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Introduction to HotSpot Internals

Starting out with HotSpot

CREATE
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FUTURE

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- Oracle Corp.

- Sep 29, 2014

Introduction

- Intended audience
  - Beginners with HotSpot internals
- Speaker bio
  - System-level design and debugging for Bell Labs, Bellcore and Ameritech
  - Now Principle Engineer in JVM Sustaining at Oracle
- Takeaways
  - HotSpot source code layout, fundamental data structures and algorithms
  - Focus on HotSpot “Runtime”

Session Agenda

1. Introduction
2. Summary of JVM Model
3. Navigating HotSpot Source
4. Classloading and Metadata
5. Template Interpreter
6. Threads

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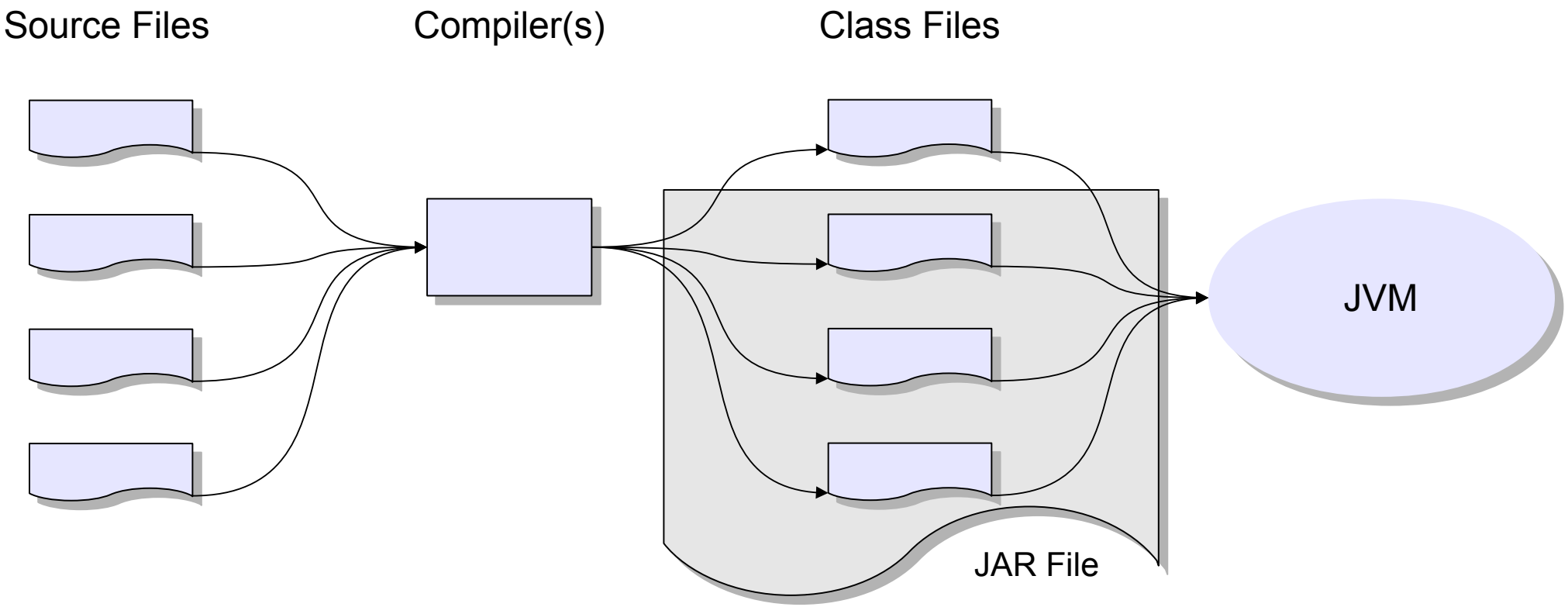
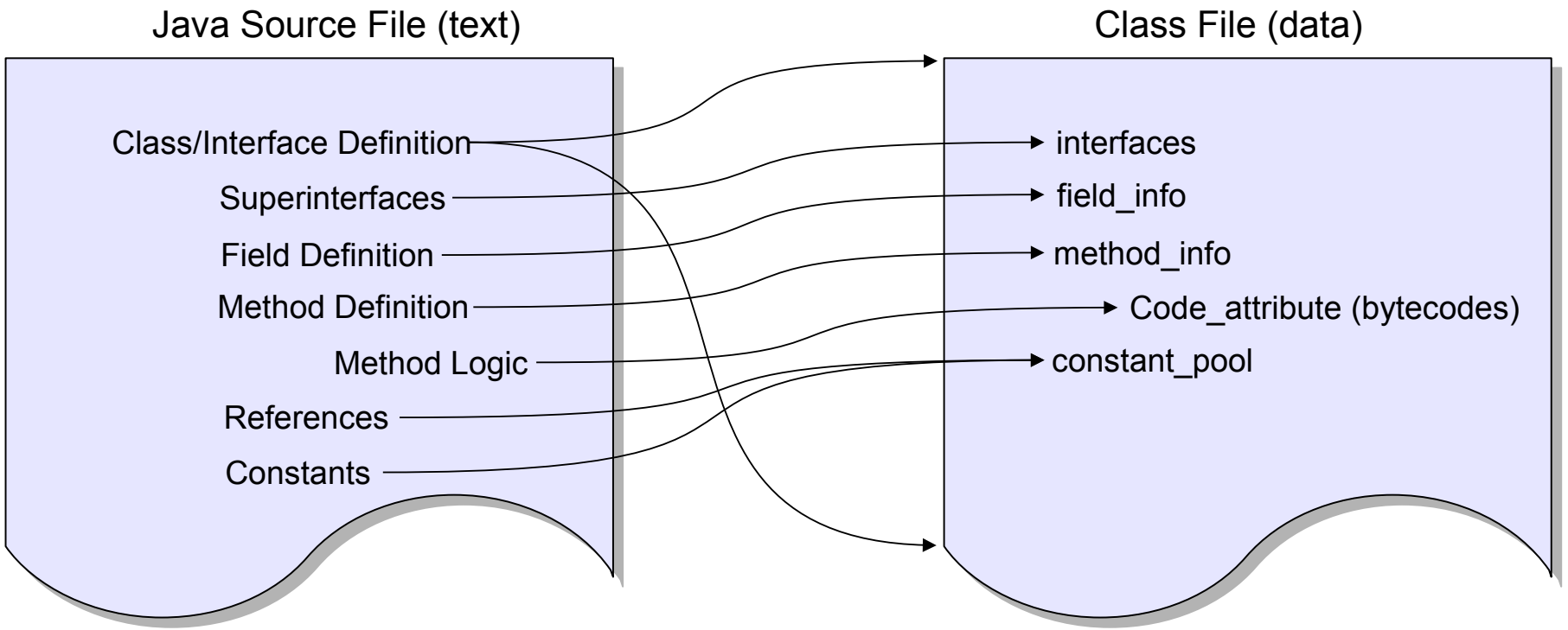
Review of JVM Model



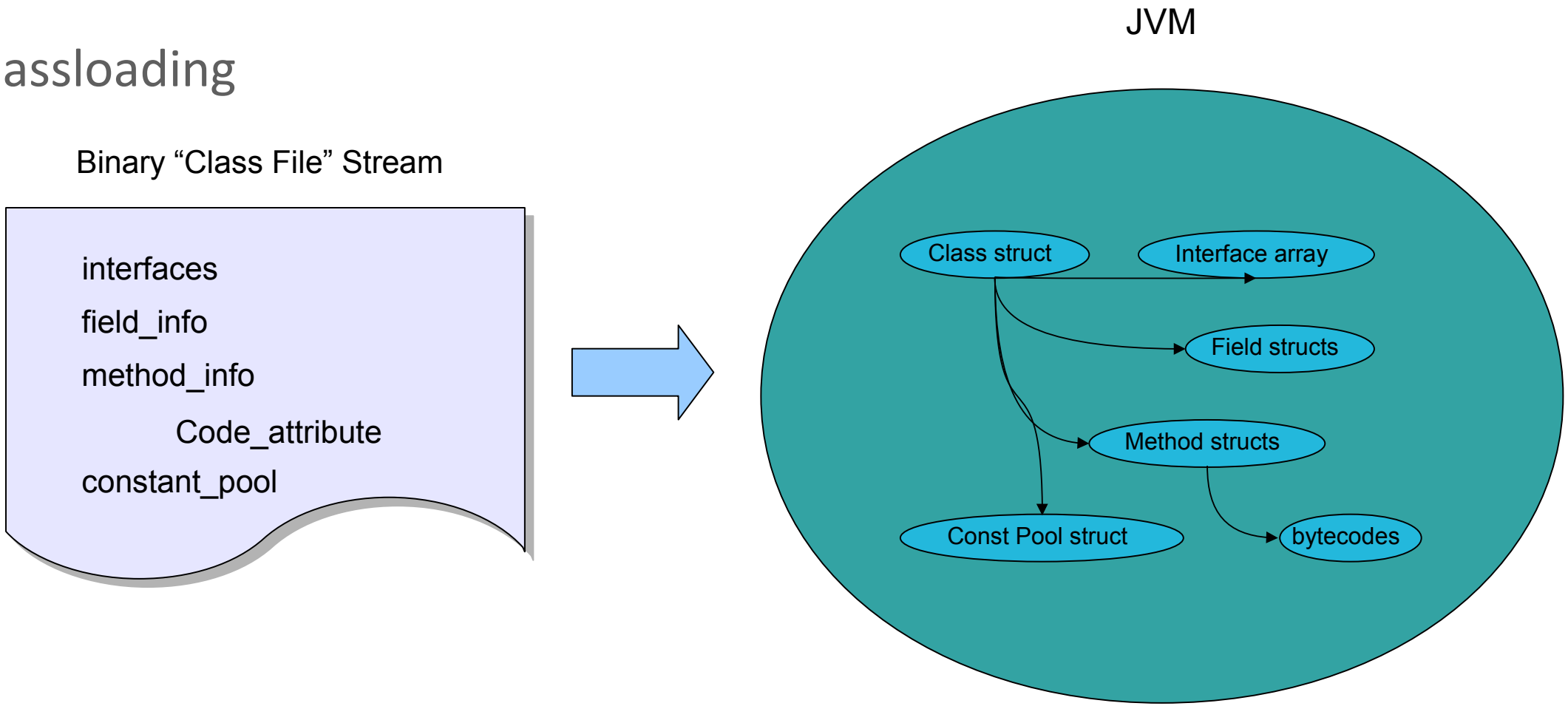
Review of JVM Model

- Java Compilation



Review of JVM Model

- Classloading



Review of JVM Model

- Class Preparation

  Loading - parse binary data into internal data structures

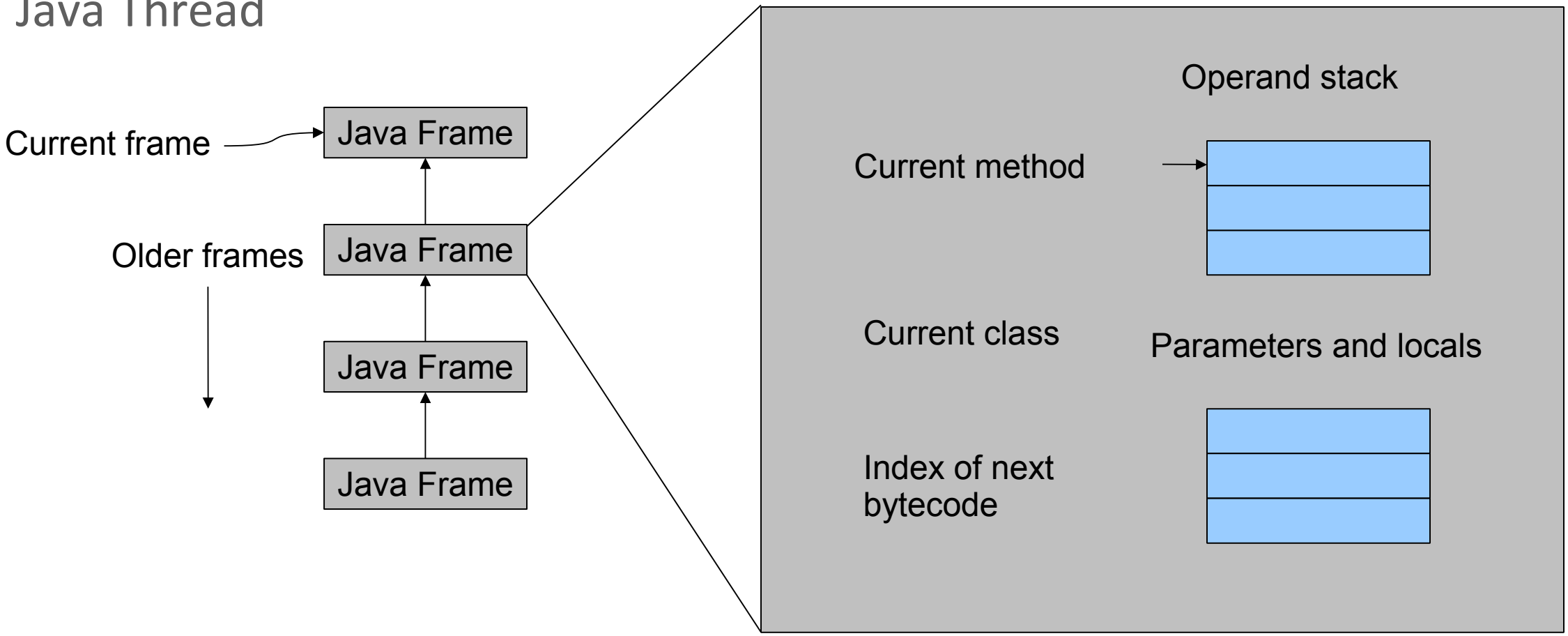
  Verification - ensure the type won't violate integrity of JVM

  Linking - replace symbolic references with direct references

  Initializing - atomically run static initializers

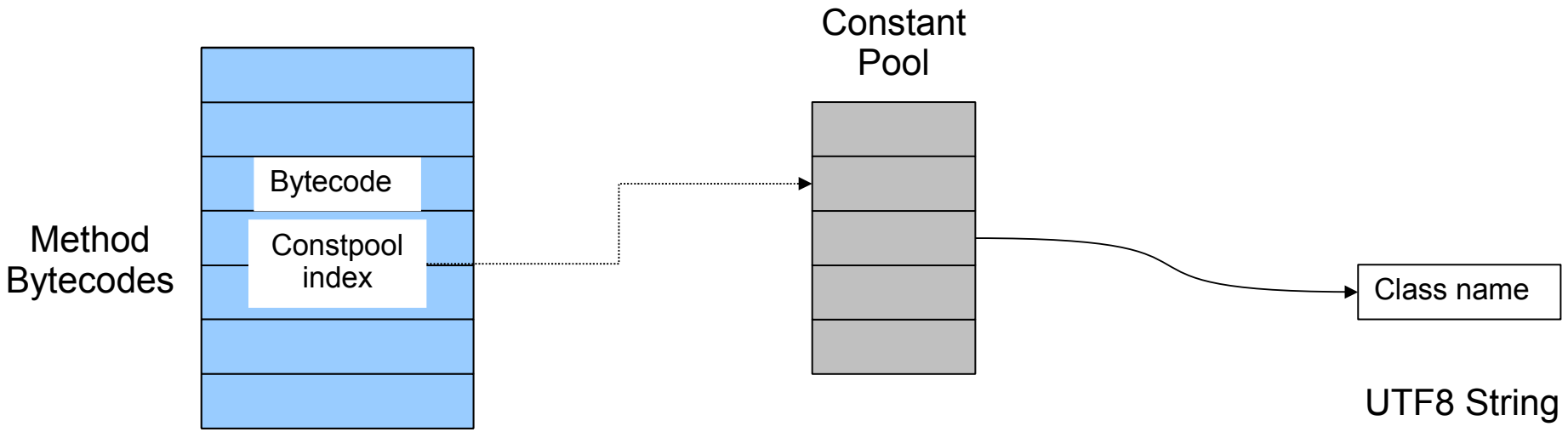
Review of JVM Model

- Java Thread



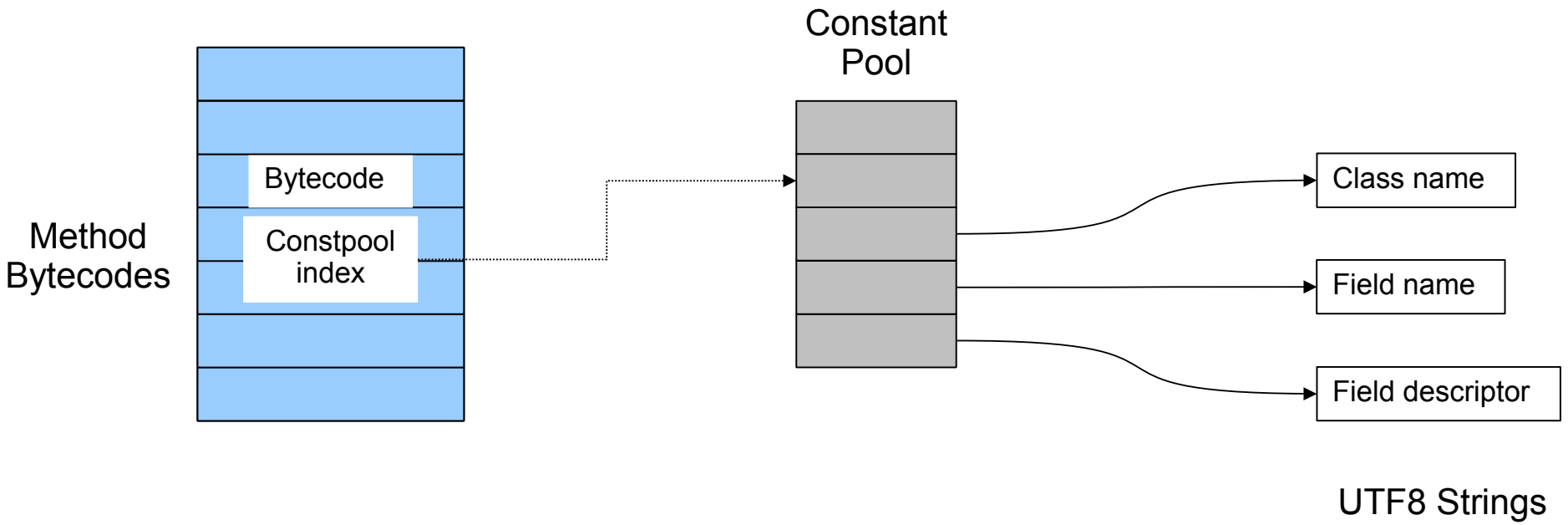
Review of JVM Model

- “new” bytecode



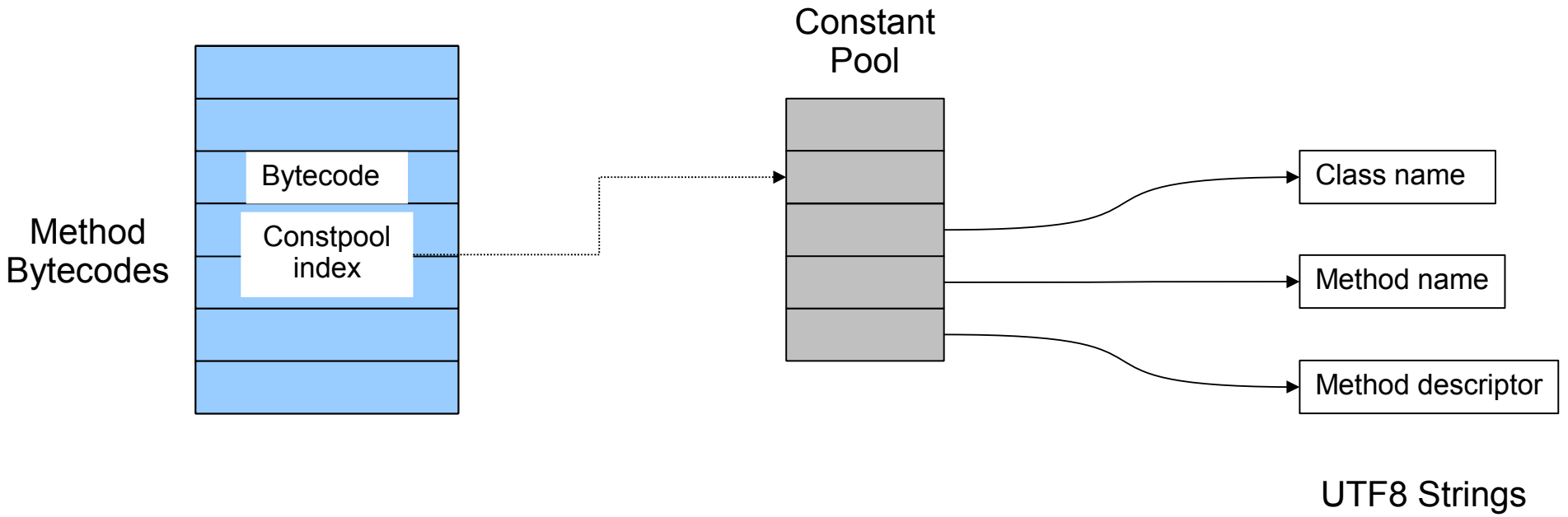
Review of JVM Model

- getfield / getstatic / putfield / putstatic bytecodes



Review of JVM Model

- invokestatic / invokevirtual / invokeinterface bytecodes



Review of JVM Model

- Heap
  - Contains all class instances and (Java) arrays
  - Created on JVM startup
  - Shared among all Java threads
  - May be expanded/contracted as needed
  - Unused objects automatically reclaimed

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Navigating HotSpot Source

- Getting HotSpot Source

Entire JDK:

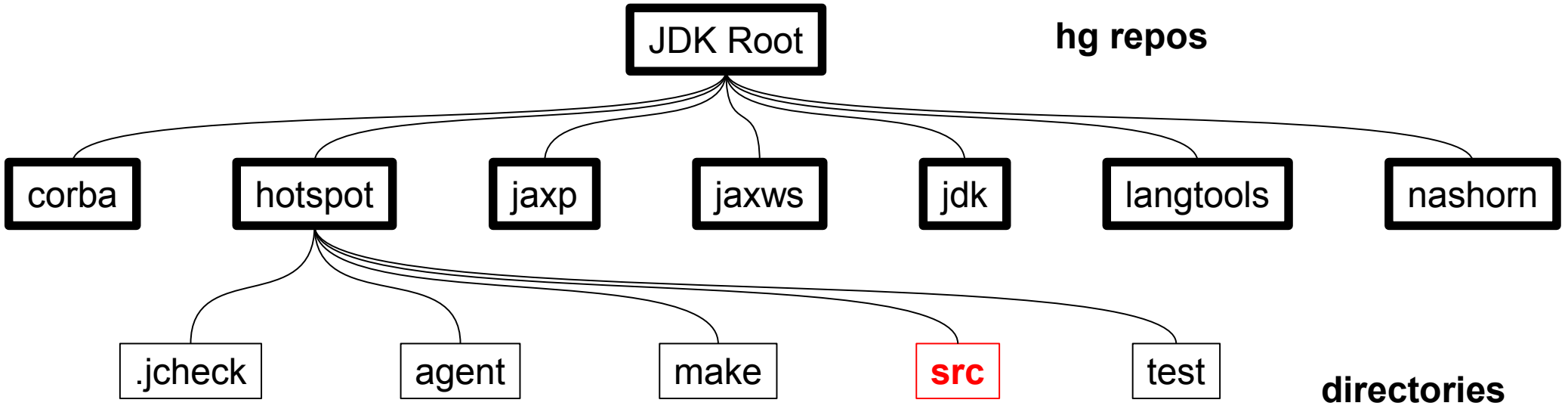
```
hg clone http://hg.openjdk.java.net/jdk8u/jdk8u
cd jdk8u
./get_source.sh
```

HotSpot only:

```
hg clone http://hg.openjdk.java.net/jdk8u/jdk8u/hotspot
```

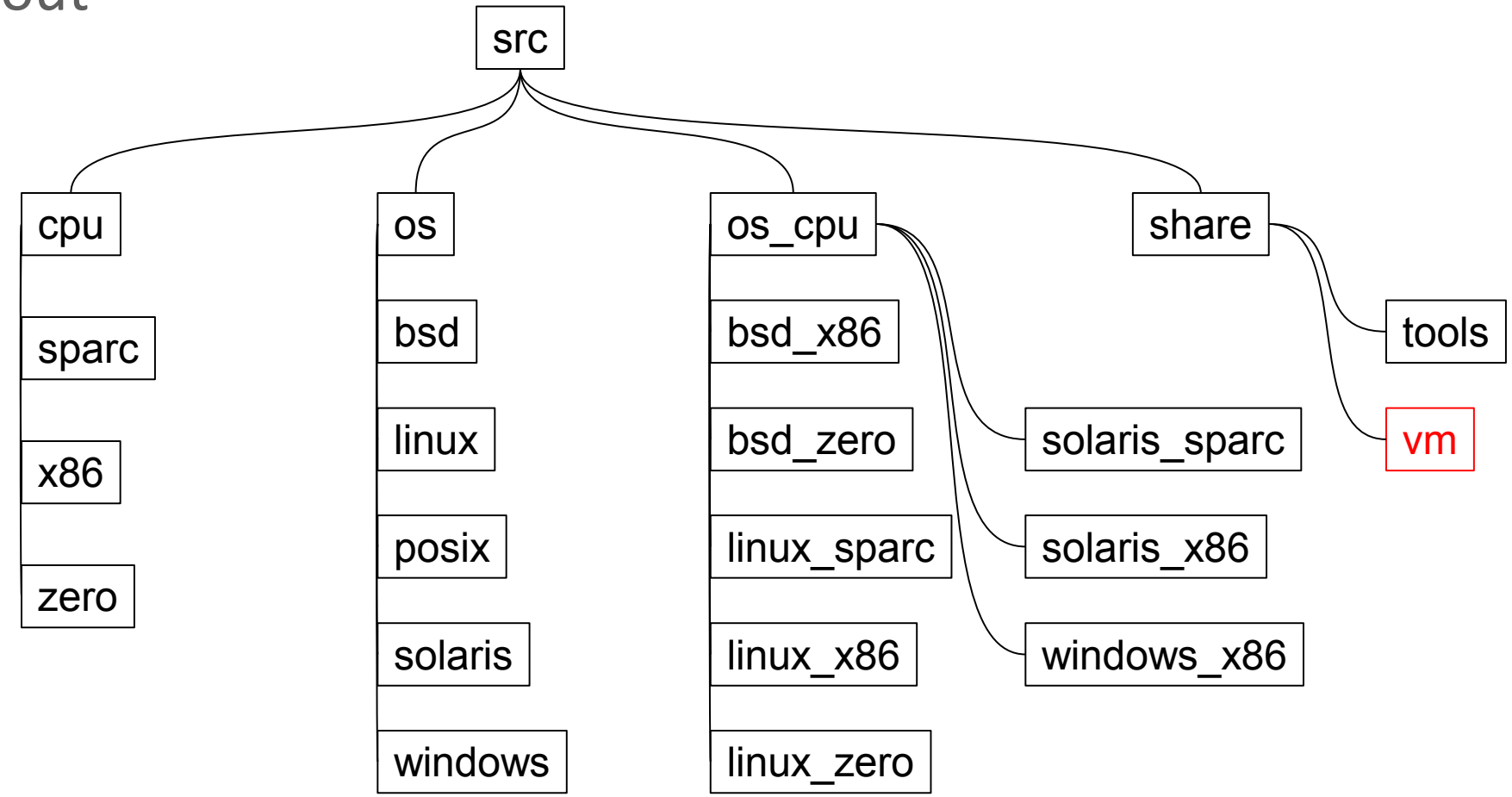
Navigating HotSpot Source

- Source Layout



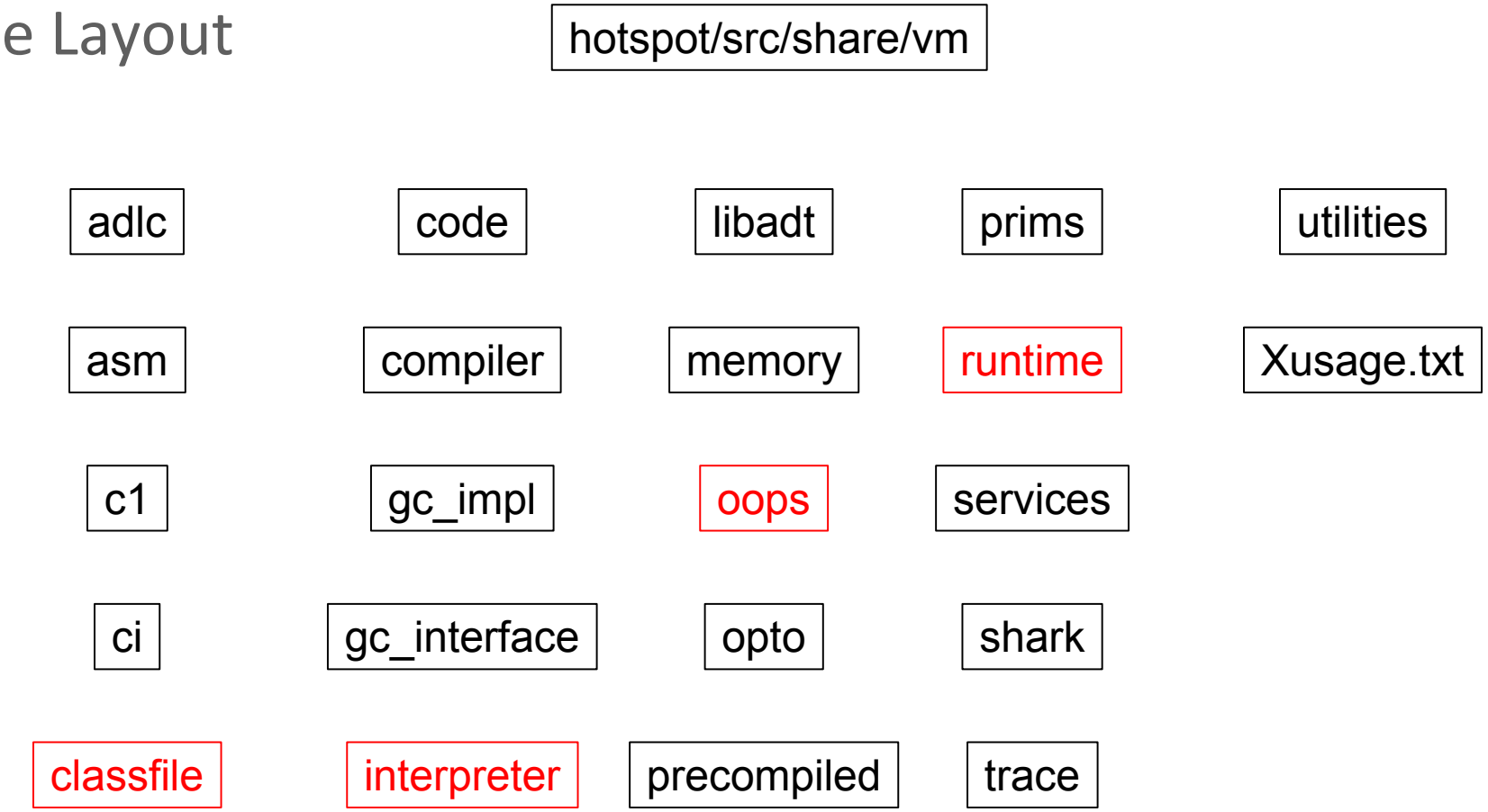
Navigating HotSpot Source

- Source Layout



Navigating HotSpot Source

- Source Layout



Navigating HotSpot Source

- Common patterns - function macro composition

```
#define COLORS(f)   \
    f(RED)   \
    f(BLUE)   \
    f(GREEN)

#define g(x)   x,
typedef enum {
    COLORS(g)
    NCOLORS
} color;

#define h(x)   #x,
const char* colorStrings[] = {
    COLORS(h)
    0
};
```

```
color fontColor;

fontColor = getPreferredFontColor();

if (logLevel >= DEBUG) {
    puts("fontColor set to " +
        colorStrings[fontColor]);
}
```

Navigating HotSpot Source

- Common patterns - resource marks

```
// some code here

{
    HandleMark hm;
    Handle foundObj(findSpecificObj());

    foundObj()->print();

}

// some other code here
```

Navigating HotSpot Source

- Common patterns - platform-specific includes

```
class TemplateInterpreter: public AbstractInterpreter {

. . .

#ifdef TARGET_ARCH_x86
# include "templateInterpreter_x86.hpp"
#endif
#ifdef TARGET_ARCH_sparc
# include "templateInterpreter_sparc.hpp"
#endif

}
```

Navigating HotSpot Source

- Important files
  - src/share/vm/runtime/globals.hpp
  - src/share/vm/oops/klass.hpp and src/share/vm/oops/*Klass.hpp
  - src/cpu/x86/vm/templateInterpreter_x86_32.cpp
  - src/cpu/x86/vm/templateInterpreter_x86_64.cpp
  - src/cpu/sparc/interpreter_sparc.cpp

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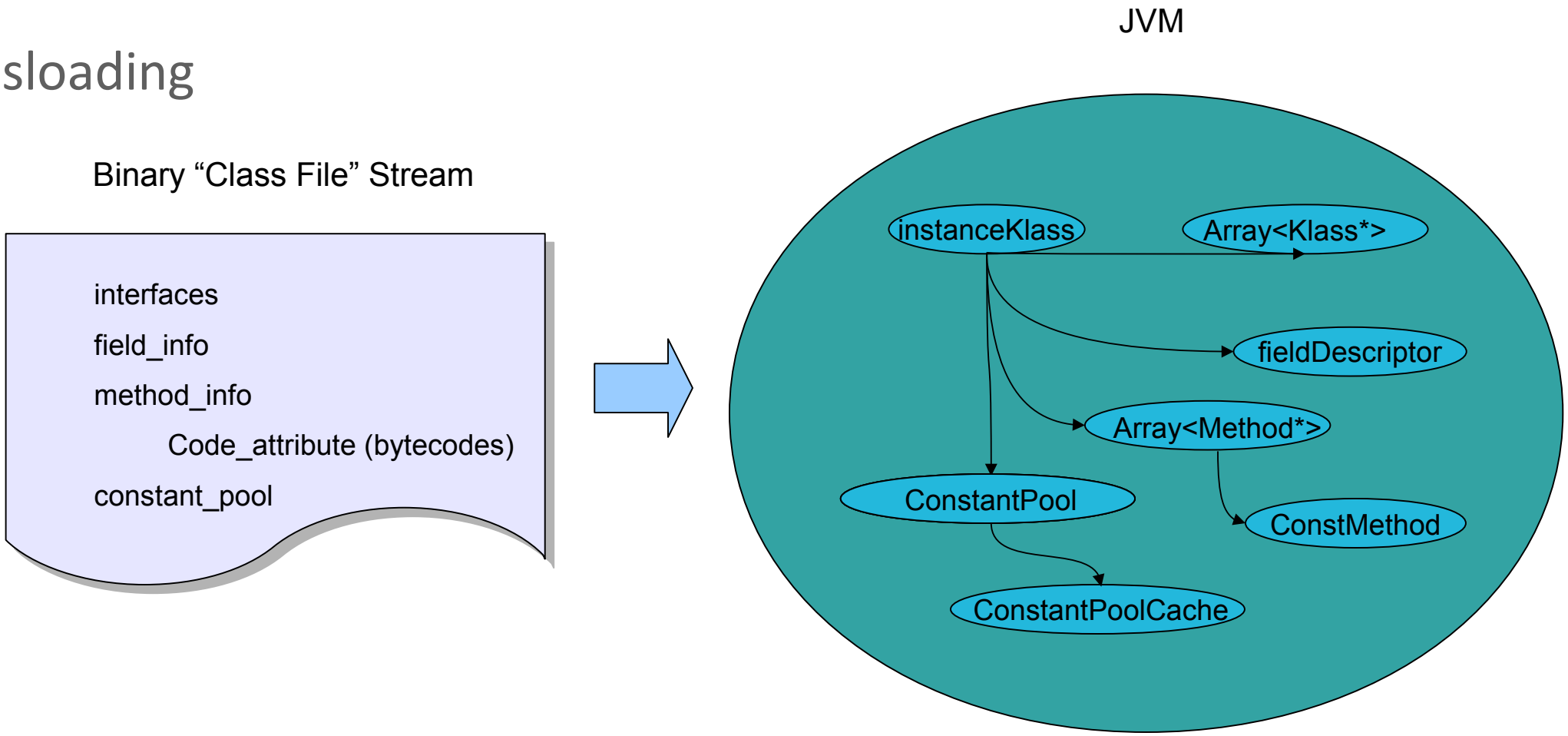
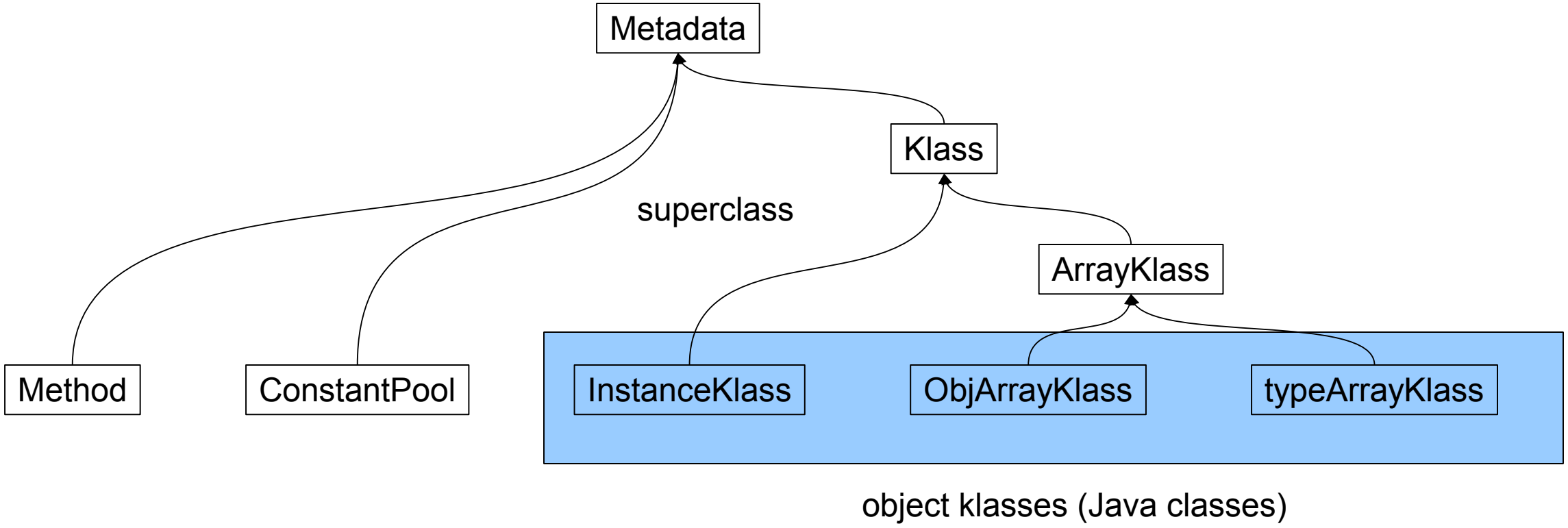
Classloading and Metadata

- Classloading



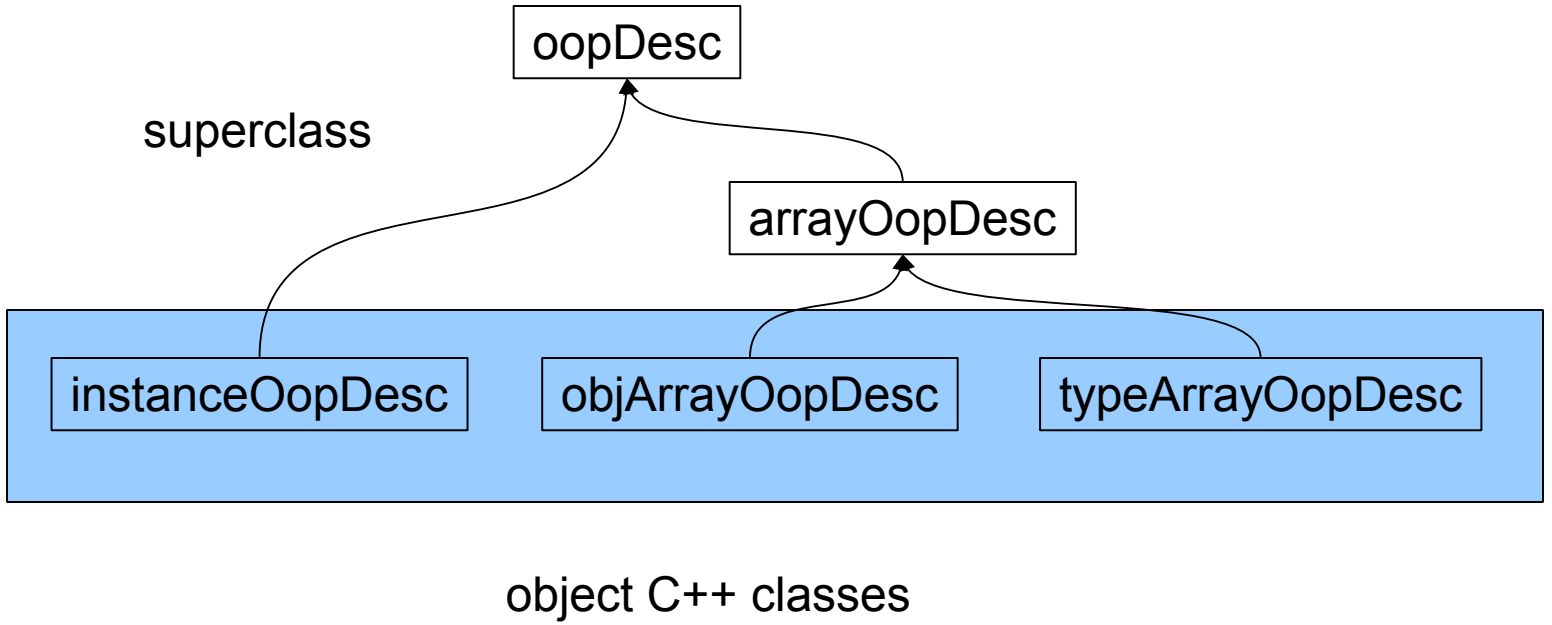
Classloading and Metadata

- Metadata hierarchy (C++ classes in src/share/vm/oops)



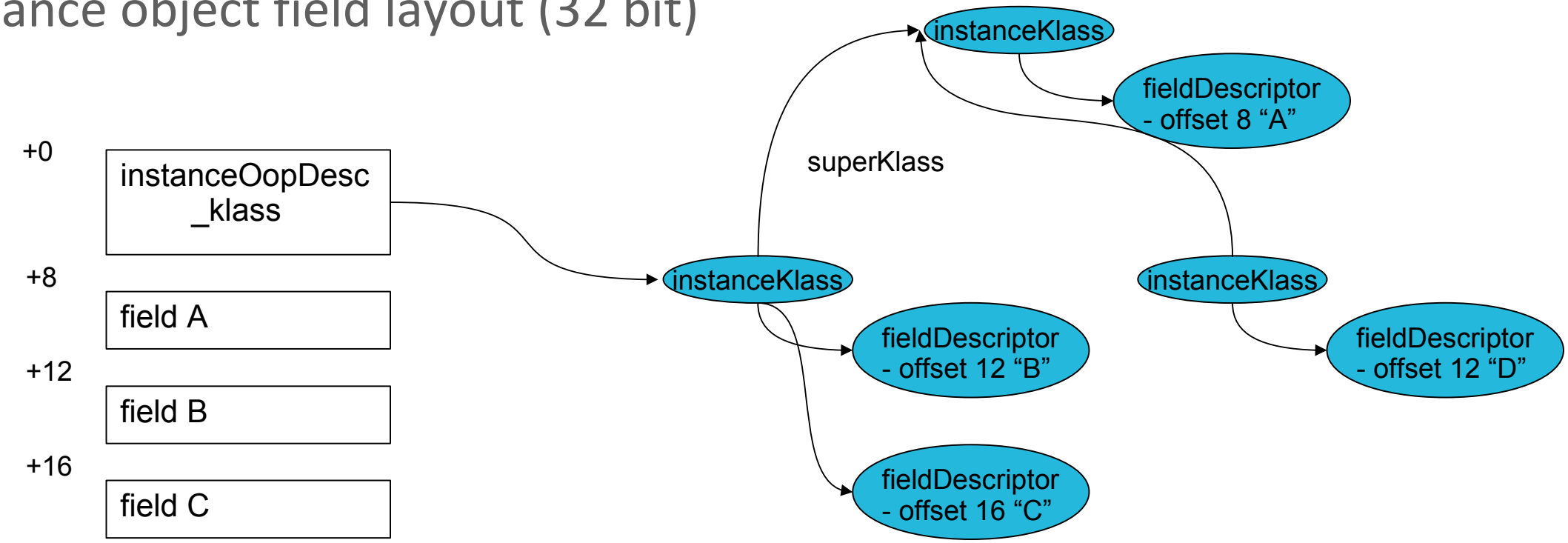
Classloading and Metadata

- Object layout (OopDesc) hierarchy



Classloading and Metadata

- Instance object field layout (32 bit)



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Template Interpreter

- Overview
  - Avoids fetch-switch-exec loop
  - Similar to Indirect Threaded Code
    - Bytecodes index into dispatch array
  - Starts with platform-independent template table
    - Converted into platform-dependent code at runtime
    - Built-in platform-specific macro assembler
  - Single word top-of-stack (TOS) register cache
  - Calls out to JVM for complex operations

Template Interpreter

- Top-of-stack cache state

```
enum TosState {          // describes the tos cache contents
  btos = 0,              // byte, bool tos cached
  ctos = 1,              // char tos cached
  stos = 2,              // short tos cached
  itos = 3,              // int tos cached
  ltos = 4,              // long tos cached
  ftos = 5,              // float tos cached
  dtos = 6,              // double tos cached
  atos = 7,              // object cached
  vtos = 8,              // tos not cached
  number_of_states,
  ilgl                   // illegal state: should not occur
};
```

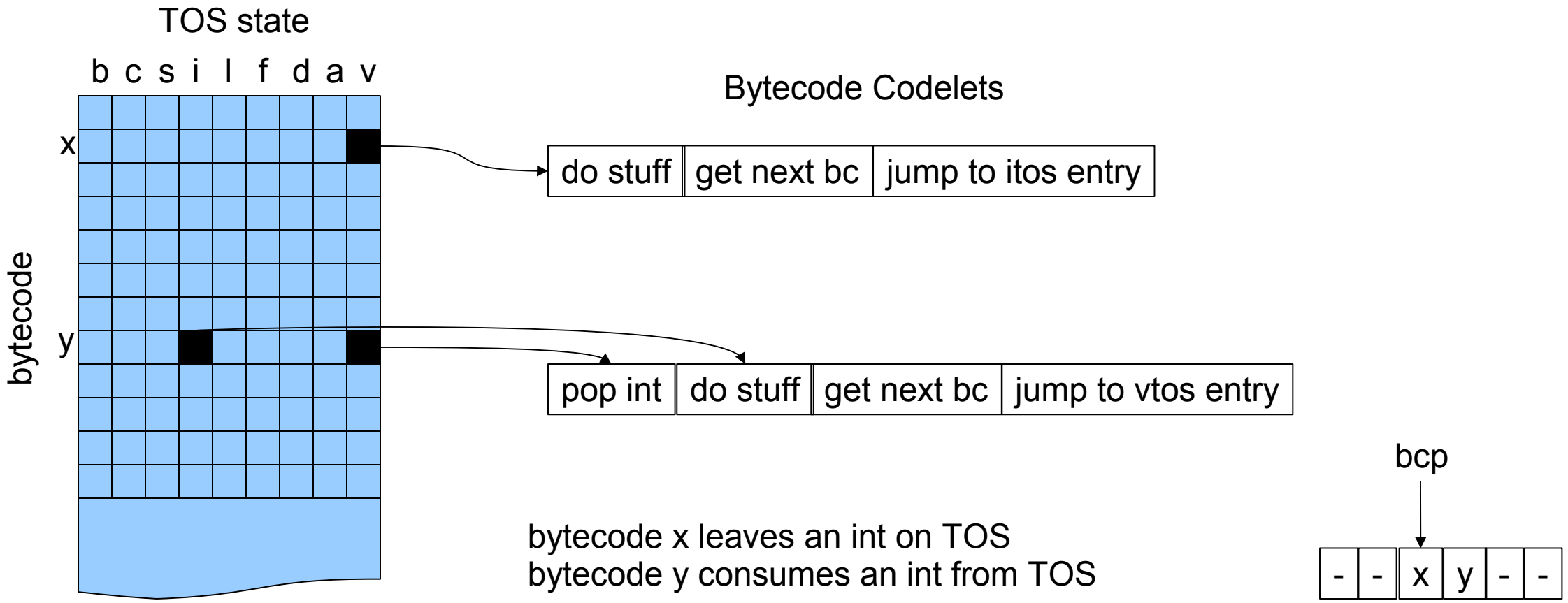
Template Interpreter

- Template Table - array of Templates

```
class Template {
private:

  typedef void (*generator)(int arg);

  int        _flags;   // describes interpreter template properties
  TosState   _tos_in;  // tos cache state before template execution
  TosState   _tos_out; // tos cache state after  template execution
  generator  _gen;     // template code generator
  int        _arg;     // argument for template code generator

  void       initialize(int flags, TosState tos_in, TosState tos_out,
                        generator gen, int arg);
. . .
}
```

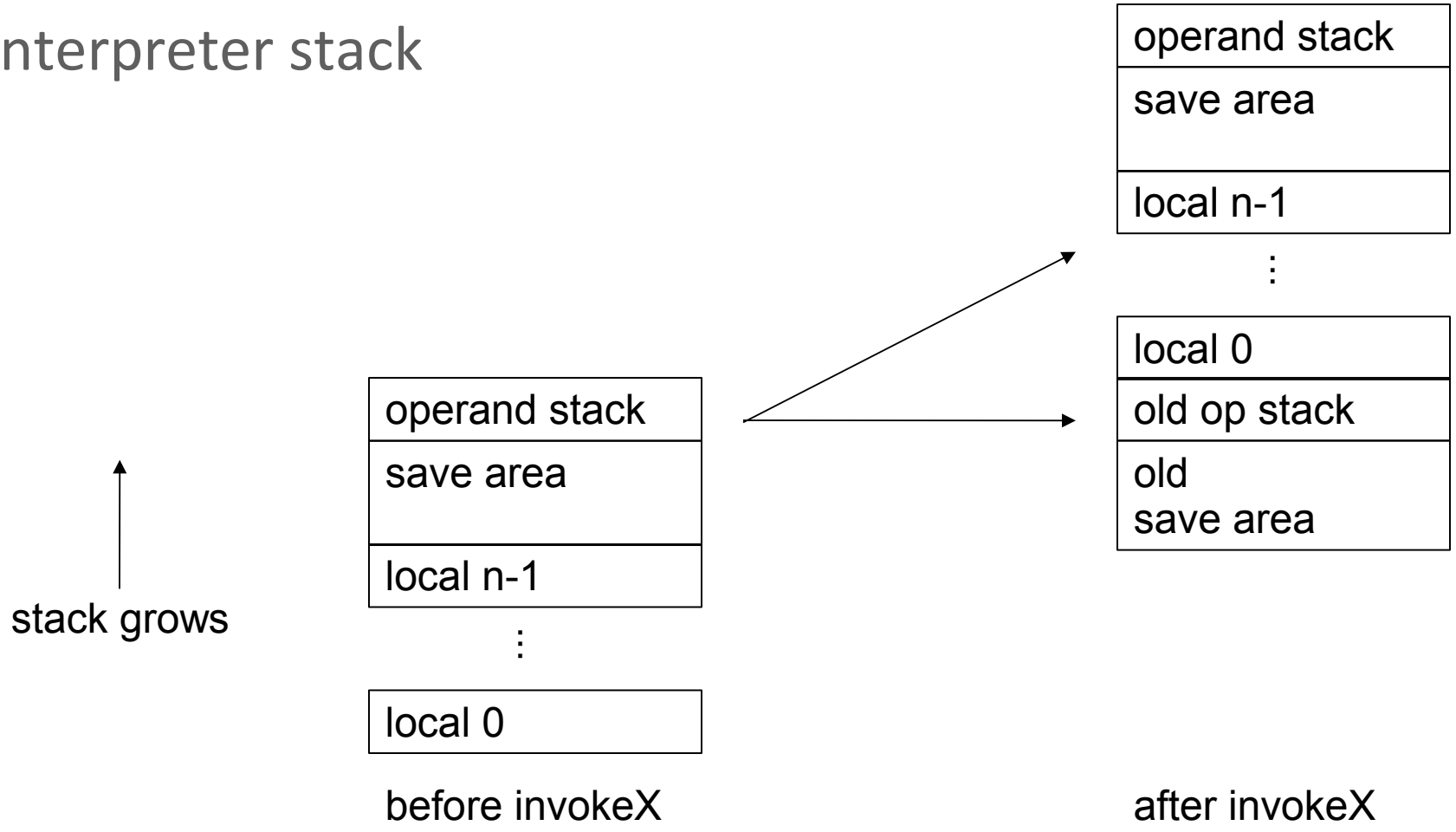
Template Interpreter

- Dispatch table and Codelets



Template Interpreter

- Interpreter stack



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Threads

- Thread hierarchy

  - Thread
    - NamedThread
      - VMThread
      - ConcurrentGCThread
      - WorkerThread
        - GangWorker
        - GCTaskThread
    - JavaThread
    - WatcherThread

Threads

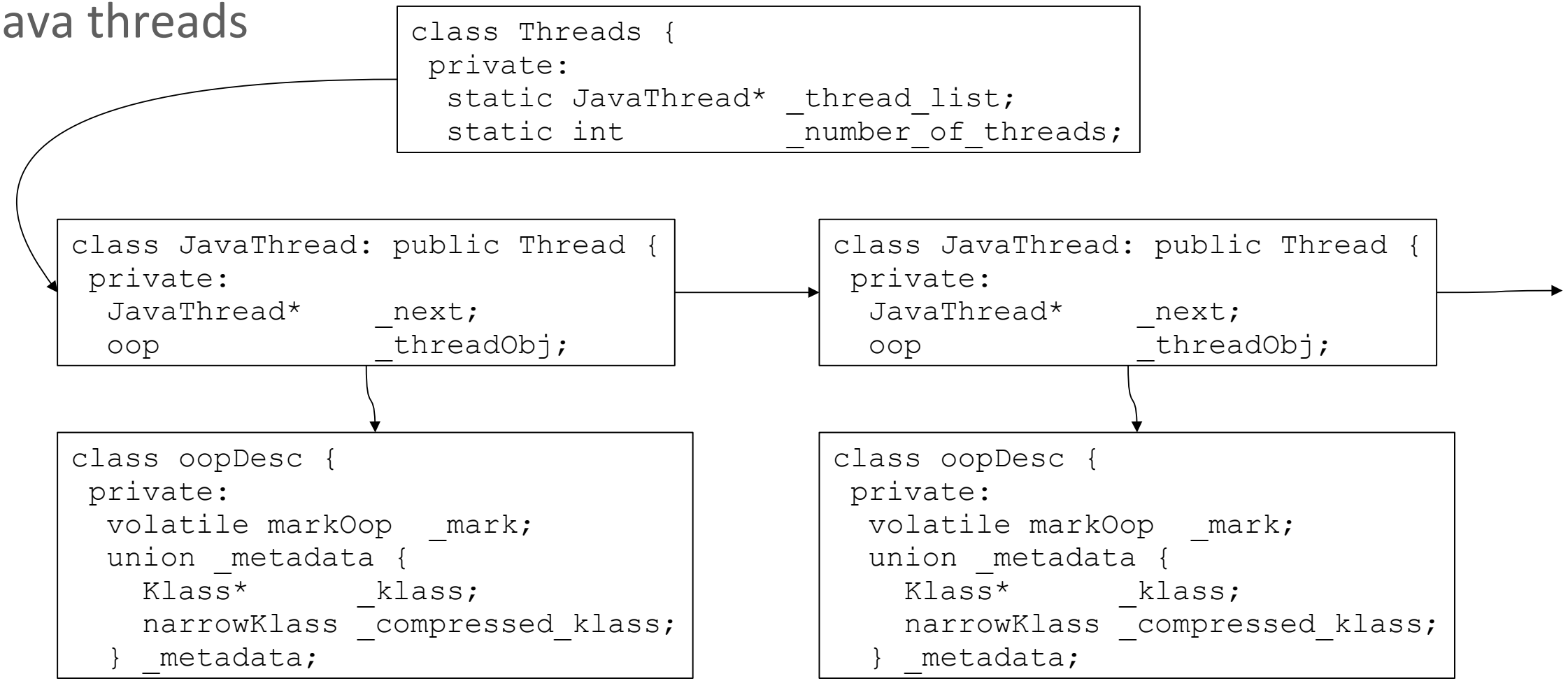
- Thread local storage

How does a thread find its (C++) Thread object quickly?

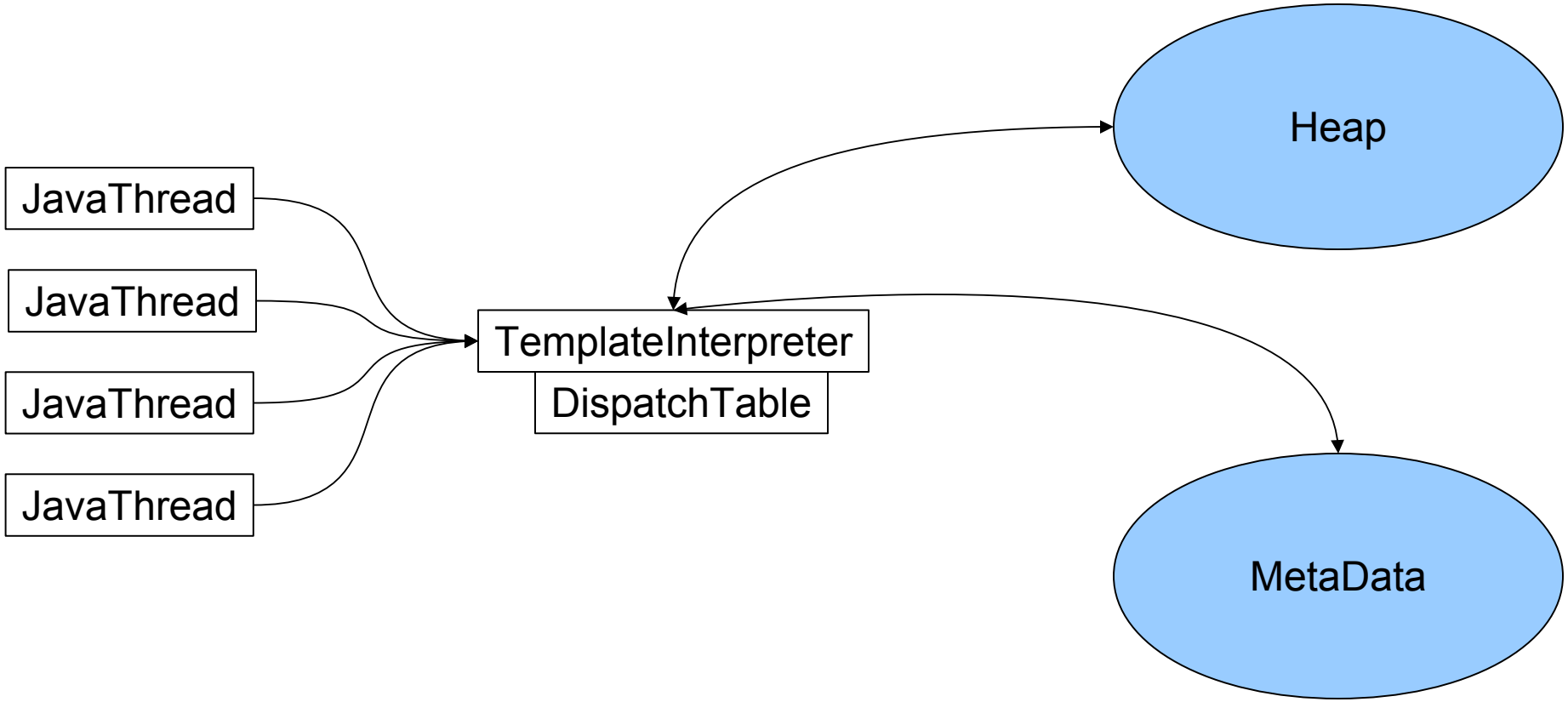
```
extern "C" Thread* get_thread();

class ThreadLocalStorage {
  public:
    static Thread* get_thread_slow();
    static void    generate_code_for_get_thread();
  ...
}
```

Threads

- Java threads



Summary



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