# CSE 250

## Data Structures

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# Day 08

# Collections, Sequences and ADTs

### Textbook Ch. 7.1, 1.7.2

# Announcements

- PA1 deadline extended to Monday
- PA1 #4 grading error was resolved
  - Any final submissions today will receive maximum bonus points

# Sequences (what are they?)

- Examples

**Fibonacci Sequence:** 1, 1, 2, 3, 5, 8, 13, 21, 34, …

**Characters in a String:** 'H', 'e', 'l', 'l', 'o', ' ', 'W', 'o', 'r', 'l', 'd'

**Lines in a File**

**People in a queue**

# Sequences (what are they?)

- Examples

**Fibonacci Sequence:** 1, 1, 2, 3, 5, 8, 13, 21, 34, …

**Characters in a String:** 'H', 'e', 'l', 'l', 'o', ' ', 'W', 'o', 'r', 'l', 'd'

**Lines in a File**

**People in a queue**

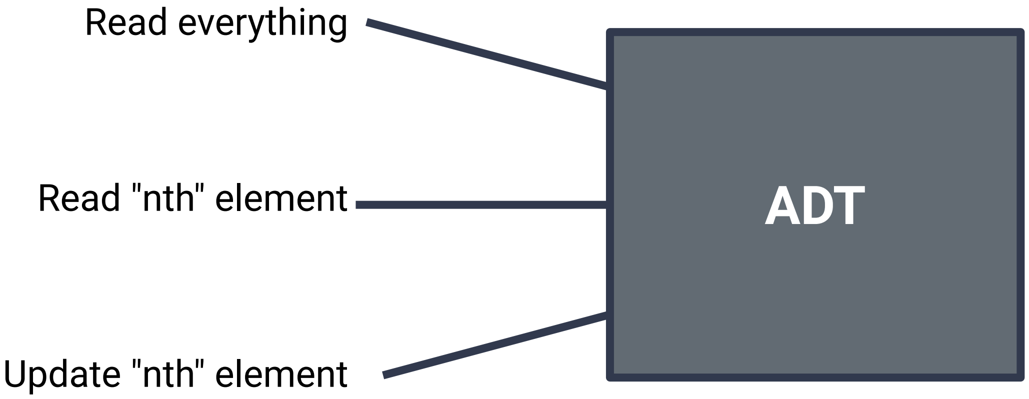
*An "ordered" collection of elements*

# Sequences (what can you do with them?)

- Enumerate every element in sequence
  - ie: print out every element, sum every element
- Get the "nth" element
  - ie: what is the first element? what is the 42nd element?
- Modify the "nth" element
  - ie: set the first element to x, set the third element to y

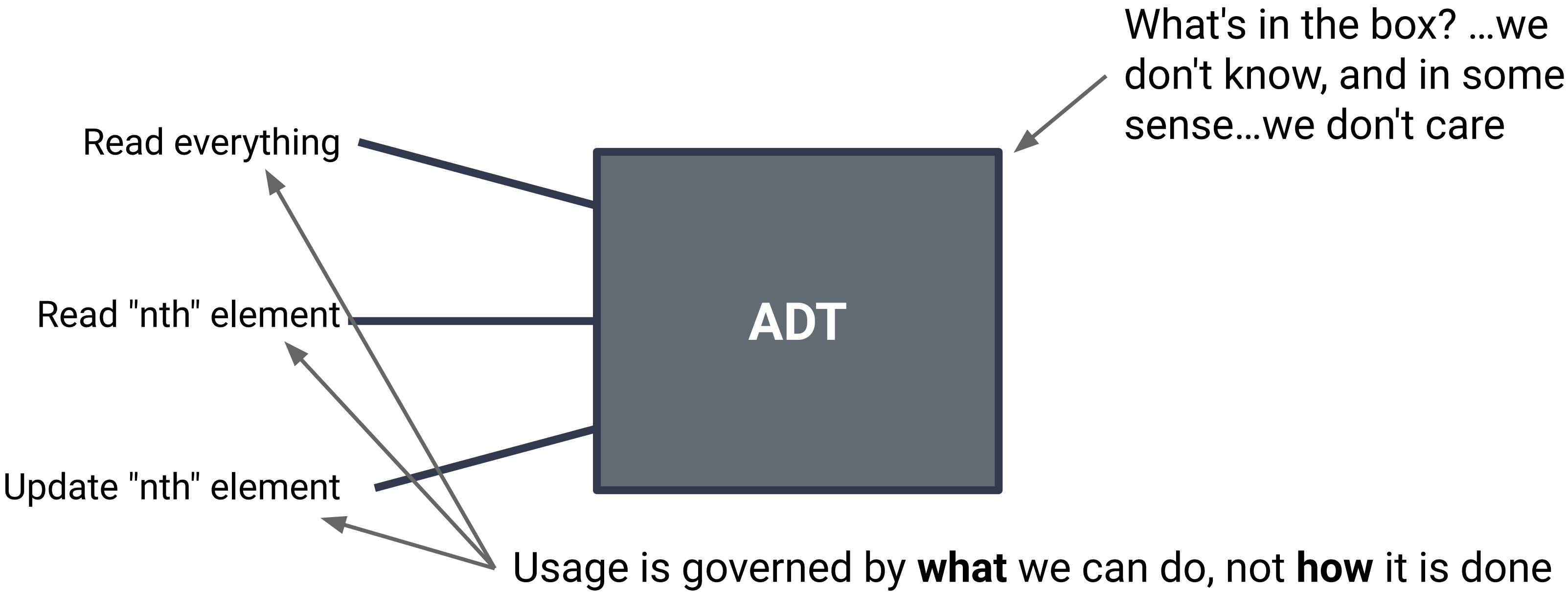
# Abstract Data Types (ADTs)

- The specification of what a data structure can do



# Abstract Data Types (ADTs)

- The specification of what a data structure can do



What's in the box? ...we don't know, and in some sense...we don't care

Usage is governed by **what** we can do, not **how** it is done

# The `Seq` ADT

**`apply(idx: Int): [A]`**

Get the element (of type **`A`**) at position **`idx`**

**`iterator: Iterator[A]`**

Get access to view all elements in the sequence, in order, once

**`length: Int`**

Count the number of elements in the seq

# The `mutable.Seq` ADT

**`apply(idx: Int): [A]`**
Get the element (of type **`A`**) at position **`idx`**

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Get access to view all elements in the sequence, in order, once

**`length: Int`**
Count the number of elements in the seq

**`insert(idx: Int, elem: A): Unit`**
Insert an element at position **`idx`** with value **`elem`**

**`remove(idx: Int): A`**
Remove the element at position **`idx`**, and return the removed value

# So...what's in the box?
# *(how do we implement it)*

# A Brief Aside on RAM (220 crossover)

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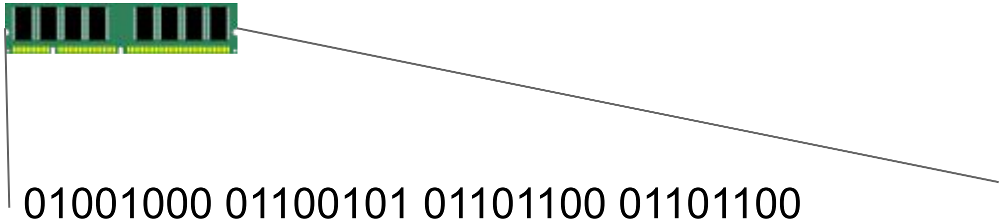
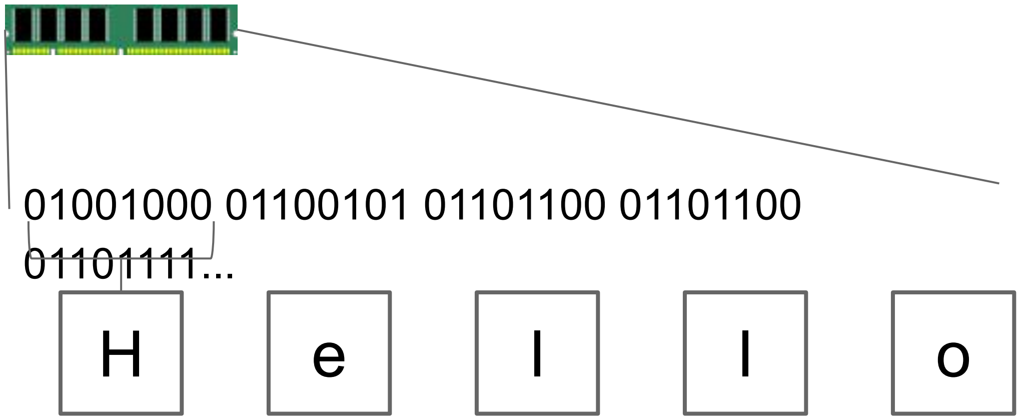


01001000 01100101 01101100 01101100 01101111...

# A Brief Aside on RAM (220 crossover)



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H e l l o

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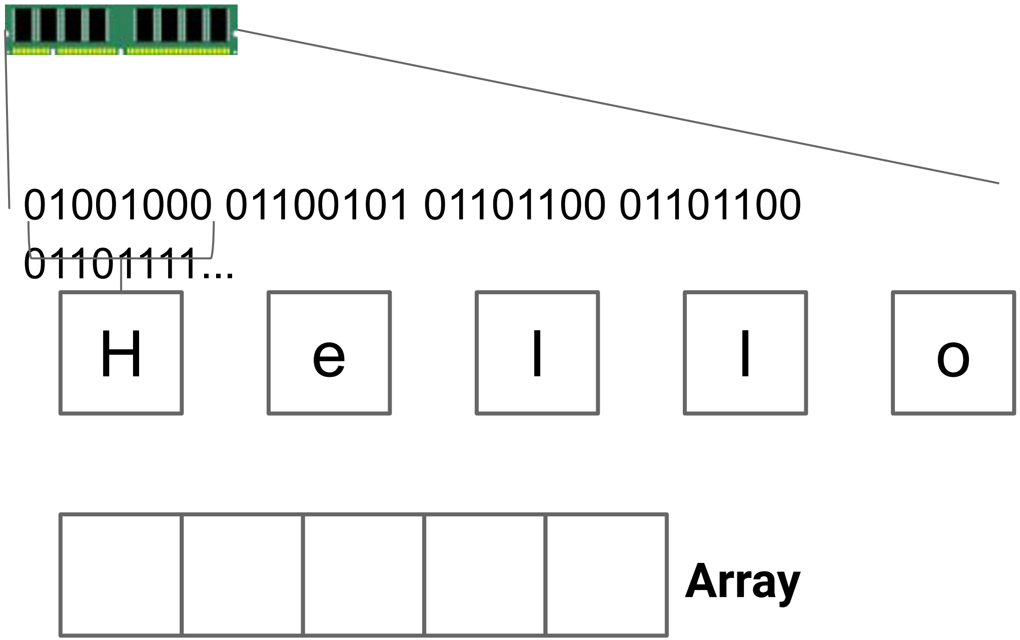

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H e l l o

Array

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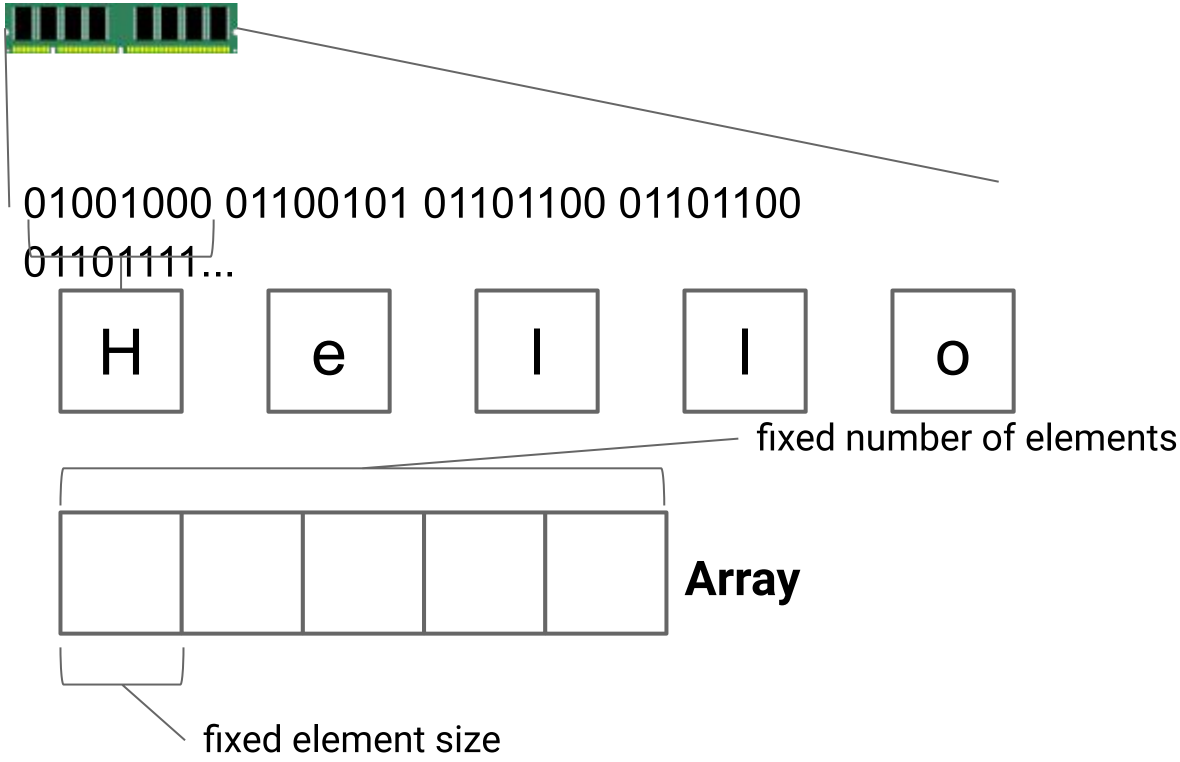

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H e l l o

fixed number of elements

**Array**

fixed element size

# RAM

**`new T()`**

Go find some unused part of memory that is big enough to fit a **`T`**, mark it as used, and return the ***address*** of that location in memory.

# RAM

`new T()`

Go find some unused part of memory that is big enough to fit a `T`, mark it as used, and return the ***address*** of that location in memory.

```
var arr = new Array[Int](50)
```

The above code allocates 50 * 4 = 200 bytes of memory
(a single Scala `Int` takes of 4 bytes in memory)

# Element Access

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If `arr` is at address *a*, where should you look for `arr(19)`?

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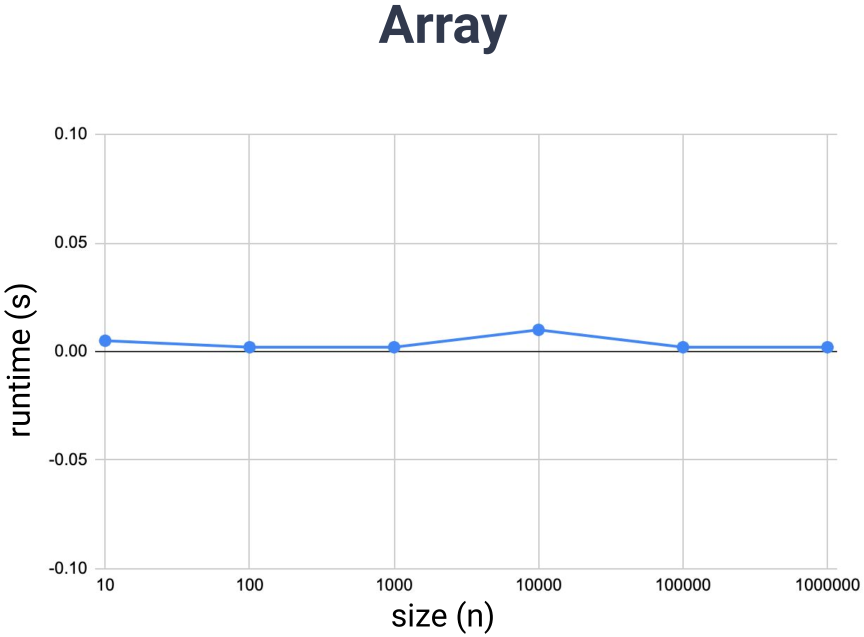
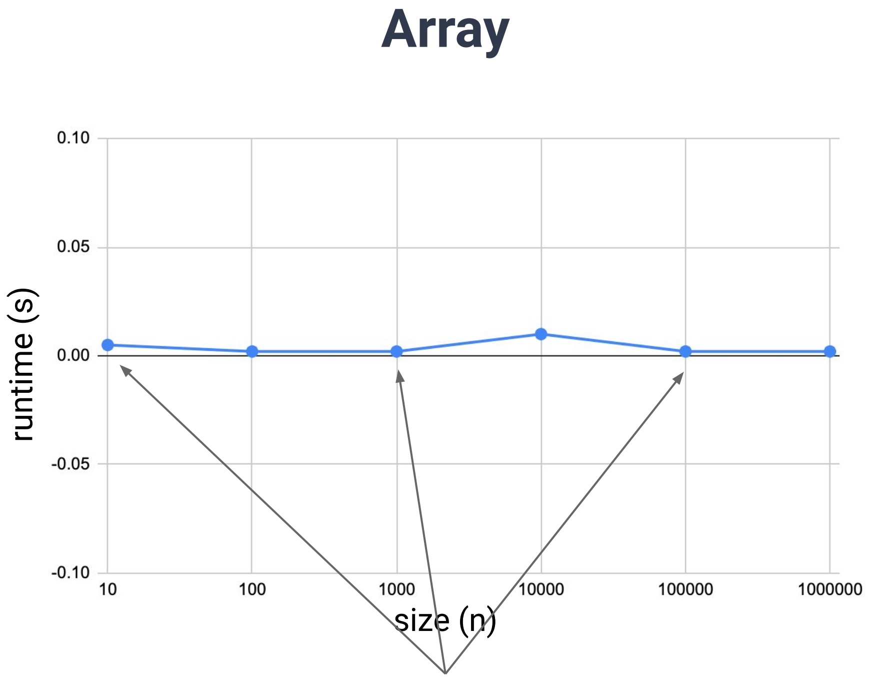
If `arr` is at address *a*, where should you look for `arr(19)`?

- *a* + 19 * 4     (a constant number of steps to compute…)

# Random Access for an Array (Lecture 04)



# Random Access for an Array (Lecture 04)



Notice how our runtime doesn't depend on the size of the array

# Element Access

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var arr = new Array[Int](50)
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If `arr` is at address *a*, where should you look for `arr(19)`?

- *a* + 19 * 4     (a constant number of steps to compute...)

What about `a(55)`?

# Element Access

```
var arr = new Array[Int](50)
```

If **`arr`** is at address *a*, where should you look for **`arr(19)`**?

- *a* + 19 * 4 (a constant number of steps to compute…)

What about **`a(55)`**?

- *a* + 55 * 4 …but that memory was not reserved for this array.
- Scala will prevent you from accessing an *out of bounds* element

# **`Array[T]:Seq[T]`**

What does an **`Array`** of *n* items of type **`T`** actually look like?

- 4 bytes for *n* (optional)
- 4 bytes for **`sizeof(T)`** (optional)
- *n* * **`sizeof(T)`** bytes for the data

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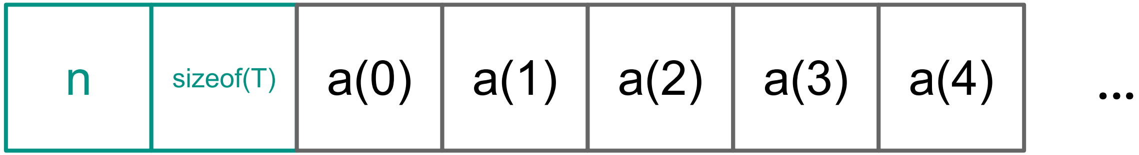

n

sizeof(T)

a(0) a(1) a(2) a(3) a(4) …

# `Array[T]:Seq[T]`

Given the structure of an **`Array`**, how would we implement the methods of the **`Seq`** ADT:

**`apply(idx: Int): [A]`**

Get the element (of type **`A`**) at position **`idx`**

**`length: Int`**

Count the number of elements in the seq

**`insert(idx: Int, elem: A): Unit`**

Insert an element at position **`idx`** with value **`elem`**

**`remove(idx: Int): A`**

Remove the element at position **`idx`**, and return the removed value

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Given the structure of an **`Array`**, how would we implement the methods of the **`Seq`** ADT:

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**`insert(idx: Int, elem: A): Unit`**

Insert an element at position **`idx`** with value **`elem`**

**`remove(idx: Int): A`**

Remove the element at position **`idx`**, and return the removed value

*Insert and remove don't make sense on arrays…*

# How can we make it mutable?

**IDEA:** What if we reserve extra space?

# `ArrayBuffer[T]:Buffer[T]`

What does an `ArrayBuffer` of *n* items of type `T` actually look like?

- 4 bytes for *n* (optional)
- 4 bytes for `sizeof(T)` (optional)
- 4 bytes for the number of **used** fields
- *n* * `sizeof(T)` bytes for the data

# ArrayBuffer[T]:Buffer[T]

What does an **`ArrayBuffer`** of *n* items of type **`T`** actually look like?

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| n | sizeof(T) | u | a(1)<br>*or*<br>None | a(2)<br>*or*<br>None | a(3)<br>*or*<br>None | a(4)<br>*or*<br>None | … |

# To be continued…