Recreation

Prove that \( \lfloor (2 + \sqrt{3})^n \rfloor \) is odd for all integer \( n \geq 0 \).

Labs are normally due at midnight Friday. Last week’s lab, however, is due this coming Friday at midnight.

Values and Containers

- **Values** are numbers, booleans, and pointers. **Values never change.** (So, for example, the assignment `3 = 2` would be invalid.)

  3       'a'       true

- **Simple containers** contain values:

  x: 3   L:   p:

Examples: variables, fields, individual array elements, parameters. The *contents* of containers can change.
Structured Containers

*Structured containers* contain (0 or more) other containers:

<table>
<thead>
<tr>
<th>Class Object</th>
<th>Array Object</th>
<th>Empty Object</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>h</strong> 3</td>
<td>0 1 2</td>
<td></td>
</tr>
<tr>
<td><strong>t</strong></td>
<td>42 17 9</td>
<td></td>
</tr>
</tbody>
</table>

**Alternative Notation**

```
<table>
<thead>
<tr>
<th>h: 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>t:</td>
</tr>
</tbody>
</table>
```

```
| 0 42 |
| 1 17 |
| 2 9  |
```
Pointers

• **Pointers** (or **references**) are values that **reference** (point to) containers.

• One particular pointer, called **null**, points to nothing.

• In Java, structured containers contain only simple containers, but pointers allow us to build arbitrarily big or complex structures anyway.
Containers in Java

- Containers may be *named* or *anonymous*.

- In Java, *all* simple containers are named, *all* structured containers are anonymous, and pointers point only to structured containers. (Therefore, structured containers contain only simple containers).

![Diagram of containers in Java]

- In Java, assignment copies values into simple containers.

- *Exactly* like Scheme and Python!

- (Python also has slice assignment, as in `x[3:7]=...`, which is shorthand for something else entirely.)
Defining New Types of Object

- Class declarations introduce new types of objects.
- Example: list of integers:

```java
public class IntList {
    // Constructor function (used to initialize new object)
    /** List cell containing (HEAD, TAIL). */
    public IntList(int head, IntList tail) {
        this.head = head; this.tail = tail;
    }

    // Names of simple containers (fields)
    // WARNING: public instance variables usually bad style!
    public int head;
    public IntList tail;
}
```
IntList Q, L;

L = new IntList(3, null);
Q = L;

Q = new IntList(42, null);
L.tail = Q;

L.tail.head += 1;
// Now Q.head == 43
// and L.tail.head == 43
Side Excursion: Another Way to View Pointers

- Some folks find the idea of “copying an arrow” somewhat odd.
- Alternative view: think of a pointer as a *label*, like a street address.
- Each object has a permanent label on it, like the address plaque on a house.
- Then a variable containing a pointer is like a scrap of paper with a street address written on it.

- One view:

```
last: [ ]
result: [5] [ ] 45
```

- Alternative view:

```
last: [#7]
result: [#7] [5] [#3] [45]
```
Another Way to View Pointers (II)

- Assigning a pointer to a variable looks just like assigning an integer to a variable.
- So, after executing “last = last.tail;” we have

  last: [Diagram of last]
  result: [Diagram of result]

- Alternative view:

  last: [Diagram of last]
  result: [Diagram of result]

- Under alternative view, you might be less inclined to think that assignment would change object #7 itself, rather than just “last”.
- BEWARE! Internally, pointers really are just numbers, but Java treats them as more than that: they have types, and you can’t just change integers into pointers.
Destructive vs. Non-destructive

Problem: Given a (pointer to a) list of integers, \( L \), and an integer increment \( n \), return a list created by incrementing all elements of the list by \( n \).

```c
/** List of all items in P incremented by n. Does not modify * existing IntLists. */
static IntList incrList(IntList P, int n) {
    return /*( P, with each element incremented by n )*/
}
```

We say \texttt{incrList} is non-destructive, because it leaves the input objects unchanged, as shown on the left. A destructive method may modify the input objects, so that the original data is no longer available, as shown on the right:

After \( Q = \text{incrList}(L, 2) \):
\[
\begin{align*}
L: & \quad 3 \quad 43 \\
Q: & \quad 5 \quad 45
\end{align*}
\]

After \( Q = \text{dincrList}(L, 2) \) (destructive):
\[
\begin{align*}
L: & \quad 5 \quad 45 \\
Q: & \quad
\end{align*}
\]
Nondestructive IncrList: Recursive

/** List of all items in P incremented by n. */
static IntList incrList(IntList P, int n) {
    if (P == null)
        return null;
    else return new IntList(P.head+n, incrList(P.tail, n));
}

• Why does incrList have to return its result, rather than just setting P?
• In the call incrList(P, 2), where P contains 3 and 43, which IntList object gets created first?
An Iterative Version

An iterative `incrList` is tricky, because it is not tail recursive. Easier to build things first-to-last, unlike recursive version:

```java
static IntList incrList(IntList P, int n) {
    if (P == null) <<<
        return null;
    IntList result, last;
    result = last
        = new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail;
        last.tail
            = new IntList(P.head+n, null);
        last = last.tail;
    }
    return result;
}
```

![Diagram showing the `incrList` function](image-url)
An Iterative Version

An iterative `incrList` is tricky, because it is not tail recursive. Easier to build things first-to-last, unlike recursive version:

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static IntList incrList(IntList P, int n) {
    if (P == null)
        return null;
    IntList result, last;
    result = last <<<
        = new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail;
        last.tail
            = new IntList(P.head+n, null);
        last = last.tail;
    }
    return result;
}
```

---

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static IntList incrList(IntList P, int n) {
    if (P == null)
        return null;
    IntList result, last;
    result = last
        = new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail; <<<
        last.tail
            = new IntList(P.head+n, null);
        last = last.tail;
    }
    return result;
}
```

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    if (P == null)
        return null;
    IntList result, last;
    result = last
        = new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail;
        last.tail <<< = new IntList(P.head+n, null);
        last = last.tail;
    }
    return result;
}
```

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    if (P == null)
        return null;
    IntList result, last;
    result = last
        = new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail;
        last.tail
            = new IntList(P.head+n, null);
        last = last.tail; <<<
    }
    return result;
}
```

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        = new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail; <<<
        last.tail
            = new IntList(P.head+n, null);
        last = last.tail;
    }
    return result;
}
```

![Diagram showing incrList function execution](image)
An Iterative Version

An iterative `incrList` is tricky, because it is not tail recursive. Easier to build things first-to-last, unlike recursive version:

```java
static IntList incrList(IntList P, int n) {
    if (P == null)
        return null;
    IntList result, last;
    result = last = new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail;
        last.tail = new IntList(P.head+n, null);
        last = last.tail;
    }
    return result;
}
```

```
P: 3 —> 43 —> 56
last: 
result: 5 —> 45 —> 58
```
An Iterative Version

An iterative incrList is tricky, because it is not tail recursive. Easier to build things first-to-last, unlike recursive version:

```java
static IntList incrList(IntList P, int n) {
    if (P == null)
        return null;
    IntList result, last;
    result = last
        = new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail;
        last.tail
            = new IntList(P.head+n, null);
        last = last.tail; <<<
    }
    return result;
}
```

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