Find Your Fun Magnets

- "The fact that True Fun is an emotional experience means that, while activities can help generate fun, activities themselves are not fun."
- "With that said, each of us has certain activities – and, for that matter, people, and settings – that are much more likely than others to trigger or enhance our feelings of playfulness, connection, and flow, and thus more likely to attract True Fun."
- "I call these "fun magnets," and each of us has a collection that's unique to us. If you want to up your chances of experiencing True Fun, you should seek out and prioritize your fun magnets as often as you can."

-- The Power of Fun: How to Feel Alive Again by Price

CSCI 136: Data Structures and Advanced Programming

Lecture 19

Iteration & Search

Instructor: Kelly Shaw

Williams

Topics

- Iterators
- Binary search
- How to resubmit work in this course

Your to-dos

1. Better not come to class **on Friday**!
2. Read **before Mon**: Bailey, Ch 12-12.5.
3. Lab 7 (partner lab), **due Tuesday 11/1 by 10pm**.

Announcements

- CS Colloquium, Fri @ 2:35 in Wege Auditorium
  Pre-registration info session
  + cookies

Announcements

Please **consider being a TA** next semester
(especially for this class!)

Applications **due Friday, Oct 28**.

https://csci.williams.edu/tatutor-application/

Iterators

What do the following have in common?

```
double[] a
// … initialize a …
double sum = 0.0;
for (int i = 0; i < a.length; i++) {
  sum += a[i];
}
```

```
List<Double> ls = new SinglyLinke
// … initialize ls …
double sum = 0.0;
for (int i = 0; i < ls.size(); i
  sum += ls.get(i);
}
```

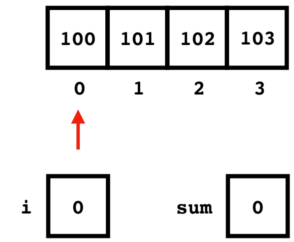
```
Stack<Double> s = new StackVect
// … initialize s …
double sum = 0.0;
while (!s.isEmpty()) {
  sum += s.pop();
}
```

Iteration

Iteration is the **repetition of a process** in order to generate a (possibly unbounded) **sequence of outcomes**. Each repetition of the process is a single iteration, and the outcome of each iteration is then the starting point of the next iteration.

Each program iterates

```
double[] a
// … initialize a …
double sum = 0.0;
for (int i = 0; i < a.length; i++) {
 sum += a[i];
}
```



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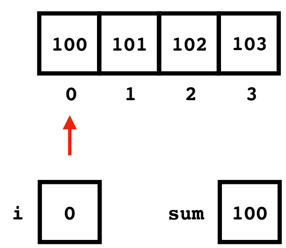

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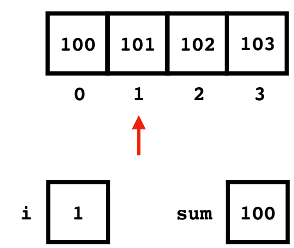

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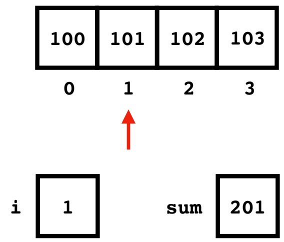

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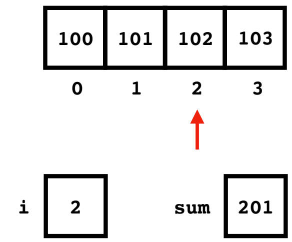

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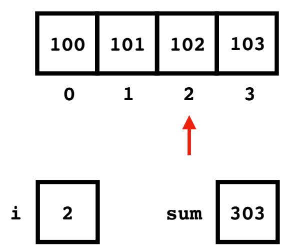

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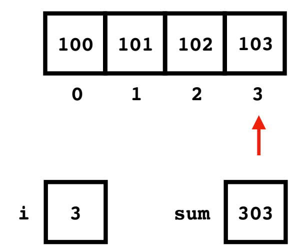

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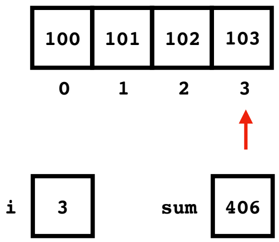

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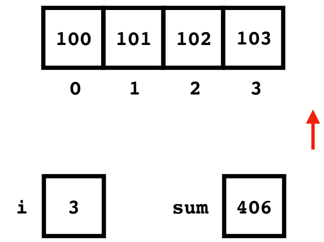

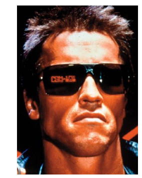

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Each program iterates

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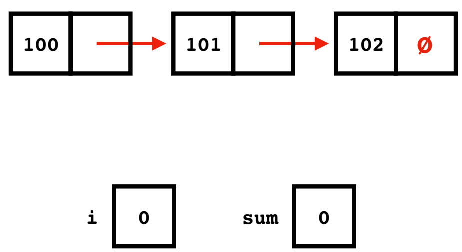

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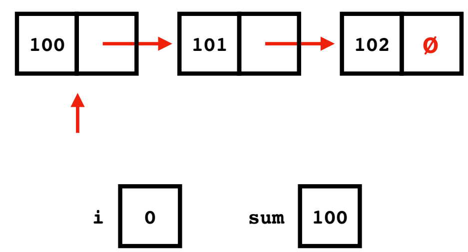

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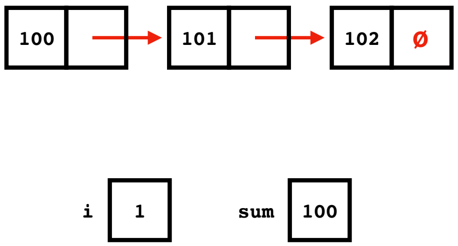

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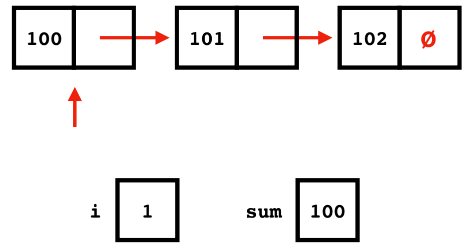

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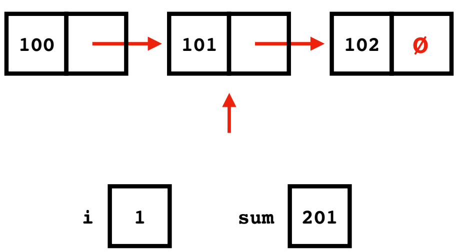

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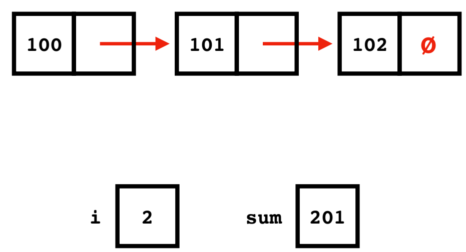

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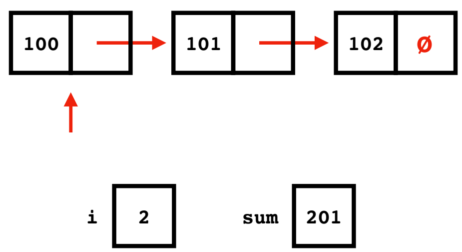

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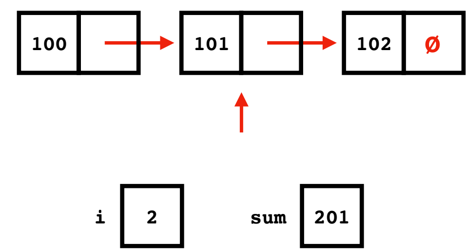

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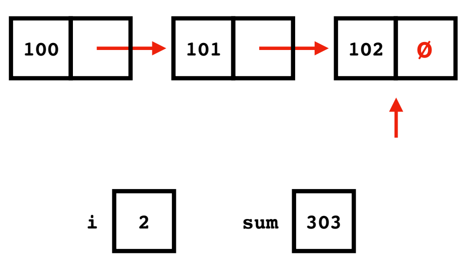

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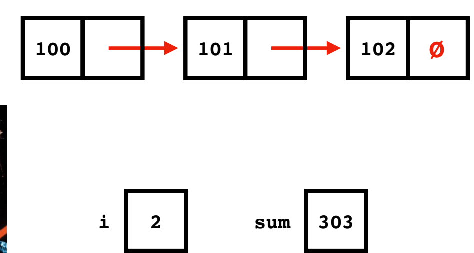
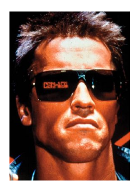
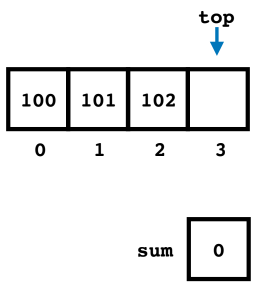




"Iteration is terminated!"

Each program iterates

```
Stack<Double> s = new StackVector<>();
// … initialize s …
double sum = 0.0;
while (!s.isEmpty()) {
  sum += s.pop();
}
```



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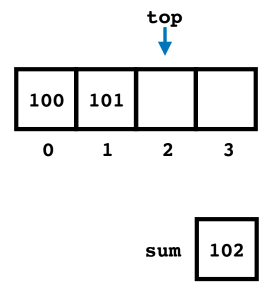

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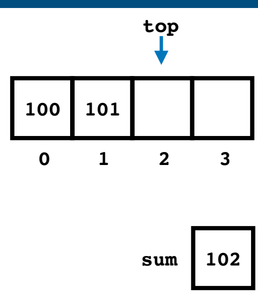

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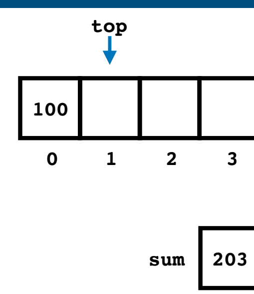

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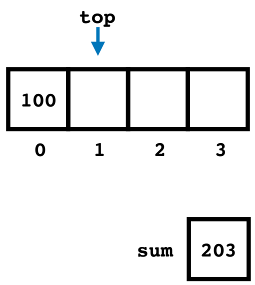

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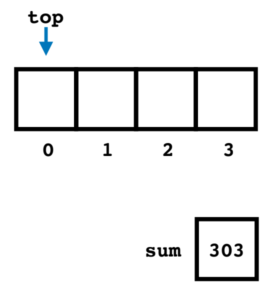

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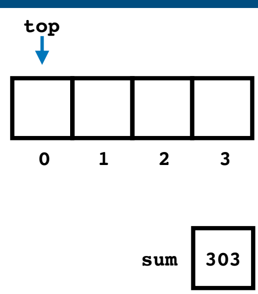

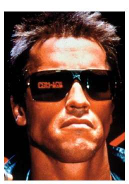

"Iteration is terminated!"

Essentially the same algorithm!

```
double[] a
// … initialize a …
double sum = 0.0;
for (int i = 0; i < a.length; i++) {
  sum += a[i];
}
```

```
List<Double> ls = new SinglyLinkedList<>();
// … initialize ls …
double sum = 0.0;
for (int i = 0; i < ls.size(); i++) {
  sum += ls.get(i);
}
```

```
Stack<Double> s = new StackVector<>();
// … initialize s …
double sum = 0.0;
while (!s.isEmpty()) {
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}
```

But the code looks different.

Problems

- **Different data structures** yield **different code for same algorithm**.
- **Data hiding** potentially causes **efficiency problems**.
- **Inspecting** data structure "from the outside" can **change the state** of a data structure (e.g., `pop()`'ing a `Stack`).

What if I told you that you could solve

all of these problems with **abstraction**?

Iteration abstraction to the rescue.

```
double[] a
// … initialize a …
double sum = 0.0;
for (double d : a) {
  sum += d;
}
```

```
List<Double> ls = new SinglyLinkedList<>();
// … initialize ls …
double sum = 0.0;
for (double d : ls) {
  sum += d;
}
```

```
Stack<Double> s = new StackVector<>();
// … initialize s …
double sum = 0.0;
for (double d : s) {
  sum += d;
}
```

Brought to you by **Iterators**.

Iterators are a really good idea.

- Invented by Barbara Liskov in 1974.
- Incidentally, **abstract data types** were also invented by Barbara Liskov in 1974.
- Both debuted in the influential PL called **CLU**.
- Barbara won the **Turing Award in 2008** for this work and more.

How does “for each” work?

```
for (int num : nums) { … }
```

All of these data structures must implement `Iterable<T>`

structure5

Interface Stack<E>

All Superinterfaces:
java.lang.Iterable<E>, Linear<E>, Structure<E>

All Known Implementing Classes:
AbstractStack, StackArray, StackList, StackVector

structure5

Interface List<E>

All Superinterfaces:
java.lang.Iterable<E>, Structure<E>

All Known Implementing Classes:
AbstractList, CircularList, DoublyLinkedList, SinglyLinkedList, Vector

(array is a special case)

What is an `Iterable<T>`?

```
public interface Iterable<T>
{
    Iterator<T> iterator();
}
```

It’s a class that returns an `Iterator<T>`.

What’s an `Iterator<T>`???

```
public interface Iterator<E>
{
    boolean hasNext();
    E next();
    …
}
```

It’s an object that lets you **iterate through a data structure**.

Importantly, `Iterator`s are **stateful**.

Why does statefulness matter? It can **save work**.

Let’s look at `SinglyLinkedList<T>`

Naive iteration makes O(n) operation O(n²)!

```
List<Double> ls = new SinglyLinkedList<>();
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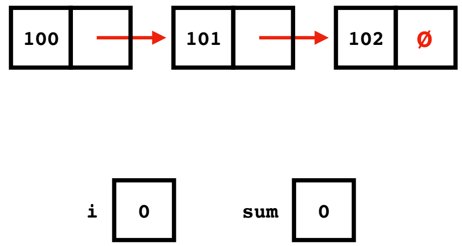

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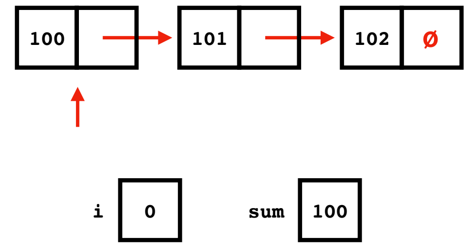

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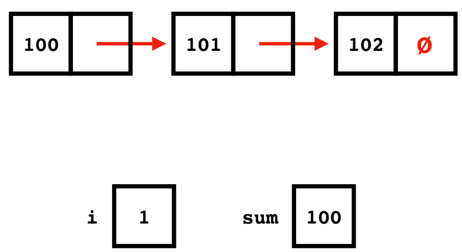

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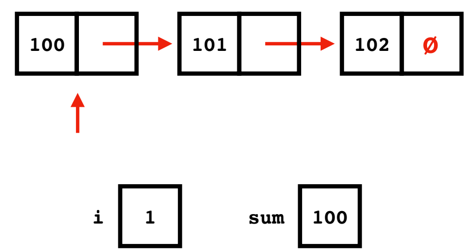

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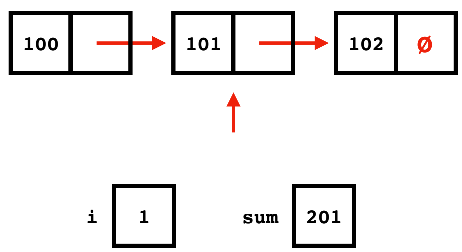

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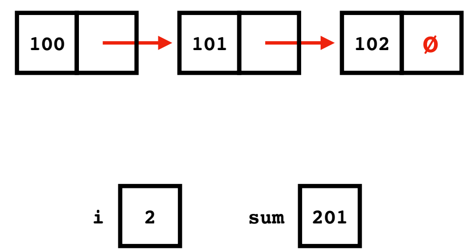

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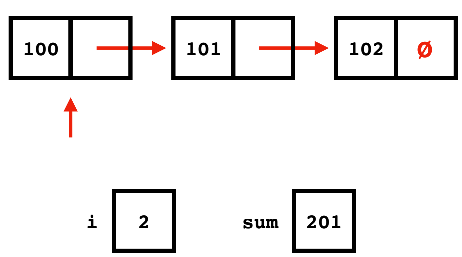

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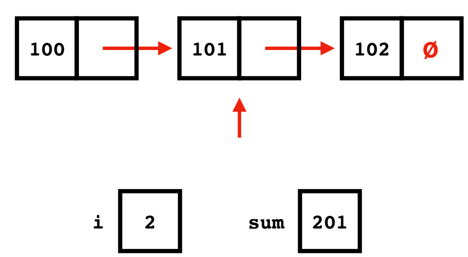

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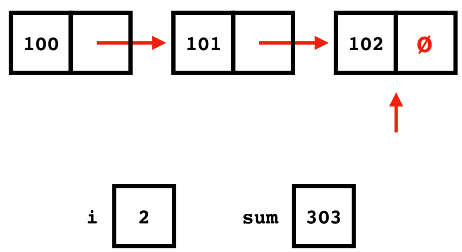

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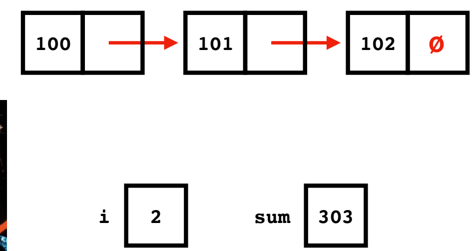
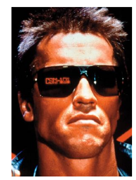




"Iteration is terminated!"

How does `for` use an `Iterator<T>`?

The following code

```
List<Integer> ls = new SinglyLinkedList<>();
// …
for (int i : ls) {
  // … work …
}
```

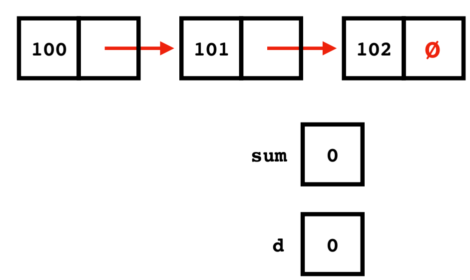
is the moral equivalent to

```
List<Integer> ls = new SinglyLinkedList<>();
// …
for (Iterator<Integer> i = ls.iterator(); i.hasNext(); ) {
  int n = i.next()
  // … work …
}
```

1. Get `Iterator<T>`
2. Get next element.
3. If there is a next element, go to 2.

Example.

```
List<Double> ls = new SinglyLinkedList<>();
// … initialize ls …
double sum = 0.0;
for (double d : ls) {
  sum += d;
}
```



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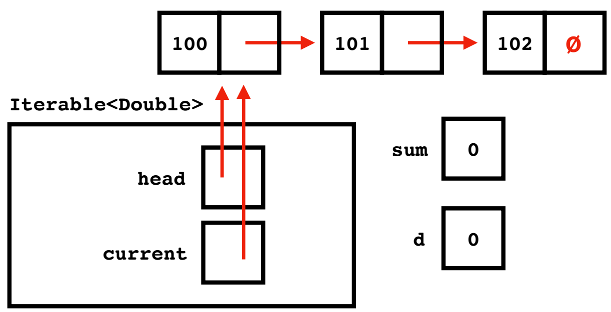

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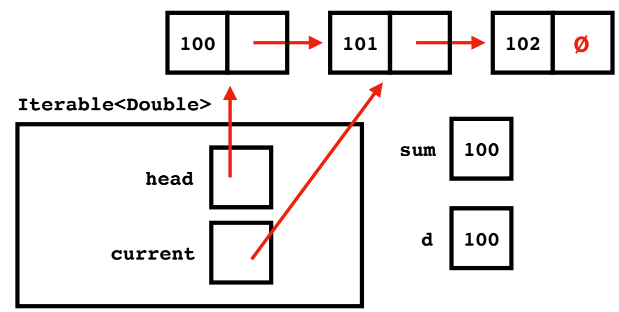

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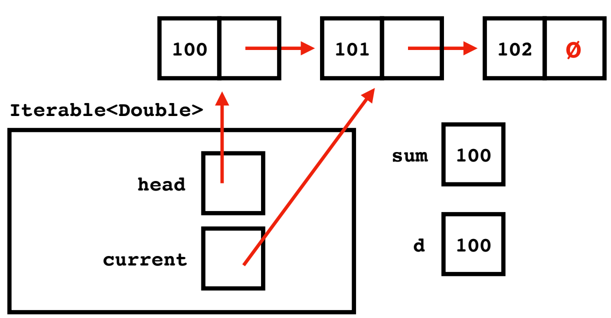

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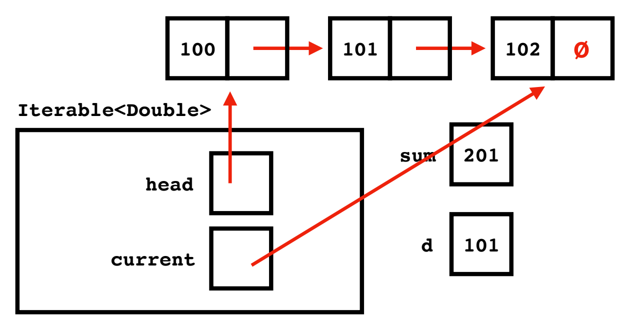

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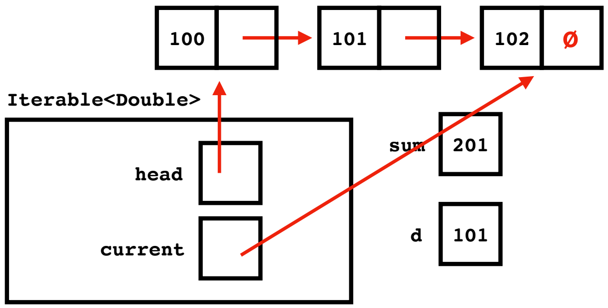

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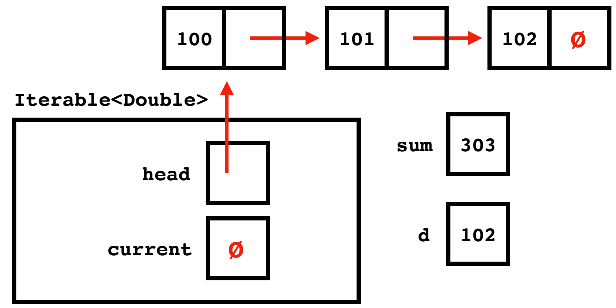

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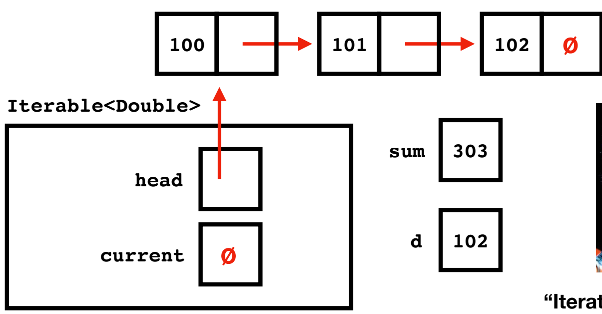

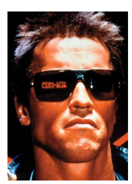

“Iteration is terminated!”

Efficient searching: binary search

Binary search

100	101	322	365	423	478	499	504
0	1	2	3	4	5	6	7

Want to know **whether** the array contains the value **322**, and if so, what its **index** is.

Binary search is a **divide-and-conquer** algorithm that solves this problem.

Binary search is **fast**: in the **worst case**, it returns an answer in $O(\log_2 n)$ steps.

Binary search

100	101	322	365	423	478	499	504
0	1	2	3	4	5	6	7

Important precondition: array must be **sorted**.

Binary search

Looking for the value **322**.

100	101	322	365	423	478	499	504
0	1	2	3	4	5	6	7

Binary search

Looking for the value **322**.

100	101	322	365	423	478	499	504
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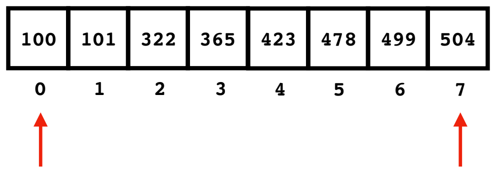
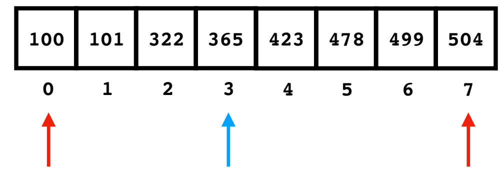


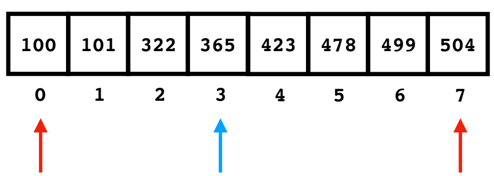
Binary search

Looking for the value **322**.



Binary search

Looking for the value **322**.

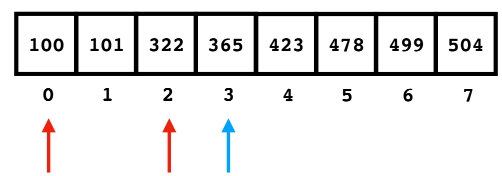


322 = 365? **no**

322 < 365? **yes**

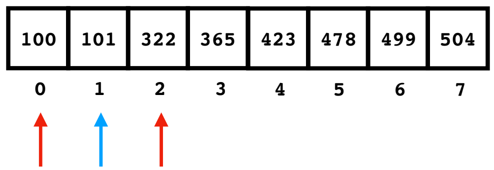
Binary search

Looking for the value **322**.



Binary search

Looking for the value **322**.



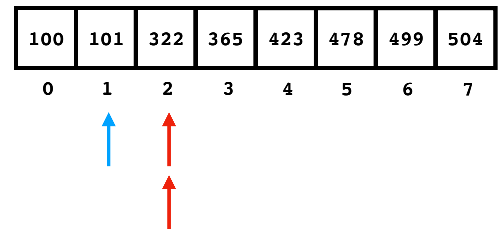
322 = 101? **no**

322 < 101? **no**

322 > 101? **yes**

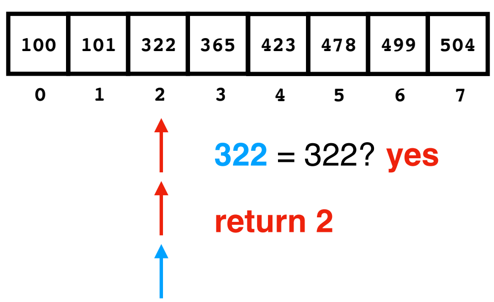
Binary search

Looking for the value **322**.



Binary search

Looking for the value **322**.



322 = 322? **yes**

return 2

Recap & Next Class

Today:

Iteration

Binary search

Next class:

Ordered structures