CSE 331
Software Design & Implementation

Winter 2023

Section 6 – HW6, Path-Finding with BFS, and Parsing

Administrivia

- HW5-part 2 due tonight!
  - We also will be reviewing the pieces from part 1, so make sure to fix things according to your feedback
- HW6 due next Thursday
- Make sure to tag your submissions correctly!
  - Commit and push everything first, then after you push the final commit, create the right tag and push that
- Any questions?

Agenda

- HW5 Reminders
- Overview of HW6
- Breadth-first search (BFS)
- Parsing a file in comma-separated-values (CSV) format
- Test scripts and the new hw6 test driver

HW5 Reminders

- Your graph should not sort anything!
  - This includes TreeMaps/TreeSets

- Your graph should not be printing anything
  - Or returning Strings for the client to print or parse (except `toString()`)

- Your graph should not have any pathfinding

- Your graph should not have generic node/edge labels – just Strings for now

More HW5 Reminders

- You should use a **`boolean`** flag to disable expensive parts of your **`checkRep()`** (see last week's section slides)

- Graph operations should be reasonably quick
  - E.g. adding a node shouldn't be **`O(n)`**

- Make sure that your Graph ADT is in the right directory

- Look at your **`staff_tests.md`** file on Gradescope
  - This is viewable after your submission is uploaded (even before feedback is released)

- Any questions?

HW6: The MarvelPaths program

- You were the implementor but now are the client of your graph ADT!
- MarvelPaths is a command-line program you write to find how two Marvel characters are connected through comic-book co-appearances
- Using a large dataset in comma-separated-values (CSV) format
  - Each entry is a particular appearance of a character in a comic book
- Dataset processed to initialize the social-network graph
- Main functionality is finding shortest path in this social network

Outline of the assignment

0. Understand the dataset (**`marvel.csv`**) and CSV format

1. Complete **`MarvelParser`** class to read CSV-formatted files

2. Implement graph initialization in **`MarvelPaths`** class

3. Implement path-finding via BFS in **`MarvelPaths`** class

4. Write suites of scripts tests and of implementation tests
   - Implement **`MarvelTestDriver`** for new test-script commands

5. Write **`main`** method in **`MarvelPaths`** for command-line usage

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3. **Implement path-finding via BFS in `MarvelPaths` class**

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Breadth-first search

- Breadth-first search (BFS) is an algorithm for path-finding
  - Works just as well on directed and undirected graphs
  - Often used to discover connectivity in a graph

- Finds a path with the least number of edges
  - Recall that a path is a chain of edges, like $\langle a, b\rangle$, $\langle b, c\rangle$, $\langle c, d\rangle$
  - Ignores edge labels, so not used for weighted graphs

- Often mentioned alongside depth-first search (DFS)
  - BFS looks "wide" whereas DFS looks "deep"
  - DFS can't promise to find the shortest path

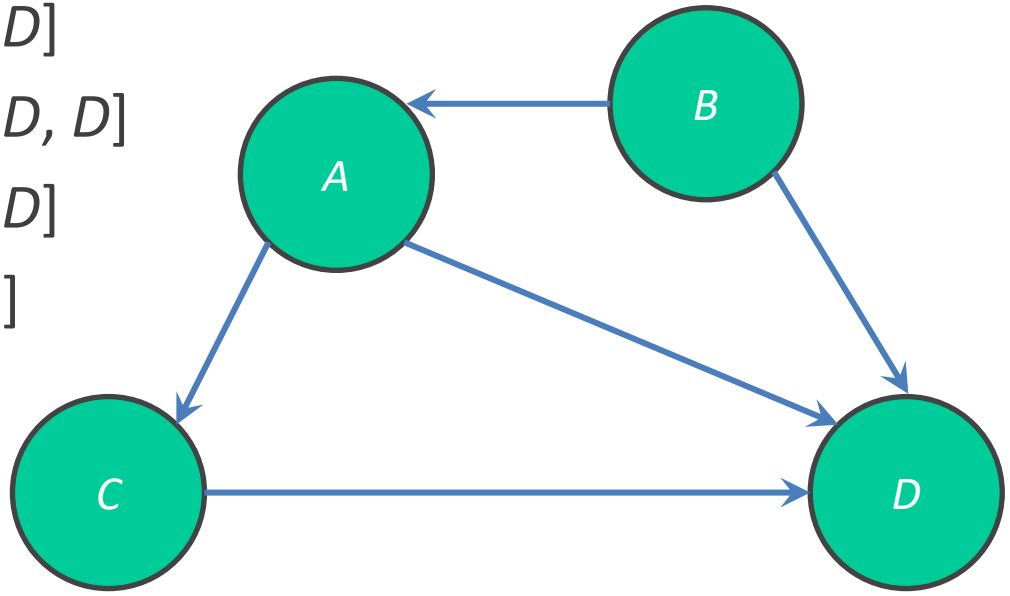
The BFS algorithm – first attempt **(incorrect)**

```
push start node onto a queue

while queue is not empty:
  pop node N off queue
  if N is goal node:
    return true
  else:
    for each node O in children of N:
        push O onto queue

return false
```

BFS: example on a simple graph

push start	Q = [*A*]
pop *A*	Q = []
push *C*	Q = [*C*]
push *D*	Q = [*D*, *C*]
pop *C*	Q = [*D*]
push *D*	Q = [*D*, *D*]
pop *D*	Q = [*D*]
pop *D*	Q = []
return false	

start = *A*
goal = *B*

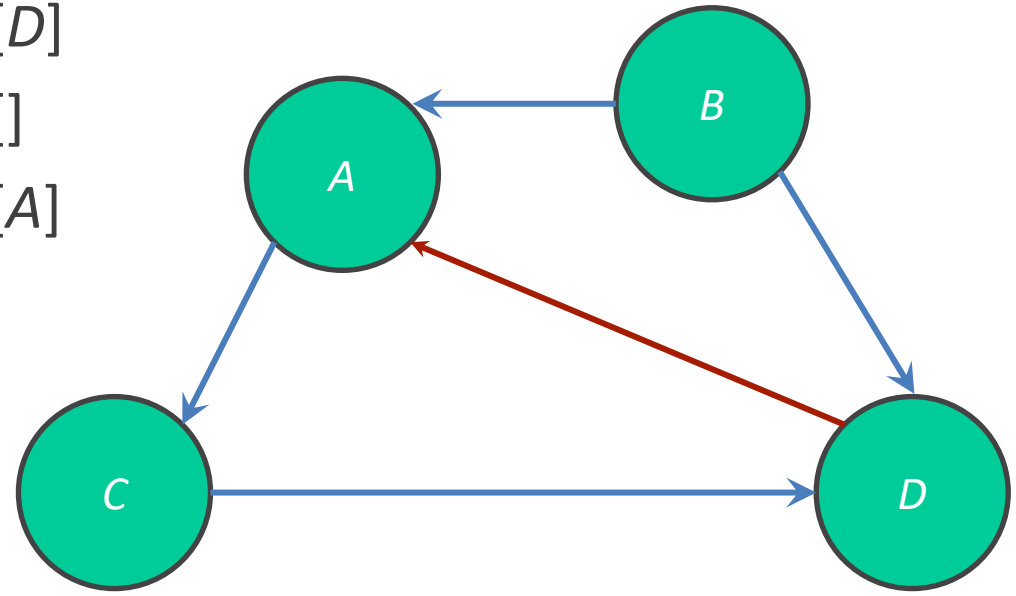


BFS: example on a cyclic graph

push start	Q = [*A*]
pop *A*	Q = []
push *C*	Q = [*C*]
pop *C*	Q = []
push *D*	Q = [*D*]
pop *D*	Q = []
push *A*	Q = [*A*]

INFINITE LOOP!

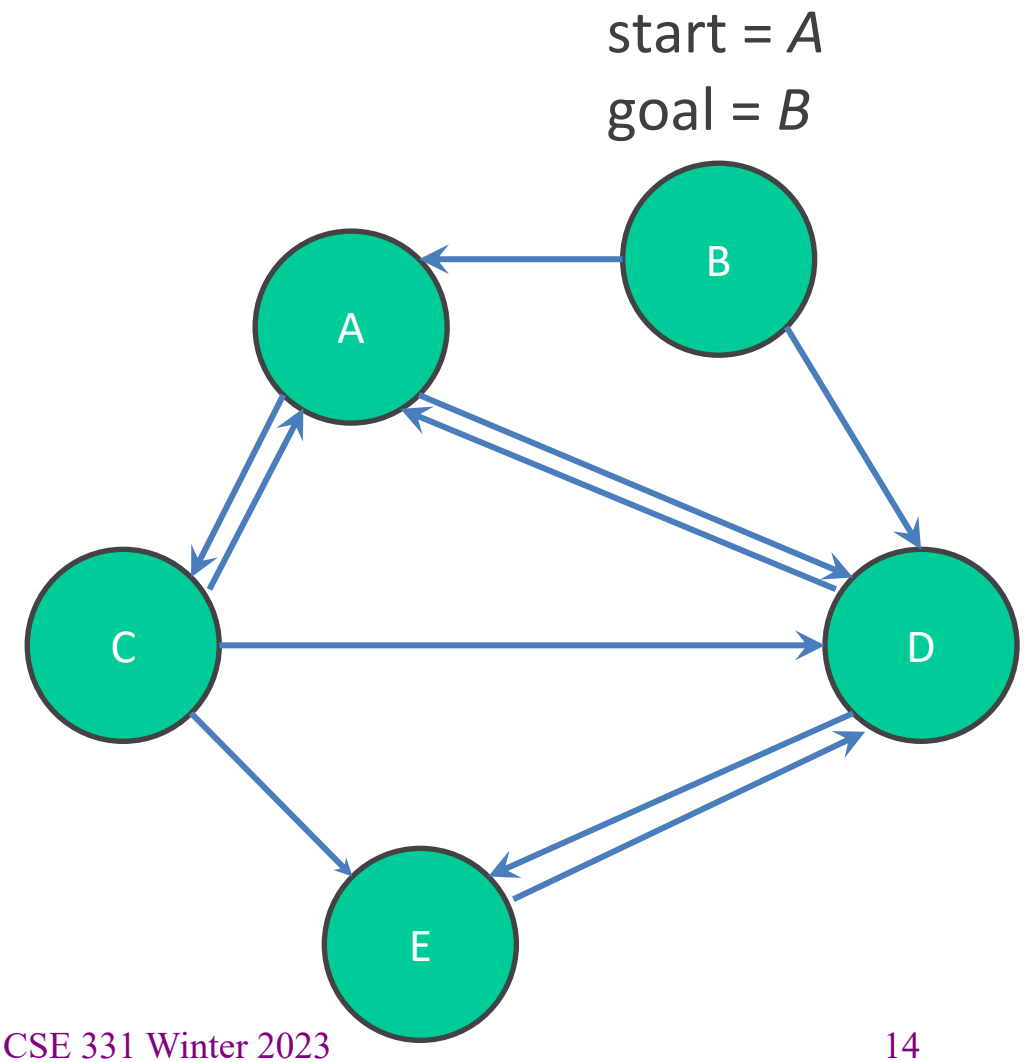
start = *A*
goal = *B*



The BFS algorithm

```
push start node onto a queue
mark start node as visited

while queue is not empty:
  pop node N off queue
  if N is goal:
    return true
  else:
    for each node O that is child of N:
      if O is not marked visited:
        mark node O as visited
        push O onto queue

return false
```

BFS: example on a cyclic graph



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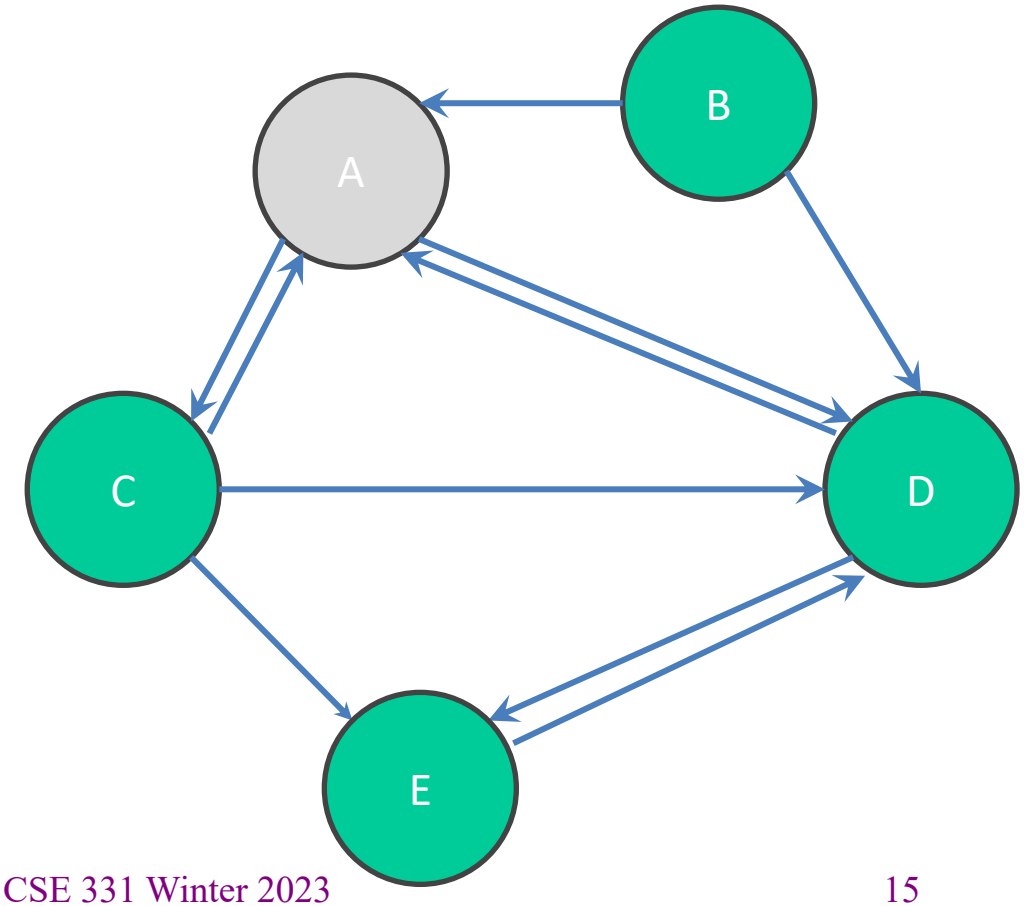

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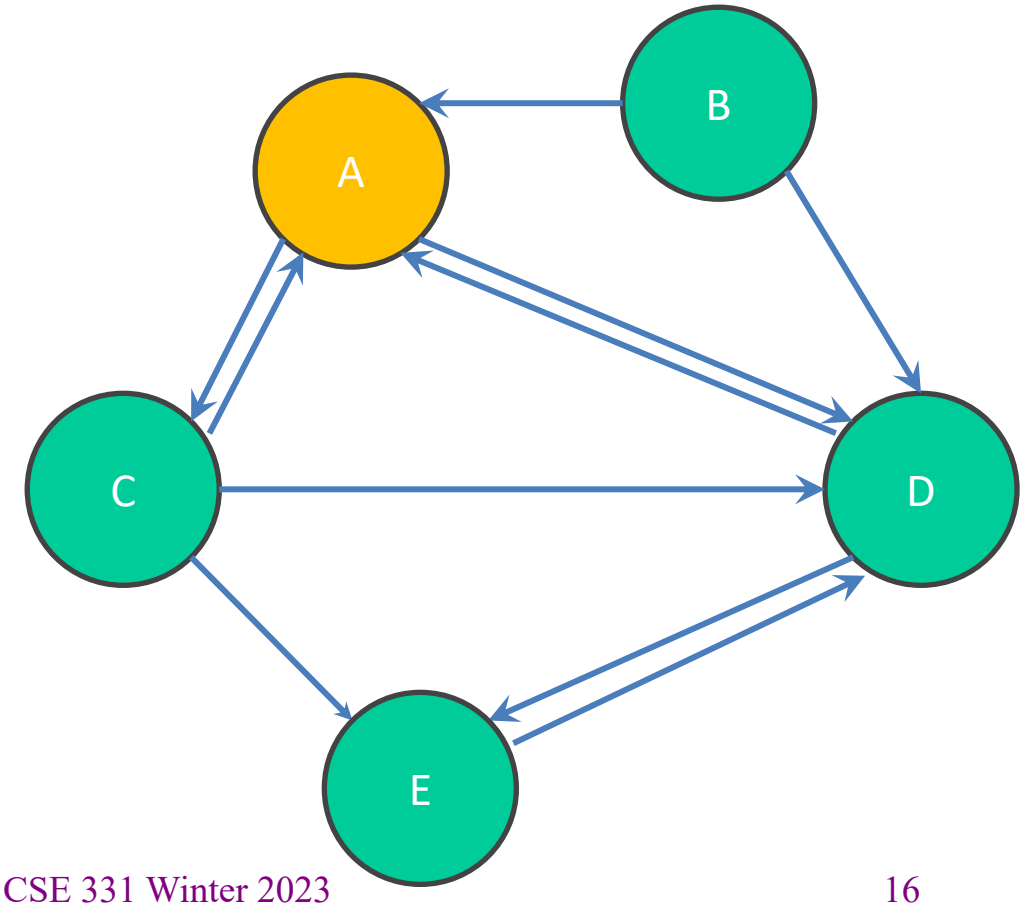

BFS: example on a cyclic graph

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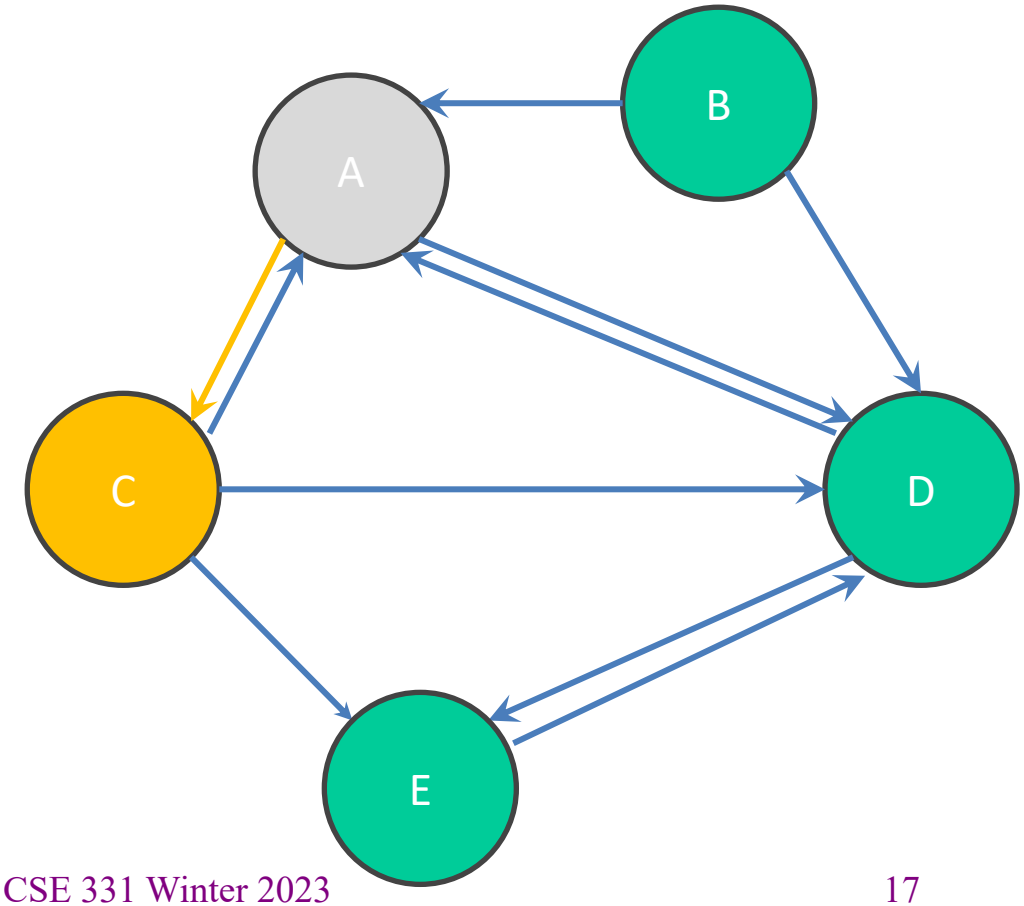

BFS: example on a cyclic graph

push start	Q = [*A*]
pop *A*	Q = []
push *C*	Q = [*C*]
push *D*	Q = [*D*, *C*]

start = *A*
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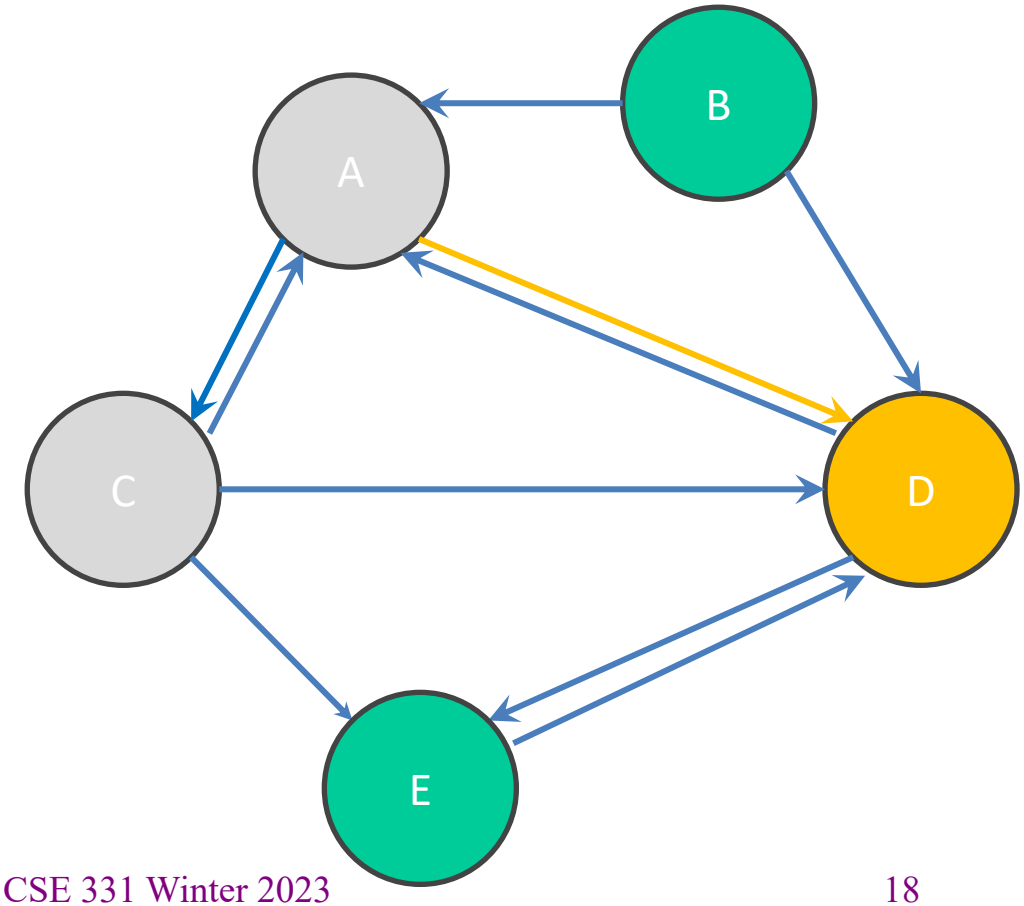

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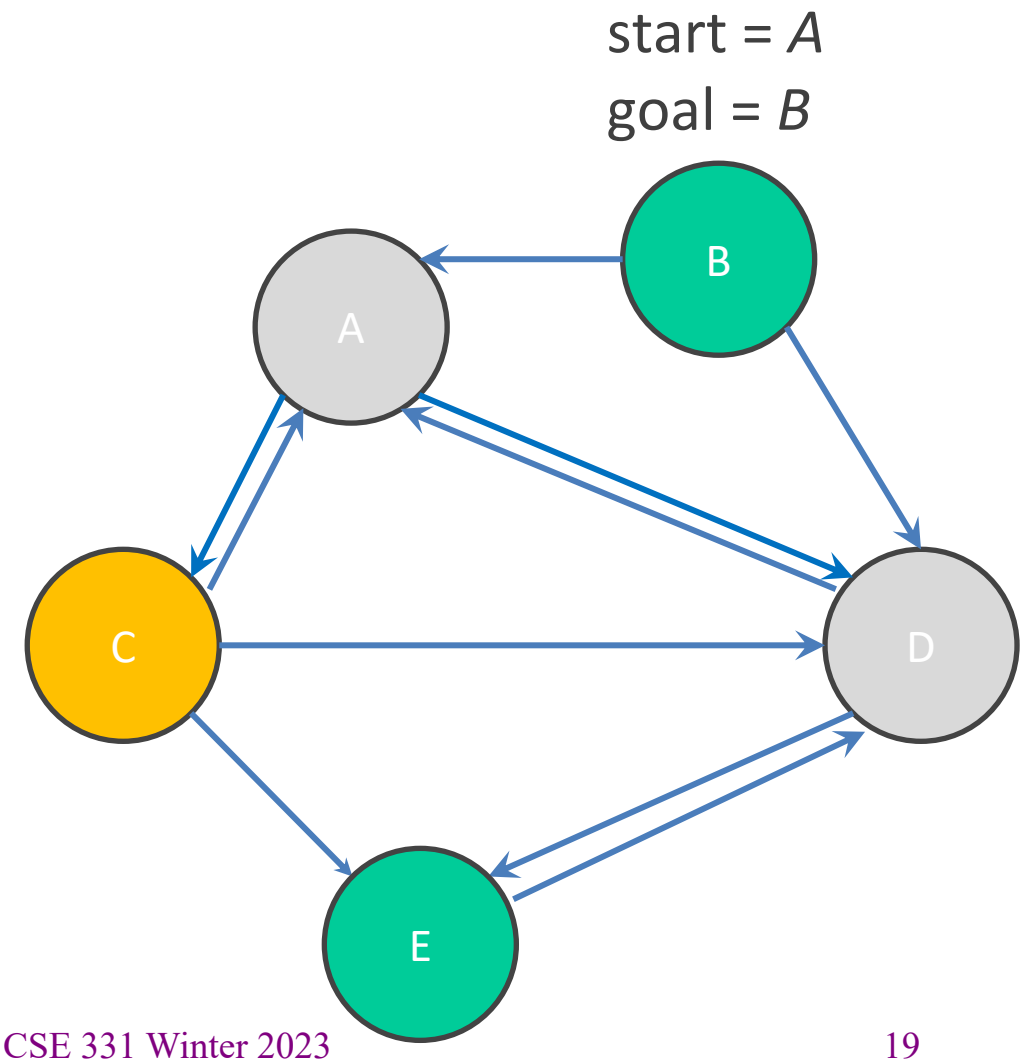

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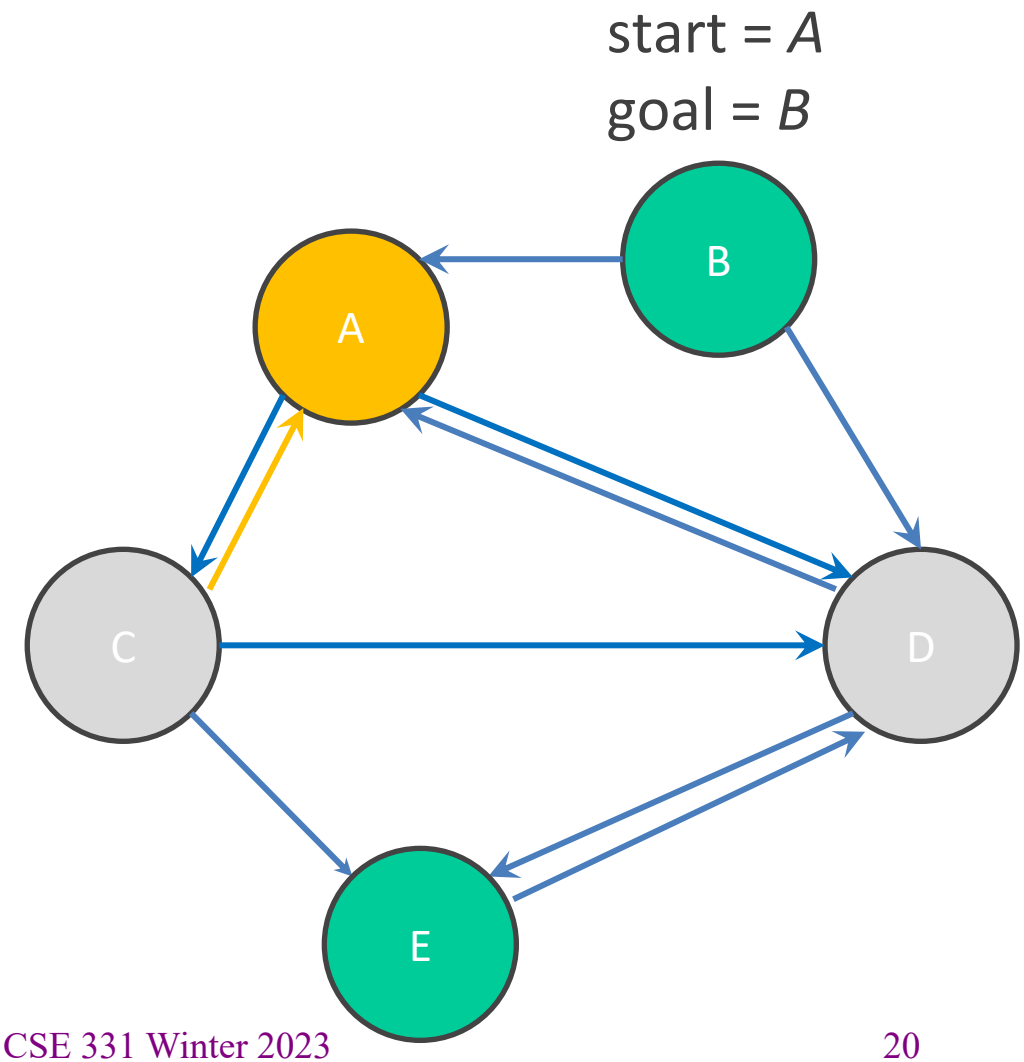

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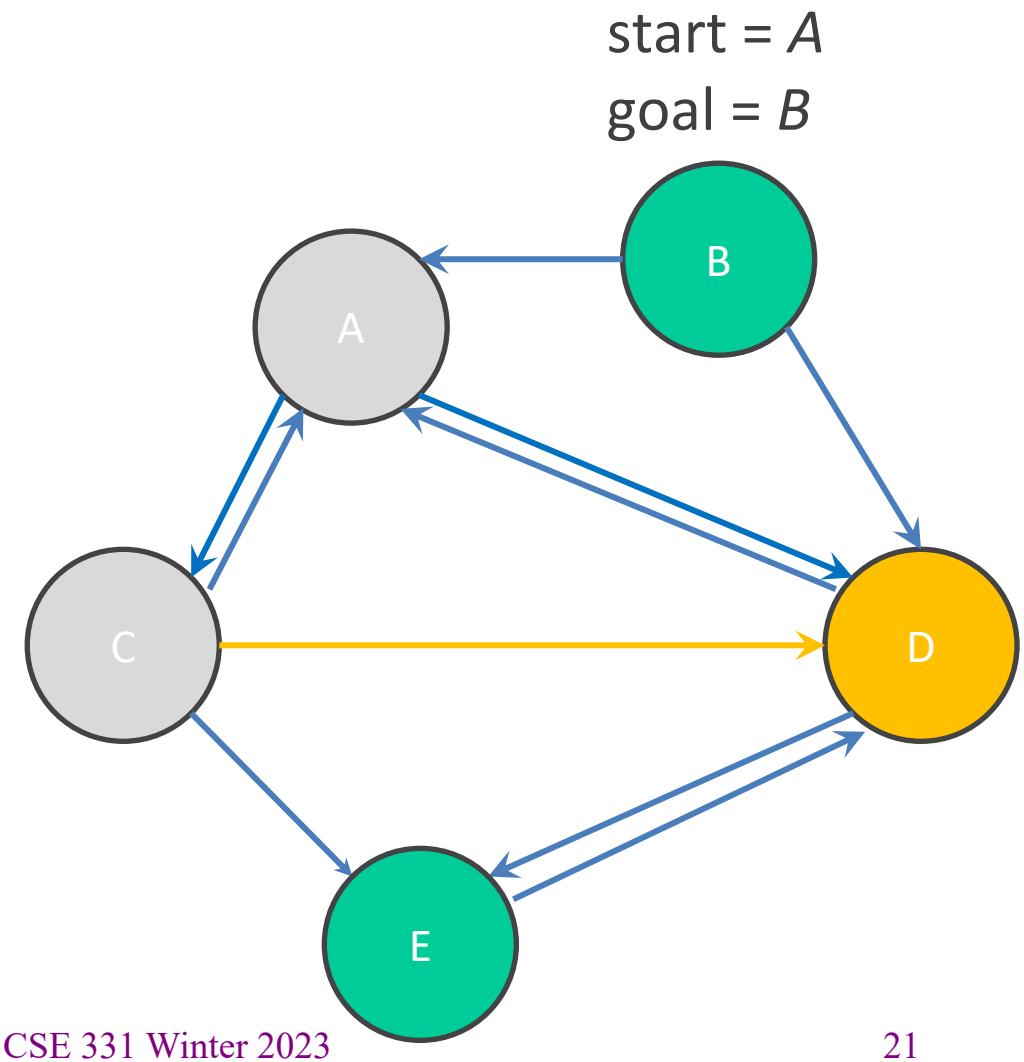

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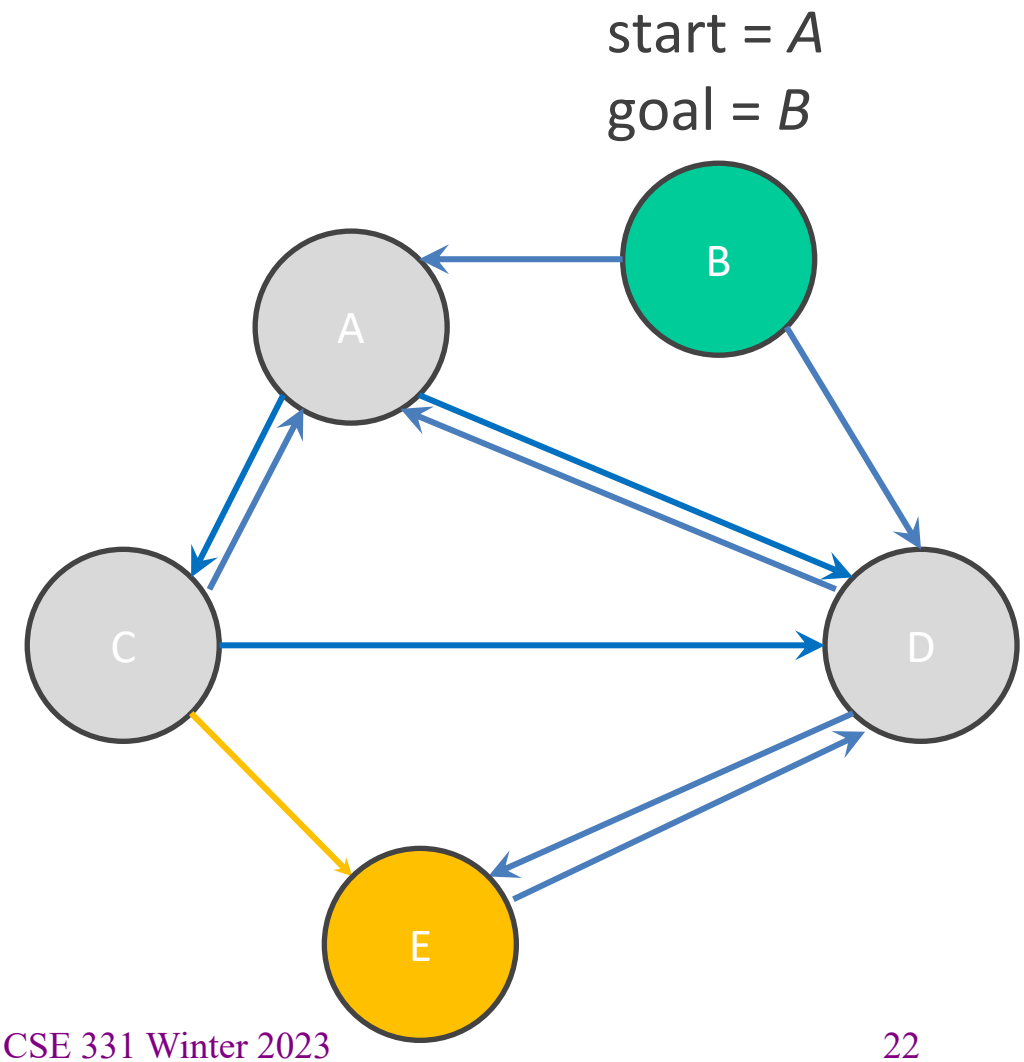

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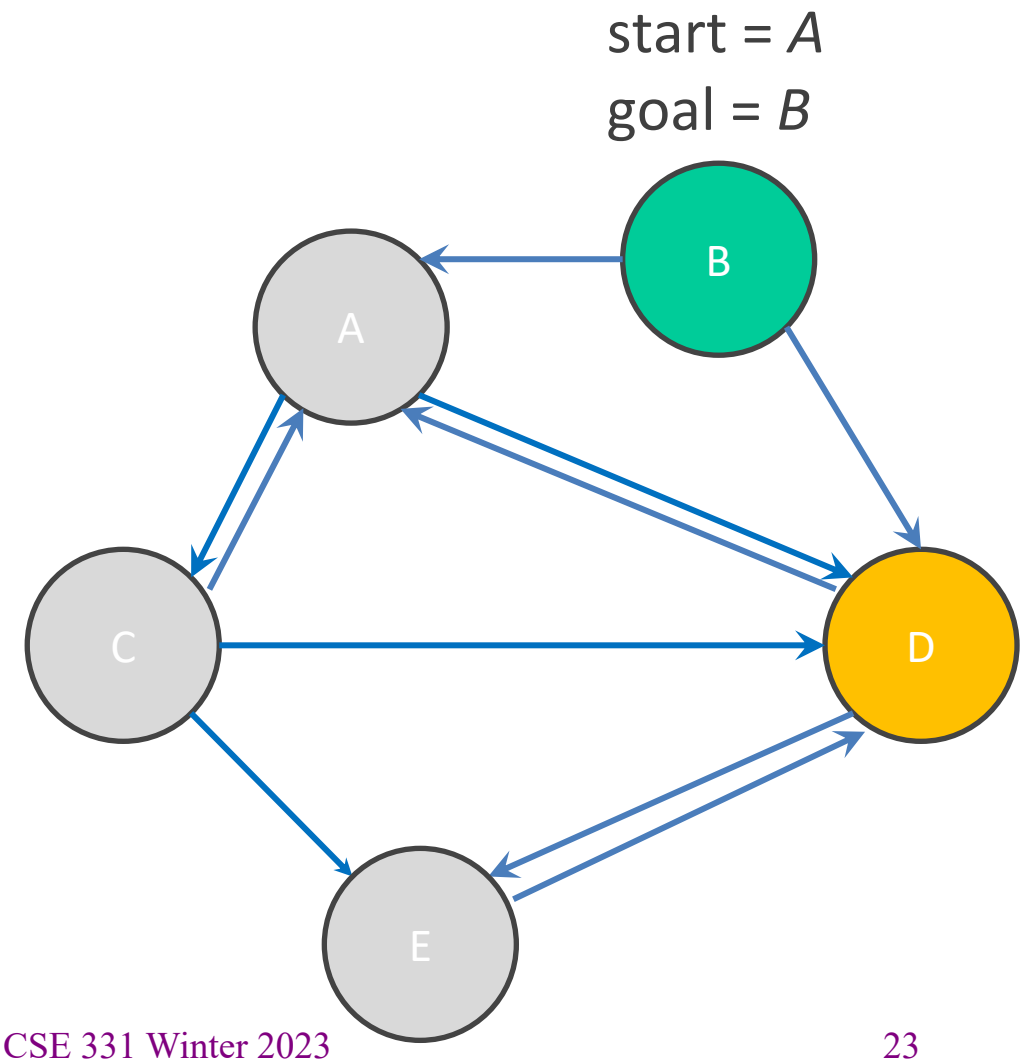

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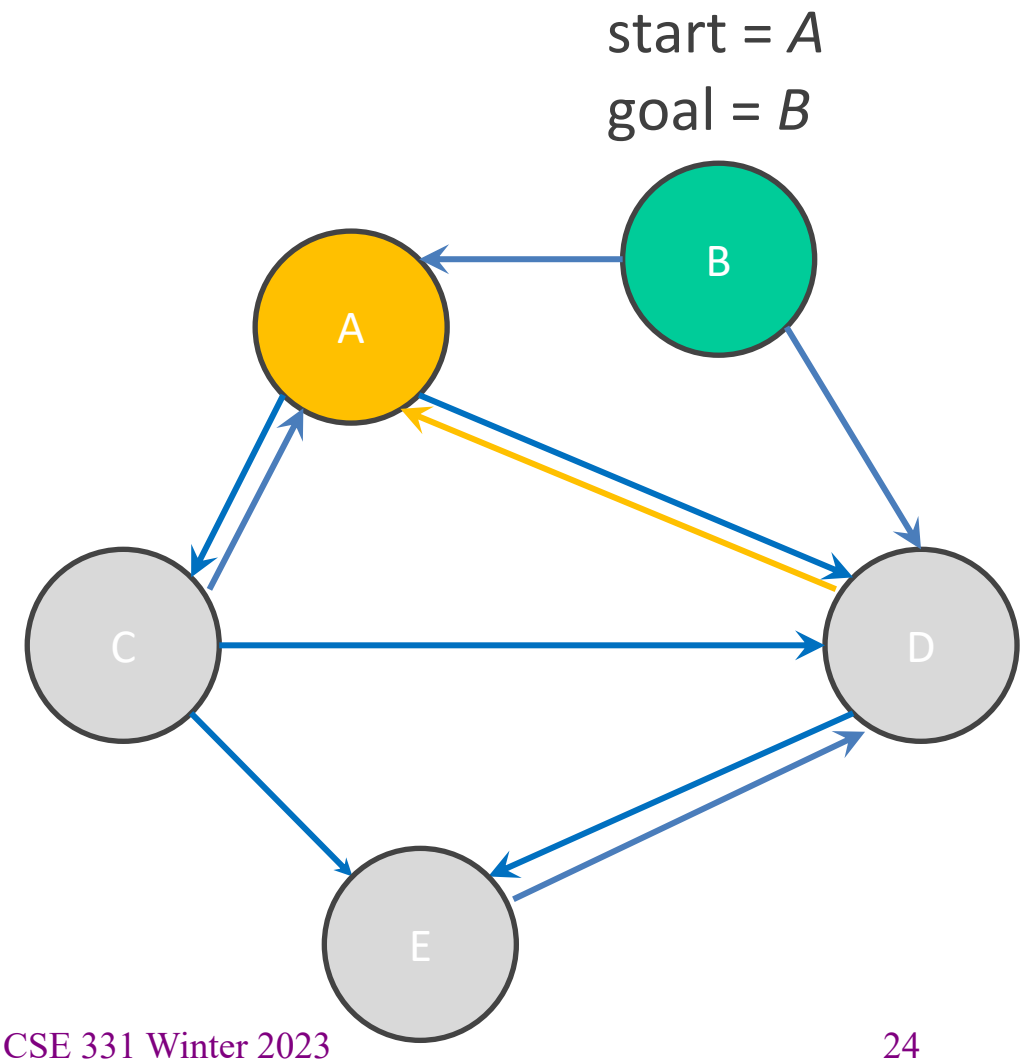

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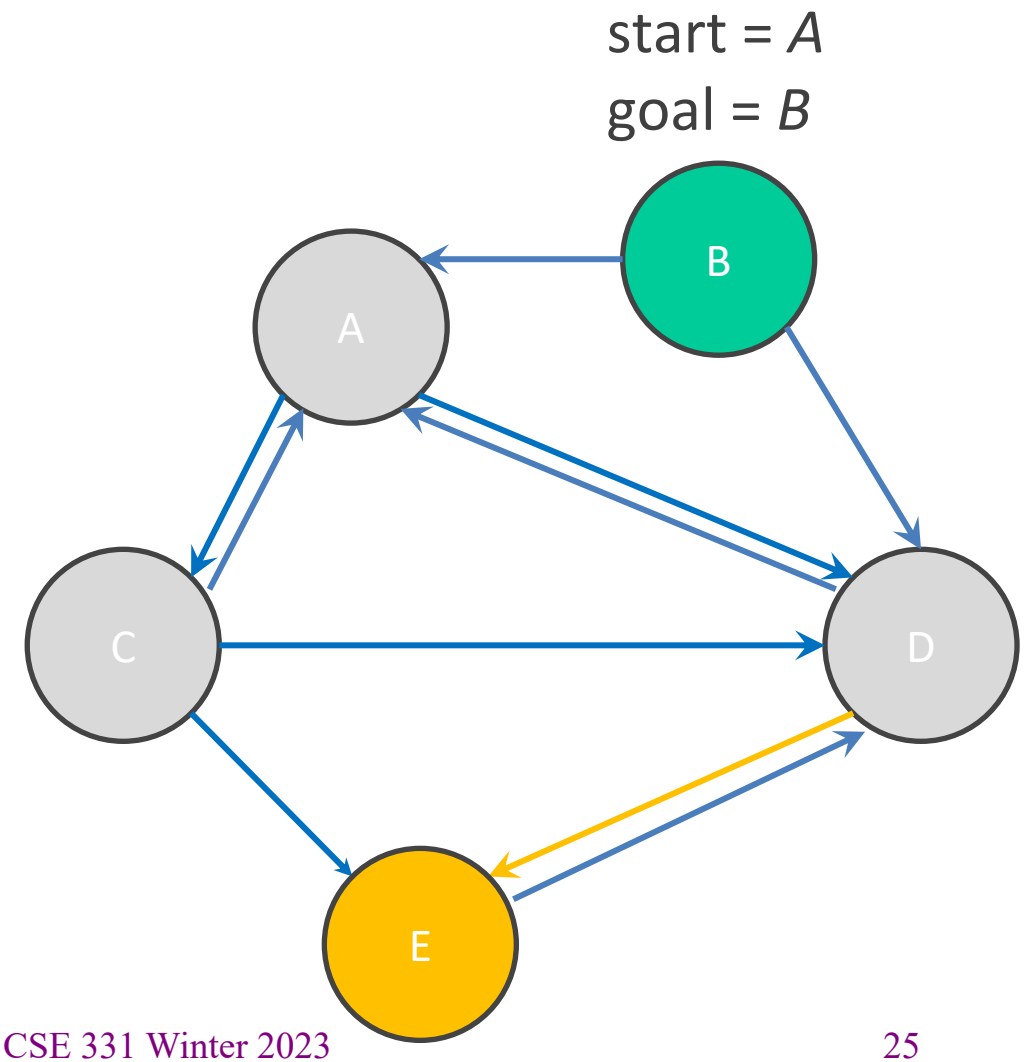

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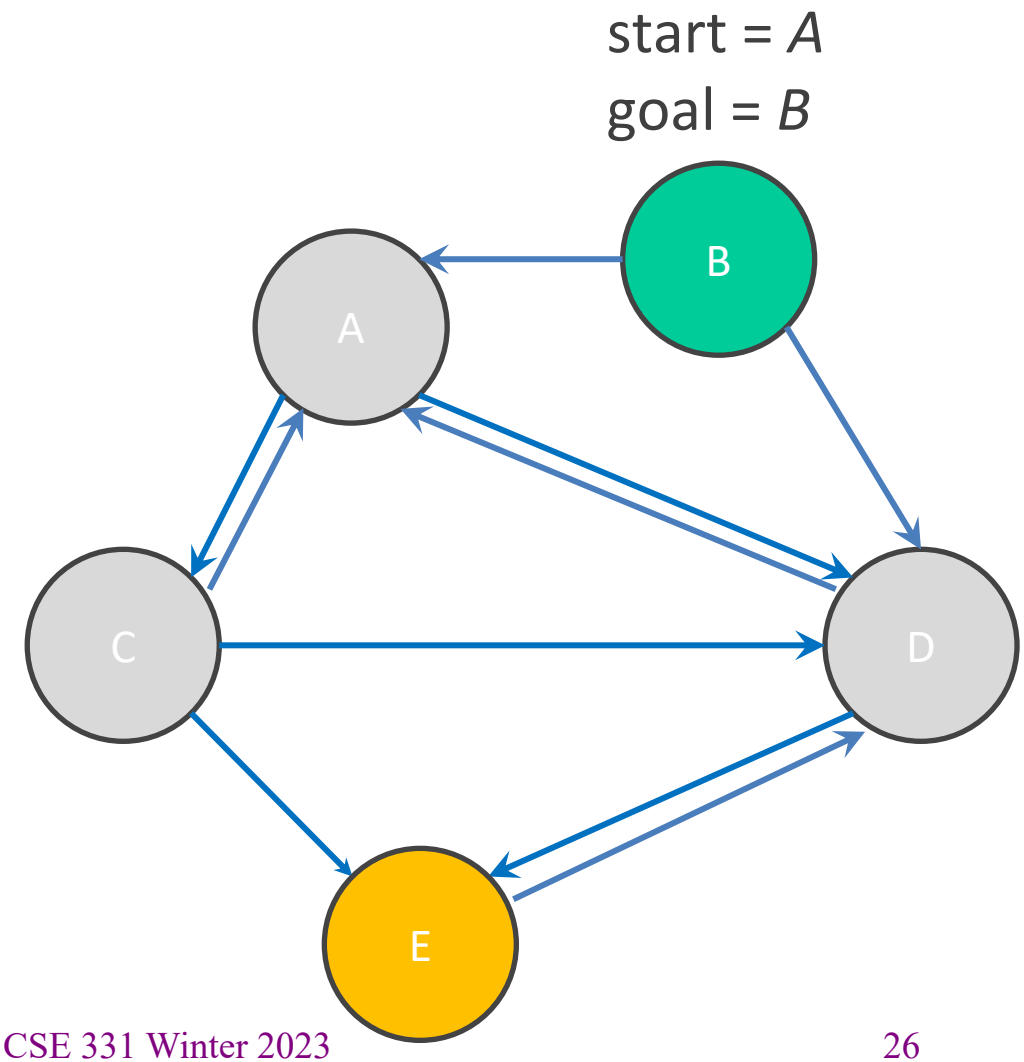

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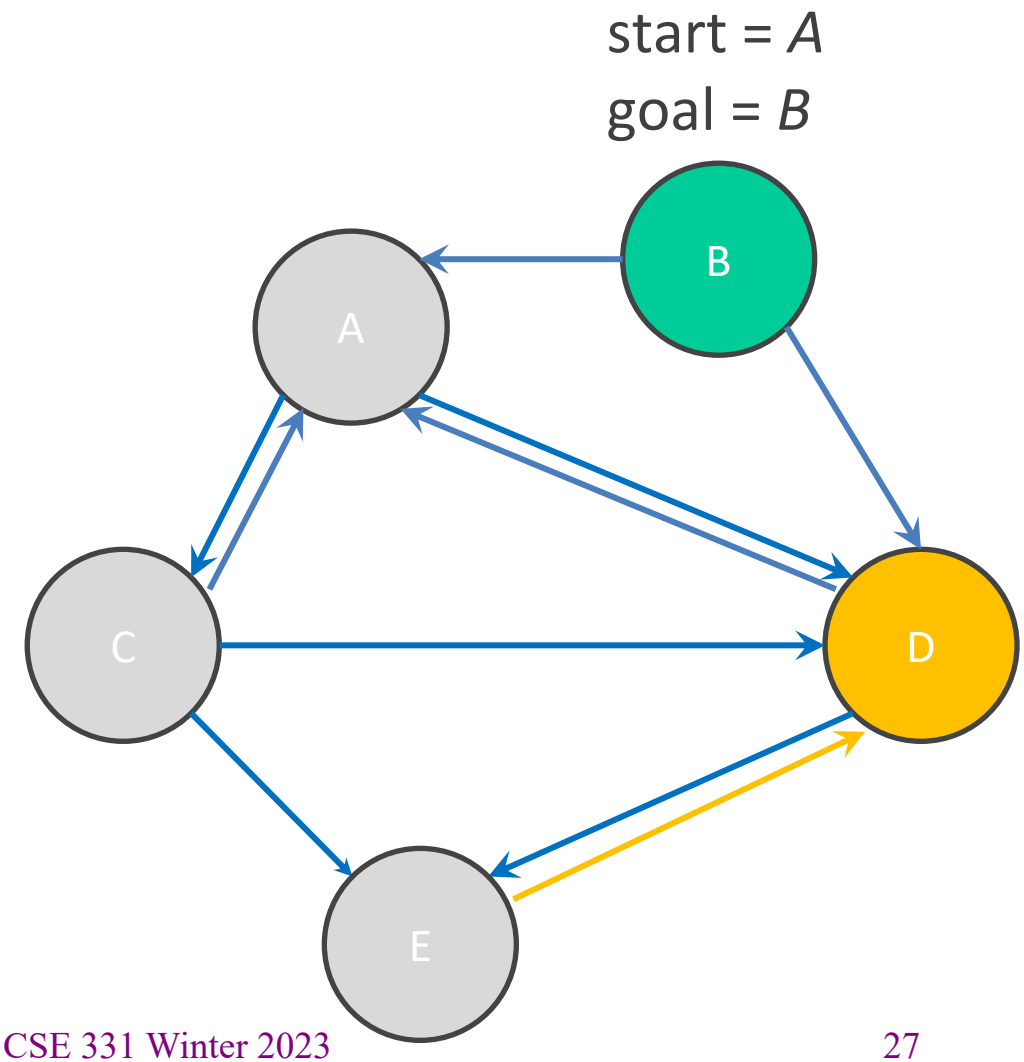

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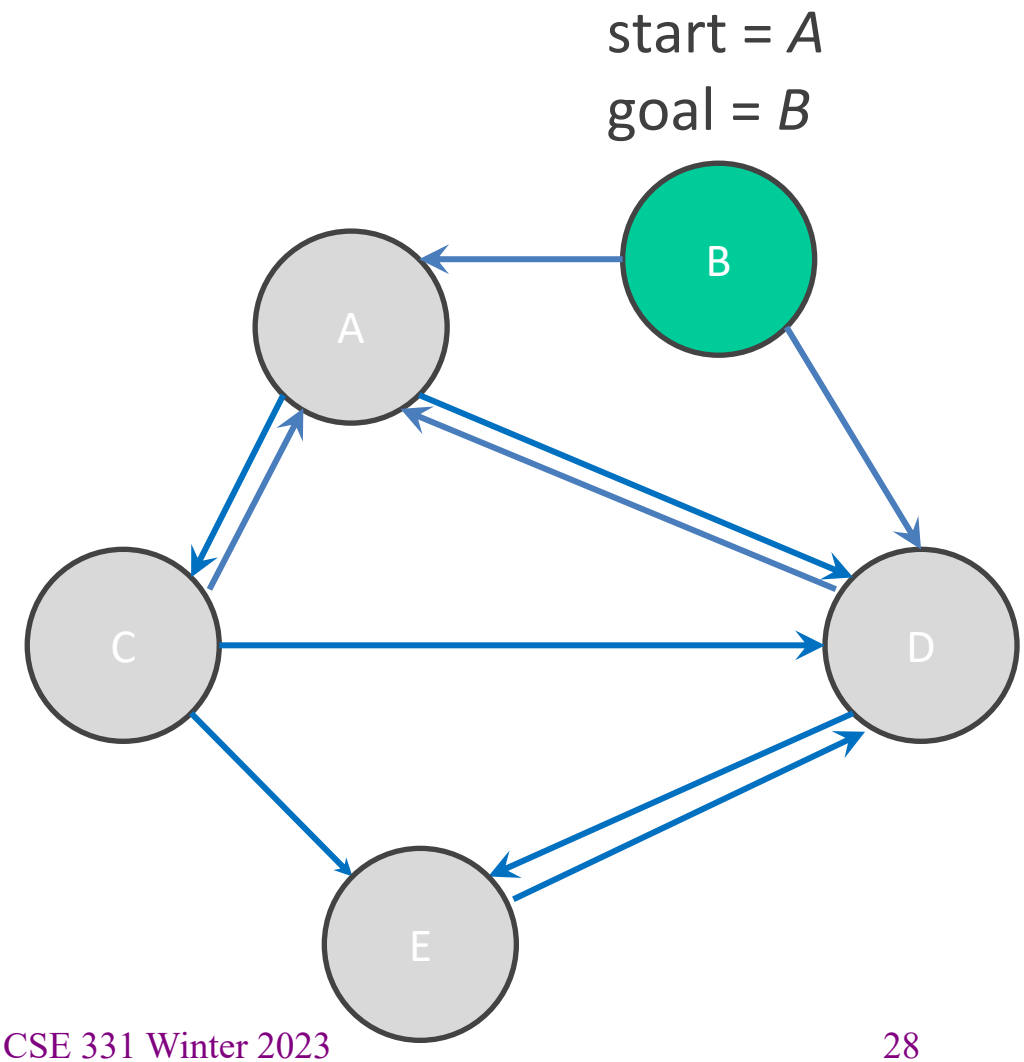
push *E*	Q = [*E*, *D*]
pop *D*	Q = [*E*]
pop *E*	Q = []
return false	



Your turn!

Try running through the BFS algorithm on the worksheet.

BFS Reminders

- BFS is done on a graph, not inside the graph
  - This is why we have you create a **`MarvelPaths`** class!

- We will eventually want to allow other kinds of searches to be done on the graph, so BFS should not be hard-wired into the core Graph ADT

- Use the debug flag to turn off expensive **`checkRep`** for testing/grading

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Reading in data

- Datasets are easily organized like a table or spreadsheet.
  - Each line is a row (*i.e.*, entry) in the dataset
  - Special characters usually separate the columns (*i.e.*, fields) of an entry
  - **Note:** fields can contain spaces

- One common data format: CSV (Comma-Separated Values)
  - Columns are separated by commas (‘,’)

Structure of a CSV dataset

- First line of the CSV just names the fields of dataset entries.
- An example dataset in CSV format:

```
name,email
Kevin Zatloukal,kevinz@cs.uw.edu
James Wilcox,jrw12@cs.uw.edu
Hal Perkins,perkins@cs.uw.edu
Mike Ernst,mernst@cs.uw.edu
Zachary Tatlock,ztatlock@cs.uw.edu
Dan Grossman,djg@cs.uw.edu
```

Parsing datasets

- Since datasets are structured, **we can interpret and parse the dataset programmatically**.

- For this assignment, we will do the file parsing for you (in a List of type String), but you need to store the results inside your graph.

- How should our graph be structured? What are the nodes? What are the edges?

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Script testing in HW6

- **Same test-script mechanism from HW5, but 2 new commands!**
  - New command **`LoadGraph`** to read and initialize graph from CSV file
  - New command **`FindPath`** to find shortest path in graph using BFS

- Must write the test driver (**`MarvelTestDriver`**) yourself
  - But you can copy/inherit most of it from **`GraphTestDriver`** in HW5

Command (in *`foo`*`.test`)	Output (in *`foo`*`.expected`)
`LoadGraph` *name file.csv*	**`loaded graph`** *name*
`FindPath` *graph* $node_1$ $node_n$	**`path from`** $node_1$ **`to`** $node_n$**`:`** $node_1$ **`to`** $node_2$ **`via`** $edge_{1,2}$ $node_2$ **`to`** $node_3$ **`via`** $edge_{2,3}$ `...` $node_{n-1}$ **`to`** $node_n$ **`via`** $edge_{n-1,n}$
`...`	`...`

`LoadGraph` and `FindPath`

- `LoadGraph` creates a *new* graph variable, much like `CreateGraph`
  - `LoadGraph` populates a graph with nodes and edges from dataset
  - **Note:** Other script commands (*e.g.*, `AddNode`, `AddEdge`) can still mutate the graph once it has been loaded!

- `FindPath` breaks ties by lexicographic (alphabetic) order
  - Necessary when there are multiple shortest paths so the test output will be deterministic
  - **Sorting should not be implemented in your Graph ADT.** Lexicographic order should be done in BFS algorithm.

- **All this specified in detail on the homework's webpage**
  - **You will need to read it to get things right :-)**

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Command Line Program

- You will need to write a **`main`** method for HW6
- Should request user input for Marvel character names and then find paths between them
- Must handle potential user error (e.g. characters that don't exist)
- Feel free to get creative! More details in the spec…

Demo

A quick walkthrough of the starter code for HW6.

HW6 notes

- Read the assignment spec carefully!
  - Ensure that you are using the right file path in the right place to read the data file
    - Most common reason for failures during grading is incorrect file paths

- Helpful to test and debug using smaller datasets
  - Faster and easier to understand what's going on

- To run MarvelPaths or any program that does console I/O, use gradlew to run the desired gradle target *using the IntelliJ terminal window* (console I/O doesn't work right otherwise )

- When you are done, you will be able to find the shortest path from your command line!