Runtime Type Information and Reflection

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Overview

- Reflection overview
- Java type representation
- Accessing a type's Class instance
- Accessing information about a type
- Accessing type member information
- Interacting with object instances
- Creating type instances
- Dynamic type loading

Reflection

Core capabilities of reflection

- Examine types at runtime
- Dynamically execute & access members

The Need for Reflection

Apps do not always control types used

- Common in advanced app designs
- Common in tools and frameworks

Often dynamically load types

- Type not known at compile time
- There's no type-specific source code

Requires special runtime type handling

- Examine types at runtime
- Dynamically execute & access members

Runtime Examination

Can fully examine objects at runtime

- Type, Base types
- Interfaces implemented
- Members

Variety of uses

- Determine a type's capabilities
- Tools development
  - Type inspector/browser
  - Schema generation

Dynamic Execution and Access

Can access full capability of type

- Construct instances
- Access fields
- Call methods

Variety of uses

- Configurable application designs
  - Specifics tasks externally controlled
- Inversion of control application designs
  - App provides fundamental behavior
  - Classes added to specialize behavior

Type as a Type

Type is the foundation of any app solution

- We use types to model biz issues
- We use types to model tech issues

Java uses types to model type issues

- Fundamental type is the Class class
  - Each type has a Class instance
  - Describes the type in detail

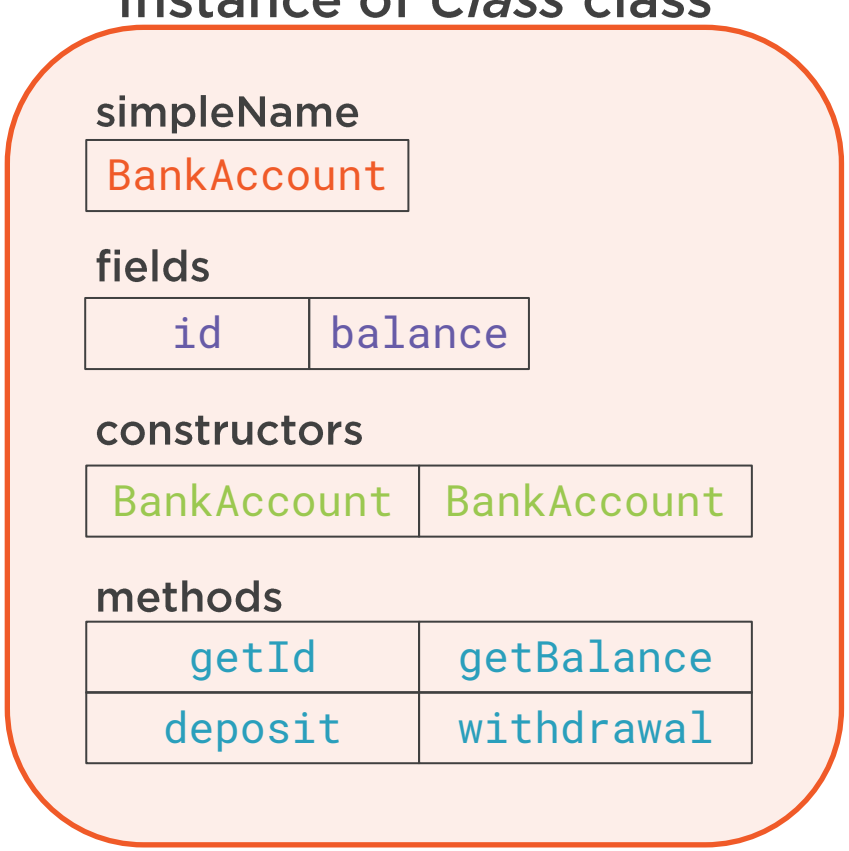
Class Declaration

```
public class BankAccount {

    private final String id;
    private int balance = 0;

    public BankAccount(String id) {...}
    public BankAccount(String id, int balance) {...}

    public String getId() {...}
    public synchronized int getBalance() {...}
    public synchronized void deposit(int amount) {...}
    public synchronized void withdrawal(int amount) {...}
}
```

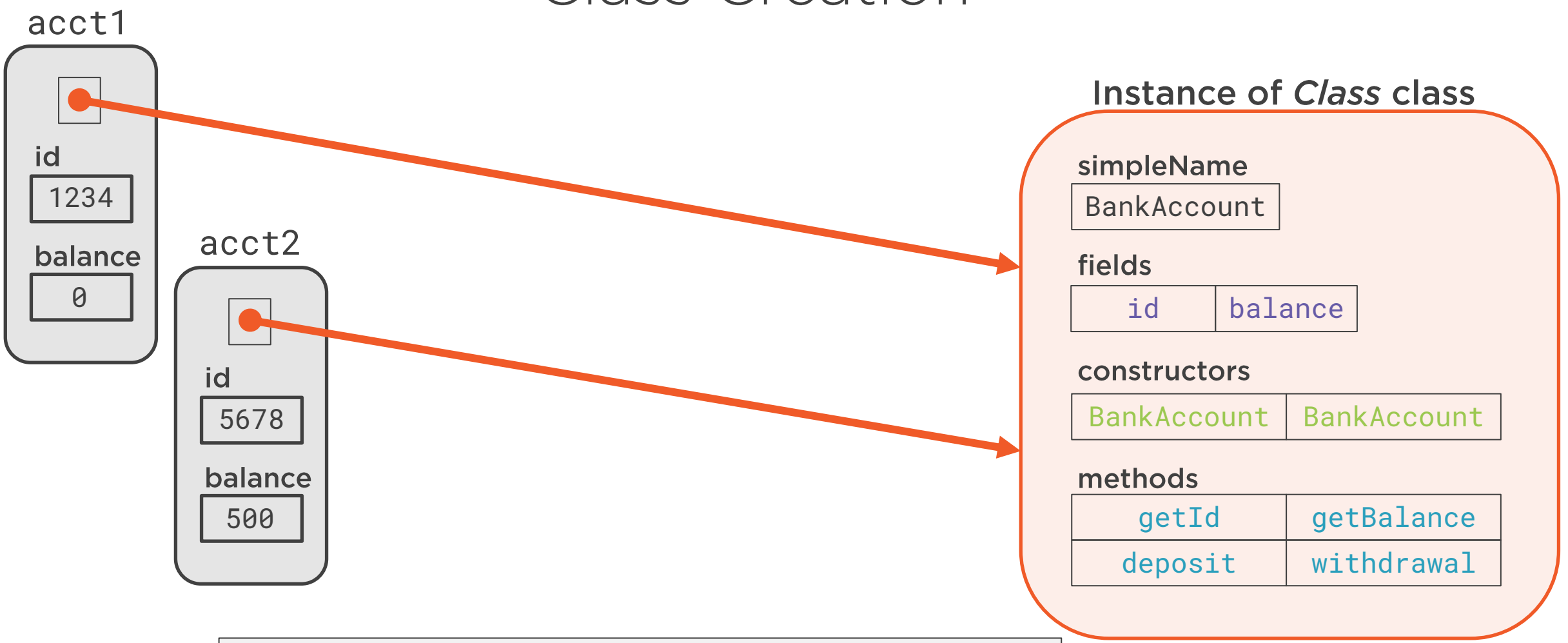
```
BankAccount acct1 = new BankAccount("1234");
BankAccount acct2 = new BankAccount("1234", 500);
```

Class Representation

```
public class BankAccount {

    private final String id;
    private int balance = 0;

    public BankAccount(String id) {...}
    public BankAccount(String id, int balance) {...}

    public String getId() {...}
    public synchronized int getBalance() {...}
    public synchronized void deposit(int amount) {...}
    public synchronized void withdrawal(int amount) {...}
}
```



Class Creation




```
BankAccount acct1 = new BankAccount("1234");
BankAccount acct2 = new BankAccount("5678", 500);
```

Accessing a Type's Class Instance

Accessing a type's Class instance

- From a type reference
  - Call getClass method
- From string name
  - Call Class.forName static method
    - Pass fully qualified type name
- From type literal
  - Use *typename*.class

Class Instance from Type Reference

```
BankAccount acct = new BankAccount("1234");
doWork(acct);
```

```
void doWork(object obj) {
  Class<?> c = obj.getClass();
  showName(c);
}
```

```
void showName(Class<?> theClass) {
  System.out.println(theClass.getSimpleName());
}
```

```
BankAccount
```

Class Instance from String Name or Type Literal

```
Class<?> c = Class.forName("com.jwhh.finance.BankAccount");
showName(c);
```

```
Class<?> c = BankAccount.class;
showName(c);
```

```
Class<BankAccount> c = BankAccount.class;
showName(c);
```

```
void showName(Class<?> theClass) {
  System.out.println(theClass.getSimpleName());
}
```

```
BankAccount
BankAccount
BankAccount
```

Type Has One Class Instance

```
BankAccount acct = new BankAccount("1234");
doWork(acct);
```

```
void doWork(object obj) {
  Class<?> c = obj.getClass();
  // . . .
}
```

```
Class<?> c = BankAccount.class;
// . . .
```

```
Class<BankAccount> c = BankAccount.class;
// . . .
```

```
Class<?> c = Class.forName("com.jwhh.finance.BankAccount");
// . . .
```

Instance of *Class* class

simpleName

BankAccount

fields

id	balance

constructors

BankAccount	BankAccount

methods

getId	getBalance
deposit	withdrawal

Accessing Type Information

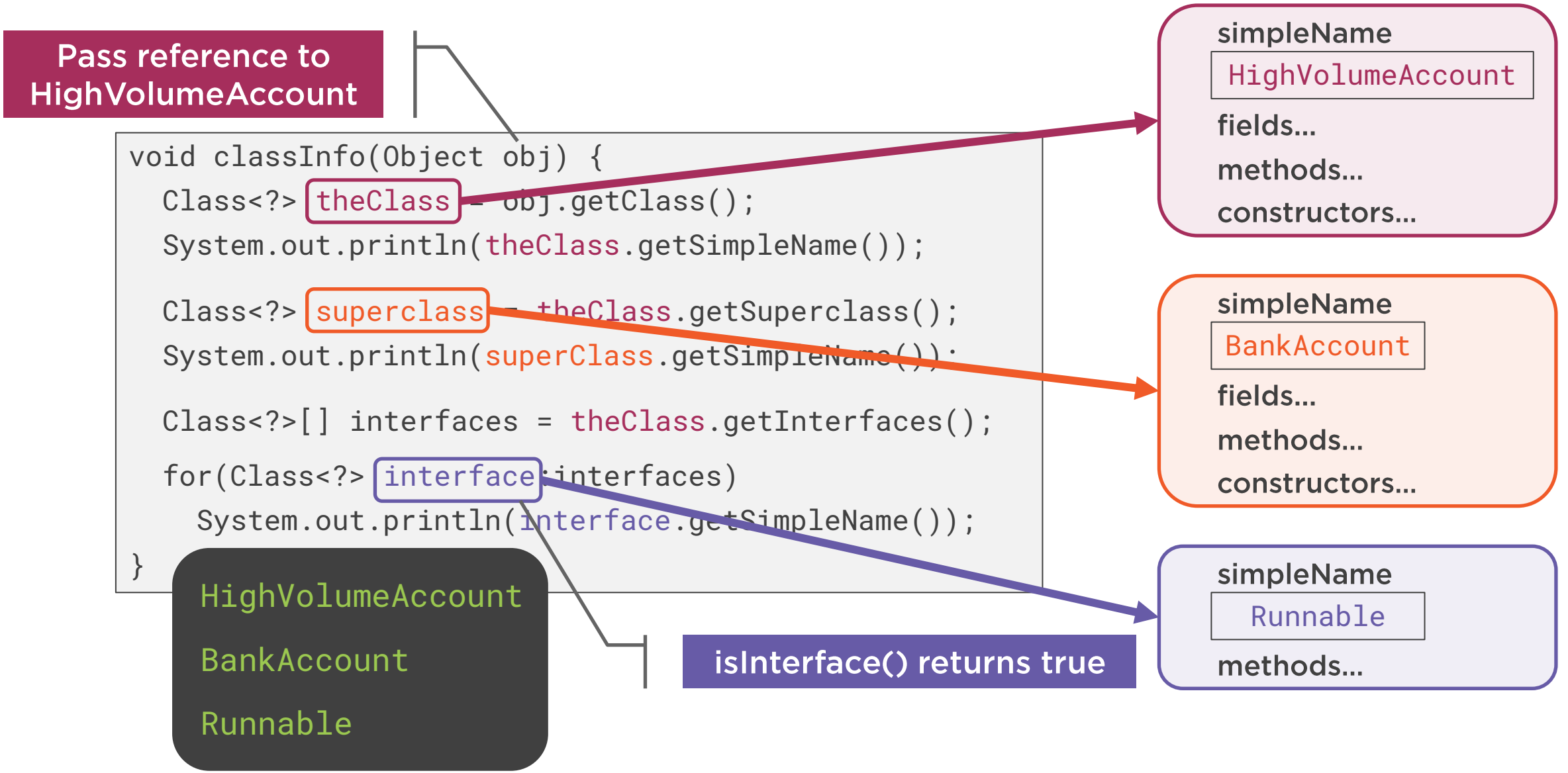
Every aspect of a type is knowable

- Superclass
- Implemented interfaces
- Modifiers
- Members

Accessing Type Information

```
public final class HighVolumeAccount extends BankAccount implements Runnable {

  public HighVolumeAccount(String id) { super(id); }
  public HighVolumeAccount(String id, int balance) { super(id, balance); }

  private int[] readDailyDeposits() {...}
  private int[] readDailyWithdrawals() {...}

  public String run() {

    for(int depositAmt:readDailyDeposits())
      deposit(depositAmt);

    for(int withdrawalAmt:readDailyWithdrawals())
      withdrawal(withdrawalAmt);
  }
}
```

Accessing Superclass and Interfaces



Type Access Modifiers

Retrieving type access modifiers

- Use getModifiers
- Returned as a single int value
  - Each modifier is a separate bit

Use Modifier class to interpret modifiers

- Provides static fields for bit comparisons
  - Requires use of bitwise and/or
- Provides static helper methods
  - Each checks for specific modifier

Type Access Modifiers

```
public final class HighVolumeAccount extends BankAccount implements Runnable {

  public HighVolumeAccount(String id) { super(id); }
  public HighVolumeAccount(String id, int balance) { super(id, balance); }

  private int[] readDailyDeposits() {...}
  private int[] readDailyWithdrawals() {...}

  public String run() {

    for(int depositAmt:readDailyDeposits())
      deposit(depositAmt);

    for(int withdrawalAmt:readDailyWithdrawals())
      withdrawal(withdrawalAmt);
  }
}
```

Type Access Modifiers

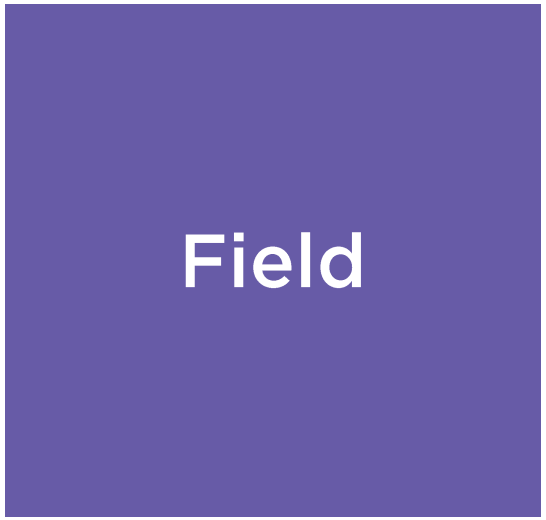
```
public final class HighVolumeAccount extends BankAccount implements Runnable {

  public HighVolumeAccount(String id) { super(id); }
  public HighVolumeAccount(String id, int balance) { super(id, balance); }

  private int[] readDailyDeposits() {...}
  private int[] readDailyWithdrawals() {...}

  public String run() {

    for(int depositAmt:readDailyDeposits())
      deposit(depositAmt);

    for(int withdrawalAmt:readDailyWithdrawals())
      withdrawal(withdrawalAmt);
  }
}
```

Retrieving Type Access Modifiers

```
void typeModifiers(Object obj) {
  Class<?> theClass = obj.getClass();
  int modifiers = theClass.getModifiers();
  if((modifiers & Modifier.FINAL) > 0)
    System.out.println("bitwise check - final");
  if(Modifier.isFinal(modifiers))
    System.out.println("method check – final");
  if(Modifier.isPrivate(modifiers))
    System.out.println("method check – private");
  else if(Modifier.isProtected(modifiers))
    System.out.println("method check – protected");
  else if(Modifier.isPublic(modifiers))
    System.out.println("method check – public");
}
```

```
bitwise check - final
method check - final
Method check - public
```

Types to Describe Type Members

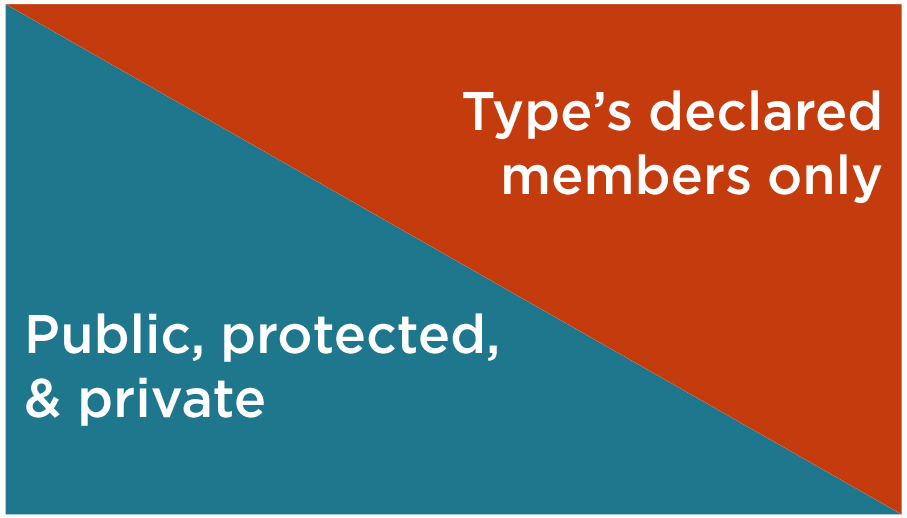


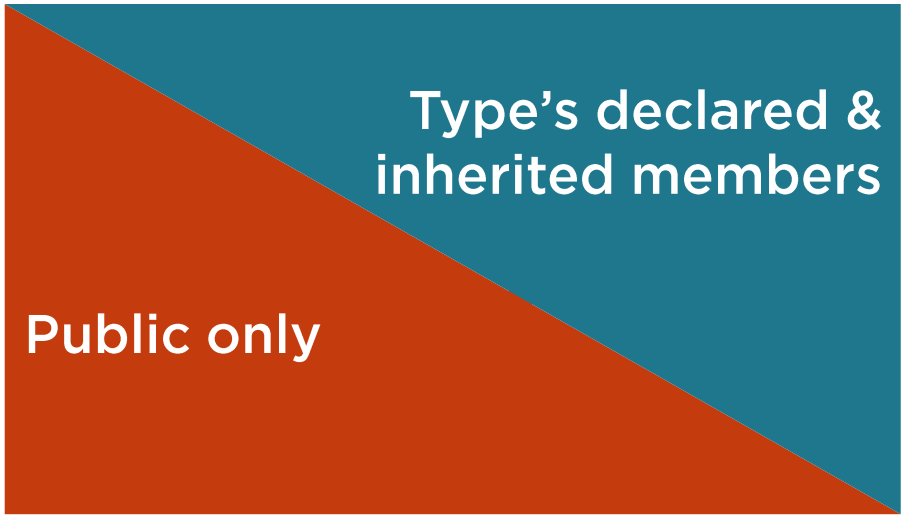
Name
Type

Name
Return type
Parameter types

Name
Parameter types

Accessing Type Members





getDeclaredFields
getDeclaredMethods
getDeclaredConstructors

getFields
getMethods
getConstructors

Limited to public on current type

Accessing Field Information

```
public class BankAccount {

    private final String id;
    private int balance = 0;

    // other members elided
}
```

```
void fieldInfo(Object obj) {
  Class<?> theClass = obj.getClass();

  Field[] fields = theClass.getFields();
  displayFields(fields);

  Field[] declaredFields = theClass.getDeclaredFields();
  displayFields(declaredFields);
}
```

```
void displayFields(Field[] arr) {
  for(Field f:arr)
    System.out.println(f.getName() + " : " + f.getType());
}
```

```
id : String

balance : int
```

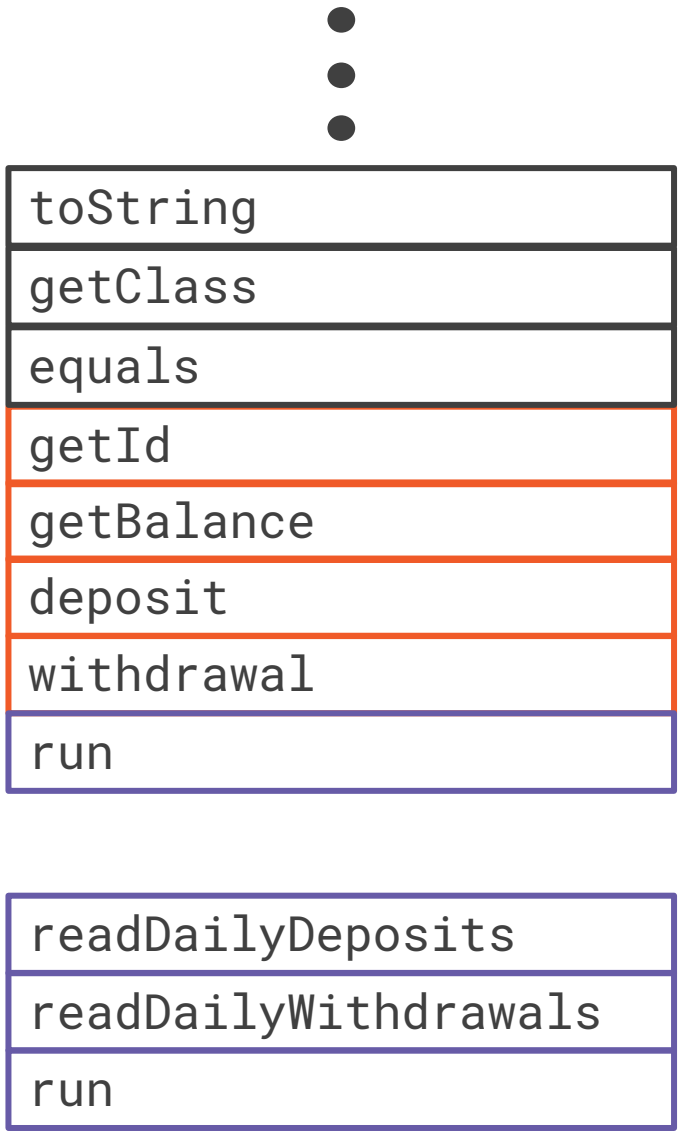
Accessing Method Information

```
public class BankAccount {

  public String getId() {...}
  public synchronized int getBalance() {...}
  public synchronized void deposit(int amount) {...}
  public synchronized void withdrawal(int amount) {...}

  // other members elided
}
```

```
public final class HighVolumeAccount extends BankAccount implements Runnable {

  private int[] readDailyDeposits() {...}
  private int[] readDailyWithdrawals() {...}
  public void run() {...}

  // other members elided
}
```

Accessing Method Information

```
void methodInfo(Object obj) {
  Class<?> theClass = obj.getClass();

  Method[] methods = theClass.getMethods();
  for(Method m:methods)
    // . . .

  Method[] declMethods = theClass.getDeclaredMethods();
  for(Method m:declMethods)
    // . . .
}
```



Excluding Object Class Methods

```
void methodInfo2(Object obj) {
  Class<?> theClass = obj.getClass();

  Method[] methods = theClass.getMethods();

  for(Method m:methods) {

    if(m.getDeclaringClass()
      System.out.println(m.getName());

  }
}
```

getId
getBalance
deposit
withdrawal
run

More About Members

Can request individual member by signature

- getField
  - Pass name
- getMethod
  - Pass name plus parameter types
- getConstructor
  - Pass parameter types

Members have access modifiers

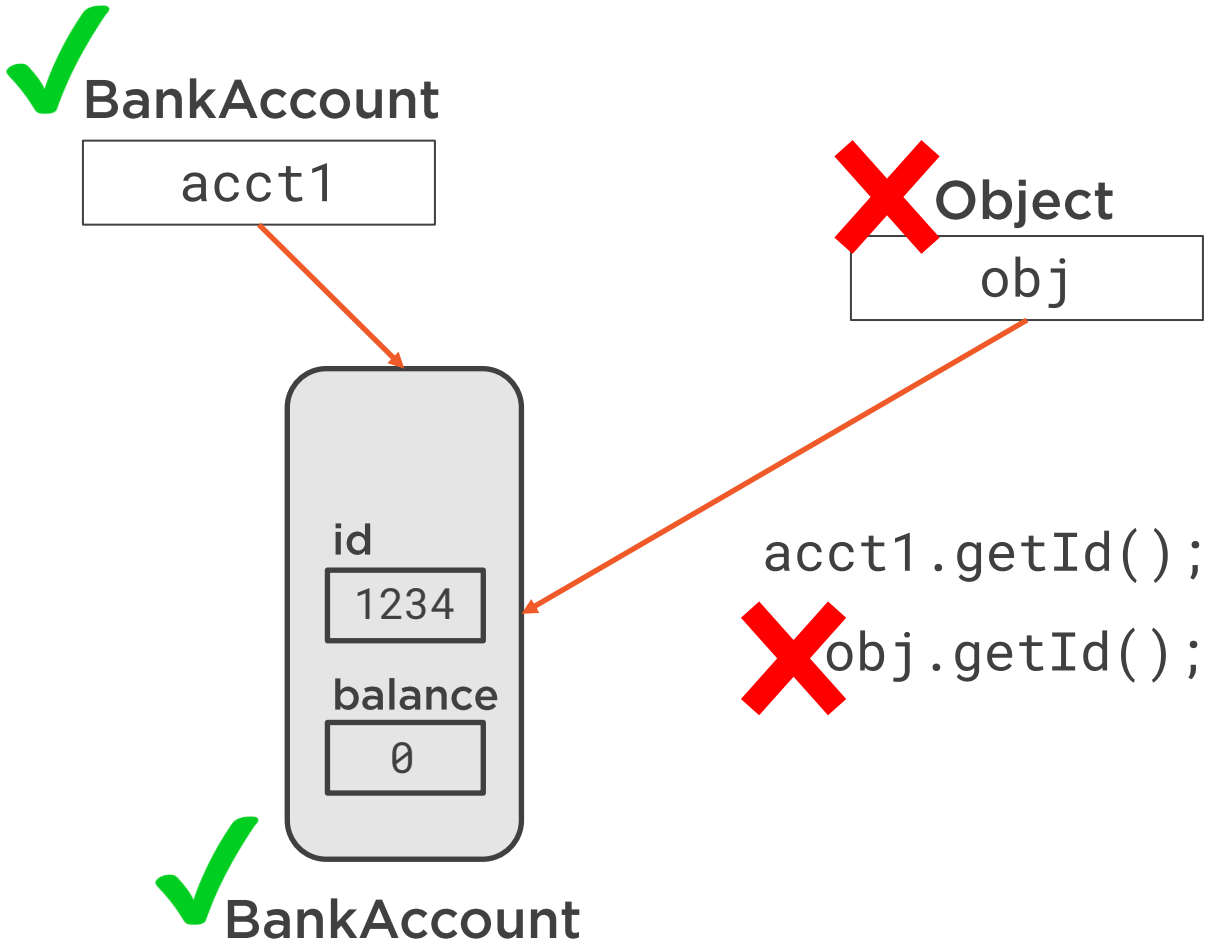
- Use getModifiers
- Interpret with Modifier class

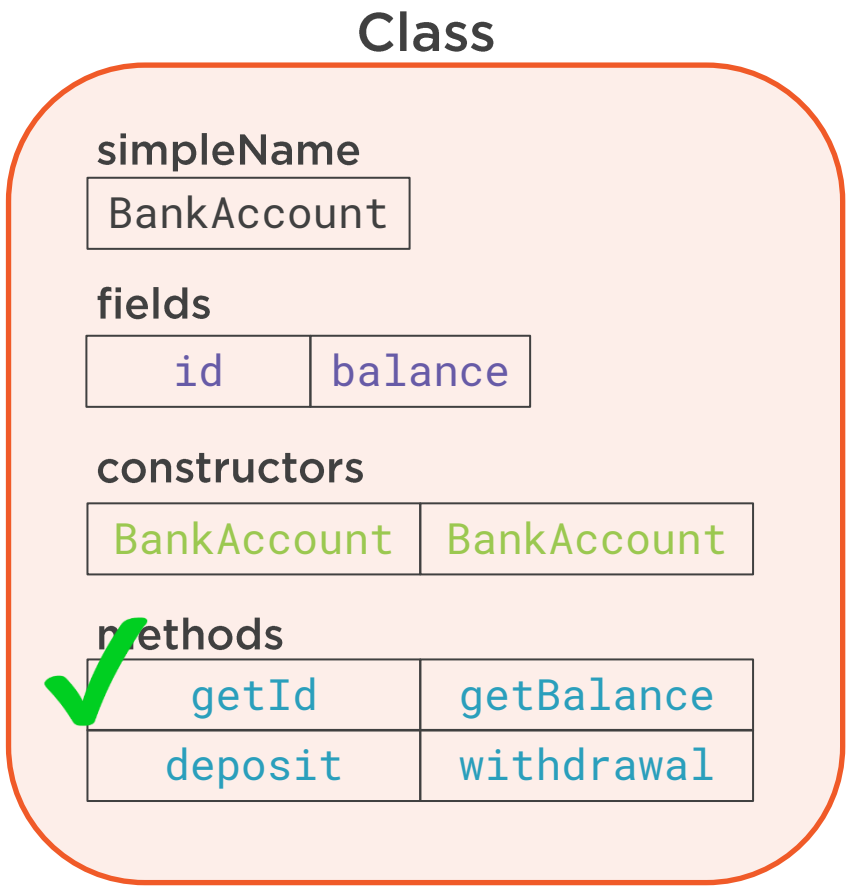
Interacting with Object Instances

Interacting with object instances

- Reflection not limited to describing types
- Can access and invoke members

Member Access





Method Access with Reflection

```
BankAccount acct1 = new BankAccount("1234");
callGetId(acct1);
```

```
Result: 1234
```

```
void callGetId(Object obj) {
  try {
    Class<?> theClass = obj.getClass();
    Method m = theClass.getMethod("getId");
    Object result = m.invoke(obj);
    System.out.println("Result: " + result);
  } catch(Exception e) {
    // . . .
  }
}
```

Method Access with Reflection

```
BankAccount acct1 = new BankAccount("1234", 500);
callDeposit(acct1, 50);
System.out.println("Balance: " + acct1.getBalance());
```

```
Balance: 550
```

```
void callDeposit(Object obj, int amt) {
  try {
    Class<?> theClass = obj.getClass();
    Method m = theClass.getMethod("deposit"
    m.invoke(obj, amt);
  } catch(Exception e) {
    // . . .
  }
}
```

Instance Creation with Reflection

Objects can be created with reflection

- Constructors can be executed
  - Use Constructor newInstance method
  - Returns a reference to new instance
- Simplified handling for no-arg constructor
  - No need to access constructor directly
  - Use Class newInstance method

Instance Creation with Reflection

Flexible work dispatch system

- Executes worker classes against targets
- Can use any worker in classpath

Method to start work accepts 2 arguments

- Name of worker type
  - Received as a String reference
- Target of work
  - Received as Object reference

Worker type requirements

- Constructor that accepts target type
- A doWork method that takes no args

Work Targets

```
public class BankAccount {

  public String getId() {...}
  public synchronized int getBalance() {...}
  public synchronized void deposit(int amount) {...}
  public synchronized void withdrawal(int amount) {...}

  // other members elided
}
```

```
public final class HighVolumeAccount extends BankAccount implements Runnable {

  private int[] readDailyDeposits() {...}
  private int[] readDailyWithdrawals() {...}
  public void run() {...}

  // other members elided
}
```

Worker

```
public class AccountWorker implements Runnable {
  BankAccount ba;
  HighVolumeAccount hva;
  public AccountWorker(BankAccount ba) { ... }
  public AccountWorker(HighVolumeAccount hva) { ... }
  public void doWork() {
    Thread t = new Thread(hva != null ? hva : this);
    t.start();
  }
```

```
public void run() {
    char txType = // read tx type
    int amt = // read tx amount
    if(txType == 'w')
      ba.withdrawal(amt);
    else
      ba.deposit(amt);
  }
}
```

Work Dispatch System Invocation

```
void startWork(String workerTypeName, Object workerTarget) {
  try {
    Class<?> workerType = Class.forName(workerTypeName);
    Class<?> targetType = workerTarget.getClass();
    Constructor c = workerType.getConstructor(targetType);
    Object worker = c.newInstance(workerTarget);
    Method doWork = workerType.getMethod("doWork");
    doWork.invoke(worker);
  } catch(Exception e) {
    // . . .
  }
}
```

```
BankAccount acct1 = new BankAccount();
startWork("com.jwhh.utils.AccountWorker", acct1);
```

Instance Creation with Reflection

Updated flexible work dispatch system

- Core requirements same as before

Method to start work

- Accepts same 2 arguments as before

Worker type requirements

- Has a no-argument constructor
- Implements TaskWorker interface

```
public interface TaskWorker {
  void setTarget(Object target);
  void doWork();
}
```

Worker Implementing Interface

```
public class AccountWorker implements Runnable                    {
  BankAccount ba;
  public void setTarget(object target) {
    if(BankAccount
      ba = (BankAccount)target;
    else
      throw new IllegalArgumentException( ... ) ;
  }
  public void doWork() {
    Thread t = new Thread(
        HighVolumeAccount.class.isInstance(ba) ? (HighVolumeAccount)ba : this);
    t.start();
  }
  public void run() {...}
}
```

Work Dispatch System Interface Invocation

```
void startWork(String workerTypeName, Object workerTarget) {
  try {
    Class<?> workerType = Class.forName(workerTypeName);
    TaskWorker worker = (TaskWorker) workerType.newInstance();
    worker.setTarget(workerTarget);
    worker.doWork();
  } catch(Exception e) {
    // . . .
  }
}
```

```
BankAccount acct1 = new BankAccount();
startWork("com.jwhh.utils.AccountWorker", acct1);
```

Summary

Every type represented by instance of Class

- Each type has exactly one instance

Accessing type's Class instance

- From type reference
  - Call getClass
- From string name
  - Call Class.forName
- From type literal
  - Use *typename*.class

Summary

All aspects of types knowable

- Superclass and interfaces
- Fields, methods, and constructors
- Access modifiers

Working with modifiers

- Returned as an int value
- Use Modifier class to interpret
  - Provides static fields for bit values
  - Provides helper methods

Summary

Interacting with object instances

- Reflection not limited to describing types
- Can access and invoke members

Objects can be created with reflection

- Constructors can be executed
  - Use Constructor newInstance method
- Simplified handling for no-arg constructor
  - Use Class newInstance method