CISC 3120
C11: Garbage Collection and Constructors

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Outline

- Recap
    - Project progress and lessons learned
- Memory management
- Java garbage collection
- Constructors
- Assignments

Memory Management in C++

- In C++: compare the following two.

```
Cat *ginger = new Cat();

ginger = nullptr;
```

```
Cat *ginger = new Cat();
delete ginger;
ginger = nullptr;
```

Memory Management in C++

- In C++: compare the following two.

```
Cat *ginger = new Cat();

ginger = nullptr;
```

✗

```
Cat *ginger = new Cat();
delete ginger;
ginger = nullptr;
```

✓

- A programmer must <u>explicitly</u> free the memory allocated to an object in a C++ program; otherwise, the memory <u>cannot</u> be reclaimed and used in the program.

Memory Management in Java

- In Java:

```
Cat ginger = new Cat();

ginger = null;
```

  - Should a programmer worry about reclaiming the memory?
  - Java Garbage Collector takes care of it.

Program Data

- We restrict the definition of program data to data associated with variables
- In C++ and Java, program data are in three categories
    - Automatic
    - Static
    - Dynamic

Automatic, Static, and Dynamic Program Data

- They differ in
  - which region of memory the data reside
  - when and how the data is allocated in memory
  - when and how the data is deallocated in memory
- Variables
  - where: scope
  - when: lifetime

Automatic Data

- Memory is automatically allocated and deallocated for automatic data
- Where: the memory is allocated in a region of memory called *stack*
- When to allocate: the memory is allocated when execution reaches the scope of the variable
- When to deallocate: the memory is deallocated when execution leaves the scope of the variable

Automatic Data: Examples

- In C++ and Java: where are the variables for automatic data?

```
int sumToNumber(int number) {
    int sum = 0;
    for (int i=0; i<number; i++) {
        sum += i;
    }
    return sum;
}
```

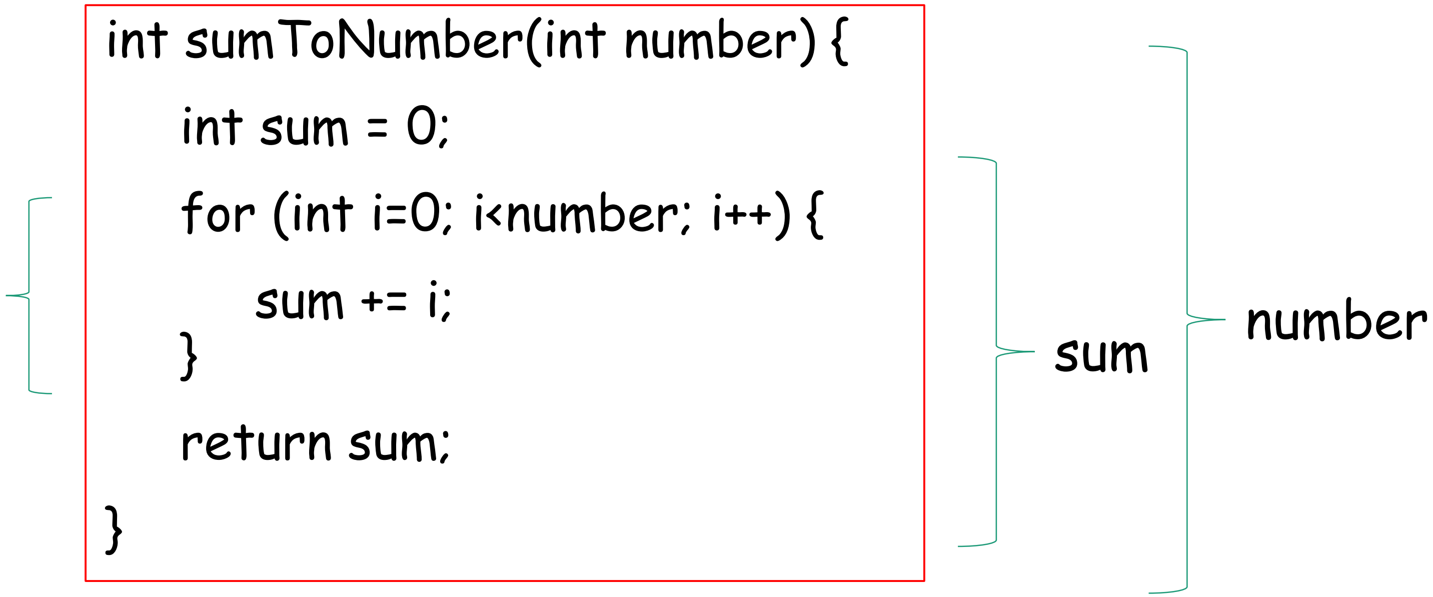
Automatic Data: Examples

- In C++ and Java: where are the variables for automatic data?
  - Parameter: number
  - Local variables:
    - sum
    - i
  - What are their scopes?

```
int sumToNumber(int number) {
    int sum = 0;
    for (int i=0; i<number; i++) {
        sum += i;
    }
    return sum;
}
```

Automatic Data: Examples

- In C++ and Java: where are the variables for automatic data?
  - What are their scopes?



```
int sumToNumber(int number) {
    int sum = 0;
    for (int i=0; i<number; i++) {
        sum += i;
    }
    return sum;
}
```

i

sum

number

Static Data

- Static data’s existence does not change during the entire execution of a program
- Where: the memory for static data is allocated in a region of memory, generically referred to as the static data segment
- When to allocate:
  - the memory is allocated when the program starts,
  - or when execution reaches the static variable declaration for the first time
- When to deallocate: the memory for static data is deallocated when the program exits

Static Data: Example in C++

- In C++: where are the variables for static data?

```
int sumToNumber(int number) {
    static int sum = 0;
    for (int i=0; i<number; i++) {
        sum += i;
    }
    return sum;
}
```

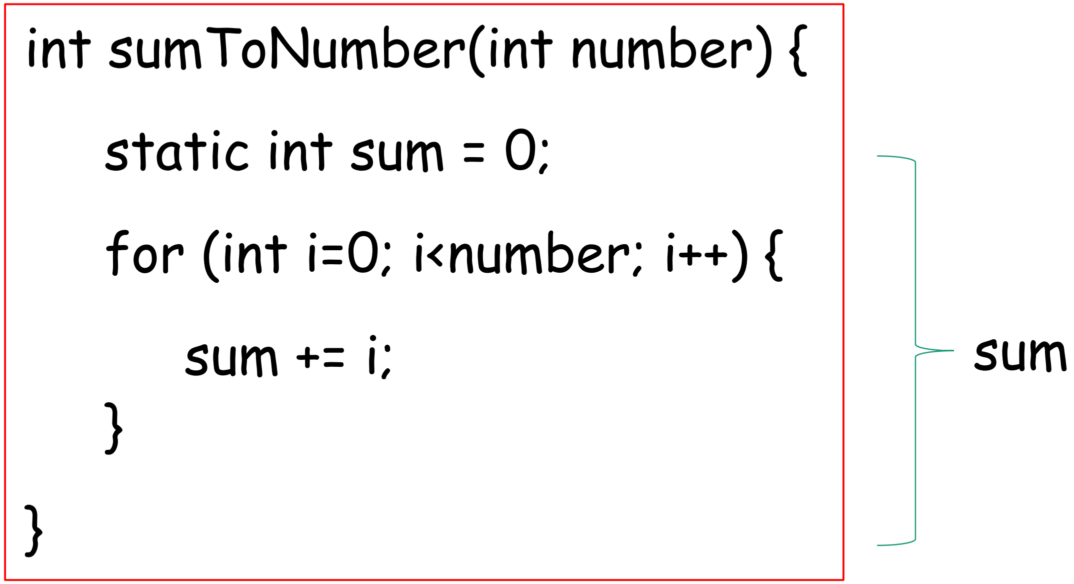
Static Data: Example in C++

- In C++: where are the variables for static data?
  - Local variable: sum
  - What is its scope?

```
int sumToNumber(int number) {
    static int sum = 0;
    for (int i=0; i<number; i++) {
        sum += i;
    }
    return sum;
}
```

Static Data: Example in C++

- In C++: where are the variables for static data?
  - What are their scopes?



```
int sumToNumber(int number) {
    static int sum = 0;
    for (int i=0; i<number; i++) {
        sum += i;
    }
}
```

sum

Static and Automatic Data: Example in C++

- In C++: when are they allocated and deallocated?

```
int sumToNumber(int number) {
     static int sum = 0;
     for (int i=0; i<number; i++) {
          sum += i;
     }
    return sum;
}
```

```
int sumToNumber(int number) {
     int sum = 0;
     for (int i=0; i<number; i++) {
          sum += i;
     }
     return sum;
}
```

Static and Automatic Data: Example in C++

- How do the lifetimes of the automatic and static variables differ?
- Compare them in running programs
  - When sum is static
  - When sum is automatic

```
cout << sumToNumber(5) << endl;

cout << sumToNumber(5) << endl;
```

Static Data in C++

- In C++
  - Variables declared as “static”
  - Additionally, variables declared outside any function and class body

Static Data: Example in Java

- Can we write the following in Java?

```
int sumToNumber(int number) {
    static int sum = 0;
    for (int i=0; i<number; i++) {
        sum += i;
    }
    return sum;
}
```

Static Data in Java

- Can we write the following in Java?

```
int sumToNumber(int number) {
    static int sum = 0;
    for (int i=0; i<number; i++) {
        sum += i;
    }
    return sum;
}
```

✗

Static Data in Java

- Java is more restrictive
  - Static variables can only declared within a class, but not within any methods
- Static variables are class variables with the scope of the class

Static Data: Example in Java

- Where are the static variables?

```
class StaticSum {
        static int sum = 0;
        int sumToNumber(int number) {
                for (int i=0; i<number; i++) {
                        sum += i;
                }
                return sum;
        }
}
```

Static Data: Example in Java

- What is its scope?

```
class StaticSum {
        static int sum = 0;
        int sumToNumber(int number) {
              for (int i=0; i<number; i++) {
                    sum += i;
              }
              return sum;
        }
}
```

Static Data: Example in Java

- What is the output of this program?

```
class StaticSum {

        public static void main(String[] args) { StaticSum s = new StaticSum();

              System.out.println(s.sumToNumber(5)); System.out.println(s.sumToNumber(5));

         }

        int sumToNumber(int number) {

             for (int i=0; i<number; i++) {

                  sum += i;
             }

             return sum;

        }

        static int sum = 0;

}
```

Static Data in Java

- Java is more restrictive
  - Static variables can only declared within a class, but not within any methods
- Static variables are class variables with the scope of the class
- Static variables has globe scope
- Static variables has the lifetime of the program

Questions?

- Start discussing memory management
  - Automatic and static program data

Dynamic Data

- Programmers are responsible for allocating dynamic data
- In C++: programmers are also responsible for deallocating the dynamic data.
- Where: the memory for static data is allocated in a region of memory, generically referred to as the *heap*
- When to allocate:
  - the memory is allocated when the programmer invokes the “new” operator.
- When to deallocate:
  - In Java: when the Java Garbage Collector reclaims the object allocated
  - In C++: when the programmer invokes the delete operator to free the memory allocated to the dynamic data

Dynamic Data in C++ and Java

- In C++, programmers can allocate memory for any data types, i.e., to use “new“ operator against any data types
- In Java, programmers can only use “new“ operator for reference data types

Dynamic Data in C++ and Java: Examples

- In Java: which one of the following is legal?

```
int  i = new int;
```

```
Cat ginger = new Cat();
```

```
int[] iArr = new int[10];
```

- In C++: which one of the following is legal?

```
int *iPtr  = new int;
```

```
Cat *gingerPtr = new Cat();
```

```
int* iArr = new int[10];
```

Dynamic Data in C++ and Java: Examples

- In Java: which one of the following is legal?

`int  i = new int;` ✗

`Cat ginger = new Cat();` ✓

`int[] iArr = new int[10];` ✓

- In C++: which one of the following is legal?

`int *iPtr  = new int;` ✓

`Cat *gingerPtr = new Cat();` ✓

`int* iArr = new int[10];` ✓

Dynamic Data: Java and C++ Comparison

- Allocation:
  - The same
    - Java and C++: dynamic data are created using the new operator
  - The different
    - In Java: dynamic data can only be objects, cannot be primitive data types.
    - In C++: dynamic data can be any data types
- Deallocation
  - The different
    - In C++: programmers use the delete operator to deallocate memory
    - In Java: Java Garbage Collector is responsible for deallocating the memory, programmers have little control.

Objects in Java and C++

- C++ can have both automatically and dynamically allocated objects

```
Cat *ginger = new Cat();

ginger->pounce();

(*ginger).pounce();
```

```
Cat ginger;

ginger.pounce();
```

- Java has only dynamically allocated objects

```
Cat ginger;

ginger.pounce();
```

```
Cat ginger = new Cat()

ginger.pounce();
```

Objects in Java and C++

- C++ can have both automatically and dynamically allocated objects

```
Cat ginger;

ginger.pounce();
```

✓

```
Cat *ginger = new Cat();

ginger->pounce();

(*ginger).pounce();
```

✓

- Java has only dynamically allocated objects

```
Cat ginger;

ginger.pounce();
```

✗

```
Cat ginger = new Cat()

ginger.pounce();
```

✓

Dynamic Data: Programming Error in C++

- Programmers are responsible for managing dynamic data, which is error-prone
- Common errors
  - Inaccessible objects
  - Memory leaks
  - Dangling pointers

Java Garbage Collector

- Java is responsible for deallocating dynamic data, and programmers are not.
- In Java, we often write

```
Cat ginger = new Cat();

ginger.pounce(new Animal());
```

✓

- In C++, we never write (although it compiles)

```
Cat *ginger = new Cat();

ginger->pounce(new Animal());
```

✗

Different Garbage Collection Algorithms

- How does a Garbage Collector figure out an object is no longer needed and can be deallocated?
- Reference counting
- Trace-based garbage collector
  - e.g., Baker's algorithm
  - Copying collector

Advantage of Garbage Collection

- Avoid bugs, such as,
  - Forget to free memory (memory leak)
  - Use already freed objects (dangling pointers)
  - Also in Java, programmers do not have direct memory access, and cannot accidentally overwrite memory.

Disadvantage of Garbage Collection

- Consume resources (memory and processor)
- Unpredictable stalls
- Memory leak still possible, but harder to understand
- No manual control

Questions

- Concept of Garbage Collector
- Programming in Java that does garbage collection

Constructors

- Like C++, constructors in Java
  - have the identical name as the name of the class,
  - do not specify return type,
  - are called when an object is created,
  - and are responsible for initializing the object (instance variables)

Default Constructor

- Java compiler provides the default constructor when no constructor is written.

```
class Cat {
    void pounce(Cat otherCat) {…}
}
```

```
Cat ginger = new Cat(); // calling default constructor
ginger.pounce(new Cat());
```

✓

Default Constructor?

```
class Cat {
    private String name;
    public Cat(String name) {this.name = name;}
    void pounce(Cat otherCat) { … }
}
```

- Can we use the default constructor now?

```
Cat ginger = new Cat();
ginger.pounce(new Cat("tiger"));
```

Default Constructor?

```
class Cat {
    private String name;
    public Cat(String name) {this.name = name;}
    void pounce(Cat otherCat) { … }
}
```

- Can we use the default constructor now?

```
Cat ginger = new Cat();
ginger.pounce(new Cat("tiger"));
```

✗

Default and Parameterized Constructors

- Java ceases to create the default constructor

```
class Cat {
    private String name;
    public Cat() {name = “cat”;}
    public Cat(String name) {this.name = name;}
    void pounce(Cat otherCat) { … }
}
```

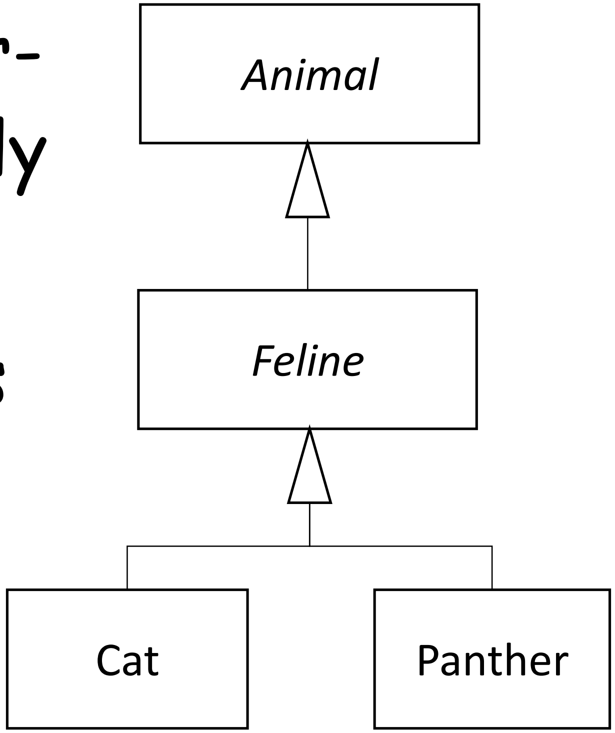
```
Cat ginger = new Cat(); …
```

✓

Constructor and Inheritance

- When we create an object of a class, constructors of all super-classes must be called explicitly or implicitly
- Can you name the constructors being called for this example?

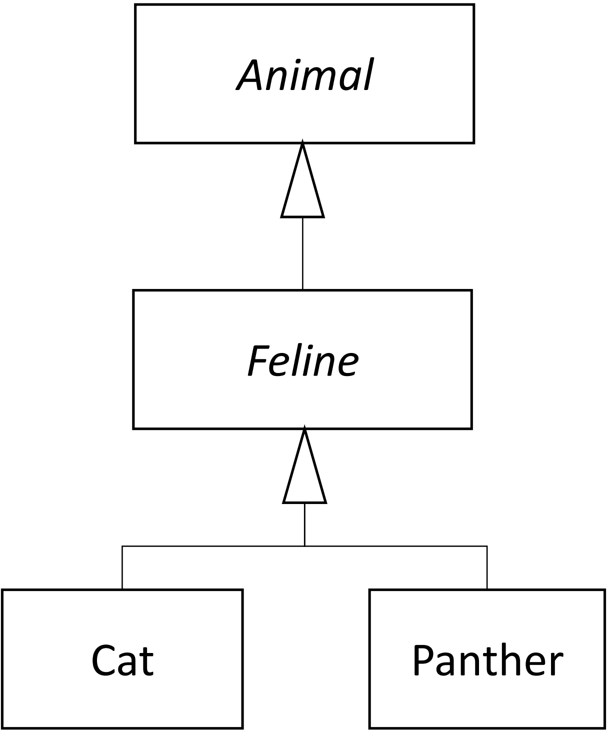
```
Panther brave = new Panther(“brave”);
```



Calling Super Class's Constructor Implicitly

- What if we write the constructor as follows,

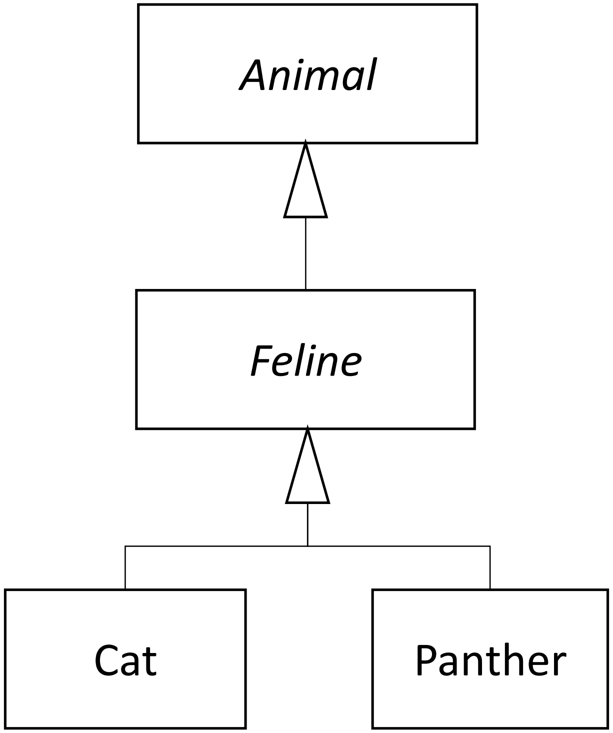
```
class Panther extends Feline {
   Color color;
   public Panther(String name, Color color) {
      this.color = color;
   }
   public void makeNoise() {…}
}
```



Calling Super Class's Constructor Implicitly

- Java compiler will call Feline's default constructor.

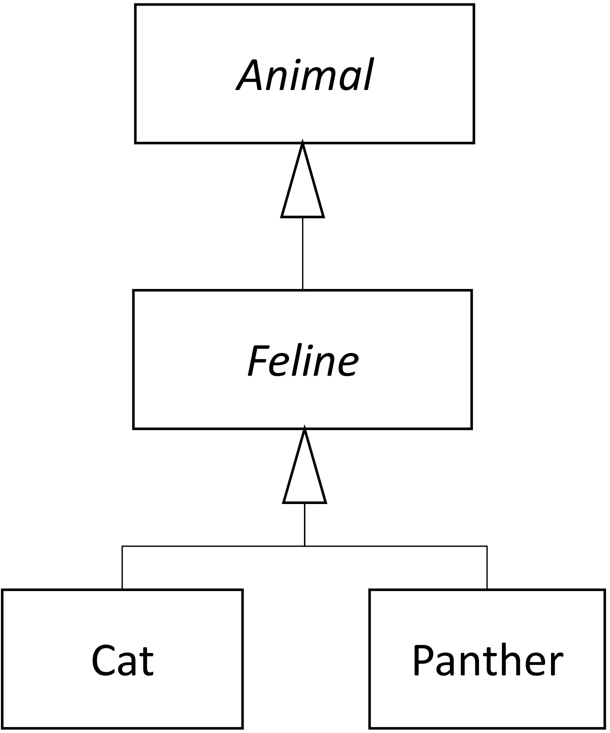
```
class Panther extends Feline {
  Color color;
  public Panther(String name, Color color) {
     this.color = color;
  }
  public void makeNoise() {…}
}
```



Calling Super Class's Constructor Explicitly

- Use "super"

```
class Panther extends Feline {
   Color color;
   public Panther(String name, Color color) {
        super(name);
        this.color = color;
   }
   public void makeNoise() {…}
}
```



Recap: Stack and Heap

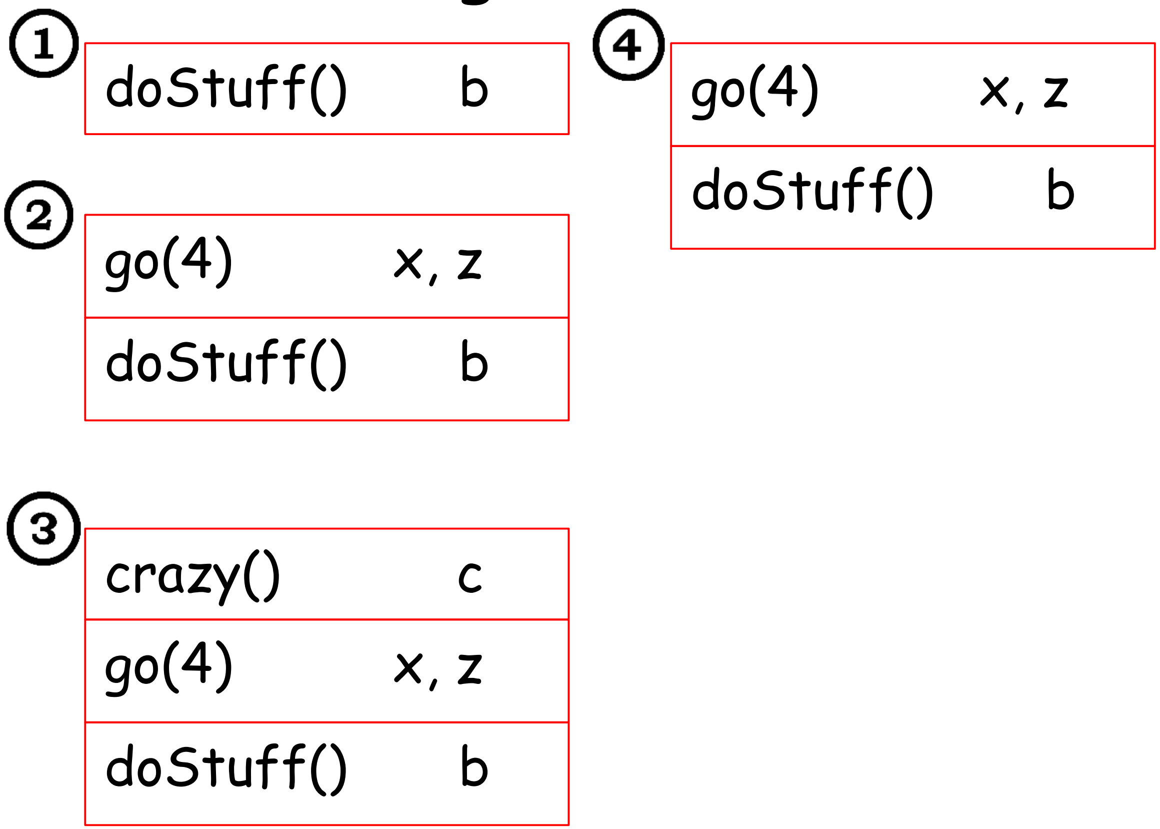
- Two important region of memories
  - Stack
  - Heap

Stack

- Methods are “stacked”
- Stack is organized as stack frames
  - A stack frame holds the state of the method (method invocation and automatic data)
    - Program counter: which line of code being executed
    - Automatic data: values of method parameters and local variables

Stack: Example

- doStuff gets called …



1

doStuff()	b

2

go(4)	x, z
doStuff()	b

3

crazy()	c
go(4)	x, z
doStuff()	b

4

go(4)	x, z
doStuff()	b

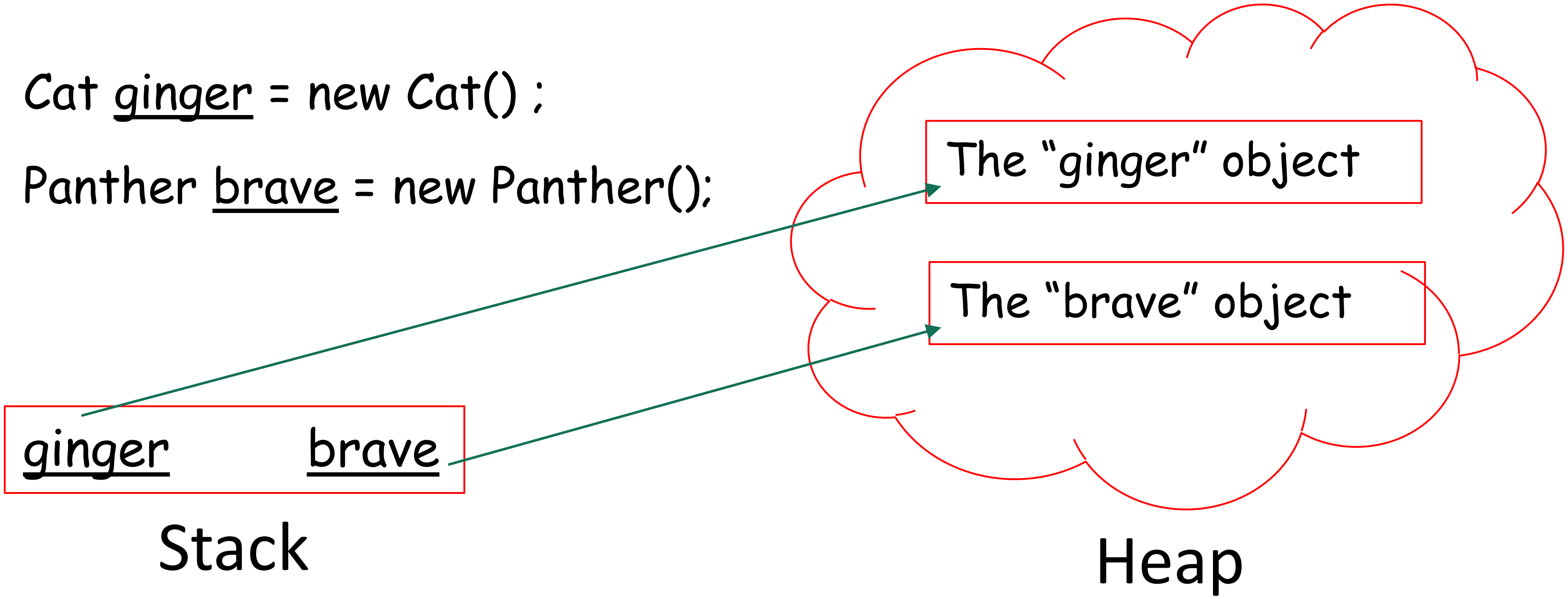
```
void doStuff() {
    boolean b = true;
    go(4);
}
void go(int x) {
    int z = x + 24;
    crazy();
}
Void crazy() {
   int c = 36;
}
```

Heap

- Objects including their instance variables live

Cat ginger = new Cat() ;

Panther brave = new Panther();



The “ginger” object

The “brave” object

ginger brave

Stack

Heap

Questions?

- Constructors
- Default constructor
- Overloading constructors
- Inheritance and constructors
- this and super
- Stack and heap

Assignments

- Project 2
    - How is it going?
- Practice assignments
    - To be available via CUNY Blackboard