# CS61BL

Lecture 2:

Inheritance

Interfaces

Iterators

Linked Lists

# FAQ

- Q: Why isn’t Eclipse working for me?
- A: Come to office hours!

# FAQ

- Q: Do we have lab on Friday?
- A: No lab or office hours on Friday. Enjoy your academic holiday!

# FAQ

- Q: When will project 1 be released?
- A: Soon! Before 8pm tonight.

# FAQ

- Q: What happens when you try to do (*blank*) in Java?
- A: Try it out on your own!

# Inheritance

- "Avoid reinventing the wheel"
  - Reuse code
- "B is a type of A"
  - B is a subclass of A
- All objects extend from Object class!

```
class B extends A {
    // rest of class body
}
```

# Inheriting Methods

```
public class Coin {
    public boolean flip() {
        return (Math.random() < 0.5);
    }
    // rest of class
}

public class Quarter extends Coin {
    // rest of class
}
```

# Inheriting Methods

```
Quarter q = new Quarter();
boolean result = q.flip();
```

# Methods inherited from Object

- `boolean equals(Object o)`
- `String toString()`
- `int hashCode()`
- `Object clone()`
- And more!

# Overriding Methods

```
public class Coin {
    public boolean flip() {
        return (Math.random() < 0.5);
    }
    // rest of class
}
public class Quarter extends Coin {
    public boolean flip() {
        System.out.println("~Ping!~");
        return (Math.random() < 0.5);
    }
    // rest of class
}
```

# Calling `super`

```
public class Coin {
    public boolean flip() {
        return (Math.random() < 0.5);
    }
    // rest of class
}
public class Quarter extends Coin {
    public boolean flip() {
        System.out.println("~Ping!~");
        return super.flip();
    }
    // rest of class
}
```

# Inheriting instance variables

```
public class Coin {
    private double p;
    public Coin(double probHeads) {
        this.p = probHeads;
    }
    // rest of class
}
public class Quarter extends Coin {



    // rest of class
}
```

# Inheriting instance variables

```
public class Coin {
    protected double p;
    public Coin(double probHeads) {
        this.p = probHeads;
    }
    // rest of class
}
public class Quarter extends Coin {



    // rest of class
}
```

# Inheriting instance variables

```
public class Coin {
    protected double p;
    public Coin(double probHeads) {
        this.p = probHeads;
    }
    // rest of class
}
public class Quarter extends Coin {
    private double p;  ???

    // rest of class
}
```

# New instance variables

```
public class Coin {
    protected double p;
    public Coin(double probHeads) {
        this.p = probHeads;
    }
    // rest of class
}
public class Quarter extends Coin {
    private double p;
    private double value = 0.25;
    // rest of class
}
```

# Inheriting constructors

```
public class Coin {
    protected double p;
    public Coin(double probHeads) {
        this.p = probHeads;
    }
    // rest of class
}
public class Quarter extends Coin {
    public Quarter (double probHeads) {
        super(probHeads);
    }
    // rest of class
}
```

# Inheriting constructors

```
public class Coin {
    protected double p;
    public Coin(double probHeads) {
        this.p = probHeads;
    }
    // rest of class
}
public class Quarter extends Coin {
    public Quarter (double probHeads) {

    }
    // rest of class
}
```

# Inheriting constructors

```
public class Coin {
    protected double p;
    public Coin() {
        this.p = 0.5;
    }
    // rest of class
}
public class Quarter extends Coin {
    public Quarter (double probHeads) {

    }
    // rest of class
}
```

# Static vs. Dynamic Type

```
Quarter q = new Quarter();
```

**Static type** **Dynamic type**

- Static type:
  - What compiler sees (compile time type binding)
  - Variable type
- Dynamic type:
  - Runtime type binding
  - Object type

# Polymorphism Puzzles: #1

```
Coin q = new Quarter();
```

**Static type** **Dynamic type**

- Polymorphism
  - "Many forms"
  - Oracle's Java documentation: "Subclasses of a class can define their own unique behaviors and yet share some of the same functionality of the parent class."

# Polymorphism Puzzles: #1

```
Coin q = new Quarter();
```

**Static type** **Dynamic type**

- Will it compile?
  - Yes! Coin is a superclass of Quarter. Variables can hold references to subclass objects. No problems here!

# Polymorphism Puzzles: #2

```
Quarter q = new Coin();
```

**Static type** **Dynamic type**

- Will it compile?
  - No! Quarter is a subclass of Coin. Not all Coins are Quarters. Can't guarantee that a Coin object will be able to run Quarter methods at runtime.

# Polymorphism Puzzles: #3

```
Coin c = new Quarter();
Quarter q = c;
```

- Will it compile?
  - No! `c`'s static type is `Coin`, so as far as the compiler knows, we're trying to have the `Quarter` variable `q` hold a reference to a `Coin` object.

# Polymorphism Puzzles: #4

```
Coin c = new Quarter();
Quarter q = (Quarter) c;
```

- Will it compile?
  - Yes! By casting, we're telling the compiler "Trust me, I know what I'm doing." We're forcing the compiler to accept that `c` is actually a `Quarter` object.

# Polymorphism Puzzles: #5

```
Coin c = new Coin();
Quarter q = (Quarter) c;
```

- Will it compile?
  - Yes, but…

# Polymorphism Puzzles: #5

```
Coin c = new Coin();
Quarter q = (Quarter) c;
```

- Will it *run*?
  - Nope. At runtime, Java realizes that you messed up with your casting. `c` isn't actually a `Quarter` object. You lied to the compiler.

# Polymorphism Puzzles: #6

```
Coin c = new Quarter();
c.value;
```

- (Assume `value` is accessible)
- Will it compile?
  - No. The compiler thinks `c` is a `Coin`, and `Coin` objects don't have a `value` instance variable.

# Polymorphism Puzzles: #7

```
Coin c = new Quarter();
c.flip();
```

- Will it compile?
  - Yes. Coin objects have a `flip` method, so this works fine.
- Whose `flip` method gets called?
  - At runtime, the method that belongs to the dynamic type of the object gets called.

# instanceof

- Lets you know whether an object's *dynamic type* is an instance of some class:

```
Coin c = new Coin();
boolean b;
b = c instanceof Coin; // true
b = c instanceof Quarter; // false
```

# instanceof

- Lets you know whether an object's *dynamic type* is an instance of some class:

```
Coin c = new Quarter();
Quarter q = new Quarter();
boolean b;
b = c instanceof Quarter; // true
b = q instanceof Coin; // true
```

# FAQ

- Q: Can a class inherit from multiple parent classes?
- A: No. (Possible in other languages: e.g. Python and C++)

- Q: Can multiple subclasses inherit from the same parent class?
- A: Yes

# FAQ

- Q: Why can't the compiler just keep track of what an object's dynamic type is?
- A:

```
Coin c;
if(Math.random() < 0.5) {
    c = new Coin();
} else {
    c = new Quarter();
}
```

# `ArrayList`

- `import java.util.ArrayList;`
- Resizable arrays!
- Some useful methods:
  - `add`: add element to the middle of the `ArrayList`
  - `get`: returns an element from the `ArrayList`
  - `remove`: removes the element at a given index within the `ArrayList`
  - And more!

# `ArrayList`: Usage Example

```
ArrayList a = new ArrayList();
a.add("Hello!");
a.add(0, new ArrayList());
a.remove(0);
String msg = a.get(0);
```

# `ArrayList`: Usage Example

```
ArrayList a = new ArrayList();
a.add("Hello!");
a.add(0, new ArrayList());
a.remove(0);
```

~~`String msg = a.get(0);`~~

```
String msg = (String) a.get(0);
```

java.util

# Class ArrayList<E> ???

java.lang.Object
    java.util.AbstractCollection<E>
        java.util.AbstractList<E>
            java.util.ArrayList<E>

**All Implemented Interfaces:**

Serializable, Cloneable, Iterable<E>, Collection<E>, List<E>, RandomAccess

**Direct Known Subclasses:**

AttributeList, RoleList, RoleUnresolvedList

---

```
public class ArrayList<E>
extends AbstractList<E>
implements List<E>, RandomAccess, Cloneable, Serializable
```

Resizable-array implementation of the `List` interface. Implements all optional list op

# Generics

- Oracle's Java documentation: "Allows a type or method to operate on objects of various types while providing compile-time type safety"
- Basically, allows us to create ArrayLists of a specific type of Object:

```
ArrayList<String> a = new ArrayList<String>();
```

**Methods**

| Modifier and Type | Method and Description |
|---|---|
| boolean | add(E e)<br>Appends the specified element to the end of this list. |

# Interfaces

- A way to promise that a class has certain methods
- Abstract: can’t make an instance of an interface
- Abstract methods: no implemented method bodies

# Interfaces: Syntax

```
interface InterfaceName {
    void methodName();
    int methodName2(int inputInt);
}
```

# Interfaces: Syntax

```
public class ClassName implements InterfaceName {
    public void methodName() {
        // implementation
    }
    public int methodName2(int inputInt) {
        // implementation
    }
    // rest of class
}
```

java.util

# Class ArrayList<E>

java.lang.Object
    java.util.AbstractCollection<E>
        java.util.AbstractList<E>
            java.util.ArrayList<E>

**All Implemented Interfaces:**

Serializable, Cloneable, Iterable<E>, Collection<E>, List<E>, RandomAccess

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```
public class ArrayList<E>
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implements List<E>, RandomAccess, Cloneable, Serializable
```

Resizable-array implementation of the `List` interface. Implements all optional list op

# Interface Example: List<T>

```
List<String> a = new ArrayList<String>();
```

```
ArrayList<String> a = new List<String>();
```

# Interface Example: Comparable<T>

- Only required method:

```
int compareTo(T o)
```

- `String, Integer, Date` all implement `Comparable`
- Usually have `T` class implement `Comparable<T>`
- Useful for sorting

# Interface Example: Iterable<T>

- Only required method:

```
Iterator<T> iterator();
```

# Interface Example: ~~Iterable<T>~~ Iterator<T>

- An iterator iterates over items in a collection
  - i.e. it returns them one at a time
  - Order is not guaranteed
  - Should not modify contents of what you're iterating over while using an iterator

# Interface Example: ~~Iterable<T>~~ Iterator<T>

- `boolean hasNext()`
  - Returns whether the iterator has items left to return
  - Not guaranteed to be called before calls to `next()`
  - Should not change state!!!
- `T next()`
  - Returns the next item
  - Behavior undefined if `hasNext()` returns `false`
- `void remove()`
  - Optional (throw `UnsupportedOperationException` if not implemented)
  - Removes item most recently returned with `next()`

# Using an Iterator

```
ArrayList<String> a;
a = new ArrayList<String>();
a.add("Hello!");
a.add("Greetings!");
a.add("Well met!");
Iterator<String> myIter = a.iterator();
String msg = myIter.next();
```

# Using an Iterator

```
ArrayList<String> a;
a = new ArrayList<String>();
// add Strings to ArrayList
Iterator<String> myIter = a.iterator();
while(myIter.hasNext()) {
    String msg = myIter.next();
    // do something with msg
}
```

# Using an Iterator

```
ArrayList<String> a;
a = new ArrayList<String>();
// add Strings to ArrayList
Iterator<String> myIter = a.iterator();
while(myIter.hasNext()) {
    String msg = myIter.next();
    // do something with msg
}
```

# Interface Example: Iterable<T>

- Only required method:

```
Iterator<T> iterator();
```

java.util

# Class ArrayList<E>

java.lang.Object
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```
public class ArrayList<E>
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Resizable-array implementation of the `List` interface. Implements all optional list op

# Special `Iterable` syntax

- ArrayList implements Iterable!
- Regular arrays are `Iterable` too!
- E.g. `int[] arrayOfInts = new int[3];`
- Which means we can do this:

```
for (String msg : a) {
    // do something with msg
}
```

# Special `Iterable` syntax

- Instead of this:

```
Iterator<String> myIter = a.iterator();
while(myIter.hasNext()) {
    String msg = myIter.next();
    // do something with msg
}
```

# FAQ

- Q: Can a class implement multiple interfaces?
- A: Yes!

```
class ClassName implements InterfaceName1,
    InterfaceName2, InterfaceName3 {
```

- Q: Can an interface implement another interface?
- A: Sort of!

```
interface InterfaceName1 extends
    InterfaceName2, InterfaceName3 {
```

# Midterm 1 Information

- Wednesday July 9, 3-5pm
- 2050 VLSB and 100 GPB
- Review Session
  - Sunday July 6, 1-3pm
  - 100 GPB

# Midterm 1 Information

- All lab and quiz material up to & including next Monday's (Generics and Iterators)
- Lectures up until now
- Next Tuesday's lab: Optional Git lab
  - Quiz
  - Time to review / study
- Next Thursday's lab: Linked Lists! (part 1)
  - No quiz

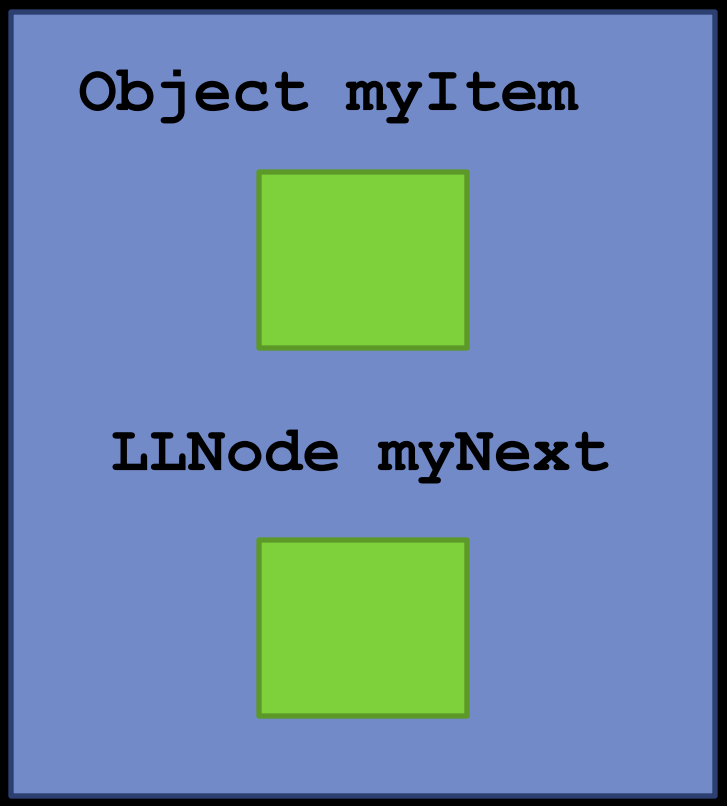
# Board Game & Dessert Potluck

- Wednesday July 16, 7-11pm
- 430/438 Soda (Wozniak Lounge)
- Bring your favorite board/card game. Bring a dessert/drink to share, potluck-style.
- Open to all CS61BL staff & students for us to get to know each other better
- Have fun!

# Linked Lists: Terminology

- Node:

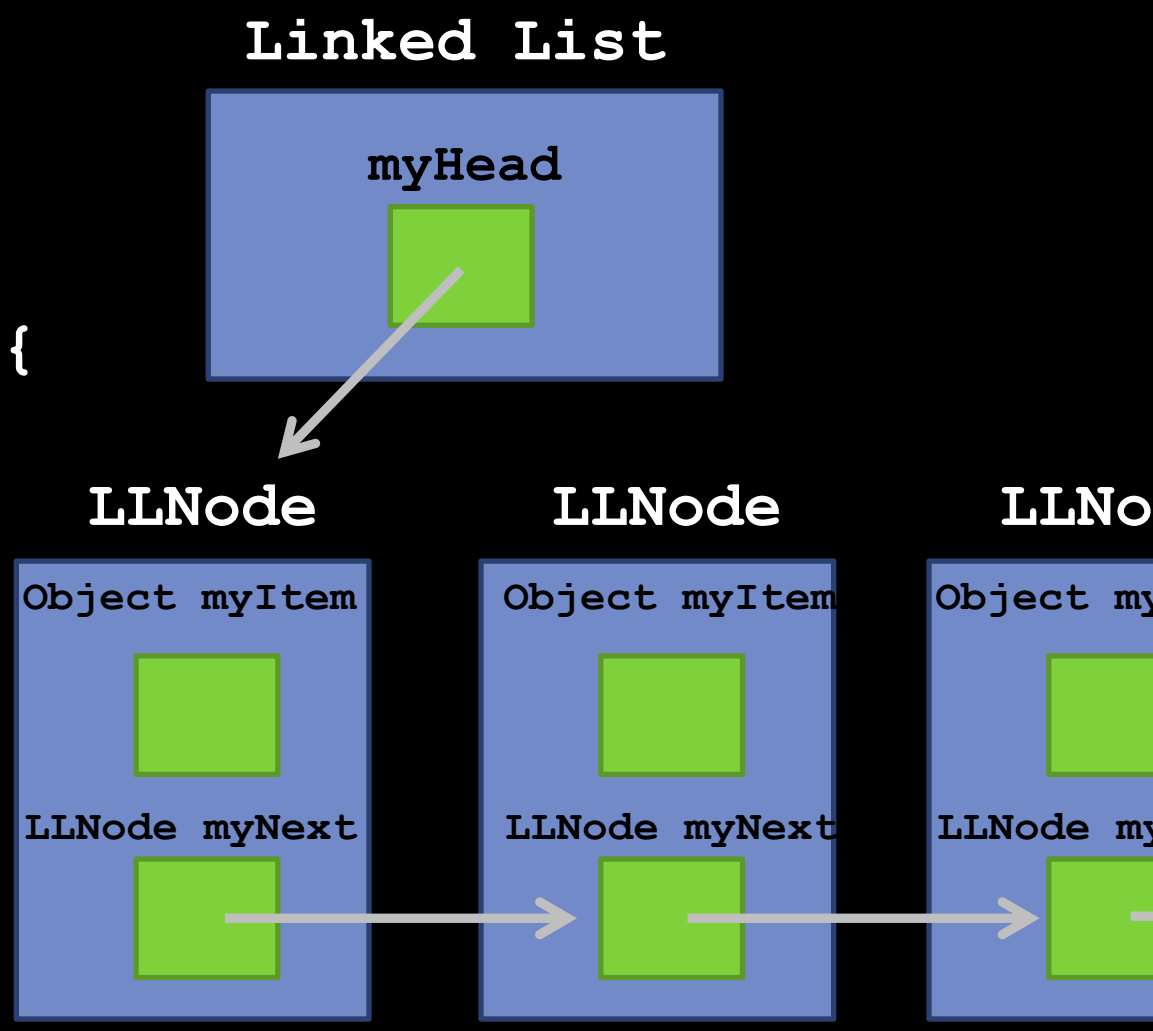
```
class LLNode {
  Object myItem;
  LLNode myNext;
  // constructors
  // & methods
}
```



# Linked Lists: Terminology

- Linked List:

```
class LinkedList {
   LLNode myHead;
   // constructors
   // & methods
}
```

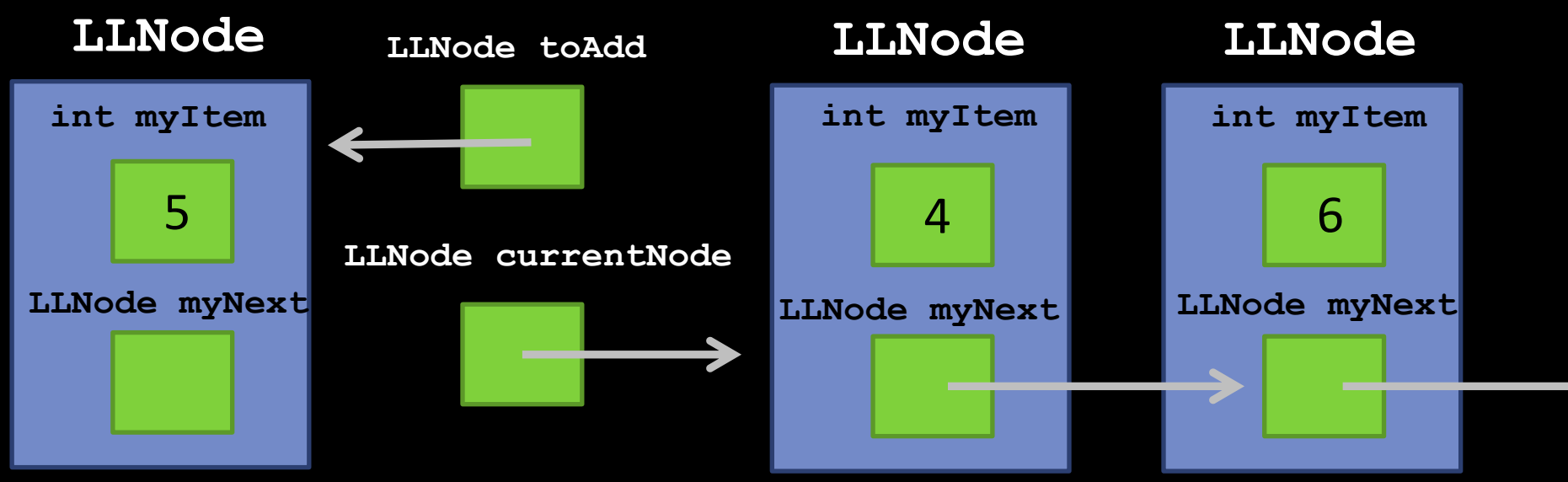


# Linked Lists: Terminology

- Constructive
  - Make a copy of the input linked list, apply changes, and return new linked list
- Destructive
  - Modify input linked list directly

# Example: Insert Node (destructive)

```
// Assume we have reference to some node
// in the linked list: LLNode currentNode
LLNode toAdd = new LLNode(5);
```



# Example: Insert Node (destructive)

```
// Assume we have reference to some node
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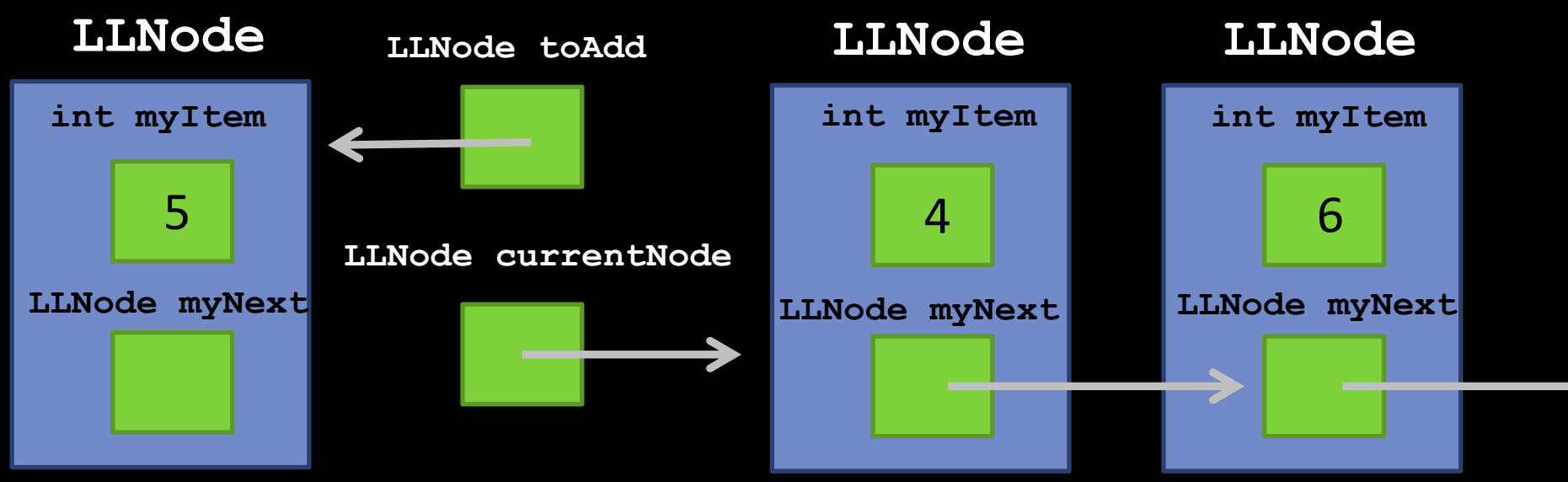
LLNode toAdd = new LLNode(5);
currentNode.myNext = toAdd;
```



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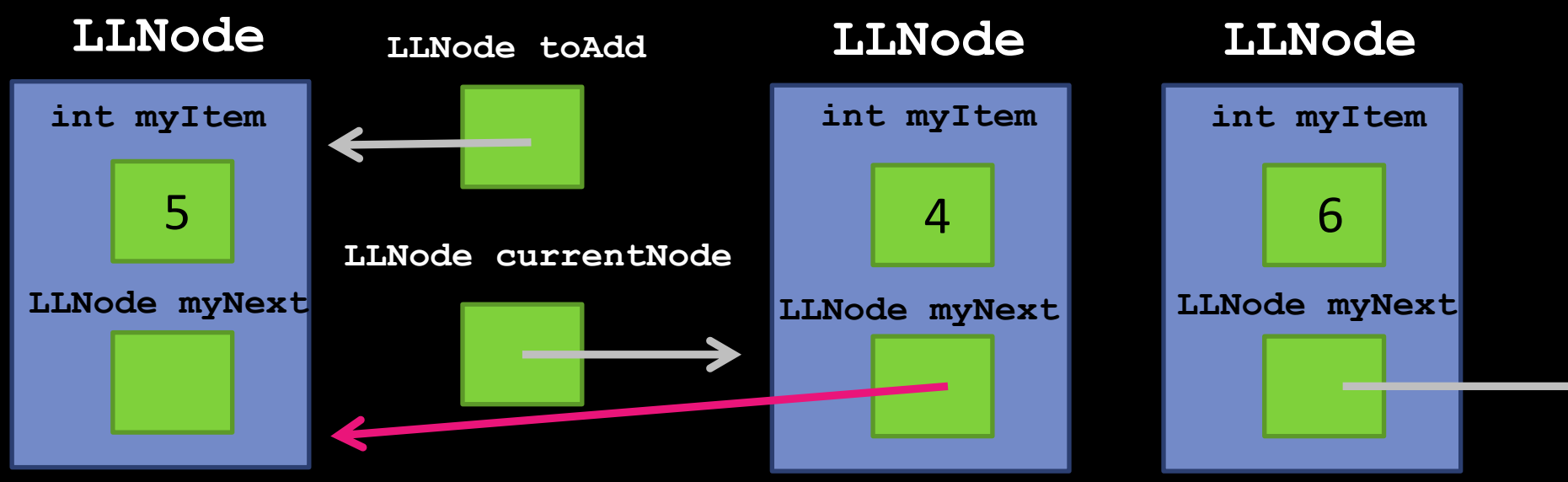

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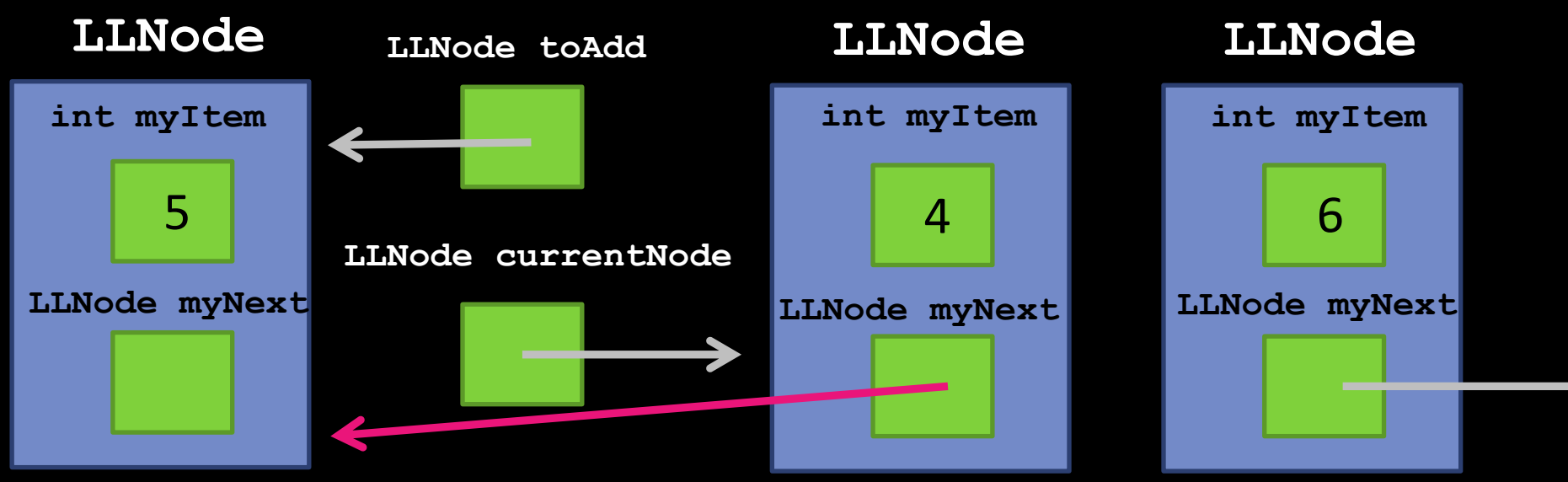
~~`currentNode.myNext = toAdd;`~~



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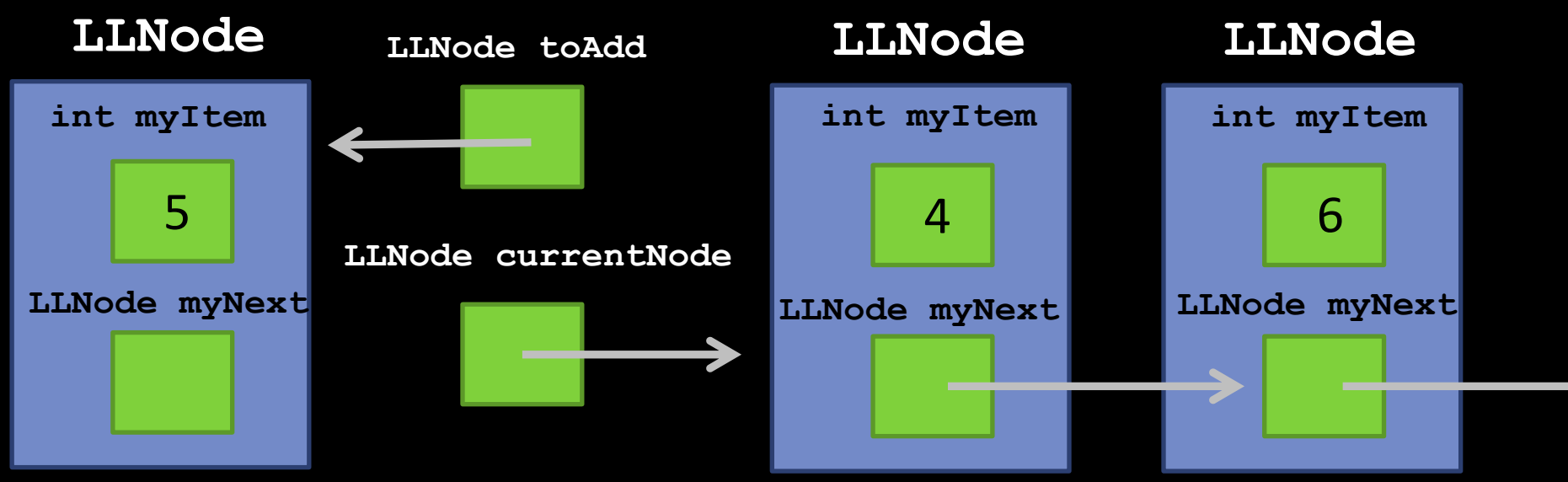

# Example: Insert Node (destructive)

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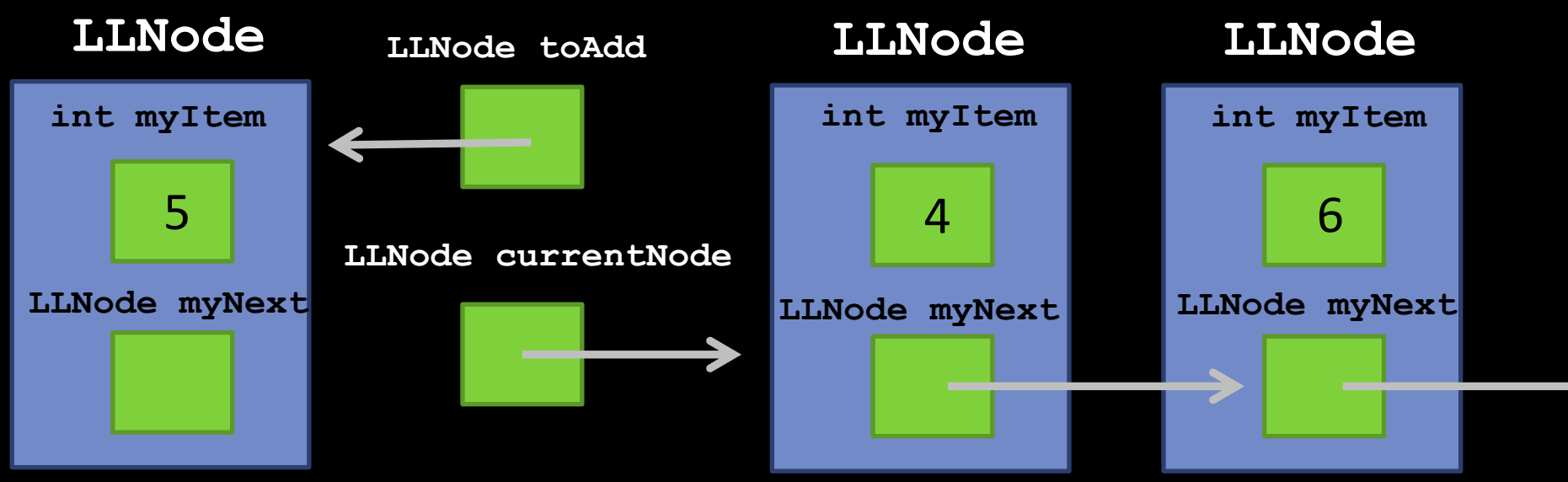

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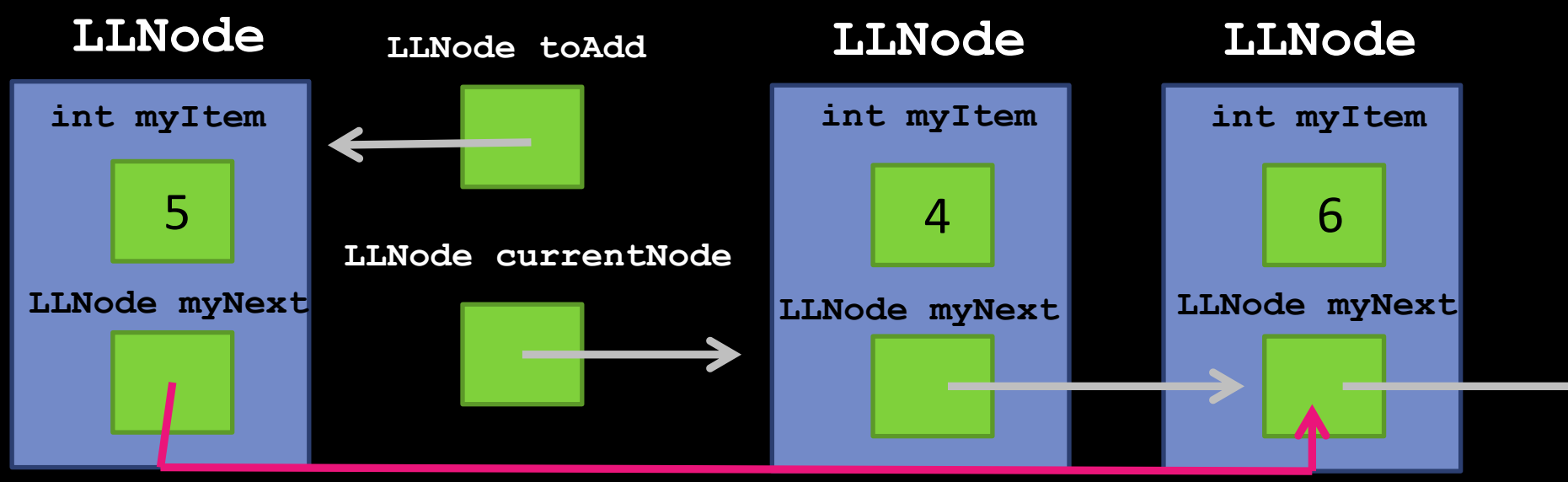

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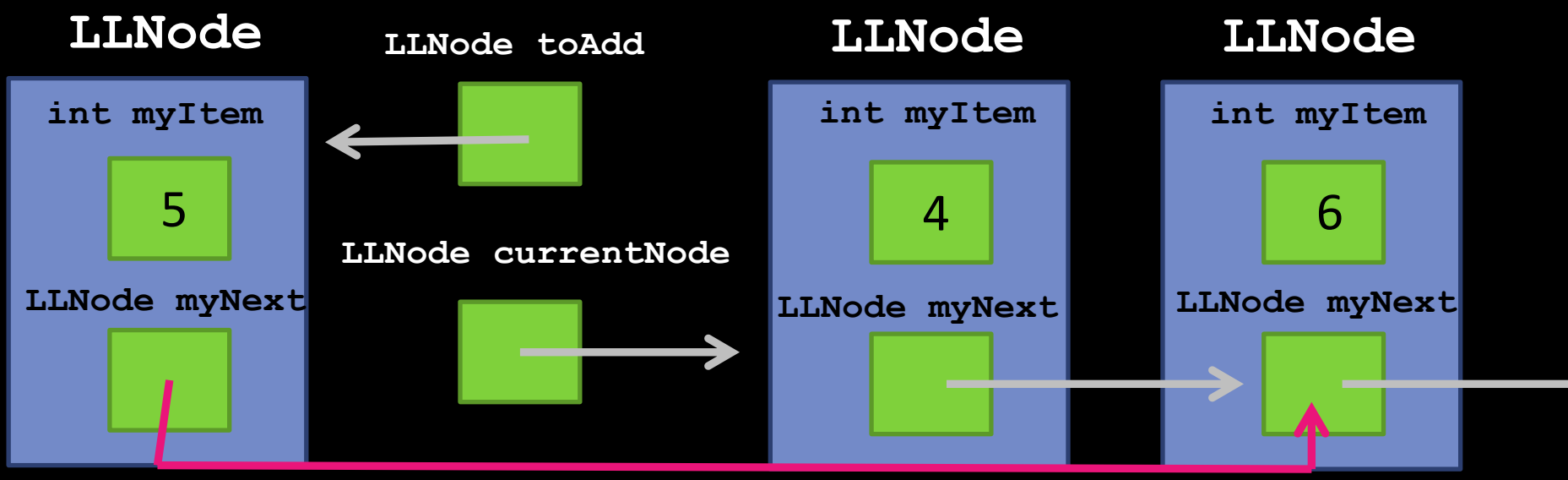

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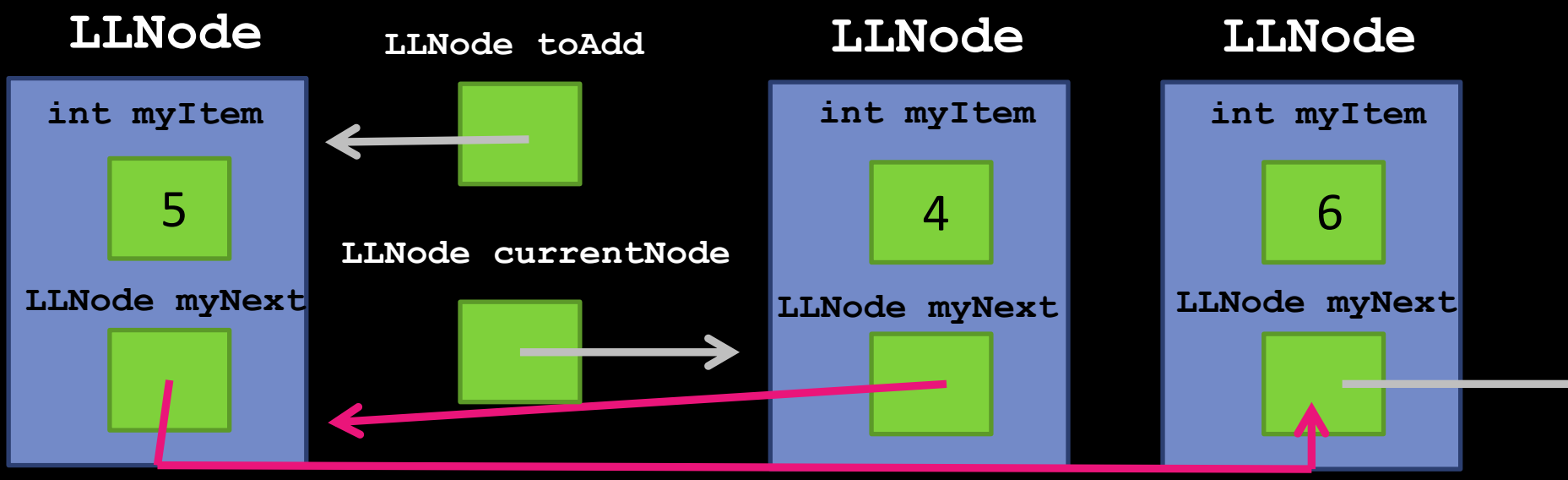

# Example: Insert Node (destructive)

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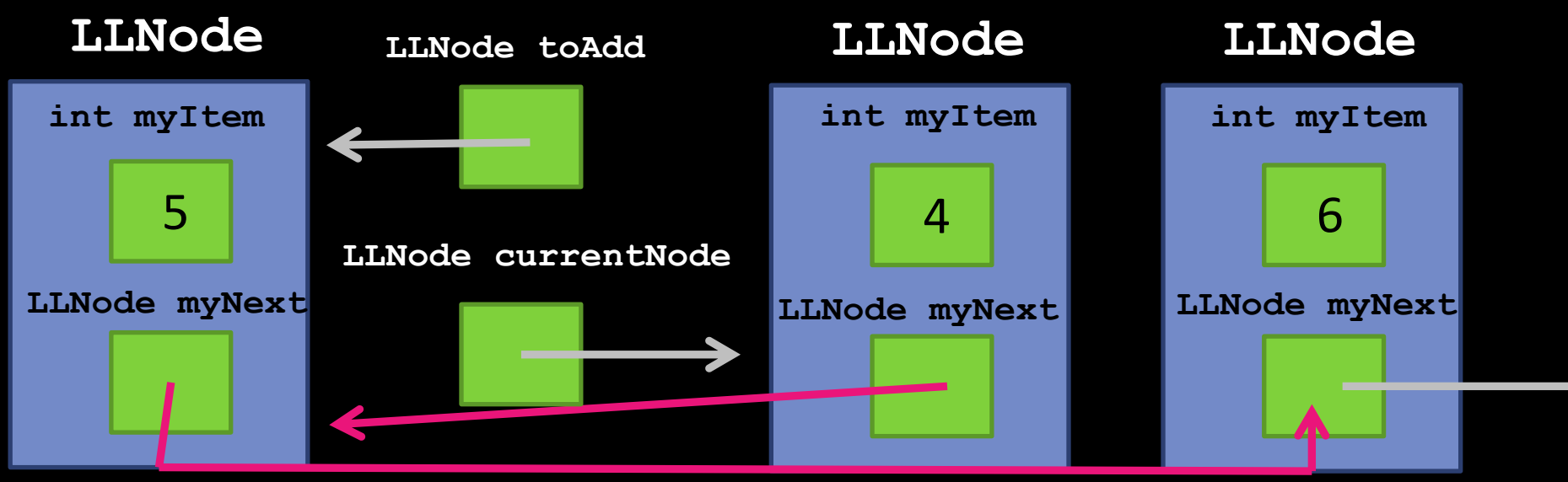
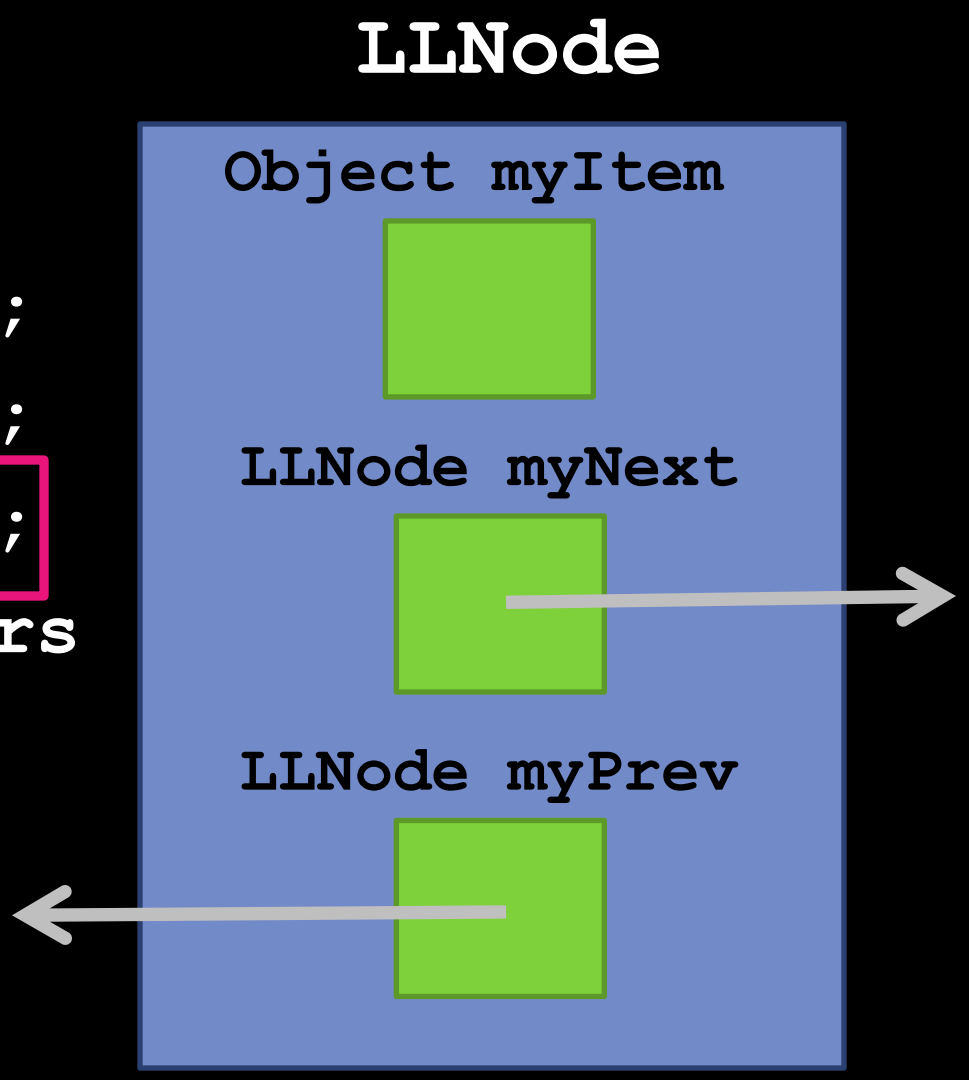


# Variant: Doubly-linked

- Node:

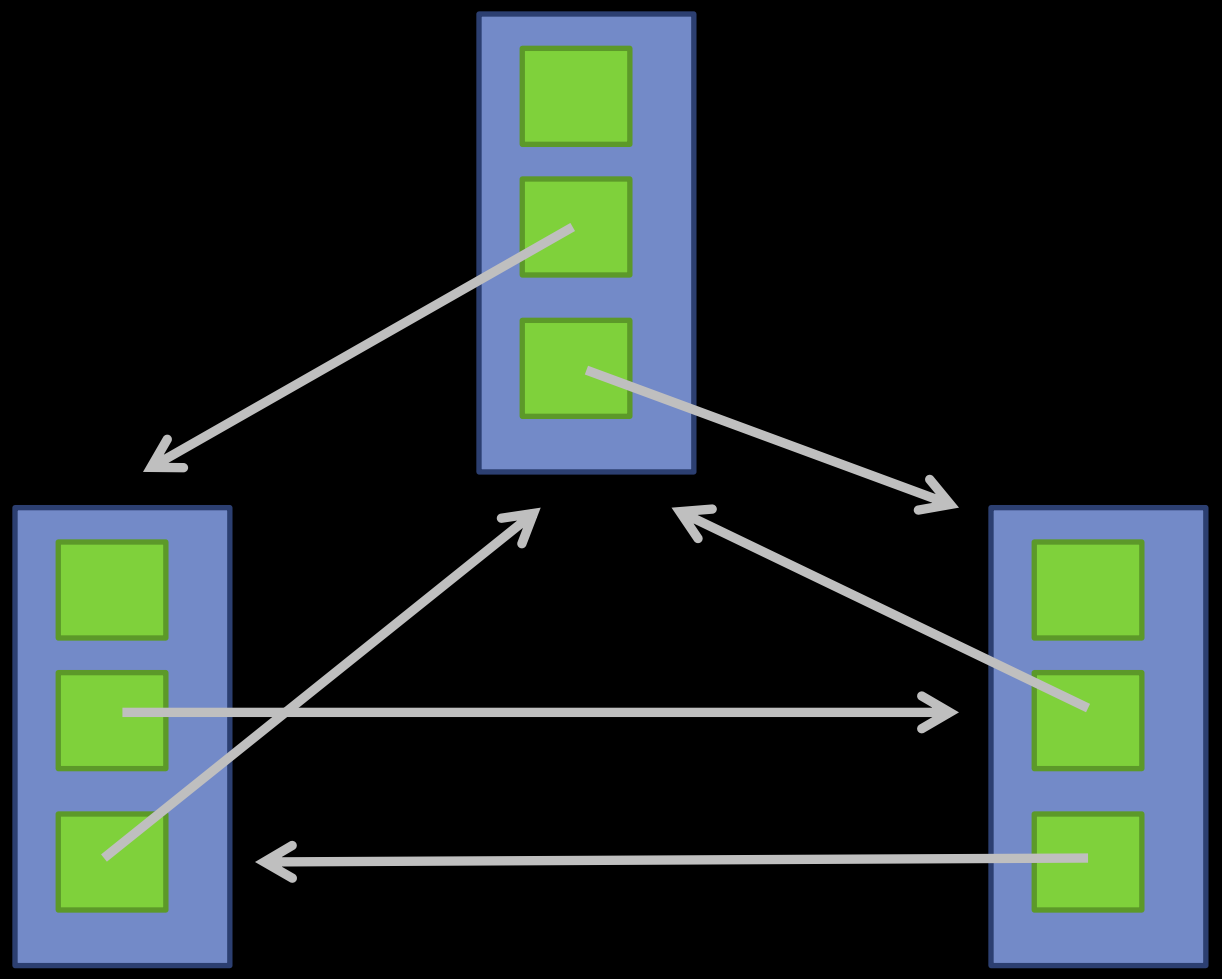
```
class LLNode {
    Object myItem;
    LLNode myNext;
    LLNode myPrev;
    // constructors
    // & methods
}
```



# Advantages of doubly-linked

- Faster to traverse in reverse, esp. if you have reference to last node
  - How much faster?
  - Next lecture: asymptotic analysis

# Variant: Circularly-linked



# Uses for circularly-linked

- Iterating over something over and over again
  - E.g. which player's turn in a board game
  - Can add/remove/modify nodes in middle
- Used in some process scheduling algorithms

# Other additions?

- Keep reference to last node
- Keep count of number of nodes
- Java's `LinkedList` class implements `List<T>`

# Problem: Linked List of length 0

- How to represent?
- Have `myHead` node be `null`?
  - Null checks are messy
- Lab's solution
  - Always have an empty "dummy" node that represents the end of linked list

Good luck next week.