```
$ export ANDROID_HOME=/path/to/my/sdk (on mac this is typically ~/Library/Android/sdk/)
```

```
$ export ANDROID_HOME=/path/to/my/sdk (on mac this is typically ~/Library/Android/sdk/)

$ git clone https://chromium.googlesource.com/chromium/tools/depot_tools.git
```

```
$ export ANDROID_HOME=/path/to/my/sdk (on mac this is typically ~/Library/Android/sdk/)

$ git clone https://chromium.googlesource.com/chromium/tools/depot_tools.git

Cloning into 'depot_tools'...
remote: Sending approximately 25.76 MiB ...
remote: Counting objects: 3, done
remote: Finding sources: 100% (3/3)
remote: Total 33588 (delta 23410), reused 33587 (delta 23410)
Receiving objects: 100% (33588/33588), 25.75 MiB | 9.92 MiB/s, done.
Resolving deltas: 100% (23410/23410), done.
```

```
$ export ANDROID_HOME=/path/to/my/sdk (on mac this is typically ~/Library/Android/sdk/)

$ git clone https://chromium.googlesource.com/chromium/tools/depot_tools.git

Cloning into 'depot_tools'...
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remote: Counting objects: 3, done
remote: Finding sources: 100% (3/3)
remote: Total 33588 (delta 23410), reused 33587 (delta 23410)
Receiving objects: 100% (33588/33588), 25.75 MiB | 9.92 MiB/s, done.
Resolving deltas: 100% (23410/23410), done.

$ export PATH=$PATH:`pwd`/depot_tools
```

```
$ export ANDROID_HOME=/path/to/my/sdk (on mac this is typically ~/Library/Android/sdk/)

$ git clone https://chromium.googlesource.com/chromium/tools/depot_tools.git

Cloning into 'depot_tools'...
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remote: Total 33588 (delta 23410), reused 33587 (delta 23410)
Receiving objects: 100% (33588/33588), 25.75 MiB | 9.92 MiB/s, done.
Resolving deltas: 100% (23410/23410), done.

$ export PATH=$PATH:`pwd`/depot_tools

$ git clone https://r8.googlesource.com/r8
```

```
$ git clone https://chromium.googlesource.com/chromium/tools/depot_tools.git

Cloning into 'depot_tools'...
remote: Sending approximately 25.76 MiB ...
remote: Counting objects: 3, done
remote: Finding sources: 100% (3/3)
remote: Total 33588 (delta 23410), reused 33587 (delta 23410)
Receiving objects: 100% (33588/33588), 25.75 MiB | 9.92 MiB/s, done.
Resolving deltas: 100% (23410/23410), done.

$ export PATH=$PATH:`pwd`/depot_tools

$ git clone https://r8.googlesource.com/r8

Cloning into 'r8'...
remote: Sending approximately 38.71 MiB ...
remote: Counting objects: 386, done
remote: Finding sources: 100% (218/218)
remote: Total 107455 (delta 48242), reused 107418 (delta 48242)
Receiving objects: 100% (107455/107455), 38.60 MiB | 4.72 MiB/s, done.
Resolving deltas: 100% (48242/48242), done.
```

```
$ git clone https://chromium.googlesource.com/chromium/tools/depot_tools.git
Cloning into 'depot_tools'...
remote: Sending approximately 25.76 MiB ...
remote: Counting objects: 3, done
remote: Finding sources: 100% (3/3)
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$ cd r8
```

```
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Cloning into 'depot_tools'...
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Receiving objects: 100% (107455/107455), 38.60 MiB | 4.72 MiB/s, done.
Resolving deltas: 100% (48242/48242), done.

$ cd r8

$ export R8_HOME=`pwd`
```

```
remote: Finding sources: 100% (3/3)
remote: Total 33588 (delta 23410), reused 33587 (delta 23410)
Receiving objects: 100% (33588/33588), 25.75 MiB | 9.92 MiB/s, done.
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Receiving objects: 100% (107455/107455), 38.60 MiB | 4.72 MiB/s, done.
Resolving deltas: 100% (48242/48242), done.

$ cd r8

$ export R8_HOME=`pwd`

$ tools/gradle.py d8 r8
```

```
remote: Finding sources: 100% (3/3)
remote: Total 33588 (delta 23410), reused 33587 (delta 23410)
Receiving objects: 100% (33588/33588), 25.75 MiB | 9.92 MiB/s, done.
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$ export PATH=$PATH:`pwd`/depot_tools

$ git clone https://r8.googlesource.com/r8
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remote: Sending approximately 38.71 MiB ...
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Resolving deltas: 100% (48242/48242), done.

$ cd r8

$ export R8_HOME=`pwd`

$ tools/gradle.py d8 r8
(... gradle output removed…)
(... this takes time...)
```

Obfuscation:
The Fundamentals

Presented By:
Dustin Summers

Overview

- Introduction
- Compilation in Action
  - Test File 1
- Compiling with DX
  - Test File 1
- Multiple Classes > One Dex
  - Test File 2

- Introducing… Lambdas!
  - Test File 3
- Compiling with D8
  - Test File 3
- Dedupe with D8
  - Test File 4
- Compiling with R8 / Looking at APKs
  - Test File 5

```
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Cloning into 'r8'...
remote: Sending approximately 38.71 MiB ...
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Resolving deltas: 100% (48242/48242), done.

$ cd r8

$ tools/gradle.py d8 r8
(... gradle output removed…)
(... this takes time...)

$ BUILD SUCCESSFUL in 1m 57s
```

```
$ git clone https://r8.googlesource.com/r8
Cloning into 'r8'...
remote: Sending approximately 38.71 MiB ...
remote: Counting objects: 386, done
remote: Finding sources: 100% (218/218)
remote: Total 107455 (delta 48242), reused 107418 (delta 48242)
Receiving objects: 100% (107455/107455), 38.60 MiB | 4.72 MiB/s, done.
Resolving deltas: 100% (48242/48242), done.

$ cd r8

$ tools/gradle.py d8 r8
(... gradle output removed…)
(... this takes time...)

$ BUILD SUCCESSFUL in 1m 57s

#ONLY DOWNLOAD IF INTERESTED!!!
$ tools/test.py --no-internal
(... gradle output removed…)
(... this takes even longer...)
```

Goals

- Comfortable reading Dalvik/Smali
- Understand Android Compilation, and how it plays into Obfuscation
- The stages that transform source code into bytecode

What this course will not teach...

- Various keep rules and examples (follow-on lesson)
- How to hack...

Whats in an APK?

Entry	Notes
AndroidManifest.xml	the manifest file in binary XML format.
classes.dex	application code compiled in the dex format.
resources.arsc	file containing precompiled application resources, in binary XML.
res/	folder containing resources not compiled into resources.arsc
assets/	optional folder containing applications assets, which can be retrieved by AssetManager.
lib/	optional folder containing compiled code - i.e. native code libraries.
META-INF/	folder containing the MANIFEST.MF file, which stores meta data about the contents of the JAR. which sometimes will be store in a folder named original.The signature of the APK is also stored in this folder.

Why .dex and not just .class?

- Typical Java runs multiple .class files in JVM (jar)

- .dex optimized to run on Android in Android VM's (~~Dalvik~~/ART)

- Combine everything from all .class files into one .dex file
  - or multiple if you hit the 64k method limit and use the -multidex option)

- Duplicate strings/other constants used in multiple class files can be included only once in the .dex output to conserve space.

Compilation Pipeline

Source	Source Compilers	ByteCode
TestFile1.java	Javac/Kotlinc	TestFile1.class
(Java/Kotlin)		

Compilation in Action

Test File 1

```
$ cd ..

#(Note: You can make a separate directory for test files if you wish)
$ git clone https://github.com/dustinsummers/obfuscation.git

$ cd obfuscation/TestFile1

$ ls
TestFile1.java

$ javac -source 1.7 -target 1.7 TestFile1.java
```

```
$ cd obfuscation/TestFile1

$ ls
TestFile1.java

$ javac -source 1.7 -target 1.7 TestFile1.java

$ ls
TestFile1.class  TestFile1.java
```

```
$ cd obfuscation/TestFile1

$ ls
TestFile1.java

$ javac -source 1.7 -target 1.7 TestFile1.java

$ ls
TestFile1.class  TestFile1.java

$ java TestFile1
```

```
$ cd obfuscation/TestFile1

$ ls
TestFile1.java

$ javac -source 1.7 -target 1.7 TestFile1.java

$ ls
TestFile1.class  TestFile1.java

$ java TestFile1
Hello, I'm compiled now
```

Compiling with DX

```
Source
TestFile1.java
(Java/Kotlin)
```
→ Source Compilers
Javac/Kotlinc →
```
ByteCode
TestFile1.class
```
→ Dex Compilers
DX →
```
Dalvik Bytecode
classes.dex
```

```
$ cd obfuscation/TestFile1

$ ls
TestFile1.java

$ javac -source 1.7 -target 1.7 TestFile1.java

$ ls
TestFile1.class  TestFile1.java

$ dx --dex --verbose TestFile1.class
```

```
$ cd obfuscation/TestFile1

$ ls
TestFile1.java

$ javac -source 1.7 -target 1.7 TestFile1.java

$ ls
TestFile1.class  TestFile1.java

$ dx --dex --verbose --output=TestFile1.dex TestFile1.class
processing TestFile1.class...                                          |
```

```
$ cd obfuscation/TestFile1

$ ls
TestFile1.java

$ javac -source 1.7 -target 1.7 TestFile1.java

$ ls
TestFile1.class  TestFile1.java

$ dx --dex --verbose --output=TestFile1.dex TestFile1.class
processing TestFile1.class...                                        |

$ ls
```

```
$ cd obfuscation/TestFile1

$ ls
TestFile1.java

$ javac -source 1.7 -target 1.7 TestFile1.java

$ ls
TestFile1.class  TestFile1.java

$ dx --dex --verbose --output=TestFile1.dex TestFile1.class
processing TestFile1.class...                                                  |

$ ls
TestFile1.class  TestFile1.dex  TestFile1.java
```

```
$ cd obfuscation/TestFile1

$ ls
TestFile1.java

$ javac -source 1.7 -target 1.7 TestFile1.java

$ ls
TestFile1.class  TestFile1.java

$ dx --dex --verbose --output=TestFile1.dex TestFile1.class
processing TestFile1.class...                                          |

$ ls
TestFile1.class  TestFile1.dex  TestFile1.java

#Or just type in dexdump below if you have it mapped it like I do : )
$ $ANDROID_HOME/build-tools/29.0.1/dexdump -d TestFile1.dex
```

```
$ cd obfuscation/TestFile1

$ ls
TestFile1.java

$ javac -source 1.7 -target 1.7 TestFile1.java

$ ls
TestFile1.class  TestFile1.java

$ dx --dex --verbose --output=TestFile1.dex TestFile1.class
processing TestFile1.class...                                            |

$ ls
TestFile1.class  TestFile1.dex  TestFile1.java

#Or just type in dexdump below if you have it mapped it like I do : )
$ $ANDROID_HOME/build-tools/29.0.1/dexdump -d TestFile1.dex

$ export PATH=$PATH:$ANDROID_HOME/build-tools/BUILD_TOOLS_#/
```

Multiple Classes > One Dex

Test File 2

```
$ cd ../TestFile2
```

```
$ cd ../TestFile2

$ javac -source 1.7 -target 1.7 TestFile2.java
```

```
$ cd ../TestFile2

$ javac -source 1.7 -target 1.7 TestFile2.java

$ ls
Message.class  TestFile2$Messenger.class   TestFile2$PostMan.class      TestFile2.class      TestFile2.java
```

```
$ cd ../TestFile2

$ javac -source 1.7 -target 1.7 TestFile2.java

$ ls
Message.class  TestFile2$Messenger.class  TestFile2$PostMan.class    TestFile2.class    TestFile2.java

$ java TestFile2
Sending a message: I'm implementing interfaces!!
```

```
$ cd ../TestFile2

$ javac -source 1.7 -target 1.7 TestFile2.java

$ ls
Message.class  TestFile2$Messenger.class   TestFile2$PostMan.class      TestFile2.class       TestFile2.java

$ java TestFile2
Sending a message: I'm implementing interfaces!!

$ dx --dex --verbose *.class
```

```
$ cd ../TestFile2

$ javac -source 1.7 -target 1.7 TestFile2.java

$ ls
Message.class  TestFile2$Messenger.class   TestFile2$PostMan.class     TestFile2.class     TestFile2.java

$ java TestFile2
Sending a message: I'm implementing interfaces!!

$ dx --dex --verbose *.class
processing Message.class...
processing TestFile2$Messenger.class...
processing TestFile2$PostMan.class...
processing TestFile2.class...
```

```
$ cd ../TestFile2

$ javac -source 1.7 -target 1.7 TestFile2.java

$ ls
Message.class  TestFile2$Messenger.class   TestFile2$PostMan.class      TestFile2.class       TestFile2.java

$ java TestFile2
Sending a message: I'm implementing interfaces!!

$ dx --dex --verbose *.class
processing Message.class...
processing TestFile2$Messenger.class...
processing TestFile2$PostMan.class...
processing TestFile2.class...

$ ls
```

```
$ cd ../TestFile2

$ javac -source 1.7 -target 1.7 TestFile2.java

$ ls
Message.class  TestFile2$Messenger.class   TestFile2$PostMan.class      TestFile2.class      TestFile2.java

$ java TestFile2
Sending a message: I'm implementing interfaces!!

$ dx --dex --verbose *.class
processing Message.class...
processing TestFile2$Messenger.class...
processing TestFile2$PostMan.class...
processing TestFile2.class...

$ ls
Message.class    TestFile2$PostMan.class      TestFile2.java      classes.dex
TestFile2$Messenger.class   TestFile2.class
```

```
$ cd ../TestFile2

$ javac -source 1.7 -target 1.7 TestFile2.java

$ ls
Message.class  TestFile2$Messenger.class   TestFile2$PostMan.class      TestFile2.class      TestFile2.java

$ java TestFile2
Sending a message: I'm implementing interfaces!!

$ dx --dex --verbose *.class
processing Message.class...
processing TestFile2$Messenger.class...
processing TestFile2$PostMan.class...
processing TestFile2.class...

$ ls
Message.class    TestFile2$PostMan.class      TestFile2.java      classes.dex
TestFile2$Messenger.class   TestFile2.class

$ dexdump -d classes0.dex
```

Introducing… Lambdas!!!!

TestFile3

```
$ cd ../TestFile3
```

```
$ cd ../TestFile3

$ javac TestFile3.java
```

```
$ cd ../TestFile3

$ javac TestFile3.java

$ ls
 TestFile3.class   TestFile3.java  'TestFile3$PostMan.class'
```

```
$ cd ../TestFile3

$ javac TestFile3.java

$ ls
TestFile3.class   TestFile3.java 'TestFile3$PostMan.class'

$ java TestFile3
Sending a message: I'm Using Lamdas
```

```
$ cd ../TestFile3

$ javac TestFile3.java

$ ls
TestFile3.class   TestFile3.java 'TestFile3$PostMan.class'

$ java TestFile3
Sending a message: I'm Using Lamdas

$ dx --dex --verbose *.class
```

```
$ cd ../TestFile3

$ javac TestFile3.java

$ ls
TestFile3.class   TestFile3.java 'TestFile3$PostMan.class'

$ java TestFile3
Sending a message: I'm Using Lamdas

$ dx --dex --verbose --output=TestFile3.dex *.class
processing TestFile3$PostMan.class...

Uncaught translation error: com.android.dx.cf.code.SimException: ERROR in
TestFile3.main:([Ljava/lang/String;)V: invalid opcode ba - invokedynamic requires --min-sdk-version >= 26
(currently 13)
1 error; aborting
```

What Happened?

Source
TestFile3.java
(Java/Kotlin)

→ Source Compilers
Javac/Kotlinc →

ByteCode
TestFile3.class

→ Dex Compilers
DX →

Dalvik Bytecode
TestFile3.dex

Compilation Pipeline

Source
TestFile3.java
(Java/Kotlin)

Source Compilers
Javac/Kotlinc

Transformers
DeSugar

```
$ dx --dex --verbose --output=TestFile2.dex *.class
processing TestFile3$PostMan.class...

PARSE ERROR:
unsupported class file version 55.0
...while parsing TestFile3$PostMan.class
processing TestFile3.class...

PARSE ERROR:
unsupported class file version 55.0
...while parsing TestFile3.class
2 errors; aborting

$ javac -source 1.7 -target 1.7 TestFile3.java
warning: [options] bootstrap class path not set in conjunction with -source 7
TestFile3.java:7: error: lambda expressions are not supported in -source 7
            PostMan postMan = message -> System.out.println(message);
                    ^
  (use -source 8 or higher to enable lambda expressions)
1 error
1 warning
```

Compilation Pipeline

Source
TestFile3.java
(Java/Kotlin)

→ **Source Compilers**
Javac/Kotlinc

→ **Transformers**
DeSugar

→ **ByteCode**
TestFile3.class

→ **Dex Compilers**
DX

→ ❌

Compilation Pipeline

Source
TestFile3.java
(Java/Kotlin)

→ Source Compilers
Javac/Kotlinc

→ Transformers
~~DeSugar~~

ByteCode
TestFile3.class

→ Dex Compilers
~~DX,~~
D8(DeSugar)

Dalvik
Bytecode
TestFile3.dex

DeSugaring in Action

TestFile3… continued

```
$ dx --dex --verbose --output=TestFile2.dex *.class
processing TestFile3$PostMan.class...

PARSE ERROR:
unsupported class file version 55.0
...while parsing TestFile3$PostMan.class
processing TestFile3.class...

PARSE ERROR:
unsupported class file version 55.0
...while parsing TestFile3.class
2 errors; aborting

$ javac -source 1.7 -target 1.7 TestFile3.java
warning: [options] bootstrap class path not set in conjunction with -source 7
TestFile3.java:7: error: lambda expressions are not supported in -source 7
            PostMan postMan = message -> System.out.println(message);
                    ^
  (use -source 8 or higher to enable lambda expressions)
1 error
1 warning
```

```
PARSE ERROR:
unsupported class file version 55.0
...while parsing TestFile3.class
2 errors; aborting

$ javac -source 1.7 -target 1.7 TestFile3.java
warning: [options] bootstrap class path not set in conjunction with -source 7
TestFile3.java:7: error: lambda expressions are not supported in -source 7
            PostMan postMan = message -> System.out.println(message);
                        ^
  (use -source 8 or higher to enable lambda expressions)
1 error
1 warning

$ java -jar $R8_HOME/build/libs/d8.jar \
    --lib $ANDROID_HOME/platforms/android-29/android.jar \
    --release \
    --output . \
    *.class
```
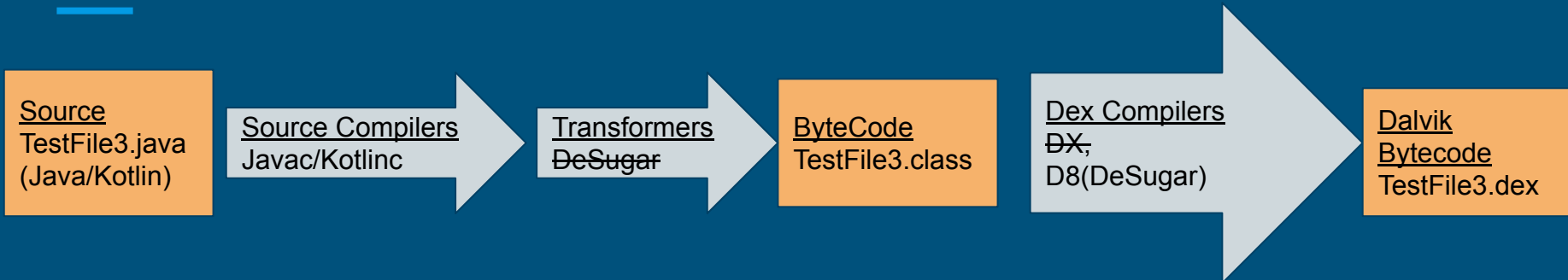
```
PARSE ERROR:
unsupported class file version 55.0
...while parsing TestFile3.class
2 errors; aborting

$ javac -source 1.7 -target 1.7 TestFile3.java
warning: [options] bootstrap class path not set in conjunction with -source 7
TestFile3.java:7: error: lambda expressions are not supported in -source 7
            PostMan postMan = message -> System.out.println(message);
                    ^
  (use -source 8 or higher to enable lambda expressions)
1 error
1 warning

$ java -jar $R8_HOME/build/libs/d8.jar \
    --lib $ANDROID_HOME/platforms/android-29/android.jar \
    --release \
    --output . \
    *.class

$ ls
```

```
PARSE ERROR:
unsupported class file version 55.0
...while parsing TestFile3.class
2 errors; aborting

$ javac -source 1.7 -target 1.7 TestFile3.java
warning: [options] bootstrap class path not set in conjunction with -source 7
TestFile3.java:7: error: lambda expressions are not supported in -source 7
            PostMan postMan = message -> System.out.println(message);
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  (use -source 8 or higher to enable lambda expressions)
1 error
1 warning

$ java -jar $R8_HOME/build/libs/d8.jar \
    --lib $ANDROID_HOME/platforms/android-29/android.jar \
    --release \
    --output . \
    *.class

$ ls
 classes.dex   TestFile3.class   TestFile3.java  'TestFile3$PostMan.class'
```

```
$ javac -source 1.7 -target 1.7 TestFile3.java
warning: [options] bootstrap class path not set in conjunction with -source 7
TestFile3.java:7: error: lambda expressions are not supported in -source 7
            PostMan postMan = message -> System.out.println(message);
                  ^
  (use -source 8 or higher to enable lambda expressions)
1 error
1 warning

$ java -jar $R8_HOME/build/libs/d8.jar \
    --lib $ANDROID_HOME/platforms/android-29/android.jar \
    --release \
    --output . \
    *.class

$ ls
 classes.dex   TestFile3.class   TestFile3.java  'TestFile3$PostMan.class'

$ dexdump -d classes.dex > TestFile3_dump.txt
```

```
[000280] TestFile3.main:([Ljava/lang/String;)V
0000: sget-object v1, L-$$Lambda$TestFile3$1;.INSTANCE:L-$$Lambda$TestFile3$1; // field@0000
0002: const-string v0, "Sending a message: I'm Using Lamdas" // string@0011
0004: invoke-interface {v1, v0}, LTestFile3$PostMan;.letterTime:(Ljava/lang/Object;)V // method@0003
0007: return-void

[000264] TestFile3.lambda$main$0:(Ljava/lang/Object;)V
0000: sget-object v0, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0001
0002: invoke-virtual {v0, v1}, Ljava/io/PrintStream;.println:(Ljava/lang/Object;)V // method@0007
0005: return-void

|[0001fc] -$$Lambda$TestFile3$1.<clinit>:()V
|0000: new-instance v0, L-$$Lambda$TestFile3$1; // type@0000
|0002: invoke-direct {v0}, L-$$Lambda$TestFile3$1;.<init>:()V // method@0001
|0005: sput-object v0, L-$$Lambda$TestFile3$1;.INSTANCE:L-$$Lambda$TestFile3$1; // field@0000
|0007: return-void

|[000234] -$$Lambda$TestFile3$1.letterTime:(Ljava/lang/Object;)V
|0000: invoke-static {v1}, LTestFile3;.lambda$main$0:(Ljava/lang/Object;)V // method@0005
|0003: return-void
```

[000280] TestFile3.main:([Ljava/lang/String;)V
0000: sget-object v1, L-$$Lambda$TestFile3$1;.INSTANCE:L-$$Lambda$TestFile3$1; // field@0000
0002: const-string v0, "Sending a message: I'm Using Lamdas" // string@0011
0004: invoke-interface {v1, v0}, LTestFile3$PostMan;.letterTime:(Ljava/lang/Object;)V // method@0003
0007: return-void

[000264] TestFile3.lambda$main$0:(Ljava/lang/Object;)V
0000: sget-object v0, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0001
0002: invoke-virtual {v0, v1}, Ljava/io/PrintStream;.println:(Ljava/lang/Object;)V // method@0007
0005: return-void

|[0001fc] -$$Lambda$TestFile3$1.<clinit>:()V
|0000: new-instance v0, L-$$Lambda$TestFile3$1; // type@0000
|0002: invoke-direct {v0}, L-$$Lambda$TestFile3$1;.<init>:()V // method@0001
|0005: sput-object v0, L-$$Lambda$TestFile3$1;.INSTANCE:L-$$Lambda$TestFile3$1; // field@0000
|0007: return-void

|[000234] -$$Lambda$TestFile3$1.letterTime:(Ljava/lang/Object;)V
|0000: invoke-static {v1}, LTestFile3;.lambda$main$0:(Ljava/lang/Object;)V // method@0005
|0003: return-void

```
[000280] TestFile3.main:([Ljava/lang/String;)V
0000: sget-object v1, L-$$Lambda$TestFile3$1;.INSTANCE:L-$$Lambda$TestFile3$1; // field@0000
0002: const-string v0, "Sending a message: I'm Using Lamdas" // string@0011
0004: invoke-interface {v1, v0}, LTestFile3$PostMan;.letterTime:(Ljava/lang/Object;)V // method@0003
0007: return-void

[000264] TestFile3.lambda$main$0:(Ljava/lang/Object;)V
0000: sget-object v0, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0001
0002: invoke-virtual {v0, v1}, Ljava/io/PrintStream;.println:(Ljava/lang/Object;)V // method@0007
0005: return-void

|[0001fc] -$$Lambda$TestFile3$1.<clinit>:()V
|0000: new-instance v0, L-$$Lambda$TestFile3$1; // type@0000
|0002: invoke-direct {v0}, L-$$Lambda$TestFile3$1;.<init>:()V // method@0001
|0005: sput-object v0, L-$$Lambda$TestFile3$1;.INSTANCE:L-$$Lambda$TestFile3$1; // field@0000
|0007: return-void

|[000234] -$$Lambda$TestFile3$1.letterTime:(Ljava/lang/Object;)V
|0000: invoke-static {v1}, LTestFile3;.lambda$main$0:(Ljava/lang/Object;)V // method@0005
|0003: return-void
```

```
[000280] TestFile3.main:([Ljava/lang/String;)V
0000: sget-object v1, L-$$Lambda$TestFile3$1;.INSTANCE:L-$$Lambda$TestFile3$1; // field@0000
0002: const-string v0, "Sending a message: I'm Using Lamdas" // string@0011
0004: invoke-interface {v1, v0}, LTestFile3$PostMan;.letterTime:(Ljava/lang/Object;)V // method@0003
0007: return-void

[000264] TestFile3.lambda$main$0:(Ljava/lang/Object;)V
0000: sget-object v0, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0001
0002: invoke-virtual {v0, v1}, Ljava/io/PrintStream;.println:(Ljava/lang/Object;)V // method@0007
0005: return-void

|[0001fc] -$$Lambda$TestFile3$1.<clinit>:()V
|0000: new-instance v0, L-$$Lambda$TestFile3$1; // type@0000
|0002: invoke-direct {v0}, L-$$Lambda$TestFile3$1;.<init>:()V // method@0001
|0005: sput-object v0, L-$$Lambda$TestFile3$1;.INSTANCE:L-$$Lambda$TestFile3$1; // field@0000
|0007: return-void

|[000234] -$$Lambda$TestFile3$1.letterTime:(Ljava/lang/Object;)V
|0000: invoke-static {v1}, LTestFile3;.lambda$main$0:(Ljava/lang/Object;)V // method@0005
|0003: return-void
```

```
[000280] TestFile3.main:([Ljava/lang/String;)V
0000: sget-object v1, L-$$Lambda$TestFile3$1;.INSTANCE:L-$$Lambda$TestFile3$1; // field@0000
0002: const-string v0, "Sending a message: I'm Using Lamdas" // string@0011
0004: invoke-interface {v1, v0}, LTestFile3$PostMan;.letterTime:(Ljava/lang/Object;)V // method@0003
0007: return-void

[000264] TestFile3.lambda$main$0:(Ljava/lang/Object;)V
0000: sget-object v0, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0001
0002: invoke-virtual {v0, v1}, Ljava/io/PrintStream;.println:(Ljava/lang/Object;)V // method@0007
0005: return-void

|[0001fc] -$$Lambda$TestFile3$1.<clinit>:()V
|0000: new-instance v0, L-$$Lambda$TestFile3$1; // type@0000
|0002: invoke-direct {v0}, L-$$Lambda$TestFile3$1;.<init>:()V // method@0001
|0005: sput-object v0, L-$$Lambda$TestFile3$1;.INSTANCE:L-$$Lambda$TestFile3$1; // field@0000
|0007: return-void

|[000234] -$$Lambda$TestFile3$1.letterTime:(Ljava/lang/Object;)V
|0000: invoke-static {v1}, LTestFile3;.lambda$main$0:(Ljava/lang/Object;)V // method@0005
|0003: return-void
```

Quick side notes...

- "Instance" fields contain Hash
- D8 can deduplicate method references
    - Saves on overall method count
- TestFile4

```
$ cd ../TestFile4
```

```
$ cd ../TestFile4

$  javac TestFile4.java
```

```
$ cd ../TestFile4

$ javac TestFile4.java

$ java TestFile4
```

```
$ cd ../TestFile4

$ javac TestFile4.java

$ java TestFile4
My new fancy message
My second fancy message
Sending a default message
Sending a default message
```

```
$ cd ../TestFile4

$  javac TestFile4.java

$  java TestFile4
My new fancy message
My second fancy message
Sending a default message
Sending a default message

$  java -jar $R8_HOME/build/libs/d8.jar \
      --lib $ANDROID_HOME/platforms/android-29/android.jar \
      --release \
      --output . \
      *.class
```

```
$ cd ../TestFile4

$  javac TestFile4.java

$  java TestFile4
My new fancy message
My second fancy message
Sending a default message
Sending a default message

$  java -jar $R8_HOME/build/libs/d8.jar \
      --lib $ANDROID_HOME/platforms/android-29/android.jar \
      --release \
      --output . \
      *.class

$  dexdump -d classes.dex > TestFile4_dump.txt
```

```
|[000440] TestFile4.main:([Ljava/lang/String;)V
|0000: sget-object v1, L-$$Lambda$TestFile4$1;.INSTANCE:L-$$Lambda$TestFile4$1; // field@0001
|0002: invoke-static {v1}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|0005: sget-object v1, L-$$Lambda$TestFile4$2;.INSTANCE:L-$$Lambda$TestFile4$2; // field@0000
|0007: invoke-static {v1}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|000a: sget-object v1, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0003
|000c: invoke-virtual {v1}, Ljava/lang/Object;.getClass:()Ljava/lang/Class; // method@0010
|000f: new-instance v0, L-$$Lambda$3; // type@0002
|0011: invoke-direct {v0, v1}, L-$$Lambda$3;.<init>:(Ljava/io/PrintStream;)V // method@0006
 |0014: invoke-static {v0}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|0017: sget-object v1, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0003
|0019: invoke-virtual {v1}, Ljava/lang/Object;.getClass:()Ljava/lang/Class; // method@0010
|001c: new-instance v0, L-$$Lambda$3; // type@0002
|001e: invoke-direct {v0, v1}, L-$$Lambda$3;.<init>:(Ljava/io/PrintStream;)V // method@0006
|0021: invoke-static {v0}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d
|0024: return-void
```

```
|[000440] TestFile4.main:([Ljava/lang/String;)V
|0000: sget-object v1, L-$$Lambda$TestFile4$1;.INSTANCE:L-$$Lambda$TestFile4$1; // field@0001
|0002: invoke-static {v1}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|0005: sget-object v1, L-$$Lambda$TestFile4$2;.INSTANCE:L-$$Lambda$TestFile4$2; // field@0000
|0007: invoke-static {v1}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|000a: sget-object v1, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0003
|000c: invoke-virtual {v1}, Ljava/lang/Object;.getClass:()Ljava/lang/Class; // method@0010
|000f: new-instance v0, L-$$Lambda$3; // type@0002
|0011: invoke-direct {v0, v1}, L-$$Lambda$3;.<init>:(Ljava/io/PrintStream;)V // method@0006
|0014: invoke-static {v0}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|0017: sget-object v1, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0003
|0019: invoke-virtual {v1}, Ljava/lang/Object;.getClass:()Ljava/lang/Class; // method@0010
|001c: new-instance v0, L-$$Lambda$3; // type@0002
|001e: invoke-direct {v0, v1}, L-$$Lambda$3;.<init>:(Ljava/io/PrintStream;)V // method@0006
|0021: invoke-static {v0}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d
|0024: return-void
```

```
|[000440] TestFile4.main:([Ljava/lang/String;)V
|0000: sget-object v1, L-$$Lambda$TestFile4$1;.INSTANCE:L-$$Lambda$TestFile4$1; // field@0001
|0002: invoke-static {v1}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|0005: sget-object v1, L-$$Lambda$TestFile4$2;.INSTANCE:L-$$Lambda$TestFile4$2; // field@0000
|0007: invoke-static {v1}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|000a: sget-object v1, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0003
|000c: invoke-virtual {v1}, Ljava/lang/Object;.getClass:()Ljava/lang/Class; // method@0010
|000f: new-instance v0, L-$$Lambda$3; // type@0002
|0011: invoke-direct {v0, v1}, L-$$Lambda$3;.<init>:(Ljava/io/PrintStream;)V // method@0006
 |0014: invoke-static {v0}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|0017: sget-object v1, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0003
|0019: invoke-virtual {v1}, Ljava/lang/Object;.getClass:()Ljava/lang/Class; // method@0010
|001c: new-instance v0, L-$$Lambda$3; // type@0002
|001e: invoke-direct {v0, v1}, L-$$Lambda$3;.<init>:(Ljava/io/PrintStream;)V // method@0006
|0021: invoke-static {v0}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d
|0024: return-void
```

```
|[000440] TestFile4.main:([Ljava/lang/String;)V
|0000: sget-object v1, L-$$Lambda$TestFile4$1;.INSTANCE:L-$$Lambda$TestFile4$1; // field@0001
|0002: invoke-static {v1}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|0005: sget-object v1, L-$$Lambda$TestFile4$2;.INSTANCE:L-$$Lambda$TestFile4$2; // field@0000
|0007: invoke-static {v1}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|000a: sget-object v1, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0003
|000c: invoke-virtual {v1}, Ljava/lang/Object;.getClass:()Ljava/lang/Class; // method@0010
|000f: new-instance v0, L-$$Lambda$3; // type@0002
|0011: invoke-direct {v0, v1}, L-$$Lambda$3;.<init>:(Ljava/io/PrintStream;)V // method@0006
 |0014: invoke-static {v0}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d

|0017: sget-object v1, Ljava/lang/System;.out:Ljava/io/PrintStream; // field@0003
|0019: invoke-virtual {v1}, Ljava/lang/Object;.getClass:()Ljava/lang/Class; // method@0010
|001c: new-instance v0, L-$$Lambda$3; // type@0002
|001e: invoke-direct {v0, v1}, L-$$Lambda$3;.<init>:(Ljava/io/PrintStream;)V // method@0006
|0021: invoke-static {v0}, LTestFile4;.sendMessage:(LTestFile4$PostMan;)V // method@000d
|0024: return-void
```
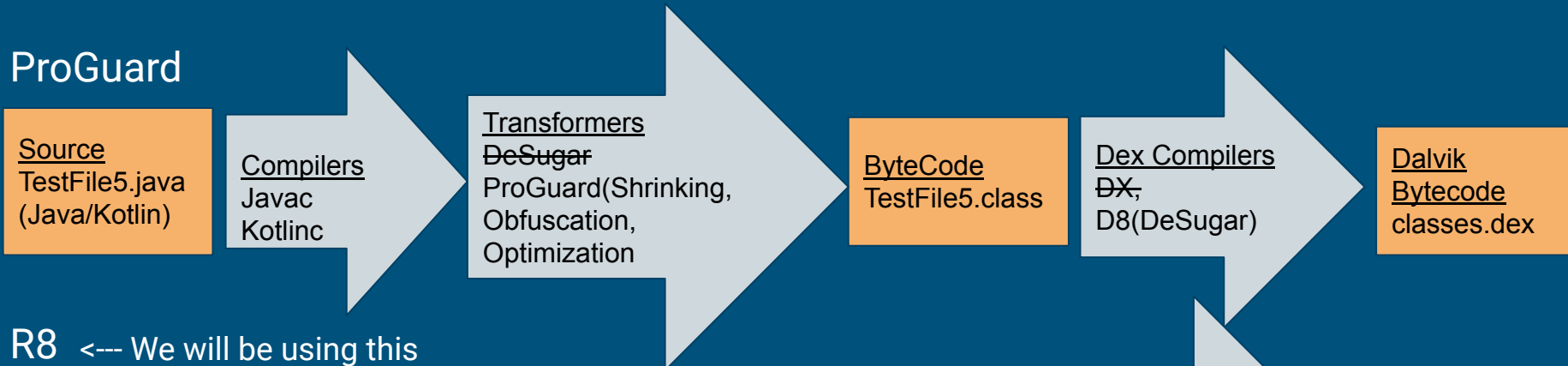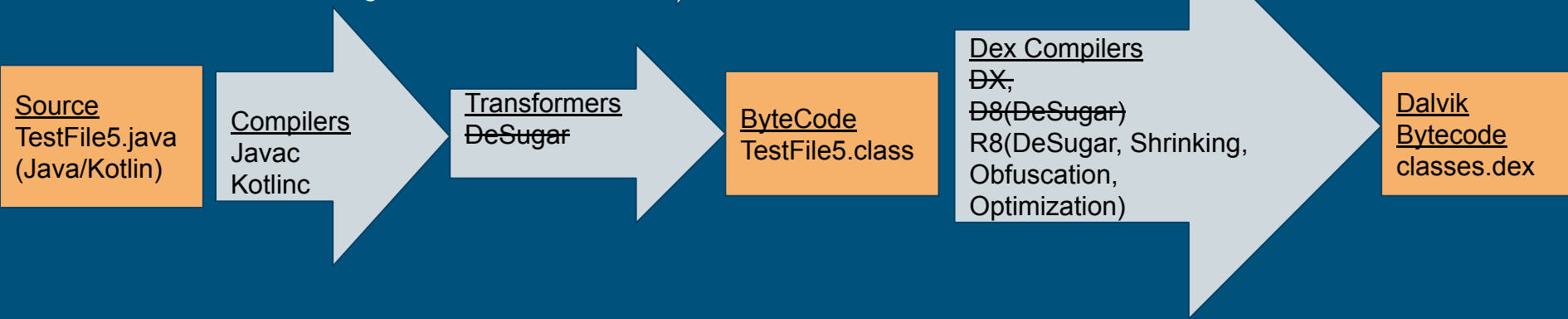
Obfuscation in Action

TestFile5

Quick Note: ProGuard vs. R8

ProGuard

Source
TestFile5.java
(Java/Kotlin)

Compilers
Javac
Kotlinc

Transformers
~~DeSugar~~
ProGuard(Shrinking,
Obfuscation,
Optimization)

ByteCode
TestFile5.class

Dex Compilers
~~DX,~~
D8(DeSugar)

Dalvik
Bytecode
classes.dex

R8 <--- We will be using this

Source
TestFile5.java
(Java/Kotlin)

Compilers
Javac
Kotlinc

Transformers
~~DeSugar~~

ByteCode
TestFile5.class

Dex Compilers
~~DX,~~
~~D8(DeSugar)~~
R8(DeSugar, Shrinking,
Obfuscation,
Optimization)

Dalvik
Bytecode
classes.dex

Compiling with R8...

Swapping over to APK's

- TestFile5

Swapping over to Android Studio

Different Keep Rules

- Be as defined as possible (point to a specific package)
- Rarely should you ever use just "-keep". Use a variant:
    - keep(doesn't run shrinking/obfuscation on class or it's members)
    - Keepclassmembers (still shrinks/optimizes/obfuscates class, but keeps the members)
    - Keepnames(still shrinks/optimizes classes and members, but doesn't obfuscate)
    - Keepclassmembernames (still shrinks/optimizes classes and members, obfuscates classes, but does not obfuscate members)

- Check out https://jebware.com/blog/?p=418 for a guide on this

State of Android Compilation

Native Languages
Java
Kotlin

Run Time Compilation
~~**JIT**~~
~~**AOT**~~
AOT & JIT

Run Time VM's
~~**Dalvik**~~
ART

Compilers
Javac
Kotlinc

Transformers
~~**DeSugar**~~
**ProGuard/DexGuard
(Shrinking/Optimization/Obfuscation)**
Custom

Package Types
~~**OBB**~~
APK

Dex Compilers
~~**Jack/Jill**~~
~~**DX**~~
D8(With DeSugar
R8(DeSugar/Shrinking/Obfuscation/Optimization)

References

https://software.intel.com/en-us/blogs/2014/06/18/art-vs-dalvik-introducing-the-new-android-x86-runtime

https://www.journaldev.com/23464/android-runtime-dvm-vs-art-aot-vs-jit

Jake Wharton Blogs/Presentations

ProGuards Website

@DanLowe0x00

@DustNSummers

Questions?