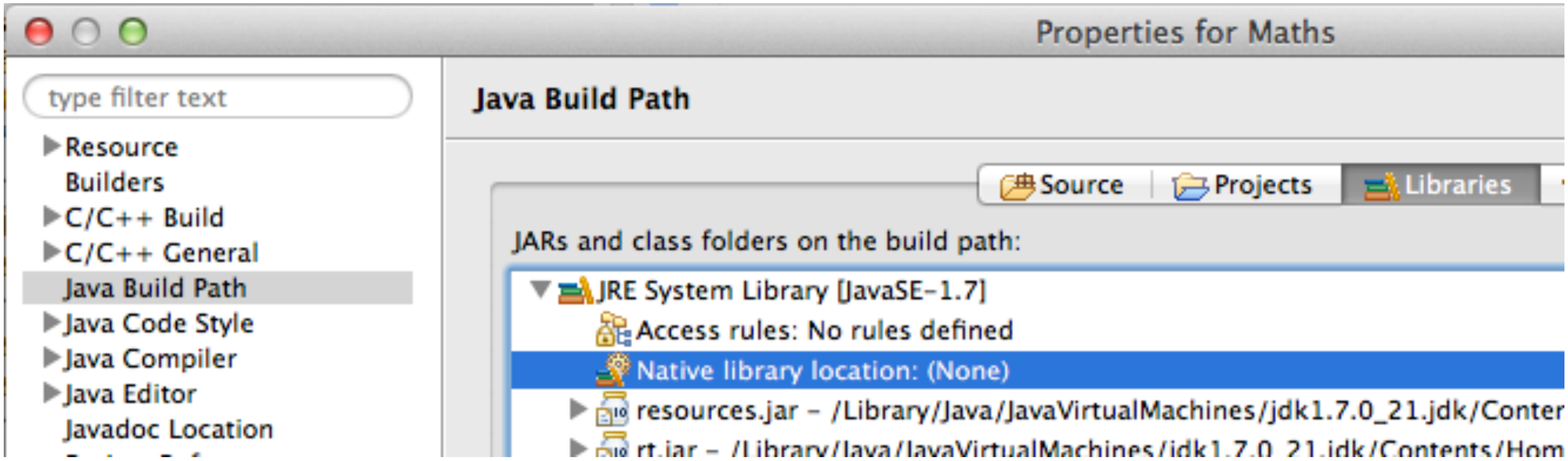


(if the path points to a symbolic link, it will be dereferenced, as here)

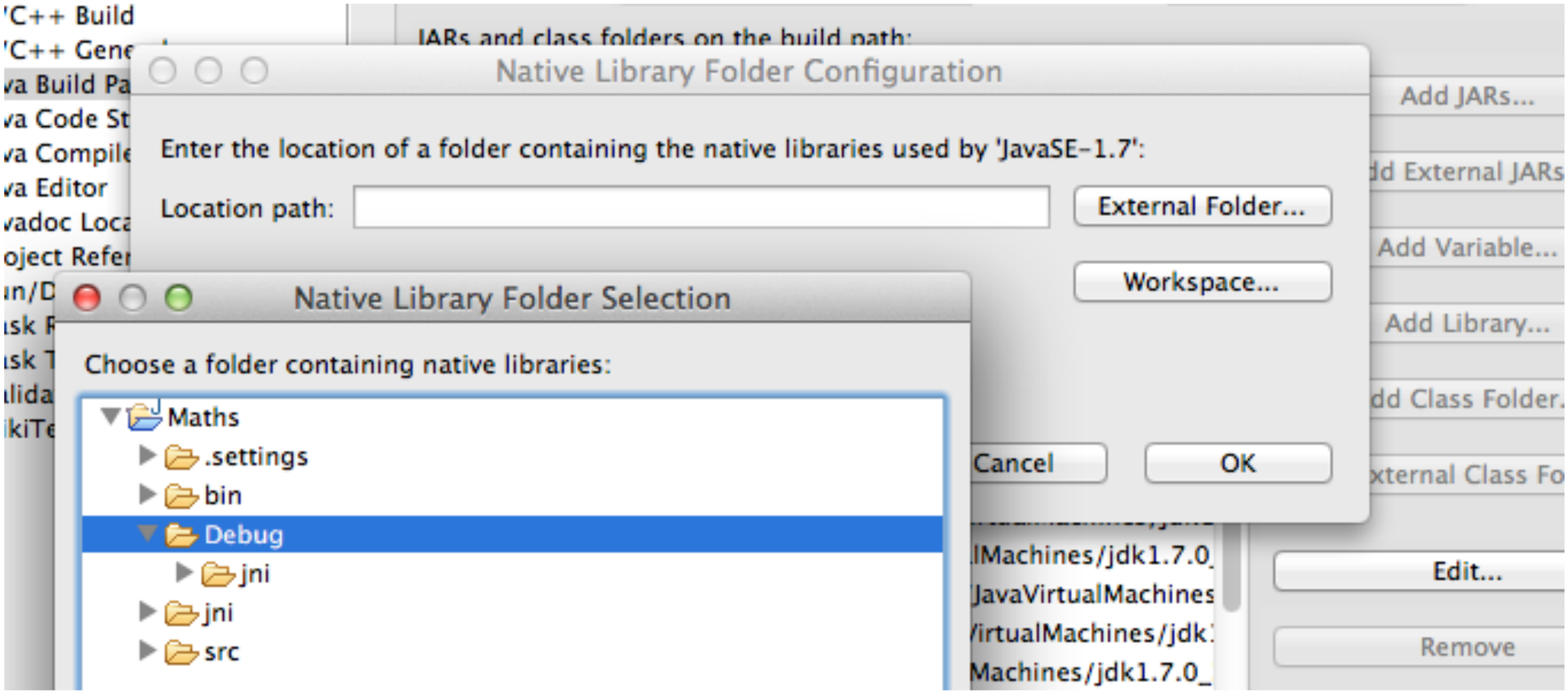
- For Linux, add: `/usr/lib/jvm/java-7-oracle/include` and `/usr/lib/jvm/java-7-oracle/include/linux`

- For 32-bit projects on Windows, add:
  `C:\Program Files (x86)\Java\jdk1.7.0_21\include` and
  `C:\Program Files (x86)\Java\jdk1.7.0_21\include\win32`

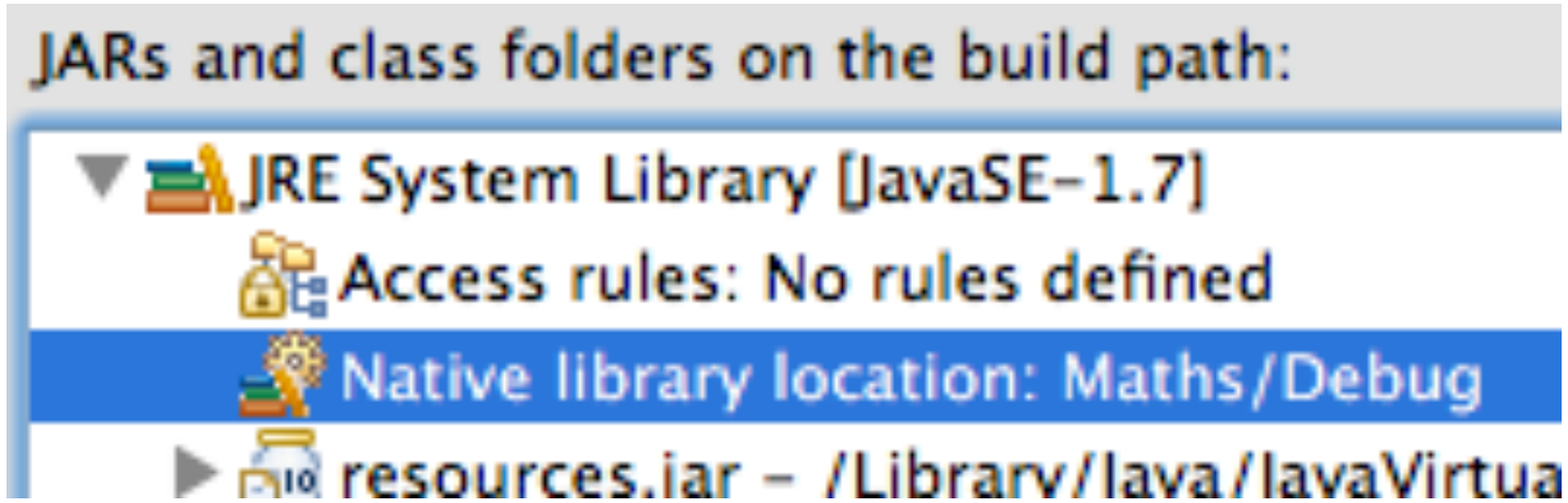
- The C/C++ library will not have been built!
- Simply select `Build Project` from the `Project` menu and the C/C++ library will be generated
- The Java project does not know where to find the library
- In the project's `Properties`, `Java Build Path`, select the `Libraries` tab
- Open up the JRE entry and select `Native library location`



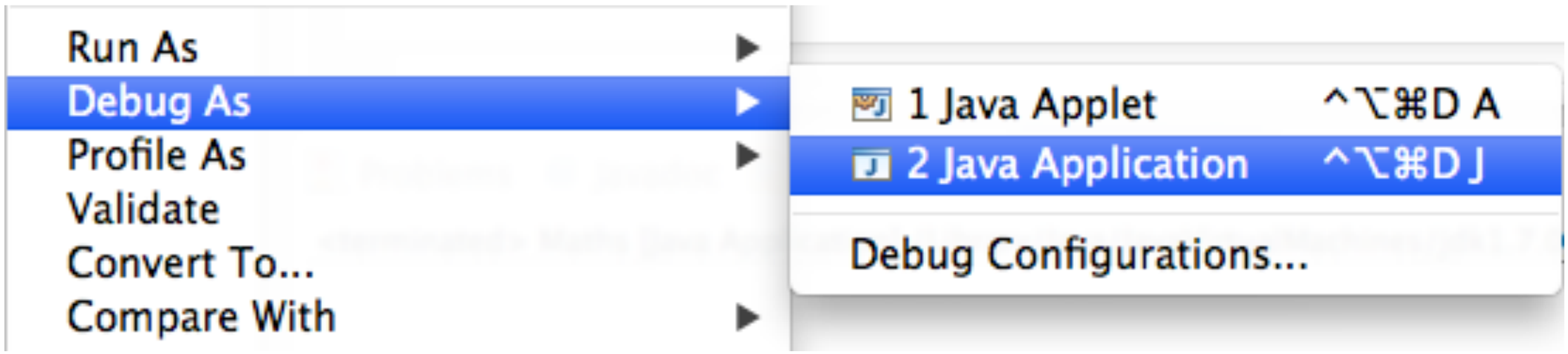
- Click the `Edit...` button followed by the `Workspace...` button
- For a debug build, the C/C++ library is in the `Debug` folder under `bin`



- You have just specified the `java.library.path` value!

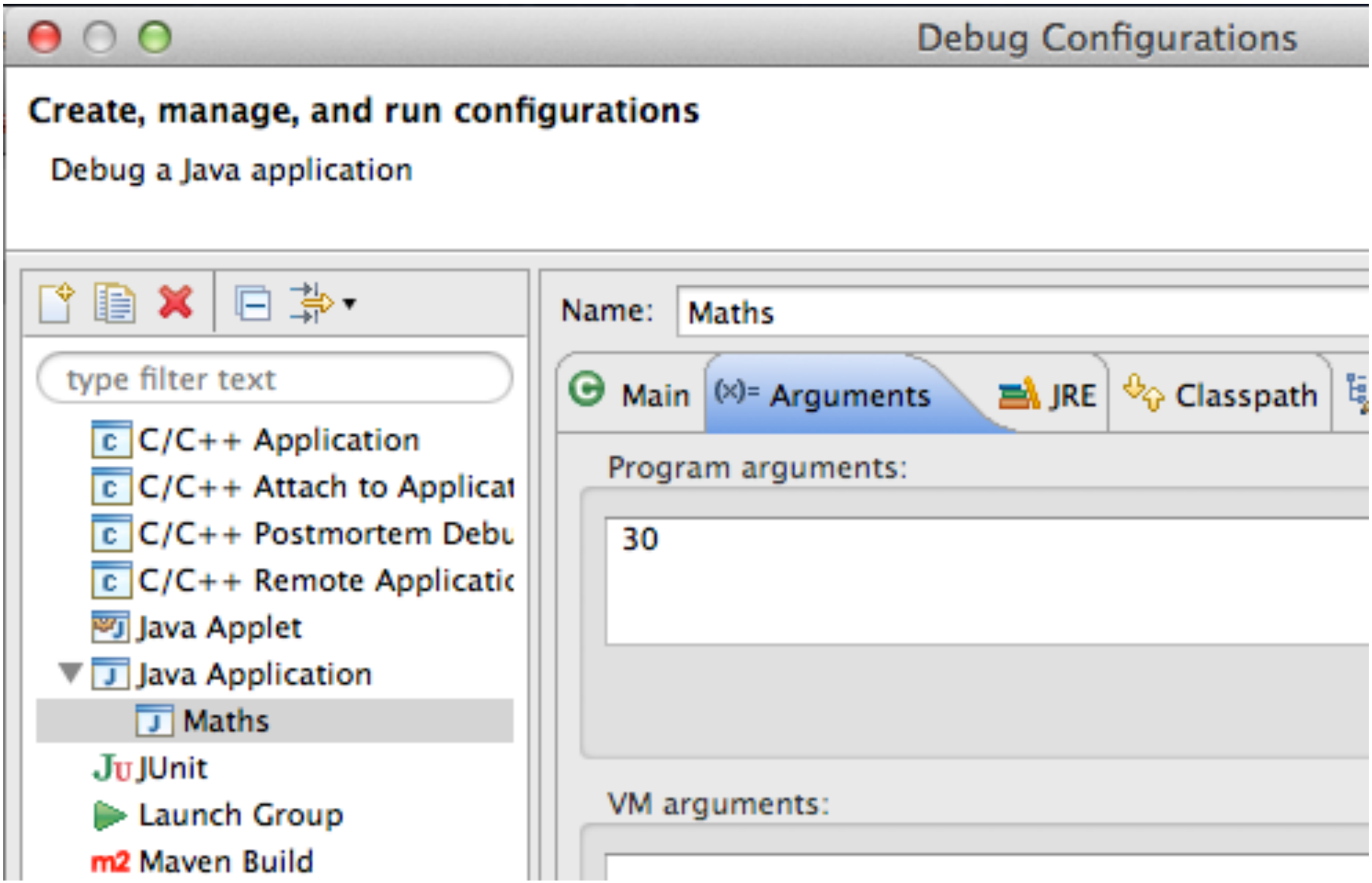


- You can now run or debug your application in the usual way



(do this to create a launch configuration)

- Our software requires a program argument
- Open up the `Debug Configurations` and enter a suitable parameter



- Click the Debug button and trace through the code

Maths.java | Maths.h | Maths.c

```
package com.cogentlogic.training.jni;

public class Maths
{
    static
    {
        System.loadLibrary("Maths");
    }

    public native int fibonacci(int n);

    public static void main(String[] args)
    {
        if (args.length == 1)
        {
            Maths maths = new Maths();
            System.out.println("" + maths.fibonacci(Integer.parseInt(args[0])));
        }
    }
}
```

Console | Tasks | Problems | Executables

```
Maths [Java Application] /Library/Java/JavaVirtualMachines/jdk1.7.0_21.jdk/Contents/Home/bin/java (7 Jun 2013 22:40:32)
832040
```

Linux-Specific Details

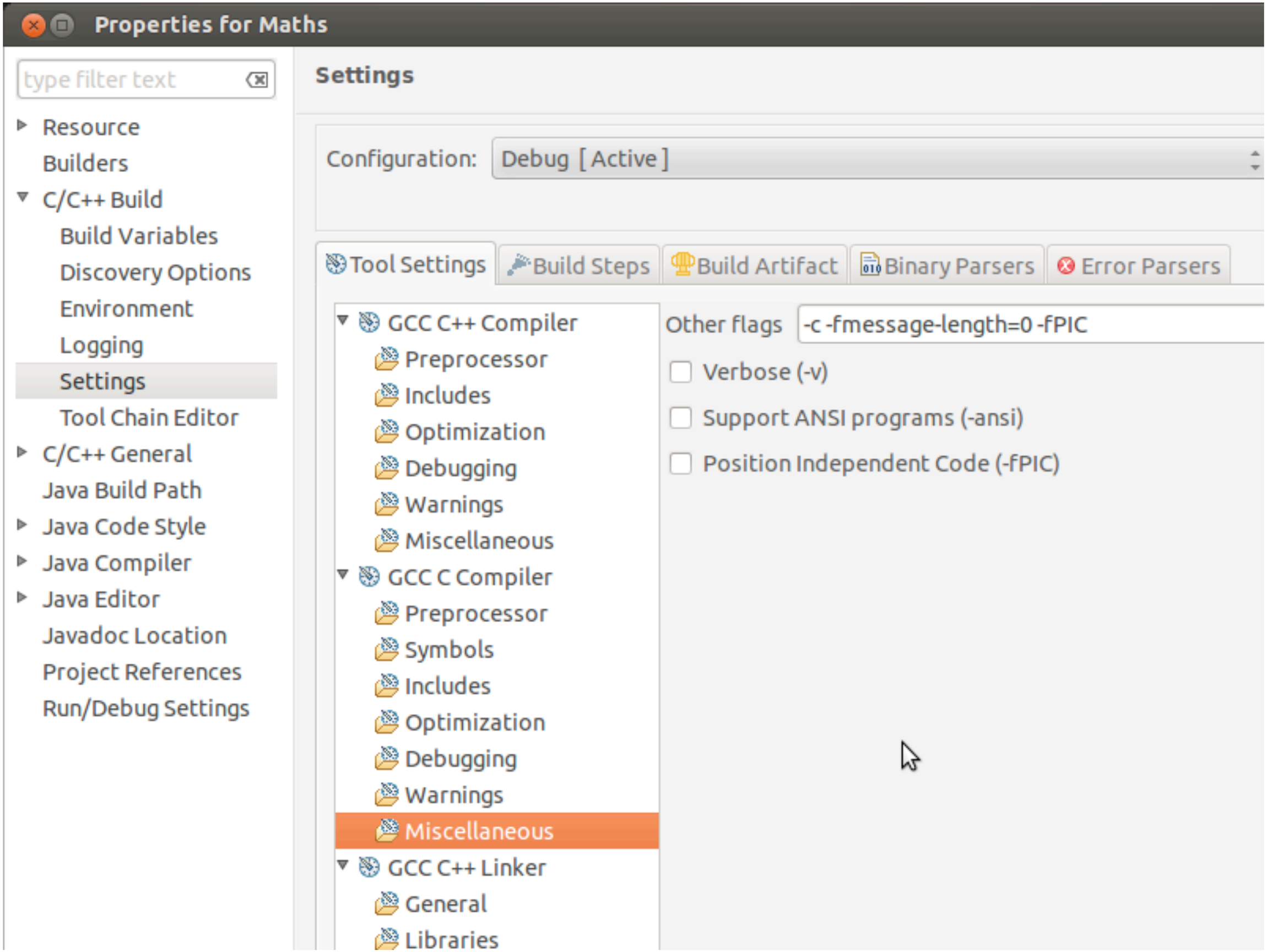
- The preceding procedure works on Linux with a few configuration changes (Unbuntu covered here)

- Firstly, if Eclipse is installed from the Ubuntu Software Centre, you might get an Unsatisfied Link Error upon launching Eclipse.
  To fix this for 64-bit software, at a command line, enter:
  `ln -s /usr/lib/jni/libswt-* ~/.swt/lib/linux/x86_64/`

- As mentioned earlier, specify the JNI header files, as:
  `/usr/lib/jvm/java-7-oracle/include` and
  `/usr/lib/jvm/java-7-oracle/include/linux`

- Remember to specify the `-fPIC` build option for the GCC compiler ...

- You must build the project from the Java perspective (not C/C++)



Windows-Specific Details

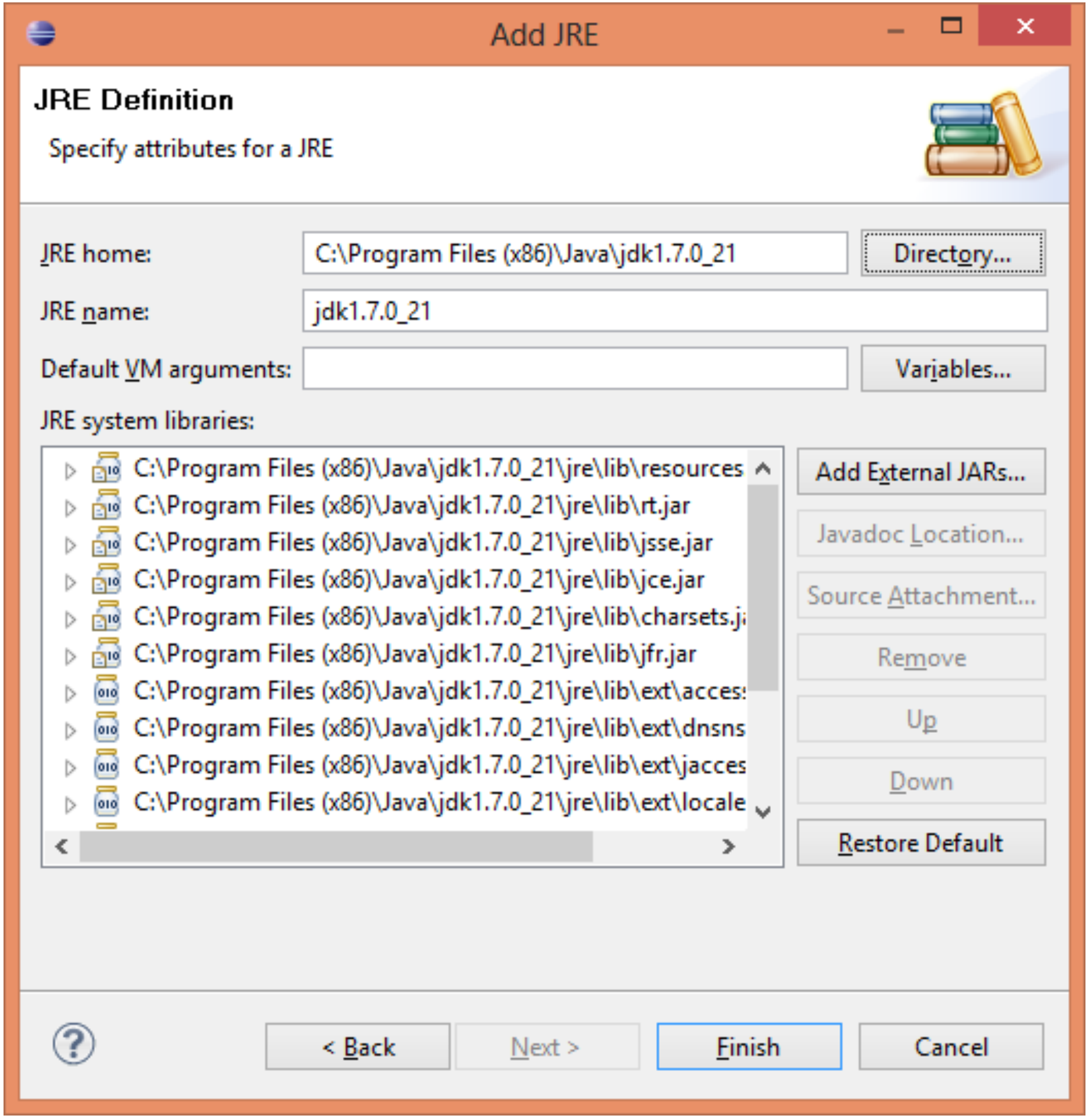
- The preceding procedure works on Windows with a few configuration changes

- Firstly, remember for 64-bit projects on Windows, MinGW-w64 and the `-m64` build flag are required

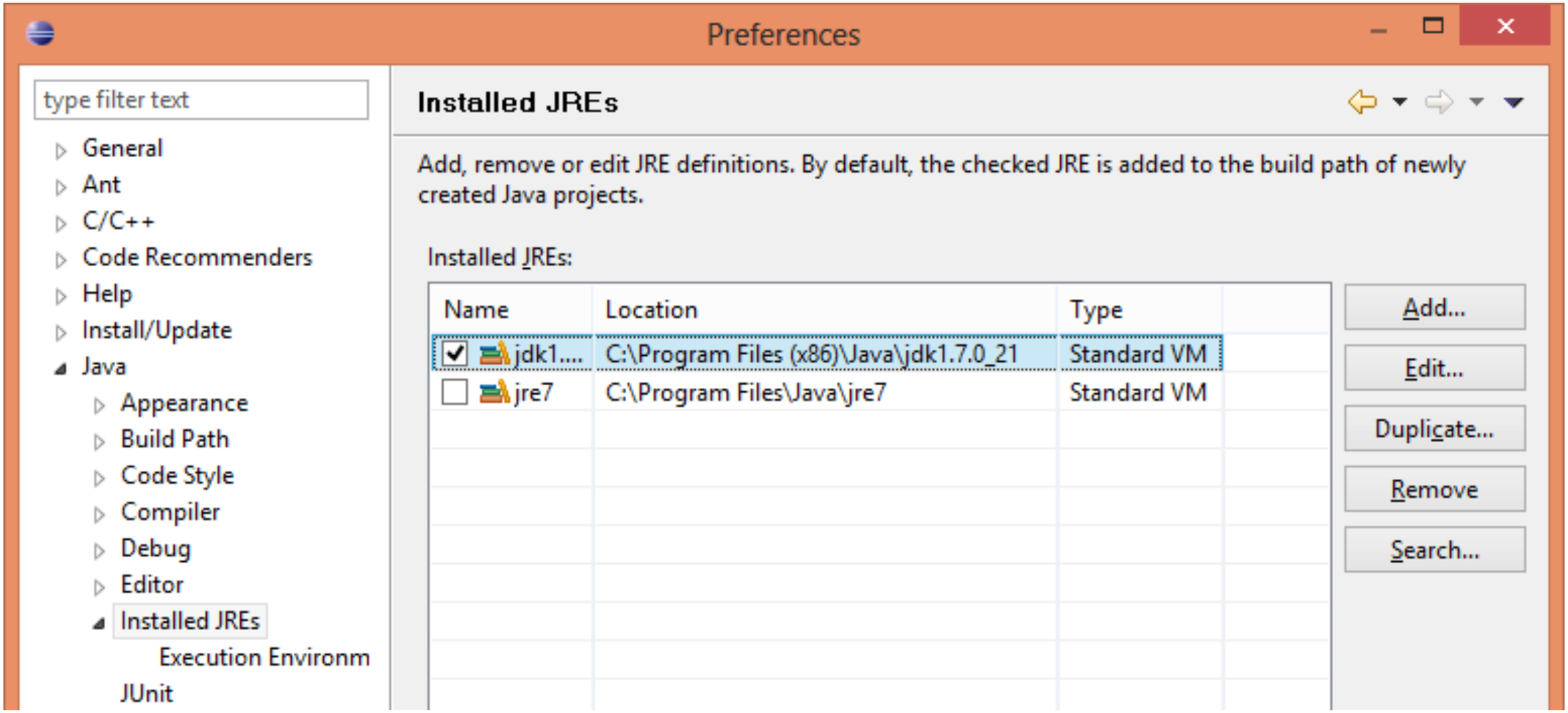
- We will consider 32-bit projects

- The Eclipse workspace must be configured to use a 32-bit JDK (or use a 32-bit version of Eclipse): from the `Windows` menu select `Preferences` then under the `Java` category select `Installed JREs`

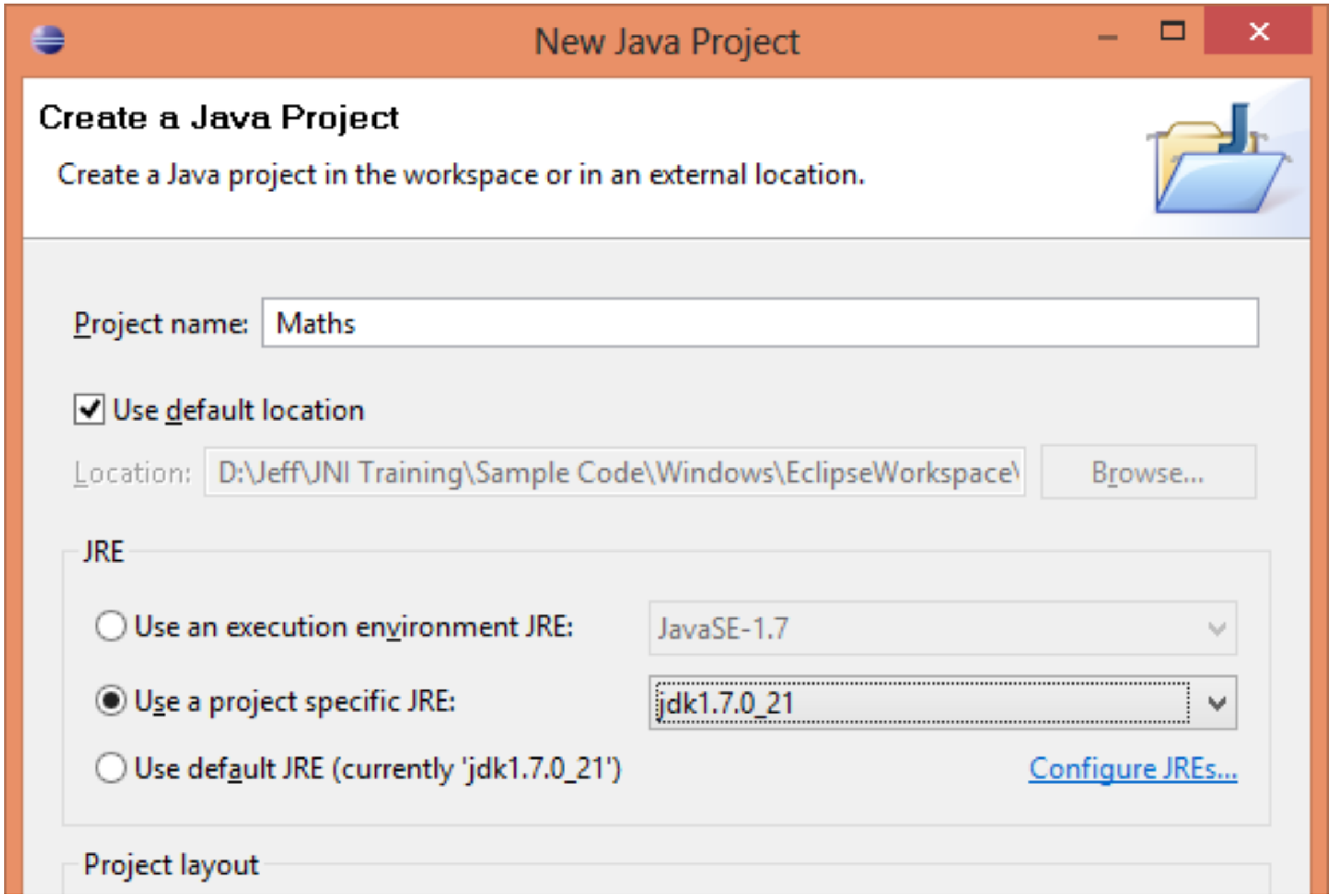
- Click the `Add...` button to add a JRE then click the `Directory...` button to specify a path to a 32-bit JRE,
  e.g. `C:\Program Files (x86)\Java\jdk1.7.0_21`



- Select the 32-bit JDK:



- When creating a Java project, be sure to select the 32-bit JDK:

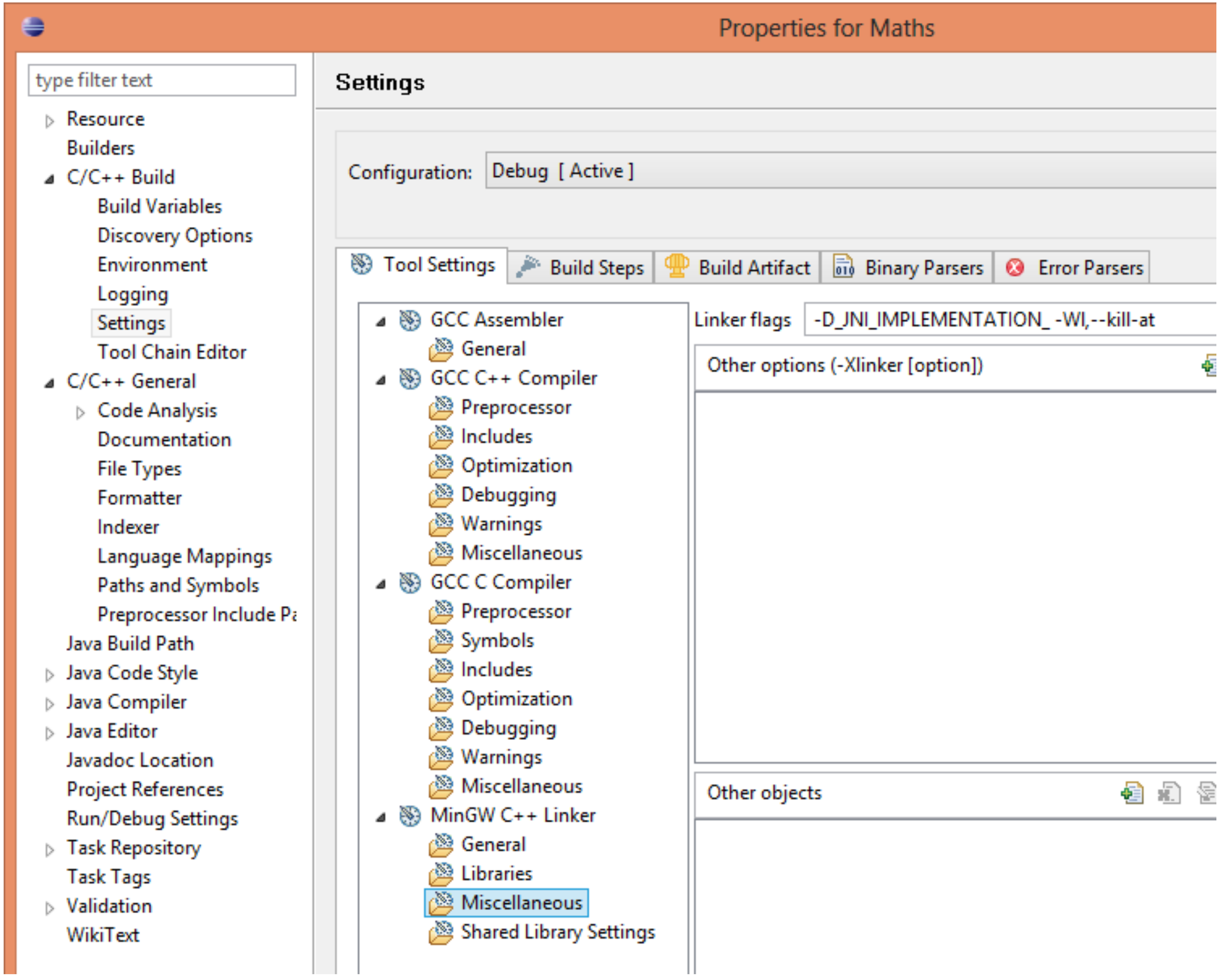


- As mentioned earlier, specify the JNI header files, as:
  `C:\Program Files (x86)\Java\jdk1.7.0_21\include` and
  `C:\Program Files (x86)\Java\jdk1.7.0_21\include\win32`

- The MinGM C++ Linker flags must be set:
  `-D_JNI_IMPLEMENTATION_ -Wl,--kill-at`
  Open the project's `Properties`, `C/C++ Build` category, `Settings` item.
  Select the `Tool Settings` tab followed by the `Miscellaneous` item under `MinGW C++ Linker`.
  Add the flags to the `Linker flags` field.

- Finally, for the Maths sample code, the generated C/C++ library will be called `libMaths.dll`; in the Windows Java source code this must be referenced with the preceding `lib`, i.e.

```
System.loadLibrary("libMaths");
```



Java Native Interface with Eclipse and Android

Mapping Strings and Other Data Types

Jeff Lawson

Contents

JNI Primitive Data Types

- Primitive data types can be passed to and returned from JNI methods without difficulty

- `jni.h` defines machine-independent 'JNI types' that map to C types:

```
typedef unsigned char  jboolean;
typedef unsigned short  jchar;
typedef short  jshort;
typedef float  jfloat;
typedef double  jdouble;
```

- These types correspond, respectively, to the Java data types:
  `boolean`, `char`, `short`, `float`, `double`

- `jni_md.h`, included in `jni.h`, defines machine-dependent mappings:

```
#if defined(__LP64__) && __LP64__ /* for -Wundef */
typedef int  jint;
#else
typedef long  jint;
#endif
typedef long long  jlong;
typedef signed char  jbyte;
```

`__LP64__` is set by the compiler to flag 64-bit builds

- These three data types map to Java data types `int`, `long` and `byte`

- `jni.h` makes use of `jint` for the definition of `jsize`:

```
  typedef jint  jsize;
```

The `javah` Tool

- `javah` can be invoked from the command line to generate C/C++ prototype methods
- `javah` runs against a Java source code file, seeking native methods and generating the corresponding C/C++ method declarations
- For `Maths.java` containing `public native int fibonacci(int n);` use:

```
javah com.cogentlogic.training.jni.Maths
```

  which will generate `com_cogentlogic_training_jni_Maths.h` containing:

```
JNIEXPORT jint JNICALL
   Java_com_cogentlogic_training_jni_Maths_fibonacci
                                (JNIEnv *, jobject, jint);
```

The `JNIEnv` Interface Pointer

- The `JNIEnv` interface pointer is always passed as the first argument to a JNI native method and provides access to general-purpose methods, e.g. `GetJavaVM`

- `JNIEnv` provides support for string and management, array operations, Java instance/static method/field invocation/access, exception handling, reflection

- See `JNIEnv` documentation at:
  `docs.oracle.com/javase/7/docs/technotes/guides/jni/spec/functions.html`

- `JNIEnv` is used for thread-local storage so it is not valid across threads, i.e. it cannot be passed to another thread

- `JNIEnv` is used differently in C and in C++: `env` is a pointer to a C++ object that must be dereferenced in C

- In C++, we can invoke methods straightforwardly:

```
JavaVM* jvm;
env->GetJavaVM(&jvm);
```

- In C, `env` must be passed as the first parameter in each `env` call:

```
JavaVM* jvm;
(*env)->GetJavaVM(env, &jvm);
```

Do not name C and C++ files the same, e.g. `X.c` and `X.cpp`. If you do then one of the files won't be

- (`JavaVM` is a reference to the Java Virtual Machine and can be used across threads. `JavaVM` enables native threads to attach to the JVM.)

JNI Strings

- Java `String` objects appear in JNI as `jstring` objects

- To make use of a `jstring` object (JVM string!) in C we must convert it to a C string, typically with `GetStringUTFChars` (for UTF-8), e.g.

  ```
  const char* pchName = env->GetStringUTFChars(strName, 0);
  ```

  which returns `0` for an out-of-memory condition (the second argument is an optional pointer to a `boolean` that tells us whether the returned string is a copy of the original string)

- When we have finished with such C strings we must release them, e.g.

  ```
  env->ReleaseStringUTFChars(strName, pchName);
  ```

- Strings can be allocated for return to the Java code with `NewString` (for Unicode) or `NewStringUTF` (see sample project *Strings*)

References to Java Objects

- JNI native methods always pass a reference object as a second parameter
- For native instance methods, the object is a `jobject` that references the Java object that invoked the method
- For native static methods, the object is a `jclass` references the Java class that invoked the method
- These objects can be used to call instance/static methods in the calling Java object/class and to access the instance/static fields
- More generally, Java objects can be passed as parameters to JNI methods and their members can be accessed too

- Native types map to Java object types as follows:

jobject	all objects
jclass	java.lang.Class
jstring	java.lang.String
jarray	all arrays
jobjectArray	Object[]
jbooleanArray	boolean[]
jbyteArray	byte[]
jcharArray	char[]
jshortArray	short[]
jintArray	int[]
jlongArray	long[]
jfloatArray	float[]
jdoubleArray	double[]
jthrowable	java.lang.Throwable

Accessing Java Arrays

- Native methods can take arrays as parameters and return arrays
- We need to transform JVM array data to C array data before use
- We can simulate pass-by-value by using a copy of the Java array data
- We can simulate pass-by-reference by using a pointer to the Java array data where possible
- In either case, we can choose to update the Java array data or leave it unchanged!

- Sample Java code to manipulate arrays: (*Arrays*)

```
package com.cogentlogic.training.jni;

public class Arrays
{
  // Forgetting to do this is one of several way to
  // produce the UnsatisfiedLinkError exception!
  static
  {
        System.loadLibrary("Arrays");
  }

  private native float[] traverse(double[] dblA, float[] fB);

  public static void main(String[] args)
  {
     double[] dblA = {1.1, 2.2, 3.3};
     float[] fB = {4.4f, 5.5f, 6.6f, 7.7f};

     Arrays arrays = new Arrays();
     float[] fC = arrays.traverse(dblA, fB);
```

- Sample Java code to manipulate arrays (continued):

```
        System.out.println("dblA:");
        for (int n=0; n<dblA.length; n++)
           System.out.println("     " + dblA[n]);

        System.out.println("fB:");
        for (int n=0; n<fB.length; n++)
           System.out.println("    " + fB[n]);

        System.out.println("fC:");
        for (int n=0; n<fC.length; n++)
           System.out.println("    " + fC[n]);
    }
}
```

- `javah com.cogentlogic.training.jni.Arrays` generates:

```
JNIEXPORT jfloatArray JNICALL
   Java_com_cogentlogic_training_jni_Arrays_traverse
                (JNIEnv *, jobject, jdoubleArray, jfloatArray);
```

- Sample C code to manipulate arrays: (*Arrays*)

```
JNIEXPORT jfloatArray JNICALL
Java_com_cogentlogic_training_jni_Arrays_traverse(JNIEnv* env,
jobject thiz, jdoubleArray dblA, jfloatArray fB)
{
  int n;
  // Get the lengths of the array parameters
  jint nLenA = (*env)->GetArrayLength(env, dblA);
  jint nLenB = (*env)->GetArrayLength(env, fB);

  // Access a copy of the double array
  jdouble dblAA[nLenA];
  (*env)->GetDoubleArrayRegion(env, dblA, 0, nLenA, dblAA);

  // Update the copy of the double array
  for (n=0; n<nLenA; n++)
     dblAA[n] += 100.0;

  // Commit the contents of the copy to the Java array reference
  (*env)->SetDoubleArrayRegion(env, dblA, 0, nLenA, dblAA);
```

- Sample C code to manipulate arrays (continued):

```
// Access the double array directly
jboolean bCopyA;
jdouble* pdblA = (*env)->GetDoubleArrayElements(env, dblA,
                                                &bCopyA);
if (pdblA)
{
   jdouble* pdbl = pdblA;       // retain for deallocation
   for (n=0; n<nLenA; n++)
      *pdbl++ += 10000.0;

   // 0 => copy back and release native array:
   (*env)->ReleaseDoubleArrayElements(env, dblA, pdblA, 0);
}
```

The `&bCopyA` parameter is optional (can be NULL):

`bCopyA == JNI_TRUE` => `pdblA` will point to a copy of the array

`bCopyA == JNI_FALSE` => `pdblA` will point to the original array

- Sample C code to manipulate arrays (continued):

```
jfloatArray fC = (*env)->NewFloatArray(env, nLenB);
if (fC)
{
  jboolean bCopyB;
  jfloat* pfB = (*env)->GetFloatArrayElements(env, fB, &bCopyB);
  if (pfB)
  {
     jboolean bCopyC;
     jfloat* pfC = (*env)->GetFloatArrayElements(env, fC, &bCopyC);
     if (pfC)
     {
        jfloat* pfb = pfB, pfc = pfC + nLenB;
        for (n=0; n<nLenB; n++)
           *--pfc = *pfb++;
        (*env)->ReleaseFloatArrayElements(env, fC, pfC, 0);
     }
     (*env)->ReleaseFloatArrayElements(env, fB, pfB, JNI_ABORT);
  }
}                          // JNI_ABORT => release but do not copy back
return fC;                 // JNI_COMMIT => copy back but do not release
                           // 0 => release and copy back
```

- Remember, the original arrays were:

```
double[] dblA = {1.1, 2.2, 3.3};
float[] fB = {4.4f, 5.5f, 6.6f, 7.7f};
```

- The corresponding output is:

```
dblA:
     10101.1
     10102.2
     10103.3
fB:                    fC:
    4.4                    7.7
    5.5                    6.6
    6.6                    5.5
    7.7                    4.4
```

- If you need to discard an array created with `New<TYPE>Array`, use `DeleteLocalRef`

Java Native Interface with Eclipse and Android

Accessing Java Methods and Fields from C/C++

Jeff Lawson

Contents

- Method and Field Descriptors
- Accessing Java Class Members

Method and Field Descriptors

- To access Java methods and fields from C/C++ we need to identify each member unambiguously by specifying their signatures and data types

- `javah com.cogentlogic.training.jni.Arrays` seen earlier, generated more that the native method prototype:

```
JNIEXPORT jfloatArray JNICALL
    Java_com_cogentlogic_training_jni_Arrays_traverse
                    (JNIEnv *, jobject, jdoubleArray, jfloatArray);
```

  it also produced:

```
Signature: ([D[F)[F
```

- `[D`, `[F`, `[F` are *descriptors,* here indicating arrays of `double` and `float`

- Descriptors enable us to specify Java methods and fields

- The Java class file disassembler, `javap`, produces class member signatures
- Consider this Java class: (*MethodsAndFields*)

```
public class MethodsAndFields
{
  private static int s_n = 123;
  private int m_n = 456;

  private static void setS(int n) {s_n = n; }
  private void setI(int n) {m_n = n;}

  private native static int mafS(int n);
  private native int mafI(int n);

  public static void main(String[] args)
  {
     System.out.println("mafS(2) returns " +
                        MethodsAndFields.mafS(2) +
                        " with s_n = " + MethodsAndFields.s_n);
     MethodsAndFields maf = new MethodsAndFields();
     System.out.println("mafI(3) returns " + maf.mafI(3) +
                        " with m_n = " + maf.m_n);
  }
}
```

- The -p option indicates include private members

- The -s option indicates show signature (that's what we're interested in!)

  ```
  javap -p -s com.cogentlogic.training.jni.MethodsAndFields
  ```

  produces:

```
private static int s_n;                                 Signature: I
private double m_dbl;                                   Signature: D
public com.cogentlogic.training.jni.MethodsAndFields();
  (constructor)                                         Signature: ()V
private static void setS(int);                          Signature: (I)V
private void setI(double);                              Signature: (D)V
private static native int mafS(int);                   Signature: (I)I
private native double mafI(double);                     Signature: (D)D
public static void main(java.lang.String[]);
                                        Signature: ([Ljava/lang/String;)V
```

Accessing Java Class Members

- Sample C code to access a static method and a static field:

(*MethodsAndFields*)

```
JNIEXPORT jint JNICALL
   Java_com_cogentlogic_training_jni_MethodsAndFields_mafS(
                                  JNIEnv* env, jclass clazz, jint n)
{
  jfieldID idFieldS = (*env)->GetStaticFieldID(env, clazz,
                                                  "s_n", "I");
  jint s_n = (*env)->GetStaticIntField(env, clazz, idFieldS);

  jmethodID idMethodS = (*env)->GetStaticMethodID(env, clazz,
                                                   "setS",
"(I)V");
  (*env)->CallStaticVoidMethod(env, clazz, idMethodS, s_n + n);

  return (*env)->GetStaticIntField(env, clazz, idFieldS) + 1;
}
```

- Sample C+ code to access an instance method and field:

(*MethodsAndFields*)

```
#ifdef __cplusplus
extern "C" {
#endif

JNIEXPORT jdouble JNICALL
   Java_com_cogentlogic_training_jni_MethodsAndFields_mafI(
                              JNIEnv* env, jobject thiz, jdouble dbl)
{
  jclass clazz = env->GetObjectClass(thiz);
  jfieldID idFieldI = env->GetFieldID(clazz, "m_dbl", "D");
  jdouble m_dbl = env->GetDoubleField(thiz, idFieldI);

  jmethodID idMethodI = env->GetMethodID(clazz, "setI", "(D)V");
  env->CallVoidMethod(thiz, idMethodI, m_dbl + dbl);

  return env->GetDoubleField(thiz, idFieldI) + 10000.0;
}

#ifdef __cplusplus
}
#endif
```

Java Native Interface with Eclipse and Android

Exception Handling

Jeff Lawson

Contents

- Throwing Exceptions from Native Methods
- Catching Exceptions in Native Methods

Throwing Exceptions from Native Methods

- Native C++ methods might have C++ exceptions to deal with. We assume that this is handled by the C++ developer. Here we are concerned only with Java exceptions!

- In project *Arrays*, we saw code the checked for out-of-memory conditions but did not handle them well e.g.

```
jdouble* pdblA = (*env)->GetDoubleArrayElements(env, dblA, 0);
if (pdblA)
{
  // Memory allocated so proceed...
```

- A better way to handle this condition would to throw an appropriate Java exception, i.e. `java.lang.OutOfMemoryError`
(this not an exception that we normally catch in Java but it handles the `GetDoubleArrayElements` condition well)

- If we need to throw an exception from a native method we do it by calling `ThrowNew`, passing a `jclass` object for the desired Java exception, e.g.

```
jclass clazz = (*env)->FindClass(env,
                                 "java/lang/OutOfMemoryError");
if (clazz)
  (*env)->ThrowNew(env, clazz, chMsg);
```

- It is important to realize that calling `ThrowNew` does *not* generate an exception in the native method: the native method continues to run to completion and should degrade gracefully, freeing resources, etc.

- The Java code should catch the exception in the usual way, of course, e.g. (*ExceptionThrowFromJNI*)

```
try
{
  float[] fC = etfj.mightThrow(dblA, fB);
}
catch (OutOfMemoryError except)
{
  except.printStackTrace();
}
```

Catching Exceptions in Native Methods

- A native method could invoke a Java method that throws an exception
- The native method can catch the exception by making an `ExceptionOccurred` call to check whether an exception was thrown!
- Sample Java code that throws an exception: (*ExceptionCatchInJNI*)

```
void dodgyCode() throws ClassCastException
{
  Object objInteger = new Integer(666);
  System.out.println((String)objInteger);
}
```

- Sample C code that ‘catches’ a Java exception: (*ExceptionCatchInJNI*)

```
jclass clazz = (*env)->GetObjectClass(env, thiz);
jmethodID idDodgy = (*env)->GetMethodID(env, clazz,
                                        "dodgyCode", "()V");
(*env)->CallVoidMethod(env, thiz, idDodgy);
jthrowable except = (*env)->ExceptionOccurred(env);
if (except)
{
  (*env)->ExceptionDescribe(env);
  (*env)->ExceptionClear(env);

  // Handle exception, e.g. scrutinize the jthrowable object
  // to determine the type of exception
  // ...

  (*env)->Throw(env, except);
  (*env)->DeleteLocalRef(env, except);
}
```

Java Native Interface with Eclipse and Android

SWIG

Jeff Lawson

Contents

- What is SWIG?
- Installing SWIG
- SWIG Use

What is SWIG?

- Simplified Wrapper and Interface Generator (SWIG) is a tool that facilitates access to C/C++ libraries from other languages such as Java
- SWIG takes an interface file (.i file extension) as input
- Interface files are just C/C++ header files will SWIG preprocessor directives, specically:
    - SWIG module declaration, e.g. %module Maths
    - Section to be copied into a C wrapper file (not parsed by SWIG)
    - Section parsed by SWIG to generate the remaining output
- For more on SWIG, see `www.swig.org`

Installing SWIG

- On Mac OS X, typically install SWIG using Homebrew:
  - Install Homebrew by running the script shown at:

    `mxcl.github.io/homebrew/`

    e.g. `ruby -e "$(curl -fsSL https://raw.github.com/mxcl/homebrew/go)"`
    - Install SWIG by entering: `brew install swig`
- On Linux (Ubuntu), enter: `sudo apt-get install swig`
- On Windows, download SWIG in a ZIP file from `www.swig.org/download.html`, extract it and add its location to the PATH variable

SWIG Use

- First, create an interface file, e.g.

```
%module Maths

// This added to the C wrapper file (not parsed by SWIG)
%{
// Put includes and other declarations here
extern int fibonacci(int);
%}

// This parsed by SWIG to generate the three output files
extern int fibonacci(int);
```

- Next run the SWIG tool against the interface file, e.g.

```
swig -java -package com.cogentlogic.training
     -outdir src/com/cogentlogic/training
     jni/swiginterface.i
```

- The three files generated from the previous command are:
  - `src/com/cogentlogic/training/Maths.java`
  - `src/com/cogentlogic/training/MathsJNI.java`
  - `jni/swiginterface_wrap.c`
- The module was specified as `Maths`, remember

- `MathsJNI.java` simply declares the native method in a Java class

```
package com.cogentlogic.training;

public class MathsJNI
{
  public final static native int fibonacci(int jarg1);
}
```

- `Maths.java` contains sample code for making use of `MathsJNI.java`:

```
package com.cogentlogic.training;

public class Maths
{
  public static int fibonacci(int arg0)
  {
     return MathsJNI.fibonacci(arg0);
  }
}
```

- `swiginterface_wrap.c` contains a good deal of SWIG code that we can ignore; it also contains the declarations made in the interface file and a skeleton JNI method with a suitable name, e.g.

```
extern int fibonacci(int);

SWIGEXPORT jint JNICALL
    Java_com_cogentlogic_training_MathsJNI_fibonacci(
                    JNIEnv *jenv, jclass jcls, jint jarg1)
```

- The skeleton native method contains: (*SWIG*)

```
jint jresult = 0 ;
int arg1 ;
int result;

(void)jenv;
(void)jcls;
arg1 = (int)jarg1;
result = (int)fibonacci(arg1);
jresult = (jint)result;
return jresult;
```

- We see typical extraneous code that is symptomatic of a tool that is capable of handling complex scenarios!

- All we need to do is implement `fibonacci` in C, typically in another source code file e.g. in `Fib.c` (with a header file `Fib.h`)

```
int fibonacci(int n)
{ return n <= 1 ? n : fibonacci(n - 1) + fibonacci(n - 2); }
```

- To use the SWIG output:
  - Create a Java project with C/C++ conversion, specifying header path(s) and referencing the Debug folder in the Java Build Path
  - Add a jni folder and add a SWIG interface file to the jni folder
  - Add suitable declarations to the interface file
  - Run the SWIG tool (this could be automated within the project)
  - Provide implementations for the JNI methods declared in the SWIG wrapper file
  - Make use of the native methods in your Java code
  - Build the project and check the library name so it can be loaded ...

Package Explorer

- Arrays
- ExceptionCatchInJNI
- ExceptionThrowFromJNI
- Maths
- MethodsAndFields
- Strings
- SWIG
  - src
    - com.cogentlogic.training
      - Maths.java
      - MathsJNI.java
      - Swig.java
  - JRE System Library [JavaSE-1.7]
  - Debug
    - jni
      - libSWIG.dylib
      - makefile
      - objects.mk
      - sources.mk
  - jni
    - Fib.c
    - Fib.h
    - swiginterface_wrap.c
    - swiginterface.i

Swig.java | Maths.java | swiginterface.i | Ma

```
package com.cogentlogic.training;

public class Swig
{
    static
    {
        System.loadLibrary("SWIG");
    }

    public static void main(String[] args)
    {
        System.out.println(Maths.fibonacci(30));
    }
}
```

Java Native Interface with Eclipse and Android

Using Standard C/C++ Libraries and Open Source Libraries

Jeff Lawson

Contents

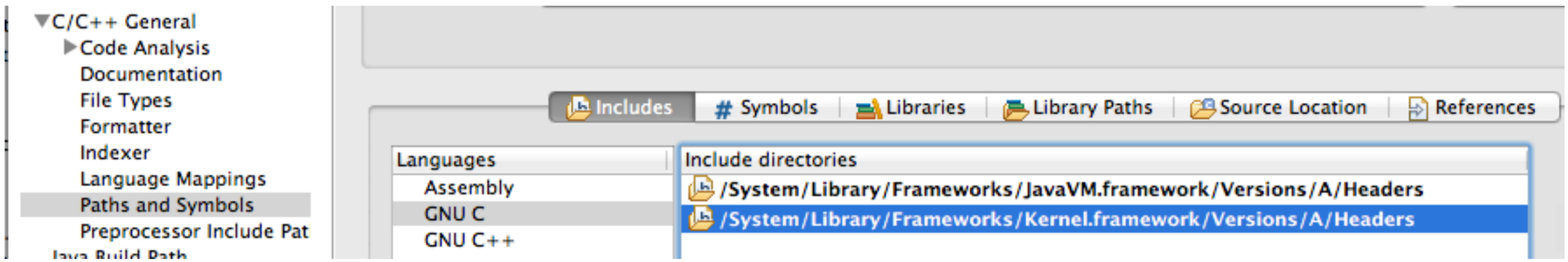
- Standard C/C++ Libraries
- Open Source Libraries
- OpenSSL

Standard C/C++ Libraries

- C/C++ compilers usually support standard libraries for i/o, strings, maths, etc., e.g. C++ Standard Template Library

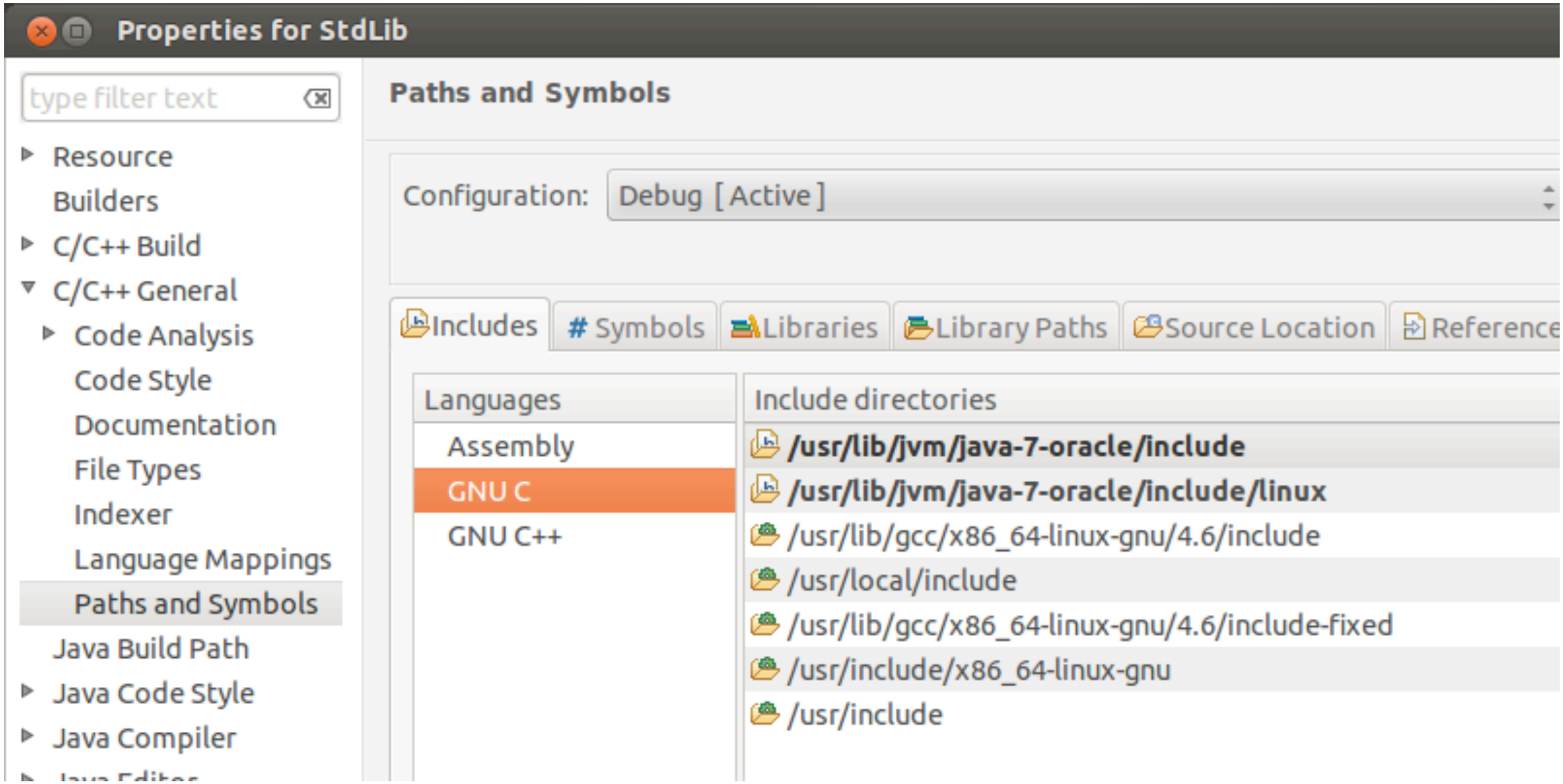
- Resolving standard libraries is system-dependent, e.g. to support `string.h` on Mac OS X, add to Paths and Symbols:

  `/System/Library/Frameworks/Kernel.framework/Headers`

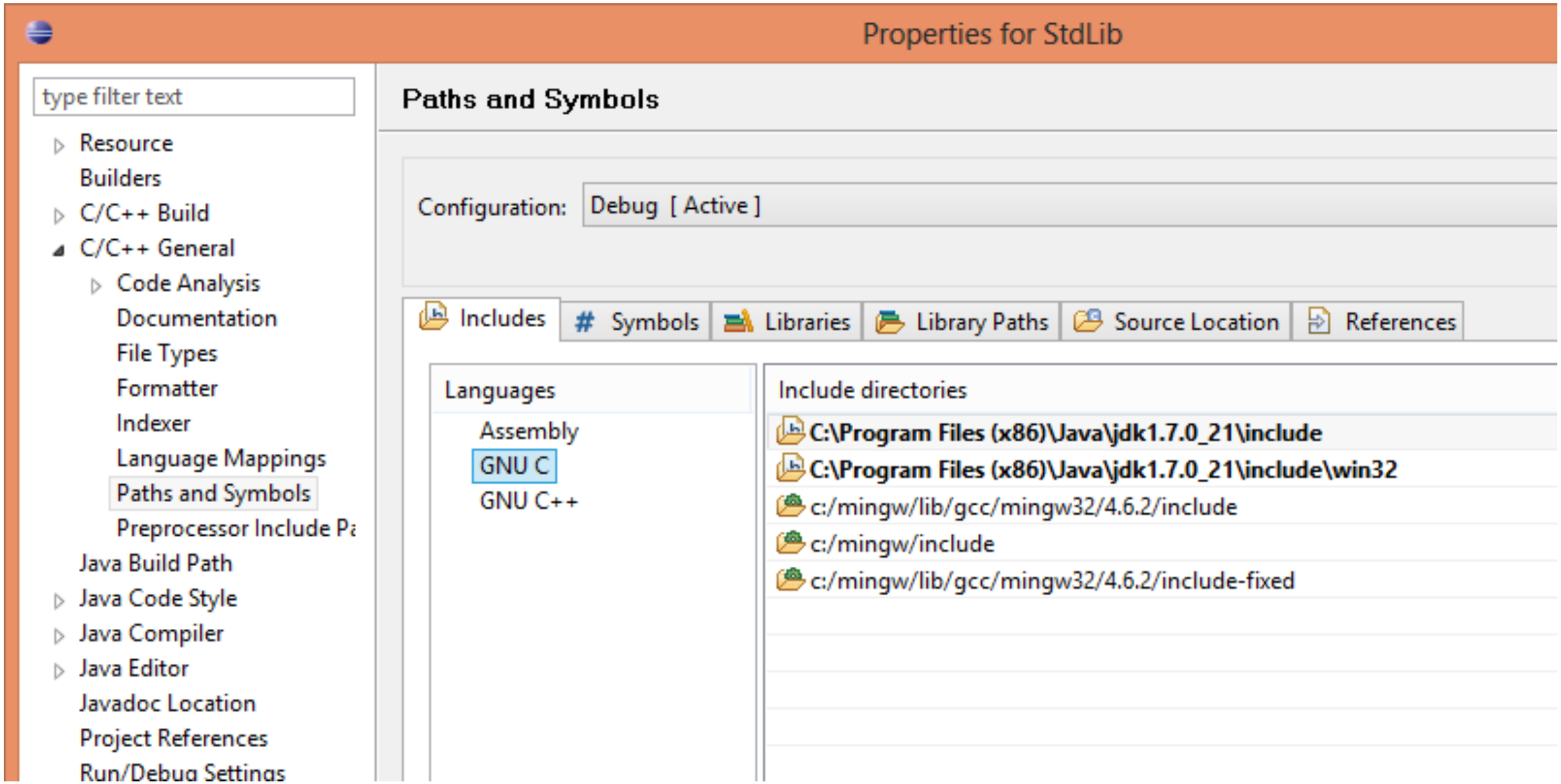


- See the sample code (*StdLib*)

- The Linux installation automatically picks up the header paths ...



- The Windows installation automatically picks up the header paths ...



Open Source Libraries

- Perhaps the most significant benefit of using the Java Native Interface is that it enables us to make use of a whole host of open source and business C/C++ libraries

- Boost provides a collection of libraries that are typically used as source code, rather library files; see:

  `http://www.boost.org`

- OpenSSL, available from `www.openssl.org`, provides a great C library for use across all platforms

- Libraries can be linked statically, using `.a` files, or dynamically, using `.o` files

OpenSSL

- To use OpenSSL, download the compressed file from:

  `www.openssl.org/source` e.g. `openssl-1.0.1e.tar.gz`

- Extract this file then build it from a command prompt be entering:
  - `./config shared` (just `./config` for static libraries)
  - `sudo make`
  - `sudo make install`

Ensure that there are no spaces in the path!

- On Ubuntu, OpenSSL will be installed in `/usr/local/ssl/` as:
  - `lib` folder containing two library files, e.g. `libcrypto.so.1.0.0` and `libssl.so.1.0.0`
  - `include` folder containing header files

- For `System.loadLibrary` to identify the library files, rename `libcrypto.so.1.0.0` and `libssl.so.1.0.0` by removing the trailing `.1.0.0`

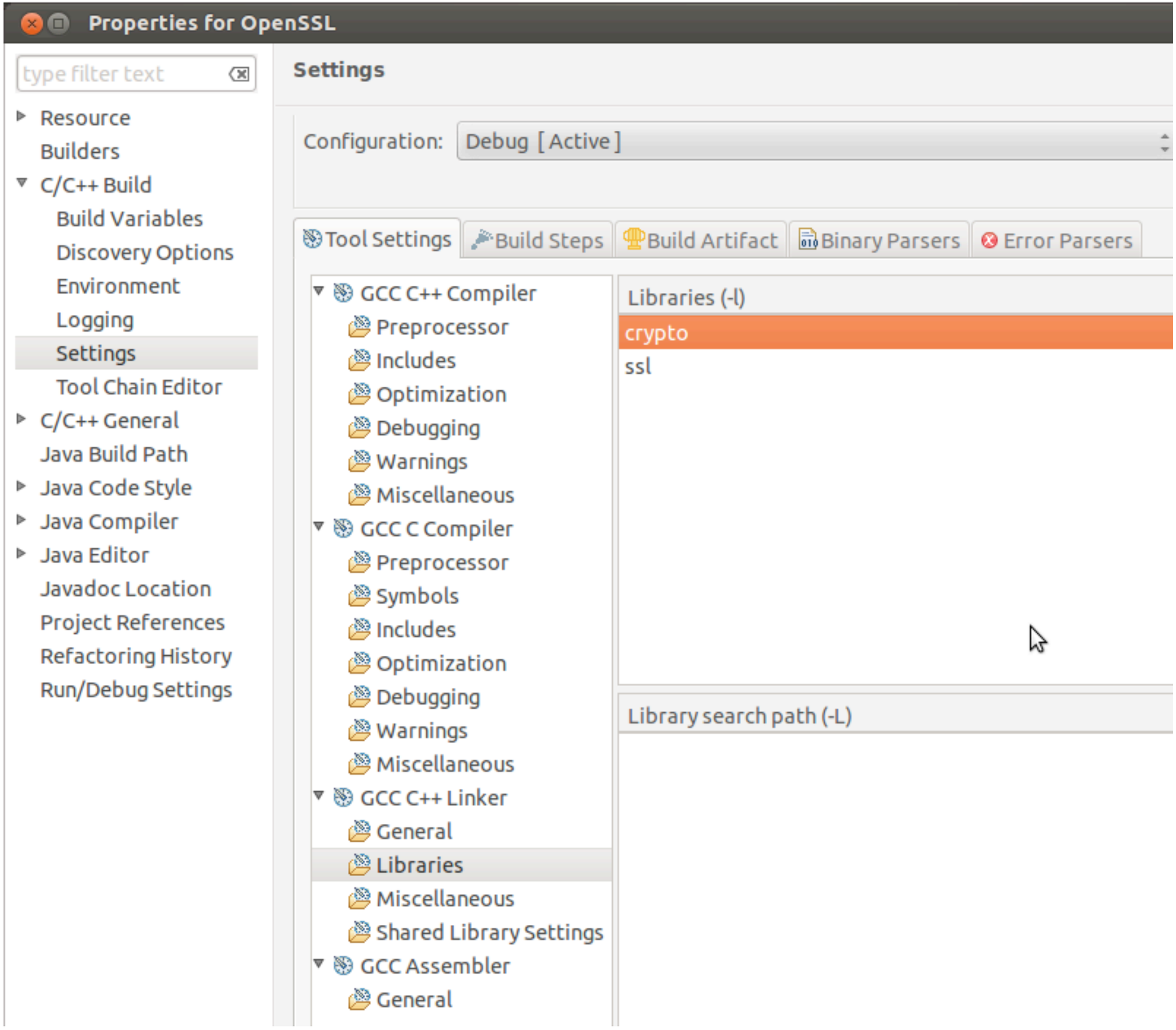
- To use OpenSSL in a JNI project, create a project in the usual way, with simple C/C++ and Java place-holder source code, and build it to produce the a library file in the `Debug` folder, then:

  - To the `Debug` folder, copy the renamed `libcrypto.so` and `libssl.so` files

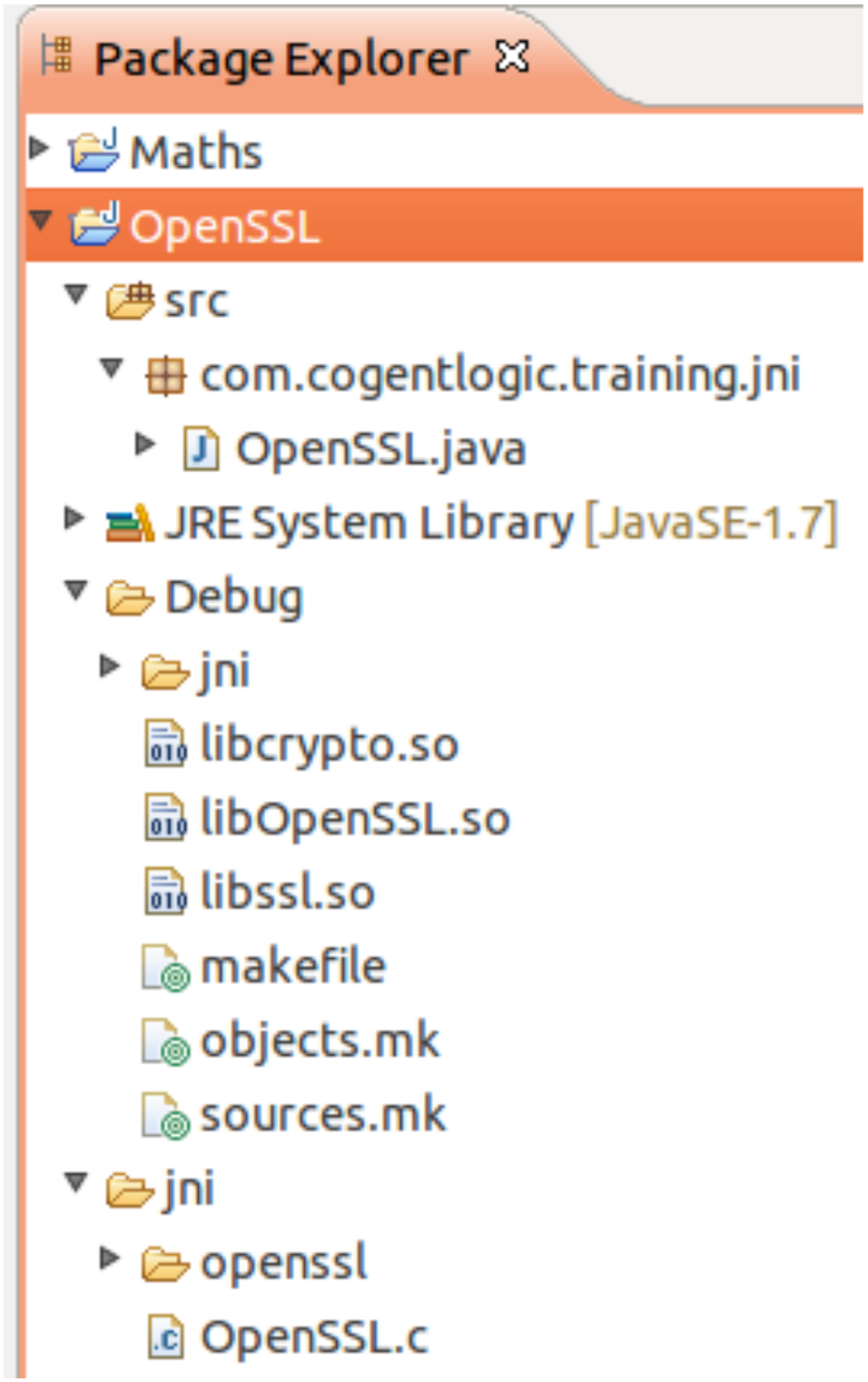
  - To the `jni` folder, copy the OpenSSL `include` folder, probably renaming it to `openssl`, for instance

  - Tell the linker to make use of both `crypto` and `ssl` libraries by adding them to `Libraries (-l)` under `C/C++ Build`, `Settings`, `GCC C++ Linker`, `Libraries`

...



- The project is constructed like this:



Do *not* add the path to the `openssl` include folder to the `Paths and Symbols` library settings.

Doing so would make them available using:

```
#include <rand.h>
```

but this could conflict with the system's version of OpenSSL (remember that system paths are already included in the library settings).

Instead, we can use:

```
#include "openssl/rand.h"
```

and there will be no confusion.

- To make use of the two OpenSSL libraries plus our own library:

```
static
{
  System.loadLibrary("crypto");
  System.loadLibrary("ssl");
  System.loadLibrary("OpenSSL");
}
```

- In the C/C++ source code, include the desired OpenSSL header files and make the desired library calls

- Build and debug/run as usual

- Sample Java code making use of OpenSSL through JNI: (*OpenSSL*)

```
public native byte[] encryptSymmetric(byte[] bytesPlain,
                                      byte[] bytesKey, byte[] bytesIV);
public native byte[] decryptSymmetric(byte[] bytesCipher,
                                      byte[] bytesKey, byte[] bytesIV);

public static void main(String[] args)
{
  byte[] bytesKey = new byte[32];
  byte[] bytesIV = new byte[16];
  String strPlainMessage =
                "The quick brown fox jumped over the lazy dogs!";
  OpenSSL openSSL = new OpenSSL();
  byte[] bytesCypher = openSSL.encryptSymmetric(
                strPlainMessage.getBytes(), bytesKey, bytesIV);
  System.out.println(Arrays.toString(bytesCypher));
  byte[] bytesRecovered =
      openSSL.decryptSymmetric(bytesCypher, bytesKey, bytesIV);
  String strRecovered = new String(bytesRecovered);
  System.out.println(strRecovered);
}
```

- In C, we have two native methods:

```
#include <stdlib.h>      // for malloc and free
#include <string.h>      // for strcpy
#include <jni.h>
#include "openssl/rand.h"
#include "openssl/evp.h"

JNIEXPORT jbyteArray JNICALL
    Java_com_cogentlogic_training_jni_OpenSSL_encryptSymmetric(
                JNIEnv* env, jobject thiz, jbyteArray bytesPlain,
                        jbyteArray bytesKey, jbyteArray bytesIV)
{ //... }

JNIEXPORT jbyteArray JNICALL
    Java_com_cogentlogic_training_jni_OpenSSL_decryptSymmetric(
                JNIEnv* env, jobject thiz, jbyteArray bytesCipher,
                        jbyteArray bytesKey, jbyteArray bytesIV)
{ //... }
```

- Extract from the C implementation in the sample project *OpenSSL:*

```
// Encrypt
int nCipherLen1;
int nCipherLen2;

EVP_CIPHER_CTX ctx;
EVP_CIPHER_CTX_init(&ctx);

EVP_EncryptInit(&ctx, EVP_aes_256_cbc(),
                      (unsigned char*)pbyteKey,
                      (unsigned char*)pbyteIV);

EVP_EncryptUpdate(&ctx, bytesCipherBuffer,
                        &nCipherLen1,
                        (unsigned char*)pbytePlain,
                        nLenPlain);

EVP_EncryptFinal(&ctx, bytesCipherBuffer + nCipherLen1,
                       &nCipherLen2);

EVP_CIPHER_CTX_cleanup(&ctx);

int nCipherLen = nCipherLen1 + nCipherLen2;
```

Java Native Interface with Eclipse and Android

JNI with the Android NDK

Jeff Lawson

Contents

- Android NDK
- Android NDK Installation
- Making Use of Native Code
- JNI Code
- Sample Android App with Native Code

Android NDK

- The Android Native Development Kit is a toolset that enables Android apps to use native code, i.e. compiled C and/or C++ (machine code)

- The NDK supports four instruction sets:
    - ARM v5TE and ARM v7-A
    - MIPS
    - x86

- Any one, two, three or all four instruction sets can be included in a single application package (.apk file)

- Android 1.5 (and later) apps can make Java Native Interface (JNI) calls into C and C++ code; Android 2.3 apps can make use of native activities

Android NDK Installation

- The Android NDK can be downloaded as a ZIP file from:

  `developer.android.com/sdk/ndk`

- Extract the ZIP file to a convenient location, referred to hereafter as `<NDK>`

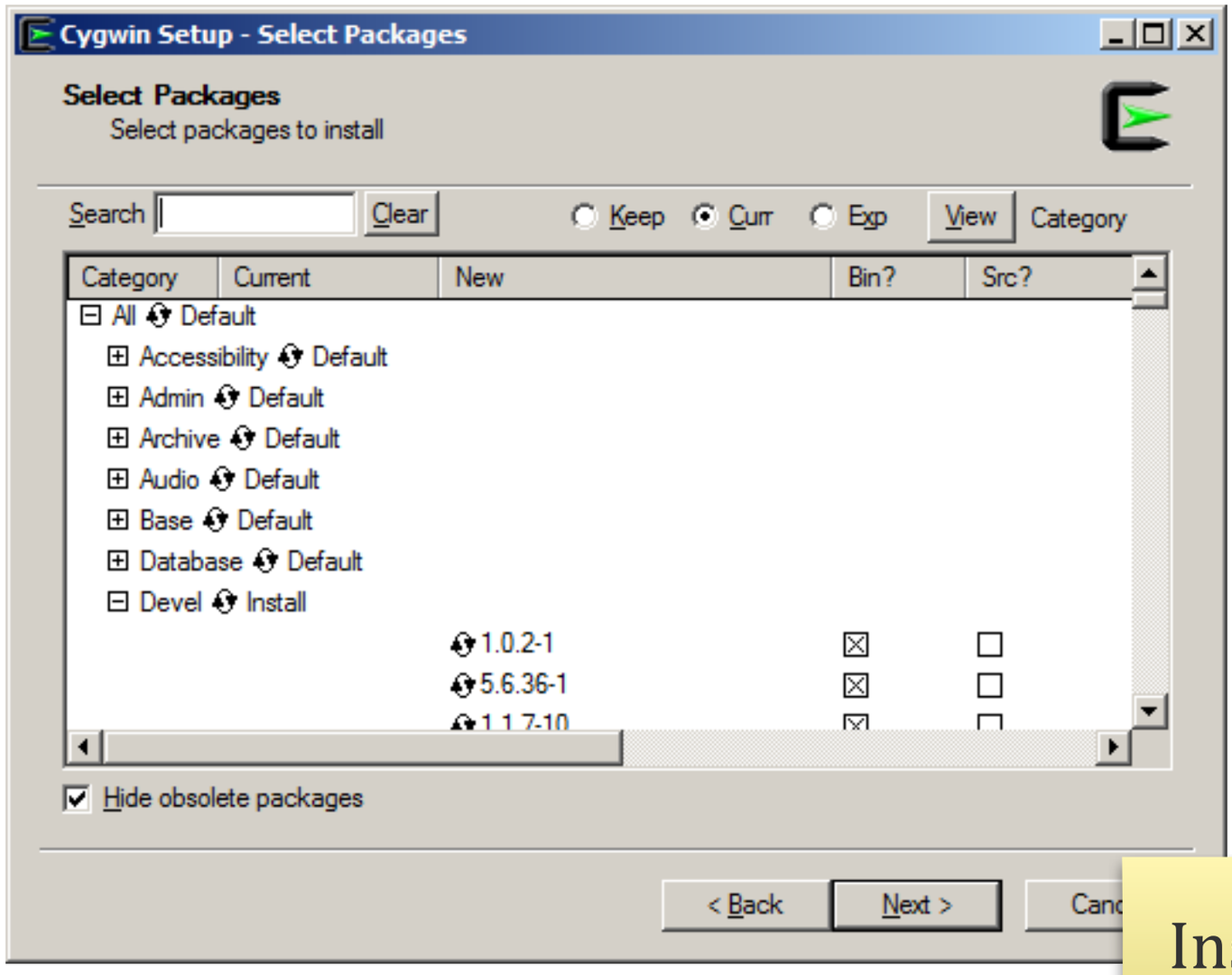
- The documentation is found in `<NDK>/docs`

- Check out `OVERVIEW.html`

- Platform-specific installation notes can be found in `INSTALL.html`, e.g. Windows requires the use of Cygwin 1.7 (Linux tools on Windows) with development tools in Devel ...

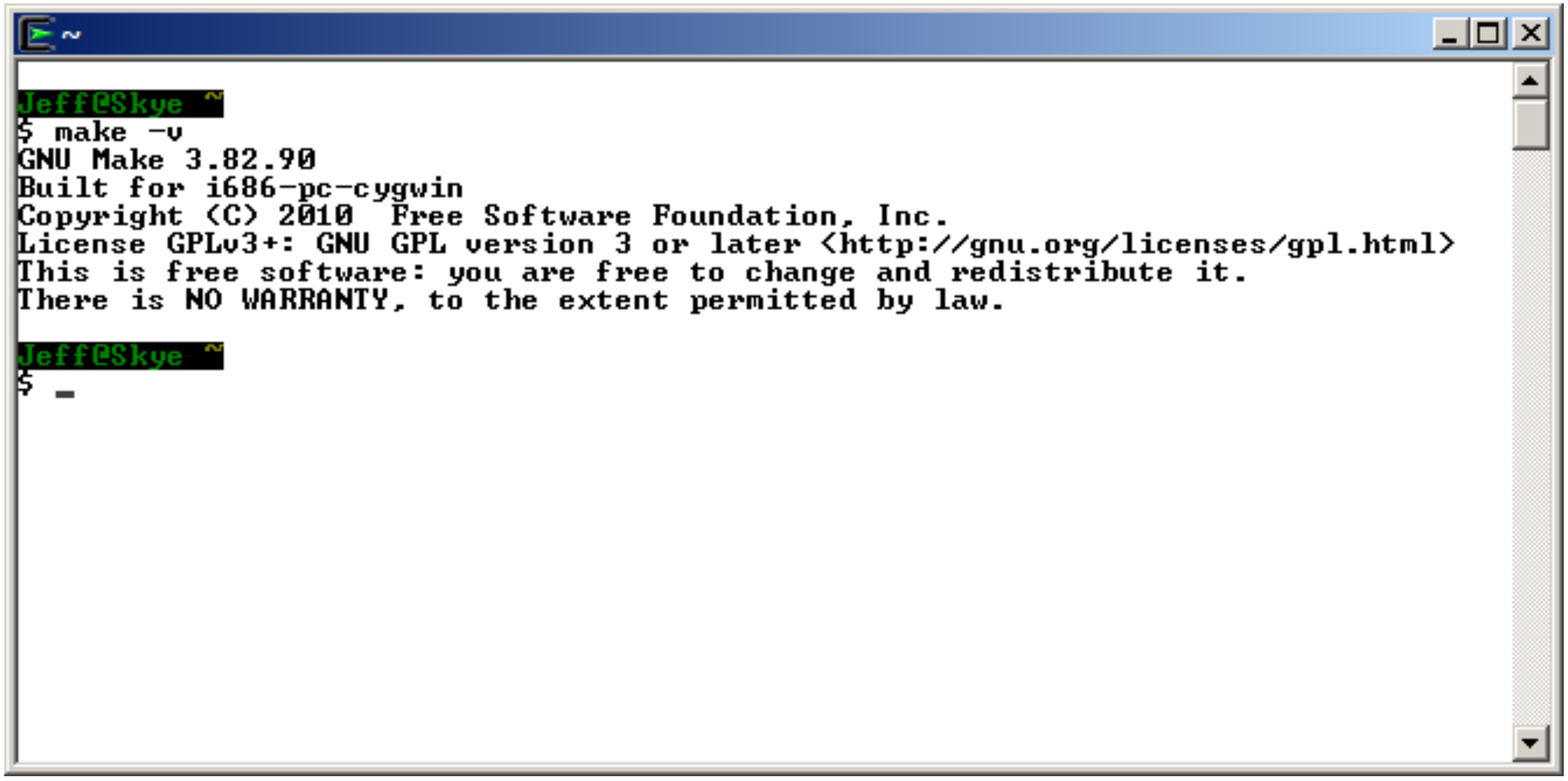
- Download and install Cygwin from `cygwin.com`

- Click *Default* along side the Devel package to change it to *Install* (for Devel, the default is that it isn't installed!)



Installation takes a *long* time!

- To test the Cygwin installation, open a bash shell and enter `make -v`



Making Use of Native Code

- Native code is typically held in a subdirectory of an Android project, called `jni`
- To describe the C/C++ code, a build script called `Android.mk` is created in `<project>/jni/` — see `ANDROID-MK.html`
- To target more than one system, a configuration file called `Application.mk` — see `APPLICATION-MK.html`
- Build native code by opening a command prompt at the `jni` directory and entering `<ndk>/ndk-build` (use `ndk-build clean` to remove defunct object code from previous builds)
- Then, build the Android app in the usual way and the native code will be included in the application package, `.apk`, file

- C/C++ code can make use of `<math.h>` plus other libraries and can access native Android APIs — see `STABLE-APIS.html`

- Declare the main C/C++ source code files, grouped as shared libraries, in `Android.mk` but *do not* declare header files for C code (C++ will need headers files for class declarations)!

- If `android:debuggable` is `true` in `AndroidManifest.xml`, then debuggable object files will be generated

- *Debug* requires Android 2.2 or higher

Sample Android App with Native Code

- Sample C code: (*MyLogic —Maths.c*)

```
#include <jni.h>

int fib(int n)
{
  return n <= 1 ? n : fib(n - 1) + fib(n - 2);
}

JNIEXPORT jint JNICALL
    Java_com_cogentlogic_training_jni_MainActivity_fibonacci(
                                    JNIEnv* penv, jobject obj, jint n)
{
  return fib(n);
}
```

- Sample C++ code: (*MyLogic —Greet.cpp*):

```
##include <jni.h>
#include "Greet.h"

static const char s_chGreeting[] = "Hello from native C++, ";

const char* Greet::getGreeting()
{
  return s_chGreeting;
}

#ifdef __cplusplus
extern "C" {
#endif

JNIEXPORT jstring JNICALL
    Java_com_cogentlogic_training_jni_MainActivity_greeting(
                        JNIEnv* env, jobject obj, jstring strName)
{
  // ...
}

#ifdef __cplusplus
}
#endif
```

- Java_com_cogentlogic_training_jni_MainActivity_greeting implementation:

```
Greet greet;
char chBuffer[100];
char* pDest = chBuffer;
const char* pSrc = greet.getGreeting();
while ((*pDest++ = *pSrc++))
  ;
const char* pchName = env->GetStringUTFChars(strName, 0);
if (!pchName)
  return 0;             // out of memory
--pDest;
pSrc = pchName;
while ((*pDest++ = *pSrc++))
  ;
*pDest = 0;
*--pDest = '!';
env->ReleaseStringUTFChars(strName, pchName);
return env->NewStringUTF(chBuffer);
```

- Calling C and C++ functions from Java requires a library to be created:
  - Sample `Android.mk`:

```
LLOCAL_PATH := $(call my-dir)
include $(CLEAR_VARS)
LOCAL_MODULE    := MyLogic
LOCAL_SRC_FILES := Greet.cpp Maths.c
include $(BUILD_SHARED_LIBRARY)
```

  - Sample `Application.mk`:

```
APP_PLATFORM := android-7
APP_ABI := all
```

- To compile C/C++ libraries o Mac OS X and Linux, open a command prompt at the jni folder and enter ndk-build:

```
jeffmacbookpro:jni Jeff$ ndk-build
Compile++ thumb  : MyLogic <= Greet.cpp
Compile thumb  : MyLogic <= Maths.c
SharedLibrary  : libMyLogic.so
Install        : libMyLogic.so => libs/armeabi-v7a/libMyLogic.so
Compile++ thumb  : MyLogic <= Greet.cpp
Compile thumb  : MyLogic <= Maths.c
SharedLibrary  : libMyLogic.so
Install        : libMyLogic.so => libs/armeabi/libMyLogic.so
Compile++ x86    : MyLogic <= Greet.cpp
Compile x86    : MyLogic <= Maths.c
SharedLibrary  : libMyLogic.so
Install        : libMyLogic.so => libs/x86/libMyLogic.so
Compile++ mips   : MyLogic <= Greet.cpp
Compile mips   : MyLogic <= Maths.c
SharedLibrary  : libMyLogic.so
Install        : libMyLogic.so => libs/mips/libMyLogic.so
```

- Ensure that there are no spaces in the path to the lib folder
  Refresh your Android project to see the newly generated files

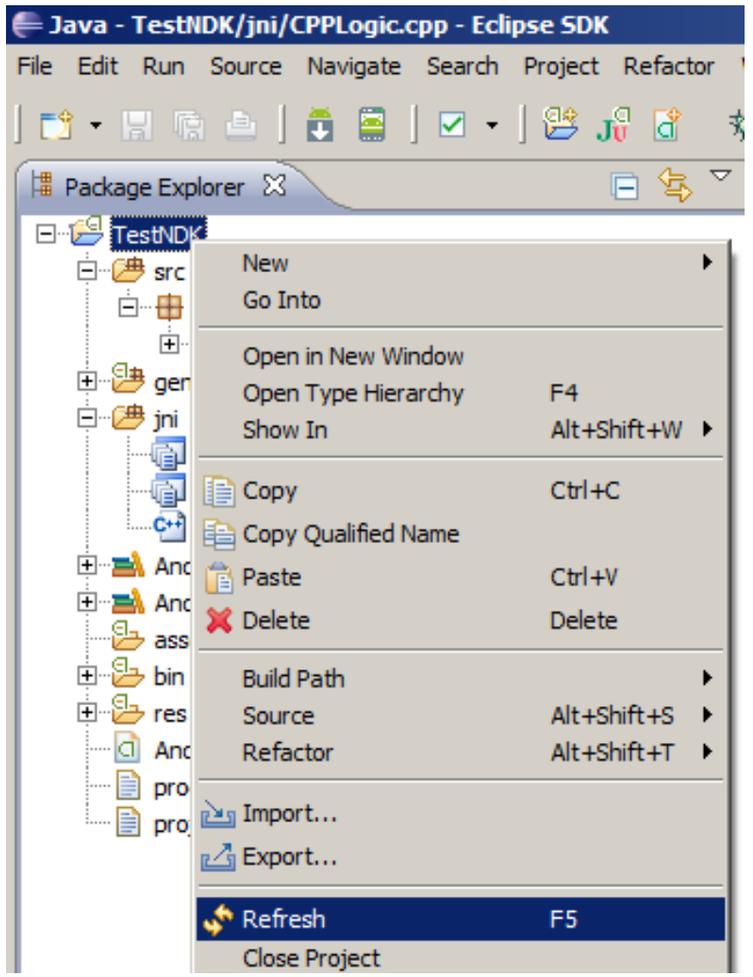
- To compile C/C++ libraries from Cygwin, for a project called `MyLogic` held on disk at `D:\workspace\`, first switch to the `jni` subdirectory with:

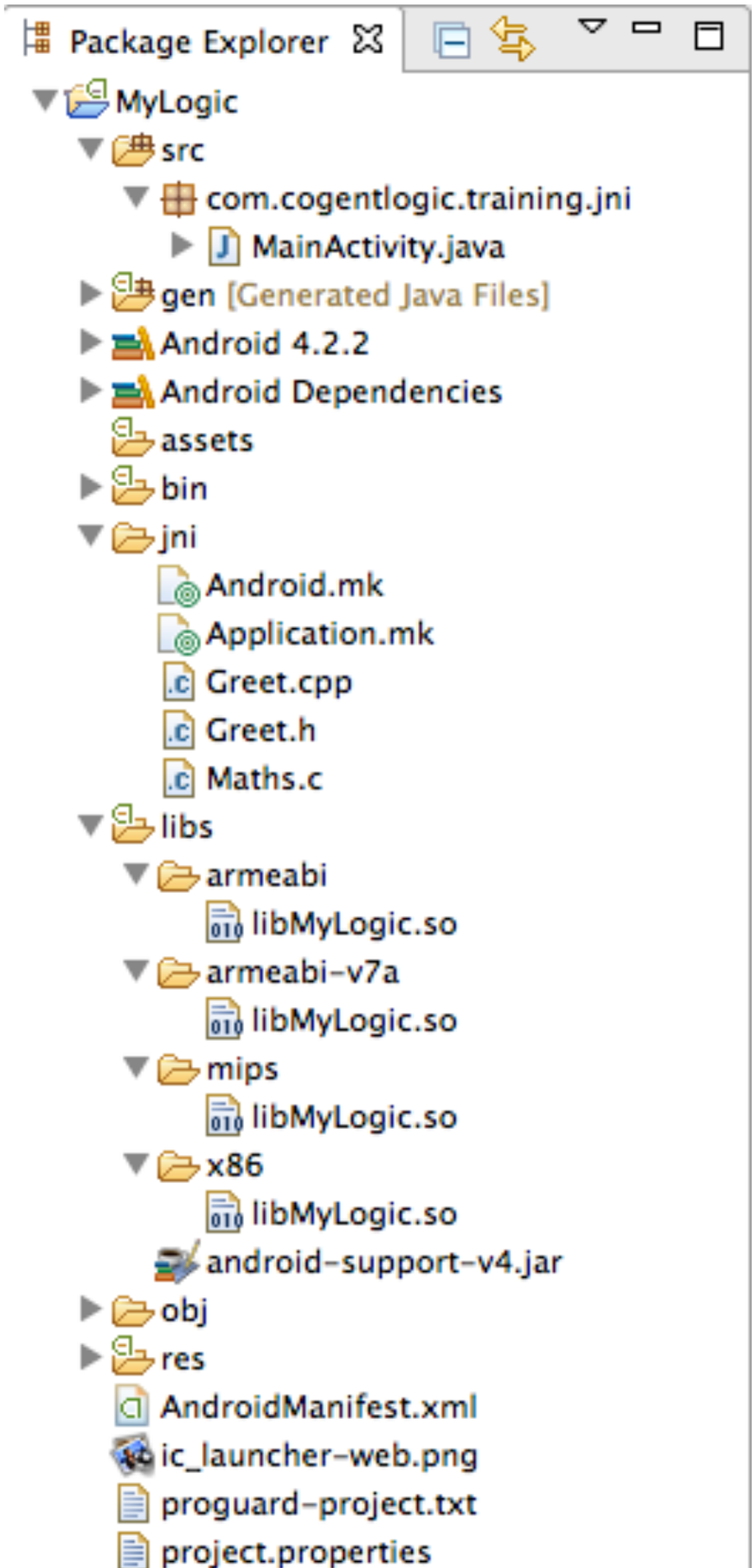
```
cd /cygdrive/d/workspace/MyLogic/jni
```

- For an NDK installation in `C:\android-ndk-r7c\`, invoke the compiler with:

```
/cygdrive/c/android-ndk-r7c/ndk-build
```

- To view the results of the compilation in Eclipse, refresh Package Explorer:





`APP_ABI := all` in `Application.mk`

results in the four object targets of

`armeabi`, `armeabi-v7a`, `mips` and `x86`

`LOCAL_MODULE := MyLogic` in `Android.mk`

results in the libraries `libMyLogic.so`

- Sample Java code: (*MyLogic — MainActivity.java*):

```
public class MainActivity extends Activity
{
  static {  System.loadLibrary("MyLogic");  }

  public native String greeting();
  public native int fibonacci(int n);

  @Override
  public void onCreate(Bundle savedInstanceState)
  {
     super.onCreate(savedInstanceState);

     // Call C++ and C
     TextView  tv = new TextView(this);
     tv.setText(greeting("Android "+ fibonacci(30)));
     setContentView(tv);
  }
}
```

Java Native Interface with Eclipse and Android

Using Native APIs

Jeff Lawson

Contents

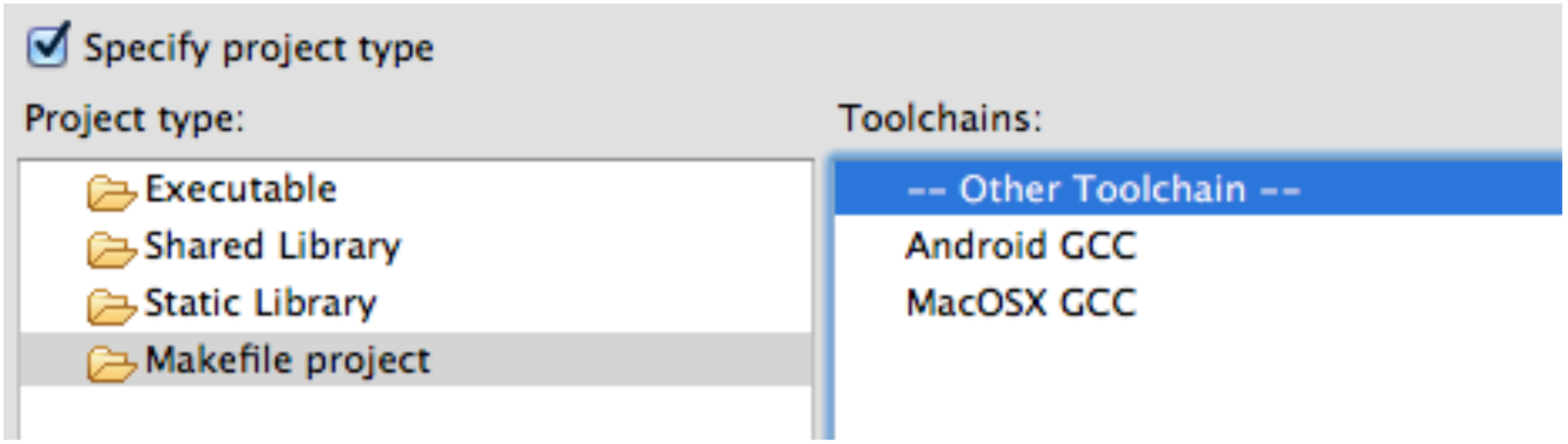
- Native APIs
- Android Logging API

Native APIs

- JNI provides a way for us to make use of the native platform that Java is supposed to dispense with!
- Android explicitly expose useful system components for access through JNI
- For details, see: `<NDK>/docs/STABLE-APIS.html`
- Note: the libraries that implement the system APIs are pre-installed on the host system, of course!
- We will look at native logging that makes use of the `/system/lib/liblog.so` library
- `Android.mk` references the logging library with `LOCAL_LDLIBS := -`

Android Logging API

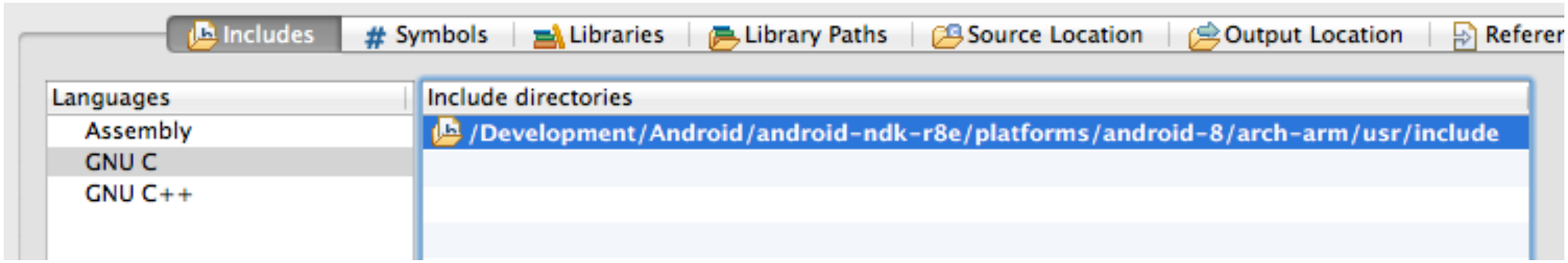
- To make use of the Android logging API, follow these steps:
  - Create an Android project and convert it for C/C++ use:
    - Select the `Specific project type` of `Makefile project` and select `-- Other Toochain --`



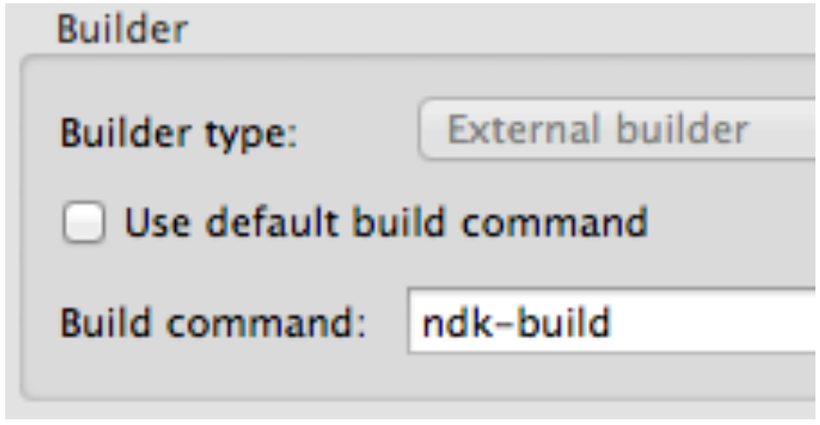
- Reference the Android header files:

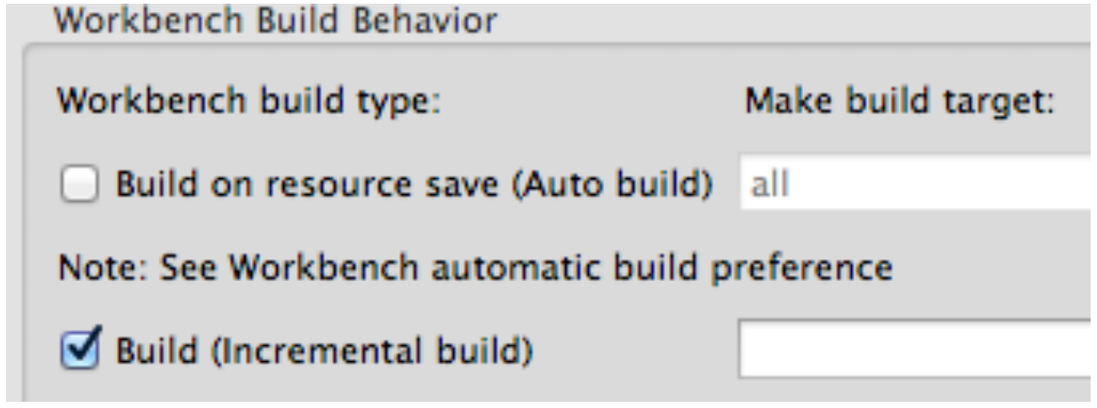
  `<NDK>/platforms/android-8/arch-arm/usr/include`

  in the usual place under `Paths and Symbols`



- In the project's `Properties`, select the `C/C++ Build` category, `Builder Settings`, clear the `Use default build command` checkbox and enter `ndk-build`; then, on the `Behaviour` tab, along-side `Build (Incremental build)`, clear the `all` entry:





- Also, under `C/C++ Build`, select the Environment category then add a `PATH` environment variable that references the NDK (so `ndk-build` can be found):

```
usr/bin:/bin:/usr/sbin:/sbin:/Development/
                                Android/android-ndk-r8e
```

Environment variables to set

Variable	Value	Origin
CWD	/Jeff/JNI_Training/SampleCode/MacOSX/AndroidWorkspace/Logr/	BUILD SYSTEM
PATH	/usr/bin:/bin:/usr/sbin:/sbin:/Development/Android/android-ndk-r8e	USER: CONFIG
PWD	/Jeff/JNI_Training/SampleCode/MacOSX/AndroidWorkspace/Logr/	BUILD SYSTEM

- Add a `jni` folder to the project and create the following files there:
  - `Android.mk`
  - `Application.mk`
  - `Logging.c`

- To `Android.mk`, add:

```
LOCAL_PATH := $(call my-dir)
include $(CLEAR_VARS)
LOCAL_MODULE    := Logging
LOCAL_SRC_FILES := Logging.c
LOCAL_LDLIBS := -llog
include $(BUILD_SHARED_LIBRARY)
```

- To `Application.mk`, add:

```
APP_PLATFORM := android-7
APP_ABI := armeabi
```

- To Logging.c, add:

```
#include <jni.h>
#include <android/log.h>

JNIEXPORT void JNICALL
   Java_com_cogentlogic_training_jni_MainActivity_log(
                  JNIEnv* env, jobject thiz, jstring strMsg)
{
  __android_log_write(ANDROID_LOG_ERROR, "LJC",
                        "on_call_tsx_state");
  const char* pchMsg = (*env)->GetStringUTFChars(env,
                                                  strMsg, 0);
  if (pchMsg)
  {
     int nThing = 123;
     __android_log_print(ANDROID_LOG_INFO,
                           "LJC", "%s : %d\n", pchMsg, nThing);
  (*env)->ReleaseStringUTFChars(env, strMsg, pchMsg);
}
```

- In the Android activity, load the library, declare the native method and invoke the native method:

```
static
{
  System.loadLibrary("Logging");
}

private native void log(String strMsg);

protected void onCreate(Bundle savedInstanceState)
{
  super.onCreate(savedInstanceState);
  setContentView(R.layout.activity_main);

  log("LCJ");
}
```

- The output will appear in ADT's LogCat, e.g.

```
06-12 15:27:54.298: E/LJC(6178): on_call_tsx_state
06-12 15:27:54.298: I/LJC(6178): LCJ : 123
```

Java Native Interface with Eclipse and Android

Debugging Native Code in Eclipse

Jeff Lawson

Contents

- C/C++ Debugging for Android

C/C++ Debugging for Android

- Android C/C++ debugging has been supported since API Level 9, hence, specify `android:minSdkVersion="9"` in the manifest

- The `android:debuggable` attribute is required in the manifest's `application` element (ignore the warning--that's just for Java!)

- To create debug support files in your project:
  - Run the project in Debug mode
  - Open a command prompt at the project's path
  - Enter: `ndk-gdb` then exit with `quit`

- These files will be added to `obj/local/armeabi` :

  `app_process` `gdb.setup` `libc.so`

- We need to edit `gdb.setup` but we don't want our changes to be overwritten when `ndk-gdb` next runs!
- Copy `gdb.setup` and name the copy `gdb2.setup` to
- Open `gdb2.setup` and delete the line comprising: `target remote :5039`
- We now need to configure several project settings...
- We need a C/C++ debug configuration:
  - From the `Run` menu, select `Debug Configurations...`
  - Select the `C/C++ Application` category and click the `New` button
  - Specify a name for the configuration and, on the `Main` tab, browse for and set the path to `obj/local/armeabi/app_process`

...

Debug Configurations

Create, manage, and run configurations

type filter text

- Android Application
  - Logr
  - MyLogic
- Android JUnit Test
- Android Native Applicati
- C/C++ Application
  - Logr Debug
- C/C++ Attach to Applic
- C/C++ Postmortem Deb
- C/C++ Remote Applicat
- C/C++ Unit
- Java Applet
- Java Application
- JUnit
- Launch Group
- Remote Java Application

Filter matched 16 of 17 items

Name: Logr Debug

Main | Arguments | Environment | Debugger | Source | Common

C/C++ Application:

/Jeff/JNI_Training/SampleCode/MacOSX/AndroidWorkspace/Logr/obj/local/armeabi/app_process

Variables... Search Project... Browse...

Project:

Logr Browse...

Build (if required) before launching

Build configuration: Default

Select configuration using 'C/C++ Application'

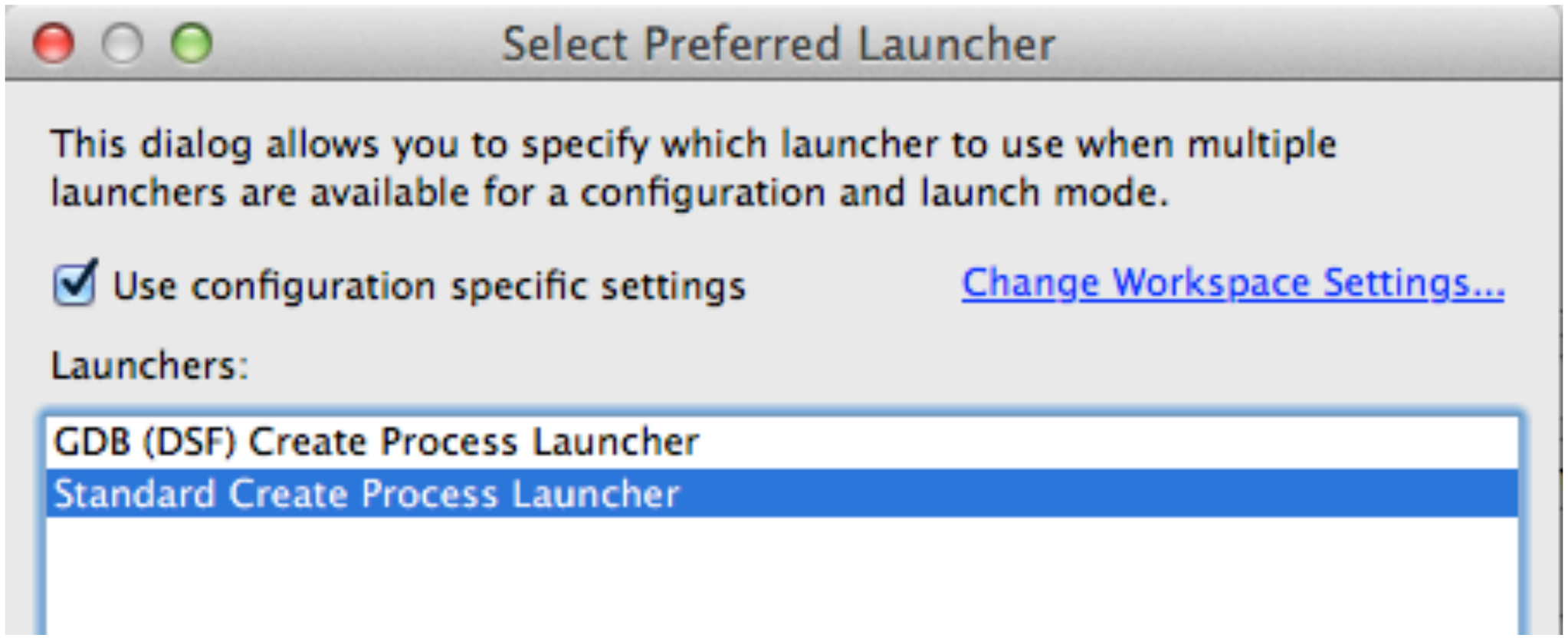
Enable auto build Disable auto build

Use workspace settings Configure Workspace Settings...

Using GDB (DSF) Create Process Launcher - Select other... Apply Revert

Close Debug

- Click blue `Select other...` link at the bottom of the `Main` tab and select the `Standard Create Process Launcher` option:



- On the `Debugger` tab, select the `gdbserver` debugger

- Set the path to GDB debugger, e.g. `/Development/Android/android-ndk-r8e/toolchains/arm-linux-androideabi-4.7/prebuilt/darwin-x86_64/bin/arm-linux-androideabi-gdb`

- Set the path to GDB command line,
  e.g. `...obj/local/armeabi/gdb2.setup`

- On the `Connection` sub-tab, specify:

  - Type: `TCP`

  - Port number: `5039`

- Click the `Apply` button and close the dialog

- Find the `ndk-gdb` file in the `<NDK>` and copy it with the name:
  `ndk-gdb-eclipse`

- Open `ndk-gdb-eclipse` and use `#` to comment-out the line:
  `$GDBCLIENT -x `native_path $GDBSETUP``

- Finally, debug! :
    - Set a breakpoint in your Java code
    - Set a breakpoint in your C/C++ code
    - Start the Android app in Debug mode
    - When the app stops at the Java breakpoint:
        - Open a command prompt at the project's folder
        - Enter the command: `ndk-gdb-eclipse`
        - From the `Run` menu, select `Debug Configurations...`
        - Select the named `C/C++ Application` configuration
        - Click the `Debug` button
    - Click the `Continue` button in the Java debugger
    - The debugger will stop at your C/C++ breakpoint