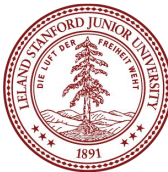


Ordered Data Structures: Grids, Queues, and Stacks

What's an example of “ordered data” that you've encountered in your life?

(Also grab a mask from the back desk if you don't have one!)

<https://pollev.com/cs106bpoll>



Examples of ordered data



Roadmap

C++ basics

User/client

vectors + grids

stacks + queues

sets + maps

Core
Tools

testing

algorithmic
analysis

recursive
problem-solving

Object-Oriented
Programming

Implementation

arrays

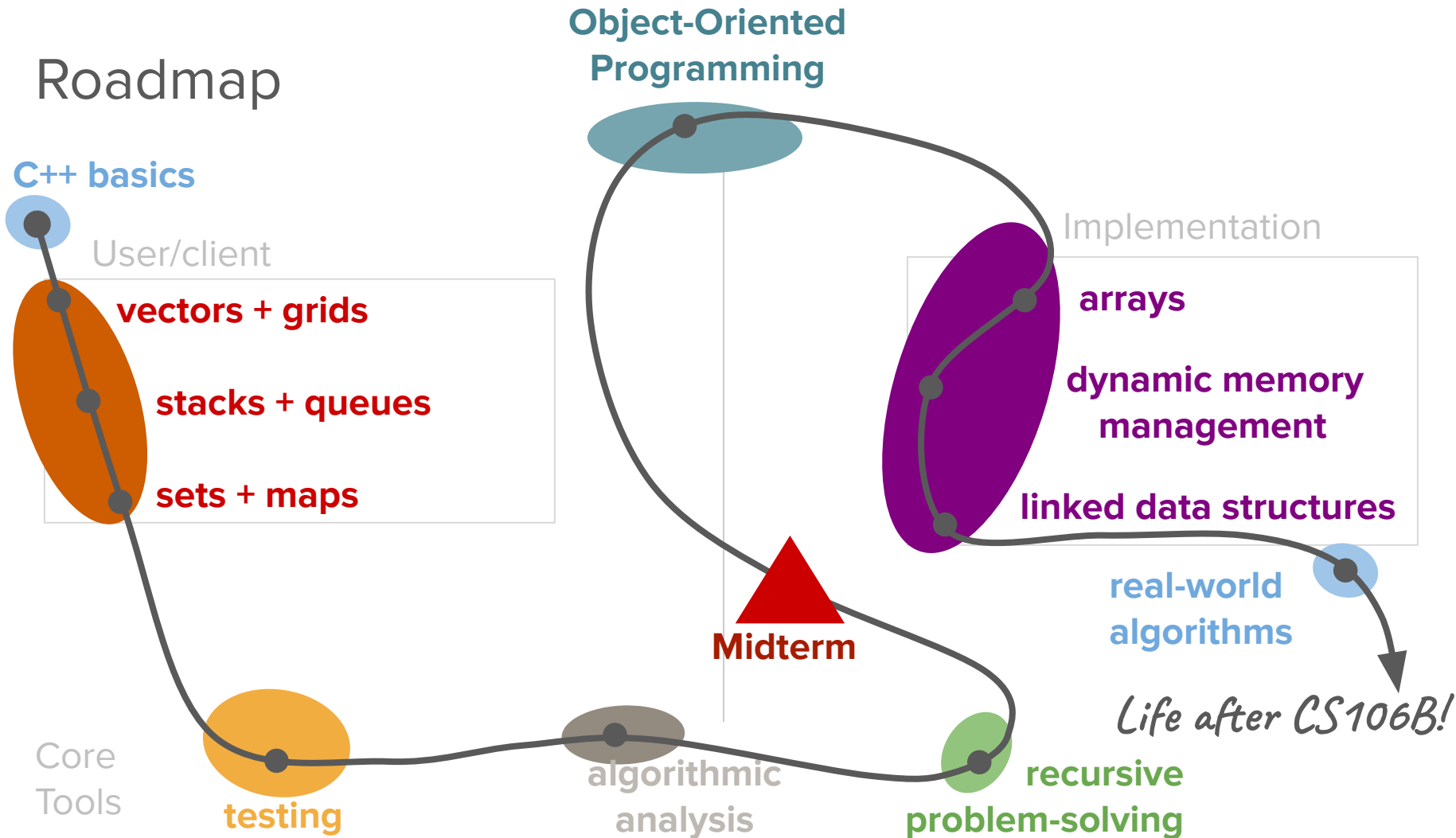
dynamic memory
management

linked data structures

real-world
algorithms

Life after CS106B!

Midterm



Roadmap

C++ basics



User/client

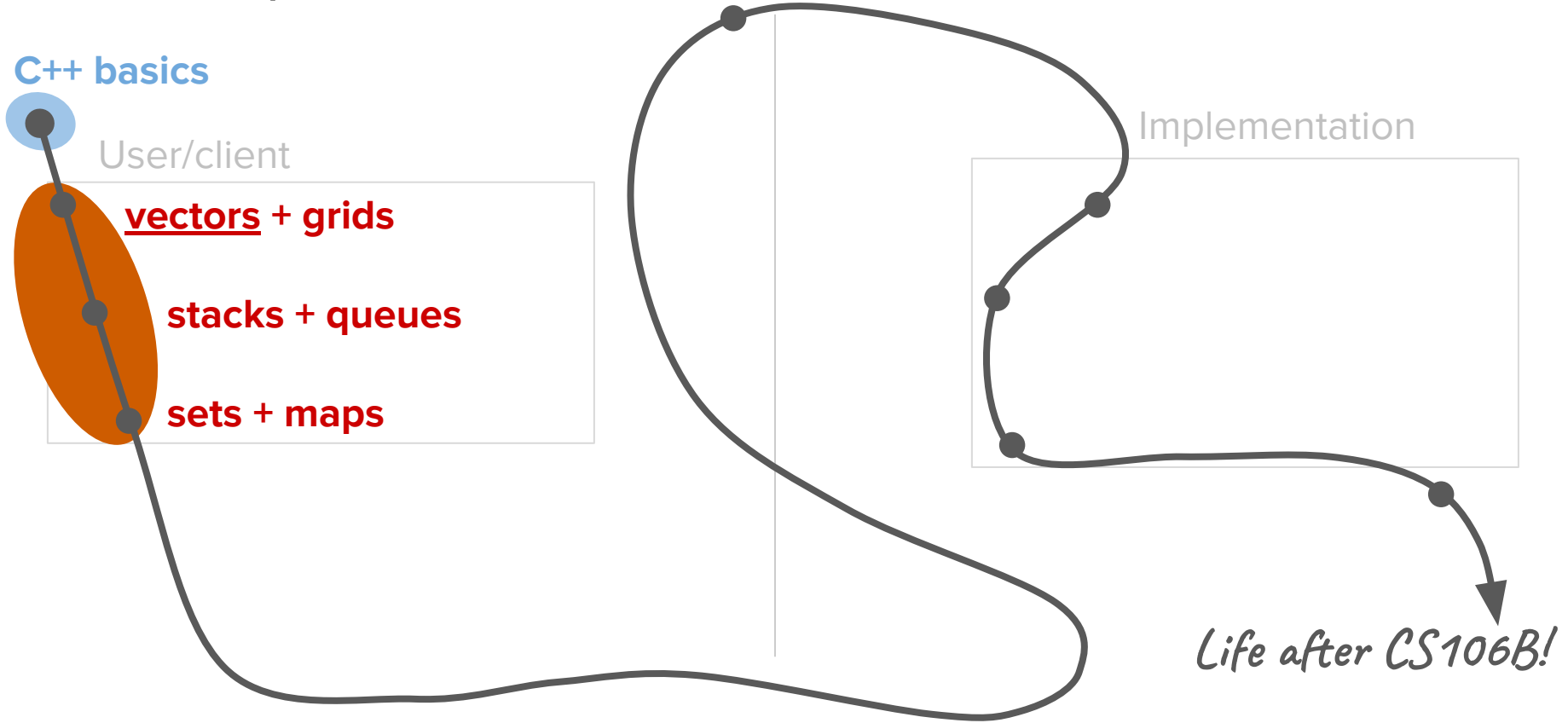
vectors + grids

stacks + queues

sets + maps

Implementation

Life after CS106B!



Roadmap

C++ basics



User/client

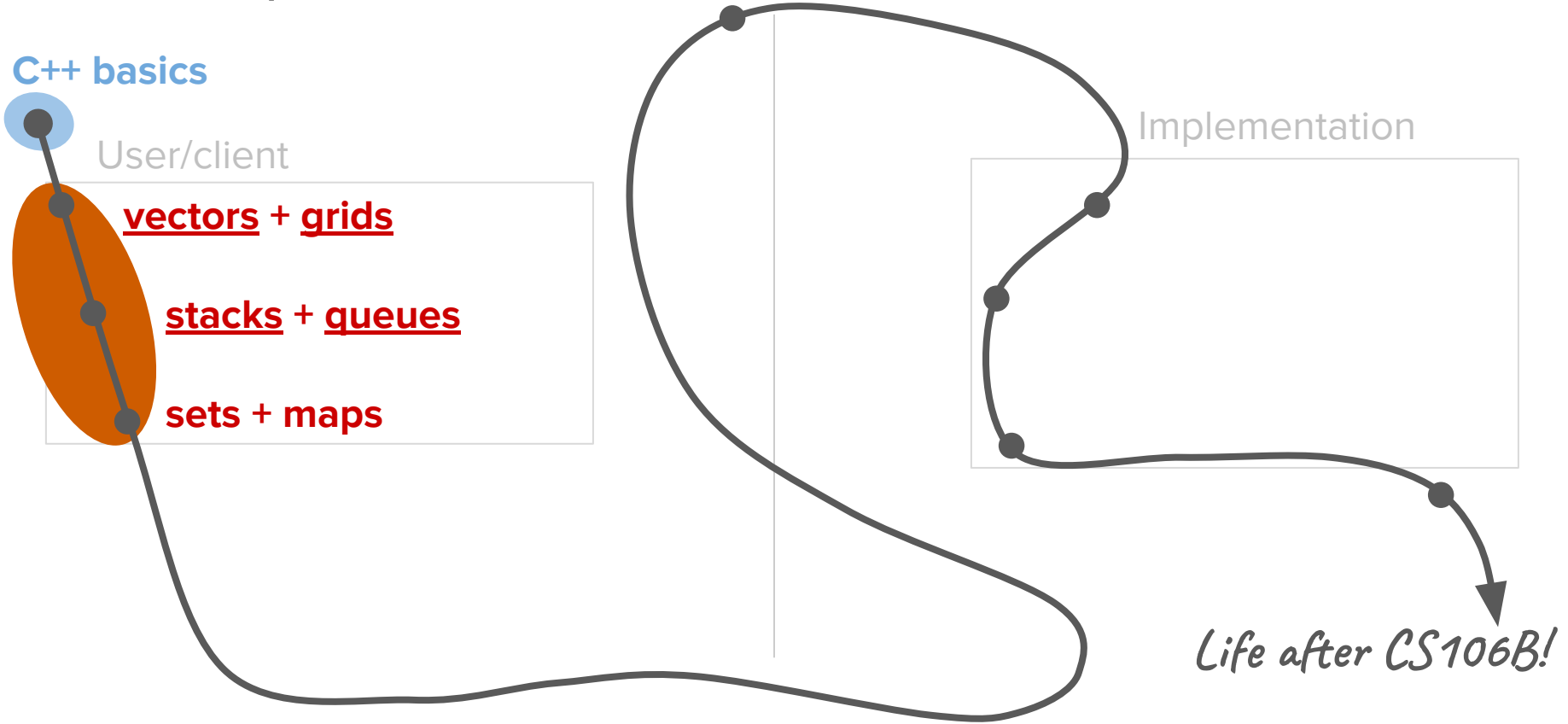
vectors + grids

stacks + queues

sets + maps

Implementation

Life after CS106B!



The image shows the exterior of a 'The Container Store' at night. The building has a light blue, horizontally-ribbed facade. The store's name is displayed in large, blue, 3D block letters with white outlines, angled upwards from left to right. Below the sign is a long, narrow horizontal window that is illuminated from within. The ground floor features large glass windows and doors, also brightly lit, revealing interior displays of various storage containers and home goods. The sky above is a clear, dark blue.

The Container Store

“Map” of the “container store”

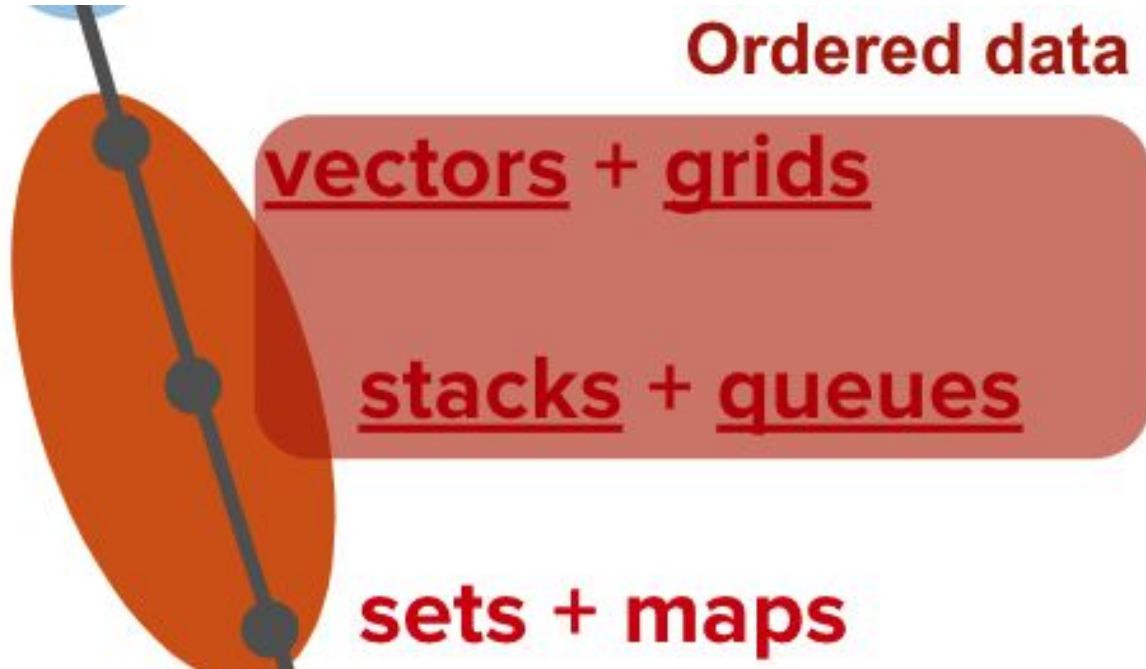


vectors + grids

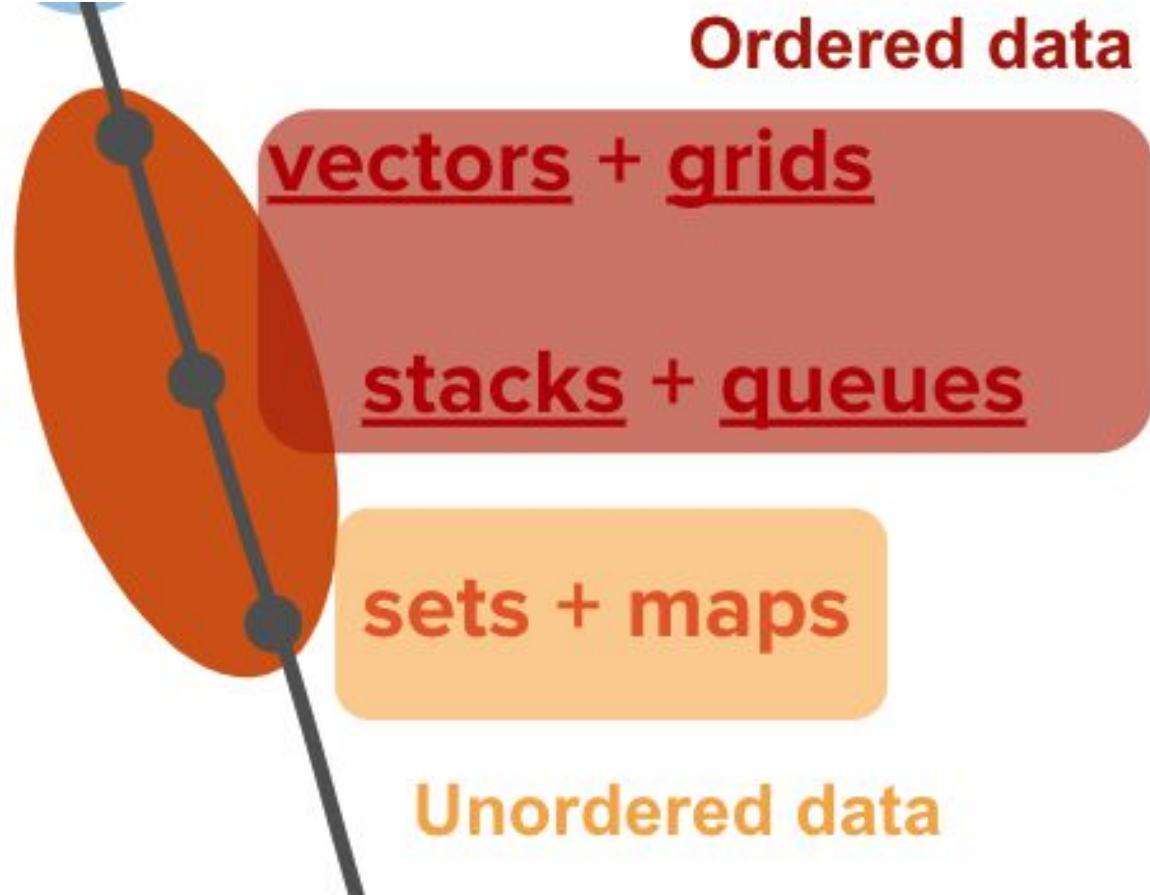
stacks + queues

sets + maps

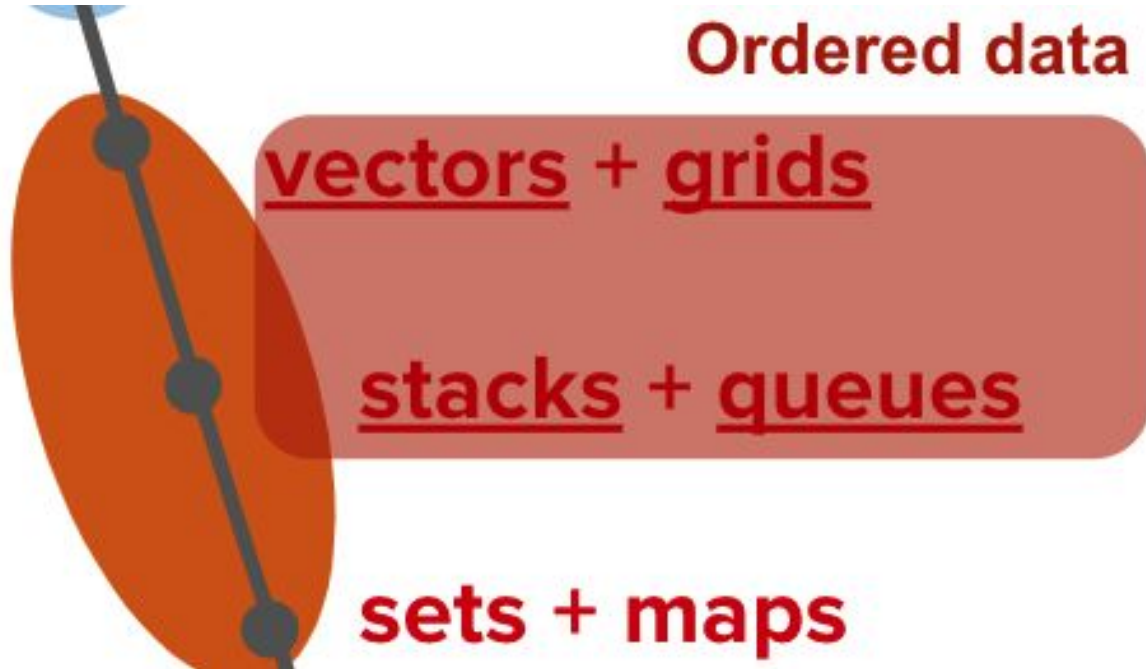
“Map” of the “container store”



“Map” of the “container store”



“Map” of the “container store”



Today's question

When is it appropriate to use different types of ordered data structures?

Today's topics

1. Review

2. Grids

[2.5 **GridLocation** + structs]

3. Queues

4. Stacks

Review

(vectors and pass-by-reference)

Containers, or Abstract Data Types, or Data Structures

- Containers are powerful abstractions that allow programmers to store data in predictable, organized ways.
- As the user, you get certain guarantees about the functionality of the container & the properties of the data inside that specific container.
- You can use ADTs **without understanding the underlying implementation!**
 - That's abstraction!

Note: while we specifically
use ADTs from the Stanford
C++ libraries, these
principles transcend
language boundaries

Stanford
^
The Container Store

The image shows the exterior of a 'The Container Store' building at night. The building has a light blue facade with a grid of rectangular panels. A large, illuminated sign for 'The Container Store' is mounted on the upper part of the facade. The sign consists of the word 'The' in a smaller font, followed by 'Container Store' in a larger, bold font, all in a light blue color. Above the word 'The', the word 'Stanford' is written in a red, italicized font, with a small red caret (^) pointing down towards the 'The'. The building has a series of windows along the top edge, and the interior lights are visible through the glass doors at the bottom.

Vectors

A photograph of a store aisle, likely a craft or home goods store, filled with shelves of colorful storage bins and containers. The bins are arranged in rows on wooden shelving units. The colors include teal, green, pink, red, and black. Some bins have handles and are stacked. The word "Vectors" is overlaid in large, white, sans-serif font across the center of the image. The background shows more shelves and a whiteboard on the left.

Our first ADT: **Vectors**

- At a high level, a vector is an ordered collection of elements of the same type that can grow and shrink in size.
- Each element in the vector has a specific location, or index.
 - 0, 1, 2 ...
- All elements in a vector must be of the same type.
- Vectors are flexible when it comes to the number of elements they can store. You can easily add and remove elements, and vectors also know their current size.

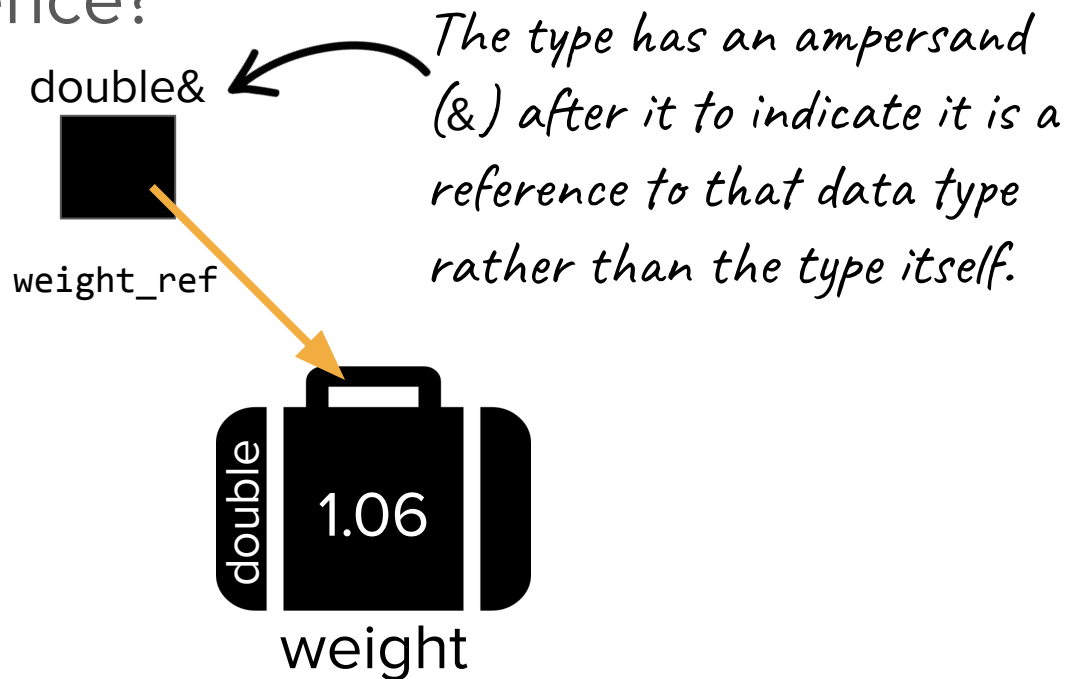
Stanford "Vector" vs STL "vector"

What you want to do	Stanford Vector<int>	std::vector<int>
Create a new, empty vector	Vector<int> vec;	std::vector<int> vec;
Create a vector with <i>n</i> copies of 0	Vector<int> vec(n);	std::vector<int> vec(n);
Create a vector with <i>n</i> copies of a value <i>k</i>	Vector<int> vec(n, k);	std::vector<int> vec(n, k);
Add a value <i>k</i> to the end of a vector	vec.add(k);	vec.push_back(k);
Remove all elements of a vector	vec.clear();	vec.clear();
Get the element at index <i>i</i>	int k = vec[i];	int k = vec[i]; (does not bounds check)
Check size of vector	vec.size();	vec.size();
Loop through vector by index <i>i</i>	for (int i = 0; i < vec.size(); ++i) ...	for (std::size_t i = 0; i < vec.size(); ++i) ...
Replace the element at index <i>i</i>	vec[i] = k;	vec[i] = k; (does not bounds check)

Credit: [CS106L](#)

What exactly is a reference?

- References look like this:




References have names and types, just like regular variables.

Types you know in C++

- `int`
- `char`
- `double`
- `string`
- `bool`
- `long`
- `Vector<int>`
- `Vector<char>`
- ...

- `int&`
- `char&`
- `double&`
- `string&`
- `bool&`
- `long&`
- `Vector<int>&`
- `Vector<char>&`
- ...



The type has an ampersand (&) after it to indicate it is a reference to that data type rather than the type itself.

When we use references

- To allow helper functions to edit data structures in other functions
 - But why don't we just return a copy of the data structure?
- To avoid making new copies of large data structures in memory
 - Passing data structures by reference makes your code more efficient!
- References also provide a workaround for **multiple return values**
 - Your function can take in multiple pieces of information by reference and modify them all. In this way you can "return" both a modified Vector and some auxiliary piece of information about how the structure was modified. This makes it as if your function is returning two updated pieces of information to the function that called it!

Definition

pass by value

When a parameter is passed into a function, the new variable *stores a copy* of the passed in value in memory

“Pass in a copy”

Definition

pass by reference

When a parameter is passed into a function, the new variable stores a *reference* to the passed in value, which allows you to directly edit the original value

*“Pass in the original under
a different name”*

In C++...

- By default, parameters are **passed by value**.
- You can **choose** to **pass by reference** in C++ by using references.

In C++...

- By default, parameters are **passed by value**.
- You can **choose** to **pass by reference** in C++ by using references.

In Python or Java?

In C++...

- By default, parameters are **passed by value**.
- You can **choose** to **pass by reference** in C++ by using references.

In Python or Java?

Seems like a straightforward question!

A meme featuring a man with glasses (Moss) looking serious. The word "FALSE" is written in large, bold, white letters with a black outline across the top of his face. Three statements about Java are overlaid on the image: "Java is only pass by value" on the left, "Java object variables are simply references" on the right, and "Java passes references by value" at the bottom center.

FALSE

“Java is only
pass by value”

“Java object
variables are
simply
references”

“Java passes
references by
value”

In C++...

- By default, parameters are **passed by value**.
- You can **choose** to **pass by reference** in C++ by using references.

In Python or Java?

Because of the way the languages are designed, pass-by-value and pass-by-reference mean slightly different things in c++ vs. python vs. java.

In C++...

- By default, parameters are **passed by value**.
- You can **choose** to **pass by reference** in C++ by using references.

In Python or Java?

By default, Python and Java treat some things as pass by value, others as pass by reference.

In C++...

- By default, parameters are **passed by value**.
- You can **choose** to **pass by reference** in C++ by using references.
- You **should** pass by value for primitives (int, string)*
- You **should** pass by reference for large data structures*

*in general

In Python or Java?

By default, Python and Java treat some things as pass by value, others as pass by reference.

Trace problem

[5-minute Ed workspace!]



KITCHEN + PANTRY

Push the
Limits of What
One Pantry
Can Hold.

Grids

What is a grid?

- A 2D array, defined with a particular width and height

a0	a1	a2
b0	b1	b2
c0	c1	c2

What is a grid?

- A 2D array, defined with a particular width and height



We say array instead of vector here because the dimensions are established when the grid is created (but vectors can change their sizes).

a0	a1	a2
b0	b1	b2
c0	c1	c2

What is a grid?

- A 2D array, defined with a particular width and height
- Useful for spreadsheets, game boards, etc.

a0	a1	a2
b0	b1	b2
c0	c1	c2

What is a grid?

- A 2D array, defined with a particular width and height
- Useful for spreadsheets, game boards, etc.
- Three ways to declare a grid
 - `Grid<type> gridName;`
 - `Grid<type> gridName(numRows, numCols);`
 - `Grid<type> gridName = {{r0c0, r0c1, r0c2}, {r1c0, r1c1, r1c2},...};`

a0	a1	a2
b0	b1	b2
c0	c1	c2

What is a grid?

- A 2D array, defined with a particular width and height
- Useful for spreadsheets, game boards, etc.
- Three ways to declare a grid
 - `Grid<type> gridName;`

```
Grid<int> board;  
board.resize(3, 3);
```

0	0	0
0	0	0
0	0	0

What is a grid?

- A 2D array, defined with a particular width and height
- Useful for spreadsheets, game boards, etc.
- Three ways to declare a grid
 - `Grid<type> gridName;`

0	0	0
0	0	0
0	0	0

```
Grid<int> board;  
board.resize(3, 3);
```

← If you declare a board with no initialization, you must resize it or reassign it before using it. Resizing will fill it with default values for that type.

What is a grid?

- A 2D array, defined with a particular width and height
- Useful for spreadsheets, game boards, etc.
- Three ways to declare a grid
 - `Grid<type> gridName;`

```
Grid<int> board;  
board.resize(3, 3);  
board[0][0] = 2;  
board[1][0] = 6;
```

2	0	0
6	0	0
0	0	0

What is a grid?

- A 2D array, defined with a particular width and height
- Useful for spreadsheets, game boards, etc.
- Three ways to declare a grid
 - `Grid<type> gridName(numRows, numCols);`

```
Grid<int> board(3, 3);  
board[0][0] = 2;  
board[1][0] = 6;
```

2	0	0
6	0	0
0	0	0

What is a grid?

- A 2D array, defined with a particular width and height
- Useful for spreadsheets, game boards, etc.
- Three ways to declare a grid
 - `Grid<type> gridName = {{r0c0, r0c1, r0c2}, {r1c0, r1c1, r1c2},...};`

`Grid<int> board = {{2,0,1}, {6,0,2}, {5,4,3}};`

2	0	1
6	0	2
5	4	3

What is a grid?

- A 2D array, defined with a particular width and height
- Useful for spreadsheets, game boards, etc.
- Three ways to declare a grid
 - `Grid<type> gridName;`
 - `Grid<type> gridName(numRows, numCols);`
 - `Grid<type> gridName = {{r0c0, r0c1, r0c2}, {r1c0, r1c1, r1c2},...};`
- **Jenny, why can't we use a combination of Vectors to simulate a 2D matrix?**

a0	a1	a2
b0	b1	b2
c0	c1	c2

What is a grid?

- A 2D array, defined with a particular width and height
- Useful for spreadsheets, game boards, etc.
- Three ways to declare a grid
 - `Grid<type> gridName;`
 - `Grid<type> gridName(numRows, numCols);`
 - `Grid<type> gridName = {{r0c0, r0c1, r0c2}, {r1c0, r1c1, r1c2},...};`
- Jenny, why can't we use a combination of Vectors to simulate a 2D matrix?
 - **You can! But a Grid is easier!**

a0	a1	a2
b0	b1	b2
c0	c1	c2

Grid methods

- The following methods are part of the grid collection and can be useful:
 - **grid.numRows()**: Returns the number of rows in the grid.
 - **grid.numCols()**: Returns the number of columns in the grid.
 - **grid[i][j]**: selects the element in the **i**th row and **j**th column.
 - **grid.resize(rows, cols)**: Changes the dimensions of the grid and re-initializes all entries to their default values.
 - **grid.inBounds(row, col)**: Returns **true** if the specified row, column position is in the grid, **false** otherwise.
- For the exhaustive list, check out the [Stanford Grid documentation](#).

Grid methods

- The following methods are part of the grid collection and can be useful:
 - `grid.numRows()`: Returns the number of rows in the grid.
 - `grid.numCols()`: Returns the number of columns in the grid.
 - `grid[i][j]`: selects the element in the **i**th row and **j**th column.
 - `grid.resize(rows, cols)`: Changes the dimensions of the grid and re-initializes all entries to their default values.
 - `grid.inBounds(row, col)`: Returns **true** if the specified row, column position is in the grid, **false** otherwise.
- For the exhaustive list, check out the [Stanford Grid documentation](#).

How to traverse a Grid

```
void printGrid(Grid<char>& grid) {  
    for(int r = 0; r < grid.numRows(); r++) {  
        for(int c = 0; c < grid.numCols(); c++) {  
            cout << grid[r][c];  
        }  
        cout << endl;  
    }  
}
```

How to traverse a Grid

```
void printGrid(Grid<char>& grid) {  
    for(int r = 0; r < grid.numRows(); r++) {  
        for(int c = 0; c < grid.numCols(); c++) {  
            cout << grid[r][c];  
        }  
        cout << endl;  
    }  
}
```

'y'	'e'
'e'	'h'
'a'	'w'

} What is the output of this function called on the provided grid going to be?

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A. yeehaw

B. yea
ehw

C. ye
eh
aw

D. None of the above

What is the output of printGrid going to be for this provided grid?

A

B

C

D

None of the above



How to traverse a Grid

```
void printGrid(Grid<char>& grid) {  
    for(int r = 0; r < grid.numRows(); r++) {  
        for(int c = 0; c < grid.numCols(); c++) {  
            cout << grid[r][c];  
        }  
        cout << endl;  
    }  
}
```

Output:

Variables:

r = 0

c = 0

'y'	'e'
'e'	'h'
'a'	'w'

How to traverse a Grid

```
void printGrid(Grid<char>& grid) {  
    for(int r = 0; r < grid.numRows(); r++) {  
        for(int c = 0; c < grid.numCols(); c++) {  
            cout << grid[r][c];  
        }  
        cout << endl;  
    }  
}
```

Output:
y

Variables:

r = 0

c = 0

'y'	'e'
'e'	'h'
'a'	'w'

How to traverse a Grid

```
void printGrid(Grid<char>& grid) {  
    for(int r = 0; r < grid.numRows(); r++) {  
        for(int c = 0; c < grid.numCols(); c++) {  
            cout << grid[r][c];  
        }  
        cout << endl;  
    }  
}
```

Output:
ye

Variables:

r = 0

c = 1

'y'	'e'
'e'	'h'
'a'	'w'

How to traverse a Grid

```
void printGrid(Grid<char>& grid) {  
    for(int r = 0; r < grid.numRows(); r++) {  
        for(int c = 0; c < grid.numCols(); c++) {  
            cout << grid[r][c];  
        }  
        cout << endl;  
    }  
}
```

Output:

ye
e

Variables:

r = 1

c = 0

'y'	'e'
'e'	'h'
'a'	'w'

How to traverse a Grid

```
void printGrid(Grid<char>& grid) {  
    for(int r = 0; r < grid.numRows(); r++) {  
        for(int c = 0; c < grid.numCols(); c++) {  
            cout << grid[r][c];  
        }  
        cout << endl;  
    }  
}
```

Output:

ye
eh

Variables:

r = 1

c = 1

'y'	'e'
'e'	'h'
'a'	'w'

How to traverse a Grid

```
void printGrid(Grid<char>& grid) {  
    for(int r = 0; r < grid.numRows(); r++) {  
        for(int c = 0; c < grid.numCols(); c++) {  
            cout << grid[r][c];  
        }  
        cout << endl;  
    }  
}
```

Output:

ye
eh
a

Variables:

r = 2

c = 0

'y'	'e'
'e'	'h'
'a'	'w'

How to traverse a Grid

```
void printGrid(Grid<char>& grid) {  
    for(int r = 0; r < grid.numRows(); r++) {  
        for(int c = 0; c < grid.numCols(); c++) {  
            cout << grid[r][c];  
        }  
        cout << endl;  
    }  
}
```

Output:

ye
eh
aw

Variables:

r = 2

c = 1

'y'	'e'
'e'	'h'
'a'	'w'




Common pitfalls when using Grids

- Don't forget to specify what data type is stored in your grid




NO: **Grid board;**

YES: **Grid<char> board;**




- Like Vectors and other ADTs, Grids should be passed by reference when used as function parameters
- Watch your variable ordering with Grid indices! Rather than using **i** and **j** as indices to loop through a grid, it's better to use **r** for rows and **c** for columns.
 - `[r][c]`
- Unlike in other languages, you can only access cells (not individual rows).
grid[0] → doing this will cause an error!

	1	2	3	4	5	6	7	8	9
A									
B									
C									
D									
E									
F									
G									
H									
I									

Battleship uses
a grid!




	0	1	2	3	4	5	6	7	8
0									
1									
2									
3									
4									
5									
6									
7									
8									

Battleship uses
a grid!

	0	1	2	3	4	5	6	7	8
0									
1									
2									
3									
4									
5									
6									
7									
8									

Battleship uses
a grid!

*What if we want to keep track of
all cells where a ship is present?*

	0	1	2	3	4	5	6	7	8
0									
1									
2									
3									
4									
5									
6									
7									
8									

Battleship uses
a grid!

*Jenny, wouldn't it be nice to label
each grid location as a index like
we did with vectors?*

Structs + **GridLocation**

Definition

struct

A way to bundle different types of information in C++ – like creating a custom data structure.

The **GridLocation** struct

- A pre-defined struct in the Stanford C++ libraries that makes it more convenient to store Grid locations:

```
struct GridLocation {  
    int row;  
    int col;  
}
```

struct definition

The **GridLocation** struct

- A pre-defined struct in the Stanford C++ libraries that makes it more convenient to store Grid locations:

```
struct GridLocation {  
    int row;  
    int col;  
}
```

} *struct members
(these can be
different types)*

The **GridLocation** struct

- A pre-defined struct in the Stanford C++ libraries that makes it more convenient to store Grid locations
- To declare a struct, you can either assign each of its members separately or assign it when it's created:

```
GridLocation origin = {0, 0};
```

```
GridLocation origin;  
origin.row = 0;  
origin.col = 0;
```

```
struct GridLocation {  
    int row;  
    int col;  
}
```

The **GridLocation** struct

- A pre-defined struct in the Stanford C++ libraries that makes it more convenient to store Grid locations
- To declare a struct, you can either assign each of its members separately or assign it when it's created:

```
GridLocation origin = {0, 0};
```

You can access members in a struct using the dot notation (no parentheses after the member name!)






```
GridLocation origin;  
origin.row = 0;  
origin.col = 0;
```

```
struct GridLocation {  
    int row;  
    int col;  
}
```

```
Vector<GridLocation> shipCells;  
GridLocation smallLeft = {0,5};  
GridLocation smallRight = {0,6};  
shipCells.add(smallLeft);  
shipCells.add(smallRight);
```

VS.

```
Vector<int> rowIndices;  
Vector<int> colIndices;  
rowIndices.add(0);  
rowIndices.add(0);  
colIndices.add(5);  
colIndices.add(6);
```

	0	1	2	3	4	5	6	7	8
0									
1									
2									
3									
4									
5									
6									
7									
8									

As an exercise on your own: Think about how you would answer the question “Is there a ship at (4, 3)?” for each of the different representations (with and without GridLocation structs).

The **GridLocation** struct

- A pre-defined struct in the Stanford C++ libraries that makes it more convenient to store Grid locations
- To declare a struct, you can either assign each of its members separately or assign it when it's created:

```
struct GridLocation {  
    int row;  
    int col;  
}
```

```
GridLocation origin = {0, 0};
```

```
GridLocation origin;  
origin.row = 0;  
origin.col = 0;
```

***NOTE:** Grids are not made up of GridLocation structs! GridLocations are just a convenient way to store an index (single cell or a path of cells) within a Grid.*

The **GridLocation** struct

- A pre-defined struct in the Stanford C++ libraries that makes it more convenient to store Grid locations
- To declare a struct, you can either assign each of its members separately or assign it when it's created:

```
GridLocation origin = {0, 0};
```

```
GridLocation origin;  
origin.row = 0;  
origin.col = 0;
```

*We can use a **GridLocation** to access a particular cell in the grid: **grid[origin]***

```
struct GridLocation {  
    int row;  
    int col;  
}
```

Announcements

Announcements

- Assignment 1 is due Friday, July 1, at 11:59pm PDT.
 - If you didn't get to attend YEAH on Monday, we highly recommend watching the recorded session for getting started (will be posted soon)!
 - We also recorded an extra video on [SimpleTest!](#)
- Sections start tomorrow! Go to cs198.stanford.edu to double-check your assigned time.
 - If you missed the signup deadline by Sunday, please go to the CS198 website to manually sign up for a section with an available slot.
- Assignment 2 will be released by the end of the day on Friday.



Queues

What is a queue?

- Like a real queue/line!
- **F**irst person **I**n is the **F**irst person **O**ut (FIFO)
 - When you remove (dequeue) people from the queue, you remove them from the front of the line.
- Last person in is the last person served
 - When you insert (enqueue) people into a queue, you insert them at the back (the end of the line)



Queue methods

- A queue must implement at least the following functions:
 - **enqueue(value)** - place an entity onto the back of the queue
 - **dequeue()** - remove an entity from the front of the queue and return it
 - **peek()** - look at the entity at the front of the queue, but don't remove it
 - **isEmpty()** - a boolean value, true if the queue is empty, false if it has at least one element.
 - note: if you try to dequeue() or peek() an empty queue, you will get a runtime error
- For the exhaustive list, check out the [Stanford Queue documentation](#).

Queue example

```
Queue<int> line;           // {}, empty queue
line.enqueue(42);         // {42}
line.enqueue(-3);         // {42, -3}
line.enqueue(17);         // {42, -3, 17}
cout << line.dequeue() << endl; // 42 (line is {-3, 17})
cout << line.peek() << endl;   // -3 (line is {-3, 17})
cout << line.dequeue() << endl; // -3 (line is {17})
```

// You can also create a queue using:

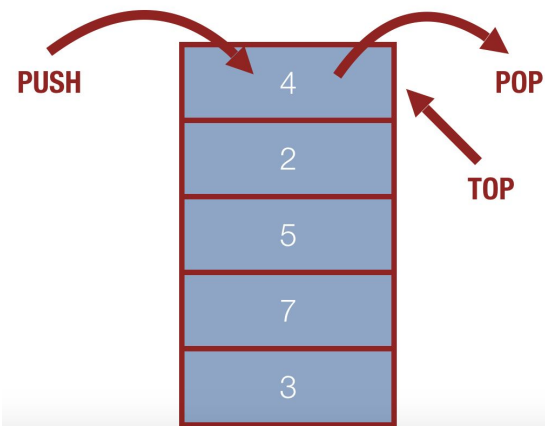
```
Queue<int> line = {42, -3, 17};
```

The image shows a dense grid of shelves filled with various storage containers. The containers are organized by color in vertical columns: white, dark blue, red, yellow, light blue, green, and orange. Some shelves also hold patterned boxes. Each container has a small white label. The word "Stacks" is centered in the middle of the image in a large, white, sans-serif font.

Stacks

What is a stack?

- Modeled like an actual stack (of pancakes)
- Only the top element in a stack is accessible.
 - The **L**ast item **I**n is the **F**irst one **O**ut. (LIFO)
- The push, pop, and top operations are the only operations allowed by the stack ADT.



The **L**ast item **I**n is the **F**irst one **O**ut.
(LIFO)



Stack methods

- A stack is an abstract data type with the following behaviors/functions:
 - **push(value)** - place an entity onto the top of the stack
 - **pop()** - remove an entity from the top of the stack and return it
 - **peek()** - look at the entity at the top of the stack, but don't remove it
 - **isEmpty()** - a boolean value, true if the stack is empty, false if it has at least one element. (Note: a runtime error occurs if a **pop()** or **peek()** operation is attempted on an empty stack.)
- For the exhaustive list, check out the [Stanford Stack documentation](#).

Stack example

```
Stack<string> wordStack;           // {}, empty stack
wordStack.push("Kylie");           // {"Kylie"}
wordStack.push("Jenny");           // {"Kylie", "Jenny"}
wordStack.push("Trip");            // {"Kylie", "Jenny", "Trip"}
cout << wordStack.pop() << endl;   // "Trip"
cout << wordStack.peek() << endl;  // "Jenny"
cout << wordStack.pop() << endl;   // "Jenny" (stack is {"Kylie"})
```

// You can also create a stack using:

```
Stack<string> wordStack = {"Kylie", "Jenny", "Trip"};
// the "top" is the rightmost element
```

The **F**irst item **I**n is the
First one **O**ut.
(FIFO)



Queue

The **L**ast item **I**n is the
First one **O**ut.
(LIFO)



Stack

The **F**irst item **I**n is the
First one **O**ut.
(FIFO)



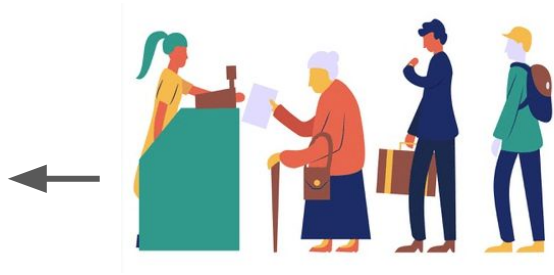
Queue

The **F**irst item **I**n is the
First one **O**ut.
(FIFO)



Queue

The **F**irst item **I**n is the
First one **O**ut.
(FIFO)



Queue

The **F**irst item **I**n is the
First one **O**ut.
(FIFO)



Queue

The **F**irst item **I**n is the
First one **O**ut.
(FIFO)



Queue

The **F**irst item **I**n is the
First one **O**ut.
(FIFO)



Queue

The **L**ast item **I**n is the
First one **O**ut.
(LIFO)



Stack

The **L**ast item **I**n is the
First one **O**ut.
(LIFO)



Stack

The **L**ast item **I**n is the
First one **O**ut.
(LIFO)



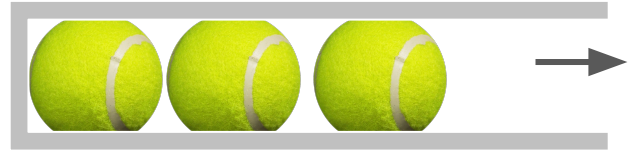
Stack

The **L**ast item **I**n is the
First one **O**ut.
(LIFO)



Stack

The **L**ast item **I**n is the
First one **O**ut.
(LIFO)



Stack

The **L**ast item **I**n is the
First one **O**ut.
(LIFO)



Stack

The **L**ast item **I**n is the
First one **O**ut.
(LIFO)



Stack

The **L**ast item **I**n is the
First one **O**ut.
(LIFO)



Stack

Tradeoffs with queues and stacks (vs. other ADTs)

- What are some downsides to using a queue/stack?
 - No random access. You get the front/top, or nothing.
 - No side-effect-free traversal — you can only iterate over all elements in the structure by removing previous elements first.
 - No easy way to search through a queue/stack.
- What are some benefits?
 - Useful for lots of problems — many real-world problems can be solved with either a LIFO or FIFO model
 - Very easy to build one from an array such that access is guaranteed to be fast. (We'll talk more about arrays later in the quarter, and we'll talk about what "fast" access means later this week.)
 - Where would you have the top of the stack be if you build one using a Vector? Why would that be fast?

Queue + Stack patterns

Common patterns and pitfalls with stacks and queues

Idioms:

1. Emptying a stack/queue (both would empty one at a time)

Idiom 1: Emptying a queue/stack

```
Queue<int> queueIdiom1;
```

```
// produce: {1, 2, 3, 4, 5, 6}
```

```
for (int i = 1; i <= 6; i++) {  
    queueIdiom1.enqueue(i);  
}
```

```
while (!queueIdiom1.isEmpty()) {  
    cout << queueIdiom1.dequeue() << " ";  
}  
cout << endl;
```

```
// prints: 1 2 3 4 5 6
```

Idiom 1: Emptying a queue/stack

```
Queue<int> queueIdiom1;
```

```
// produce: {1, 2, 3, 4, 5, 6}
```

```
for (int i = 1; i <= 6; i++) {  
    queueIdiom1.enqueue(i);  
}
```

```
while (!queueIdiom1.isEmpty()) {  
    cout << queueIdiom1.dequeue() << " ";  
}  
cout << endl;
```

```
// prints: 1 2 3 4 5 6
```

```
Stack<int> stackIdiom1;
```

```
// produce: {1, 2, 3, 4, 5, 6}
```

```
for (int i = 1; i <= 6; i++) {  
    stackIdiom1.push(i);  
}
```

```
while (!stackIdiom1.isEmpty()) {  
    cout << stackIdiom1.pop() << " ";  
}  
cout << endl;
```

```
// prints: 6 5 4 3 2 1
```

Common patterns and pitfalls with stacks and queues

Idioms:

1. Emptying a stack/queue
2. Iterating over and modifying a stack/queue → only calculate the size once before looping

Idiom 2: Iterating over and modifying queue/stack

```
Queue<int> queueIdiom2 = {1,2,3,4,5,6};
```

```
int origQSize = queueIdiom2.size();
for (int i = 0; i < origQSize; i++) {
    int value = queueIdiom2.dequeue();
    // re-enqueue even values
    if (value % 2 == 0) {
        queueIdiom2.enqueue(value);
    }
}
cout << queueIdiom2 << endl;

// prints: {2, 4, 6}
```

Idiom 2: Iterating over and modifying queue/stack

```
Queue<int> queueIdiom2 = {1,2,3,4,5,6};
```

```
int origQSize = queueIdiom2.size();
for (int i = 0; i < origQSize; i++) {
    int value = queueIdiom2.dequeue();
    // re-enqueue even values
    if (value % 2 == 0) {
        queueIdiom2.enqueue(value);
    }
}
cout << queueIdiom2 << endl;
```

```
// prints: {2, 4, 6}
```

```
Stack<int> stackIdiom2 = {1,2,3,4,5,6};
Stack<int> result;
```

```
int origSSize = stackIdiom2.size();
for (int i = 0; i < origSSize; i++) {
    int value = stackIdiom2.pop();
    // add even values to result
    if (value % 2 == 0) {
        result.push(value);
    }
}
cout << result << endl;
```

```
// prints: {6, 4, 2}
```

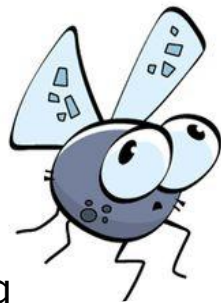
Common patterns and pitfalls with stacks and queues

Idioms:

1. Emptying a stack/queue
2. Iterating over and modifying a stack/queue → only calculate the size once before looping

Common bugs:

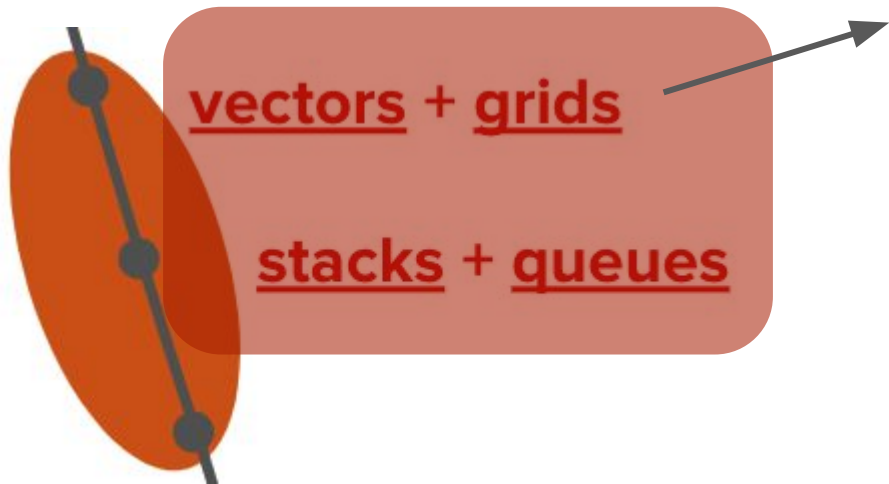
- If you edit the ADT within a loop, don't use **.size()** in the loop's conditions! The size changes while the loop runs.
- Unlike with queues, you can't iterate over a stack without destroying it → think about when it might be beneficial to make a copy instead.



ADTs summary (so far)

Summary so far:

Ordered data structures



Lets you access elements with indices

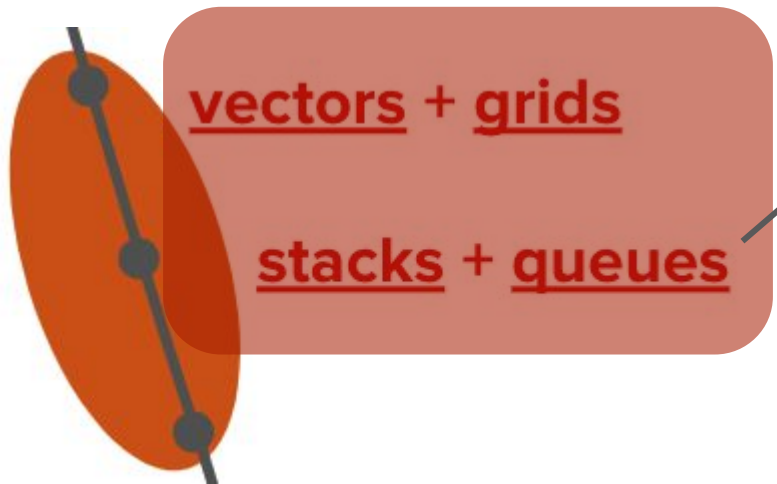
Vectors (1D)

Grids (2D)

- Easily able to search through all elements
- Can use the indices as a way of accessing specific cells
 - `myVec[1]`
 - `myGrid[2][4]`

Summary so far:

Ordered data structures



Lets you access to one element at a time (no indices)

Queues (FIFO)

Stacks (LIFO)

- Constrains the way you can insert and access data
 - Can only get top/first
 - No random access
- More efficient for solving specific LIFO/FIFO problems

Ordered ADTs with accessible indices

Types:

- Vectors (1D)
- Grids (2D)

Traits:

- Easily able to search through all elements
- Can use the indices as a way of structuring the data

Ordered ADTs where you can't access elements by index

Types:

- Queues (FIFO)
- Stacks (LIFO)

Traits:

- Constrains the way you can insert and access data
- More efficient for solving specific LIFO/FIFO problems

Attendance ticket:

<https://tinyurl.com/lec5cs106b>

Please don't send this link to students who are not here. It's on your honor!

What ADT should we
use?

For each of the tasks, pick which ADT is best suited for the task:

- The undo button in a text editor
- Jobs submitted to a printer that can also be cancelled
- LallR requests
- Your browsing history
- Google spreadsheets
- Call centers (“your call will be handled by the next available agent”)

Vectors

Grids

Queues

Stacks

For each of the tasks, pick which ADT is best suited for the task:

- **The undo button in a text editor**
- Jobs submitted to a printer that can also be cancelled
- LallR requests
- Your browsing history
- Google spreadsheets
- Call centers (“your call will be handled by the next available agent”)

Vectors

Grids

Queues

Stacks

For each of the tasks, pick which ADT is best suited for the task:

- The undo button in a text editor
- **Jobs submitted to a printer that can also be cancelled**
- L₁ cache requests
- Your browsing history
- Google spreadsheets
- Call centers (“your call will be handled by the next available agent”)

Vectors

Grids

(Queues)

Stacks

For each of the tasks, pick which ADT is best suited for the task:

- The undo button in a text editor
- Jobs submitted to a printer that can also be cancelled

Vectors

Grids

Queues

Stacks

- **LaIR requests**
- Your browsing history
- Google spreadsheets
- Call centers (“your call will be handled by the next available agent”)

For each of the tasks, pick which ADT is best suited for the task:

- The undo button in a text editor
- Jobs submitted to a printer that can also be cancelled
- LallR requests
- **Your browsing history**
- Google spreadsheets
- Call centers (“your call will be handled by the next available agent”)

Vectors

Grids

Queues

Stacks

For each of the tasks, pick which ADT is best suited for the task:

- The undo button in a text editor
- Jobs submitted to a printer that can also be cancelled
- LallR requests
- Your browsing history
- **Google spreadsheets**
- Call centers (“your call will be handled by the next available agent”)

Vectors

Grids

Queues

Stacks

For each of the tasks, pick which ADT is best suited for the task:

- The undo button in a text editor
- Jobs submitted to a printer that can also be cancelled
- LALR requests
- Your browsing history
- Google spreadsheets
- **Call centers (“your call will be handled by the next available agent”)**

Vectors

Grids

Queues

Stacks

What's next?

Roadmap

C++ basics

User/client

vectors + grids

stacks + queues

sets + maps

Core
Tools

testing

algorithmic
analysis

recursive
problem-solving

Object-Oriented
Programming

Implementation

arrays

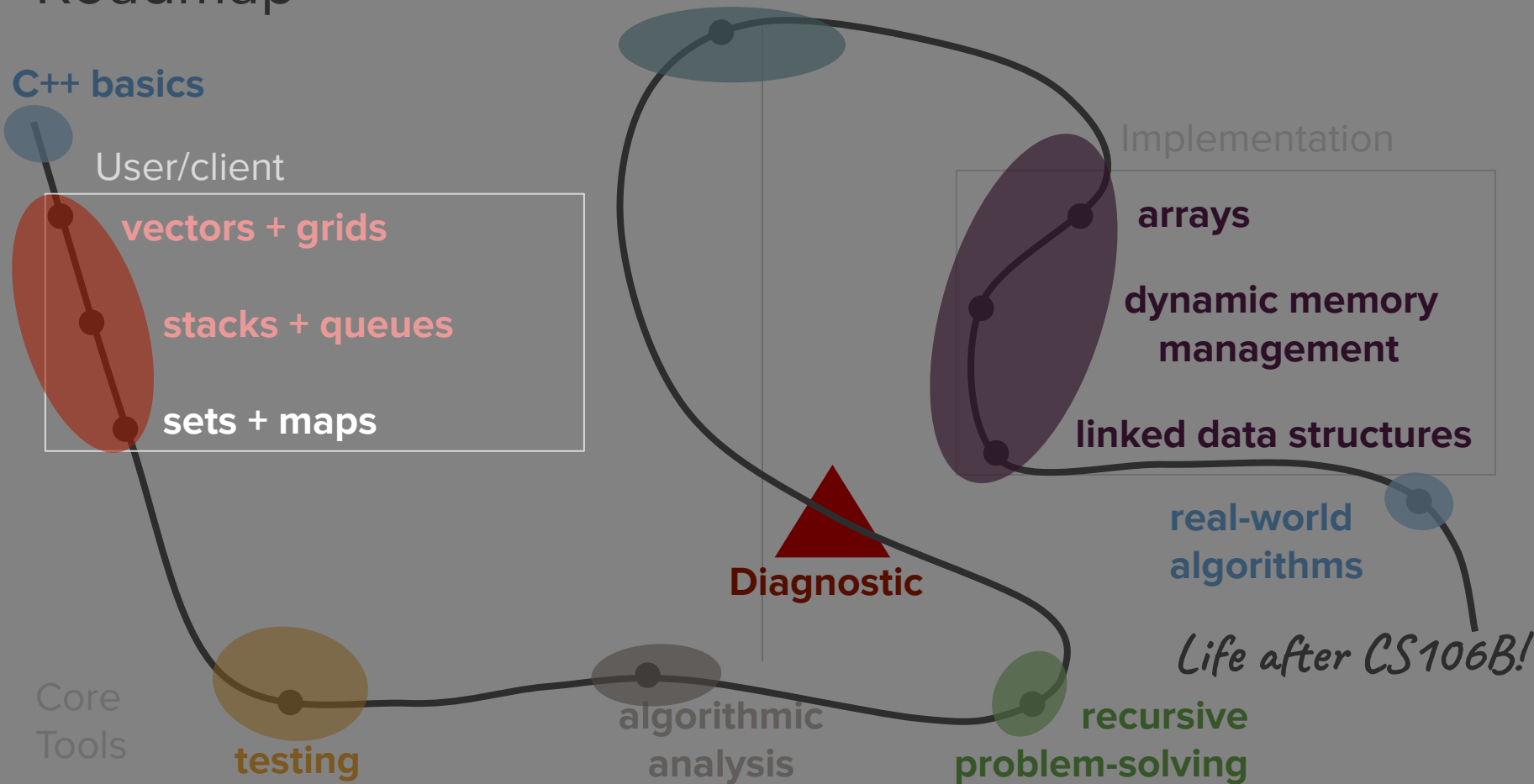
dynamic memory
management

linked data structures

real-world
algorithms

Life after CS106B!

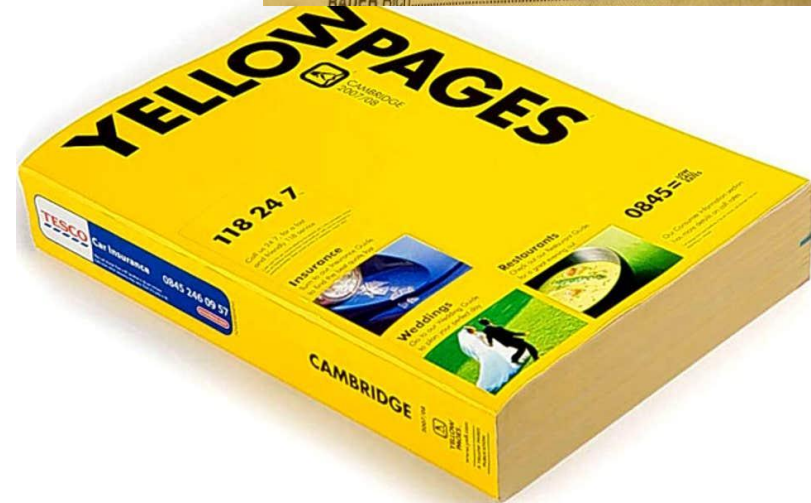
Diagnostic



Unordered ADTs: Sets and Maps

A page from a Yellow Pages directory showing a list of businesses and their phone numbers. The page is titled "Names and Numbers.com" and "Wood River Valley". The list includes businesses like BATES Paul, BATES Steve, BATES VICKY - INTERIOR MOTIVES, BATHUM Roy, BATMAN, BATT Jeffrey & Camille, BATTERSBY Patricia, BAUER Charlotte, BAUER CHARLOTTE LINDBERG, Radiance Skin Care Studio, BAUER Matt, and BAUER Rich. The phone numbers are listed next to each business name.

Business Name	Phone Number
BATES Paul 118 Willow Rd.	Hailey 788-1206
BATES Steve 105 Audubon Pl.	Hailey 788-6222
BATES VICKY - INTERIOR MOTIVES PO Box 1820	Sun Valley 788-5950
BATHUM Roy 235 Spur Ln.	Ketchum 726-0722
BATMAN	See West Adam 726-7494
BATT Jeffrey & Camille	Ketchum 726-8896
BATTERSBY Patricia 116 Ritchie Dr.	Hailey 788-4279
BAUER Charlotte 621 Northstar Dr.	
BAUER CHARLOTTE LINDBERG	Hailey 578-2214
Radiance Skin Care Studio	Hailey 578-0703
BAUER Matt 3340 Woodside Blvd.	720-0165
BAUER Rich	



Nested data structures 🤯

