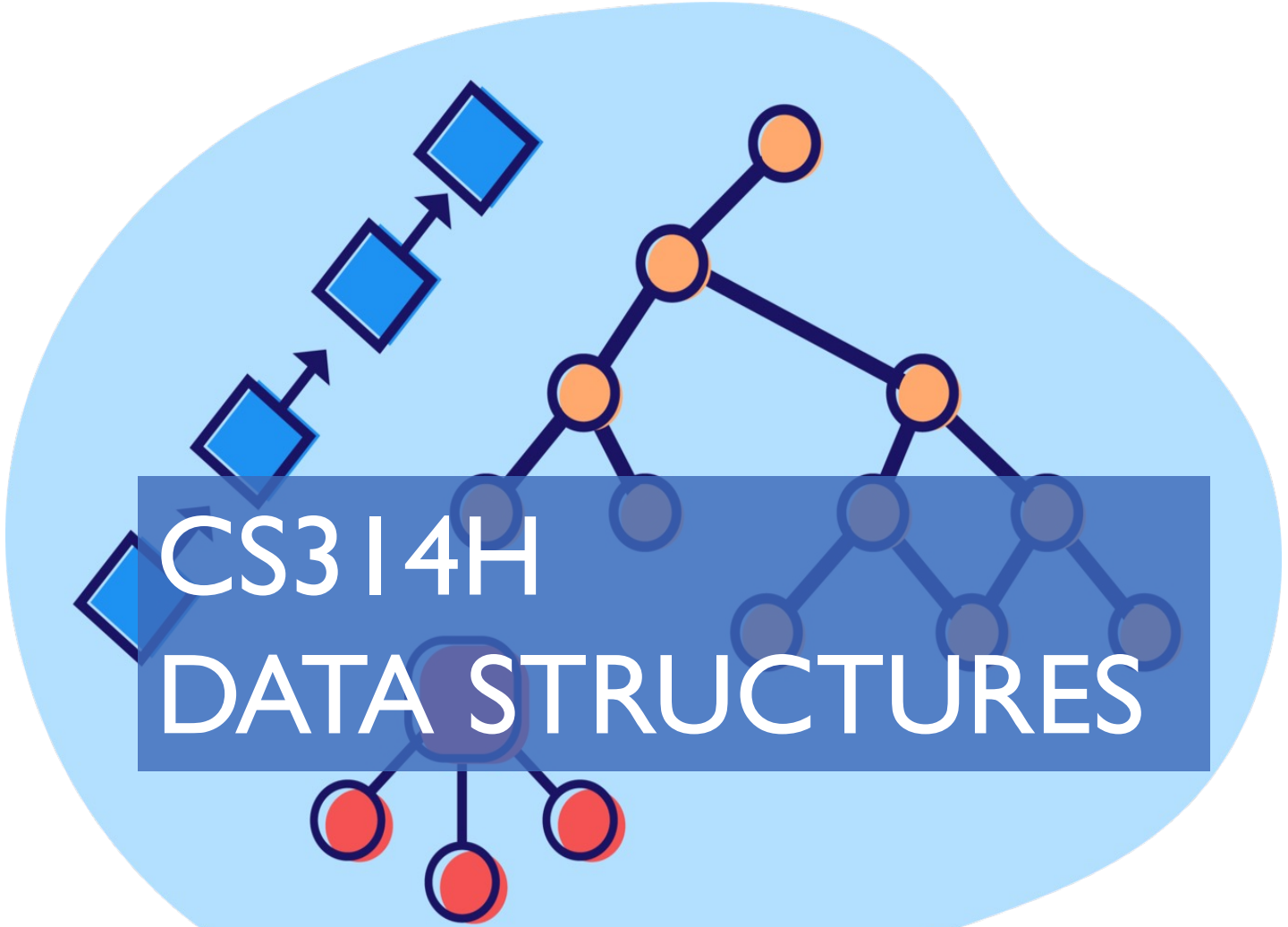

# CS314H DATA STRUCTURES

## Lecture 04 Supplementary: Object class and Equality

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Please, interrupt and ask questions AT ANY TIME !

# APM Demo

# APM Demo

- IDE is your friend!
- Practice using keyboard shortcuts

- IntelliJ shortcuts that you CANNOT miss
- My Most Useful IntelliJ shortcuts
  - For Mac
  - For Windows
- VSCode shortcuts Windows

# Inheritance and Subtype Polymorphism

- Both allows code reuse and facilitate changes
- Inheritance allows to reap the benefits now from the past
  - by reusing the past code
  - Also allows added/new behaviors
- Polymorphism allows to reap the benefits in the future from the present
  - I am writing Shape client code now
  - I think I might introduce new shape Triangle or shape Ghost, etc.
  - I can just plug in Triangle or Ghost instance to wherever Shape is expected!
  - No need to change any Shape client code

# Outline

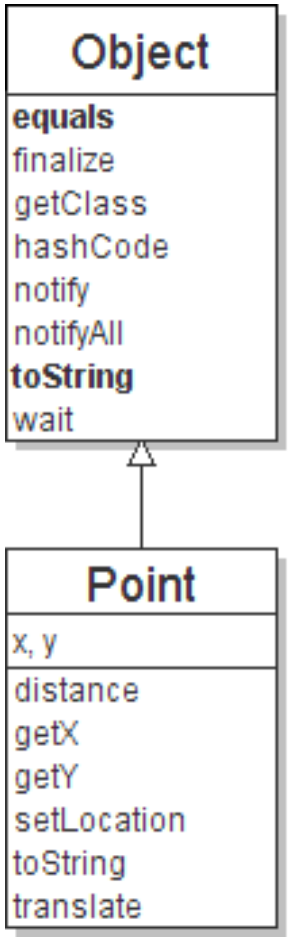
1. Recap
2. Object class

# The `Object` class;
# Object equality and the `equals` method

# The class Object

- **The class `Object` forms the root of the overall inheritance tree of all Java classes.**
  - Every class is implicitly a subclass of `Object`

- **The `Object` class defines several methods that become part of every class you write. For example:**
  - `public String toString()`
    Returns a text representation of the object, usually so that it can be printed.



# Object methods

| method | description |
|---|---|
| `protected Object clone()` | creates a copy of the object |
| `public boolean equals(Object o)` | returns whether two objects have the same state |
| `protected void finalize()` | called during garbage collection |
| `public Class<?> getClass()` | info about the object's type |
| `public int hashCode()` | a code suitable for putting this object into a hash collection |
| `public String toString()` | text representation of the object |
| `public void notify()`<br>`public void notifyAll()`<br>`public void wait()`<br>`public void wait(...)` | methods related to concurrency and locking (seen later) |

- What does this list of methods tell you about Java's design?

# Common properties of objects

- When Sun designed Java, they felt that *every* object (including arrays) should be able to:
  - be compared to other objects
  - be printed on the console or converted into a string
  - ask questions at runtime about what type/class it is
  - be created, copied, and destroyed
  - be used in hash-based collections
  - perform multi-threaded synchronization and locking

This powerful and broad set of capabilities
helped Java's adoption as an object-oriented language.

# Using the Object class

- You can store any object in a variable of type `Object`.

```
Object o1 = new Point(5, -3);
Object o2 = "hello there";
```

- You can write methods that accept an `Object` parameter.

```
public void example(Object o) {
    if (o != null) {
        System.out.println("o is " + o.toString());
    }
```

- You can make arrays or collections of `Object`s.

```
Object[] a = new Object[5];
a[0] = "hello";
a[1] = new Random();
List<Object> list = new ArrayList<Object>();
```

# How to compare objects (aka. Reference types)?

# Does == work?

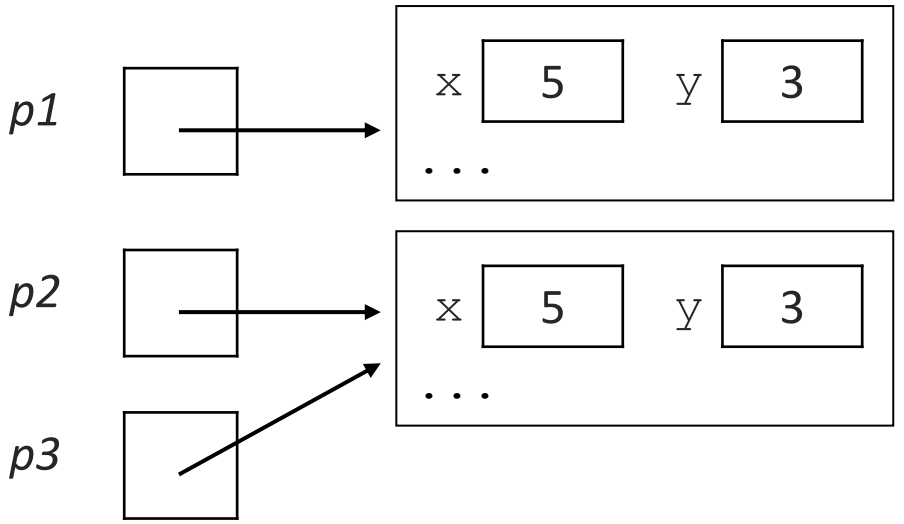
- `==` tests for referential equality, not state-based equality.

  It produces `true` only when you compare an object to itself.

```
Point p1 = new Point(5, 3);
Point p2 = new Point(5, 3);
Point p3 = p2;

// p1 == p2 is false;
// p1 == p3 is false;
// p2 == p3 is true

// p1.equals(p2)?
// p2.equals(p3)?
```



# Let's look what is the Default equals method

- **The `Object` class's `equals` implementation is very simple:**

```
public class Object {
    ...
    public boolean equals(Object o) {
        return this == o;
    }
}
```

- **However:**
  - When we have used equals with various kinds of objects, it didn't behave like == . Why not?
  - The Java API documentation for equals is elaborate. Why?
    - Because equals method gets overridden

# Overriding equals

- **The Object class is designed for inheritance.**
  - Its description and specification will apply to all other Java classes.

- **So, its specification must be flexible enough to apply to all classes.**
  - Subclasses will *override* equals to test for equality in their own way.
  - The Object equals spec enumerates basic properties that clients can rely on that method to have in all subtypes of Object.
    - (this == o) is compatible with these properties, but so are other tests.

# Flawed `equals` method 1

```
public boolean equals(Point other) {     //
bad
    if (x == other.x && y == other.y) {
        return true;
    } else {
        return false;
    }
}
```

- **Let's write an `equals` method for a `Point` class.**
  - The method should compare the state of the two objects and return `true` if they have the same x/y position.
  - What's wrong with the above implementation?

# Flaws in the method

- **The body can be shortened to the following (boolean zen):**

```
return x == other.x && y == other.y;
```

- **The parameter to equals must be of type `Object`, not `Point`.**
  - It should be legal to compare a `Point` to *any* other object:

```
// this should be allowed
Point p = new Point(7, 2);
if (p.equals("hello")) {   // false
    ...
```

  - `equals` should always return `false` if a non-`Point` is passed.
  - By writing ours to accept a Point, we have *overloaded* equals.
    - Point has two equals methods: One takes an Object, one takes a Point.

# Flawed `equals` method 2

```
public boolean equals(Object o) {     // bad
    return x == o.x && y == o.y;
}
```

- **What's wrong with the above implementation?**
  - It does not compile:

```
Point.java:36: cannot find symbol
symbol  : variable x
location: class java.lang.Object
return x == o.x && y == o.y;
                ^
```

  - The compiler is saying,
    "`o` could be any object. Not every object has an `x` field."

# Object variables

- You can store any object in a variable of type `Object`.

```
Object o1 = new Point(5, -3);
Object o2 = "hello there";
Object o3 = new Scanner(System.in);
```

- An `Object` variable only knows how to do general things.

```
String s = o1.toString();       // ok
int len = o2.length();          // error
String line = o3.nextLine();    // error
```

  - (The objects referred to by `o1`, `o2`, and `o3` still do have those methods. They just can't be called through those variables because the compiler isn't sure what kind of object the variable refers to.)

# Casting references

```
Object o1 = new Point(5, -3);
Object o2 = "hello there";

((Point) o1).translate(6, 2);       // ok
int len = ((String) o2).length();   // ok
Point p = (Point) o1;
int x = p.getX();                   // ok
```

- Watch out for precedence mistakes:

```
int len = (String) o2.length();     // error
```

# Flawed equals method 3

```
public boolean equals(Object o) {
    Point other = (Point) o;
    return x == other.x && y == other.y;
}
```

- **What's wrong with the above implementation?**
  - It compiles and works when other `Point` objects are passed, but it throws an exception when a non-`Point` is passed (see next slide).

# Comparing different types

```
Point p = new Point(7, 2);
if (p.equals("hello")) {    // should be false
    ...
}
```

- Currently our method crashes on the above code:

```
Exception in thread "main"
java.lang.ClassCastException: java.lang.String
        at Point.equals(Point.java:25)
        at PointMain.main(PointMain.java:25)
```

- The problem is the cast (cannot cast sideways in an inheritance tree):

```
public boolean equals(Object o) {
    Point other = (Point) o;
```

# The instanceof keyword

**reference** `instanceof` **type**

```
if (variable instanceof type) {
    statement(s);
}
```

- A binary, infix, `boolean` **operator.**
- Tests whether **variable** refers to an object of class **type** (or any subclass of **type**).

```
String s = "hello";
Point p = new Point();
```

| expression | result |
|---|---|
| `s instanceof Point` | `false` |
| `s instanceof String` | `true` |
| `p instanceof Point` | `true` |
| `p instanceof String` | `false` |
| `p instanceof Object` | `true` |
| `s instanceof Object` | `true` |
| `null instanceof String` | `false` |
| `null instanceof Object` | `false` |

# Flawed equals method 4a

```
// Returns true if o refers to a Point object
// with the same (x, y) coordinates as
// this Point; otherwise returns false.
public boolean equals(Object o) {
    if (o instanceof Point) {
        Point other = (Point) o;
        return x == other.x && y == other.y;
    } else {
        return false;
    }
}
```

- What's wrong with the above implementation?
  - It behaves incorrectly if the `Point` class is extended (see next slides).

# Subclassing and equals

```
public class Point3D extends Point {
    private int z;
    public Point3D(int x, int y, int z) { ...
  }
    ...
}

Point3D p1 = new Point3D(4, 5, 0);
Point3D p2 = new Point3D(4, 5, 6);
Point   p3 = new Point  (4, 5);
```

- All objects above will report that they are "equal" to each other.
  - But they shouldn't be. The objects don't have equal state.
  - In some cases, they aren't even the same type.

# Flawed equals method 4b

```
public class Point3D extends Point {
    ...
    public boolean equals(Object o) {
        if (o instanceof Point3D) {
            Point3D other = (Point3D) o;
            return super.equals(o)
                   && z == other.z;
        } else {
            return false;
        }
    }
}
```

- What's wrong with the above approach?
  - It produces *asymmetric* results when Point and Point3D are mixed.
  - We need something more strict than instanceof

# A proper equals method

- Equality is reflexive:
  - `a.equals(a)` is `true` for every object `a`
- Equality is symmetric:
  - `a.equals(b)` ↔️ `b.equals(a)`
- Equality is transitive:
  - `(a.equals(b) && b.equals(c))` ↔️ `a.equals(c)`
- No non-`null` object is equal to `null`:
  - `a.equals(null)` is `false` for every object `a`
- **Effective Java Tip #8:**
  Obey the general contract when overriding `equals`.

# The getClass method

- `getClass` **returns information about the type of an object.**
  - Commonly used for *reflection* (seen later).
  - Uses run-time type information, not the type of the variable.
  - Stricter than `instanceof`; subclasses return different results.

- `getClass` **should be used when implementing** `equals`**.**
  - Instead of `instanceof` to check for same type, use `getClass`.
  - This will eliminate subclasses from being considered for equality.
  - Caution: Must check for `null` before calling `getClass`.

# Correct equals methods

- Inside Point class

```
public boolean equals(Object o) {    // Point
    if (o != null && getClass() == o.getClass())
  {
        Point other = (Point) o;
        return x == other.x && y == other.y;
    } else {
        return false;
    }
}
```

- Inside Point3D class

```
public boolean equals(Object o) {    // Point3D
    if (o != null && getClass() == o.getClass())
  {
        Point3D other = (Point3D) o;
        return super.equals(o) && z == other.z;
    } else {
        return false;
    }
}
```