Graph Algorithms: Breadth-First Search (BFS)

Lecture 14B

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AddisCoder 2026

August 13, 2026

Lecture plan

Thursday	Morning	**14A**	Depth-First Search (DFS)
	Afternoon	**14B**	**Breadth-First Search (BFS)** ← we are here
Friday	Morning	**15A**	Quiz
	Afternoon	**15B**	Language Models

This morning: depth-first search

- Go **as deep as possible**,
  backtrack when stuck

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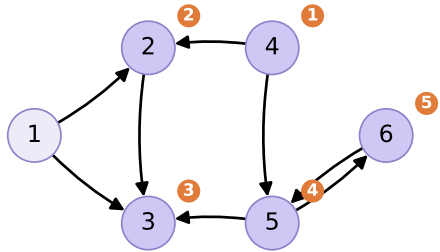

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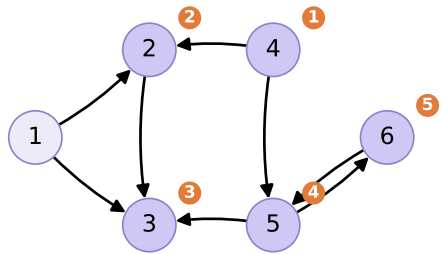
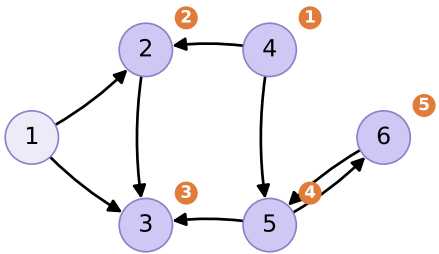


DFS from 4: 4 2 3 5 6

*This afternoon: a search that explores **level by level** instead — almost the same code, **one** data structure changes.*

Is there another sensible order?



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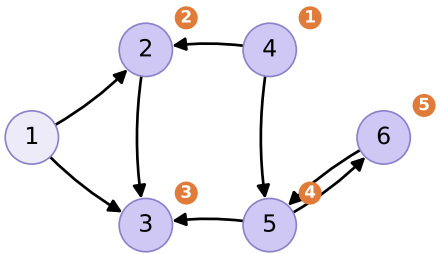

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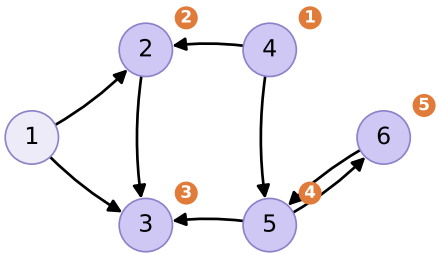

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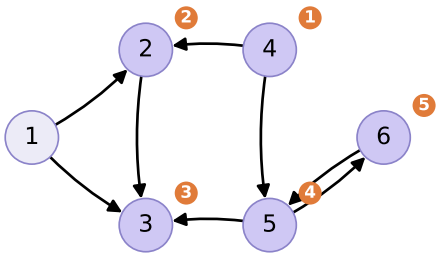
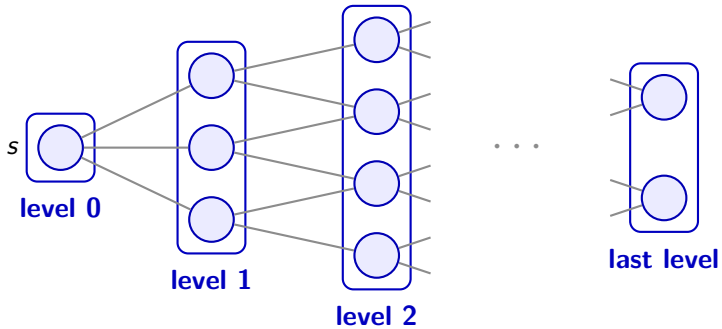


DFS from 4: 4 2 3 5 6

- DFS went **4** → **2** → **3**, all the way down, before it ever looked at **5**
- But 2 and 5 are both **one step** from 4
- **Why not visit both of them first?**

Breadth-first search: level by level



*Visit everything **one step** away,*
*then everything **two steps** away, and so on.*

The BFS algorithm

1. Start at the **starting node** of the graph

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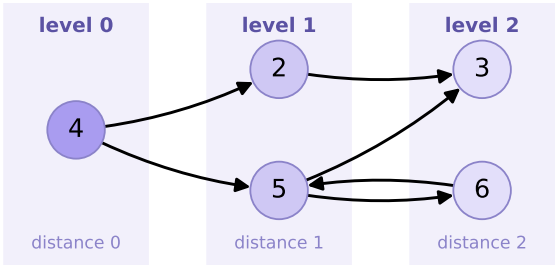
- Just like DFS, we keep a `visited` dictionary
- But to know **what to visit next**, we now need a **queue**

BFS on our graph: what order?



The same graph, redrawn by level. Vertex 1 is not reachable from 4, so it isn't here.

Discuss:

In what order does **BFS from 4** visit the nodes?

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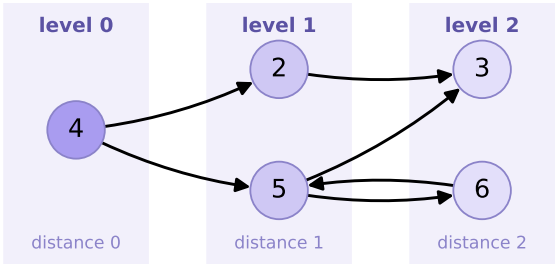

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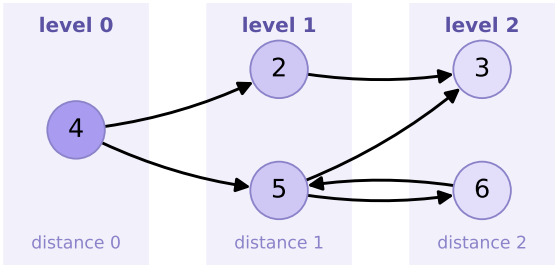

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Discuss:

In what order does **BFS from 4** visit the nodes?

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DFS said 4 2 3 5 6 — the same nodes, a different order.

What actually has to change?

- DFS never had a list of "places still to visit"... or did it?

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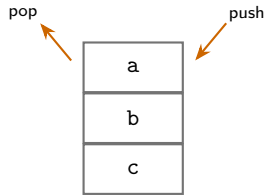
*To go level by level, we need the **opposite**: give back the **oldest** thing first. That data structure is a **queue**.*

Queues

First in, first out

Stack vs. queue

Stack (used by DFS)



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In and out at the **same** end

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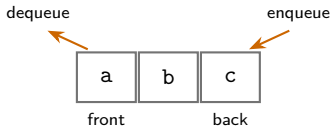

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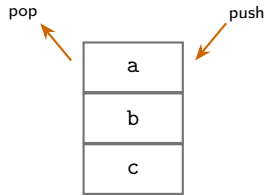

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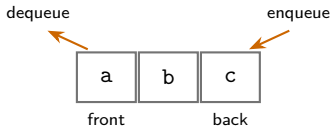

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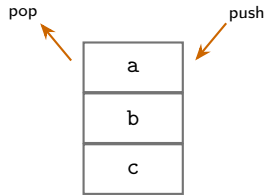

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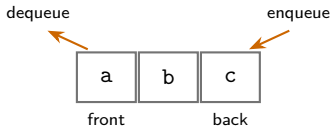

First **I**n, **F**irst **O**ut

In at one end, out at the **other**

Discuss: Which one is the queue you **stand in** at a shop?

And which one is a **pile of plates**?

Queues in Python: deque

```
# In Python, we can represent
# queues using deque:
from collections import deque

arr = [5, 7, 1, 8, 2, 10]
queue = deque(arr)
print(queue)
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deque is short for **d**ouble-**e**nded **que**ue — Python's built-in queue

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Discuss: What do the four `print()` lines put on the screen?

A queue, step by step


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queue = deque(arr)
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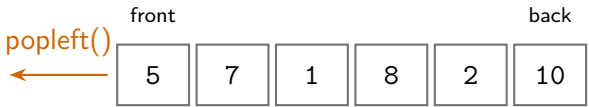
prints `deque([5, 7, 1, 8, 2, 10])`

A queue, step by step

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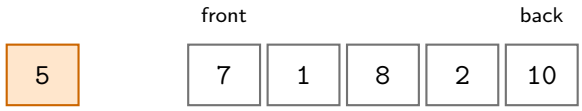
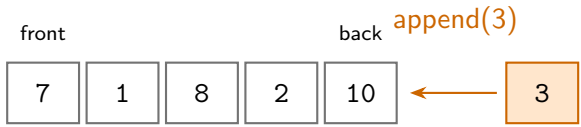


`print(front)` and `print(queue)`

prints `5` then `deque([7, 1, 8, 2, 10])`

A queue, step by step



`queue.append(3)`

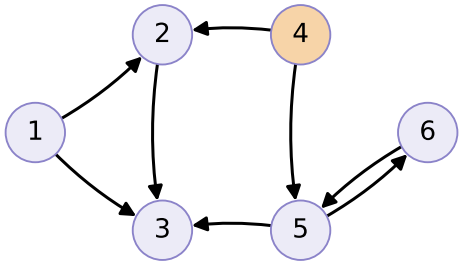
A queue, step by step

`print(queue)`

prints `deque([7, 1, 8, 2, 10, 3])`

*Out at the **front**, in at the **back** —*
and nothing ever jumps the queue.

Let's trace it by hand: BFS from 4



current in queue done not seen

Now: start at 4 — put it in the queue

`queue:` `[4]`

`visited:` `{4}`

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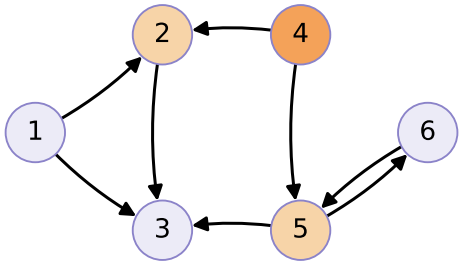

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Now: take **4** — `G[4] = [2, 5]`, add both

`queue: [2, 5]`

`visited: {4, 2, 5}`

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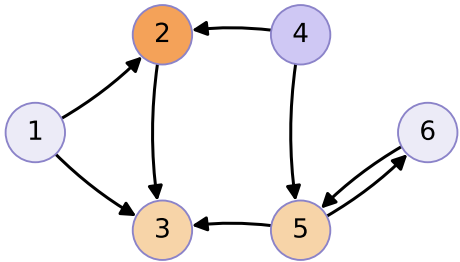

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Now: take **2** — `G[2] = [3]`, add 3

queue: `[5, 3]`

visited: `{4, 2, 5, 3}`

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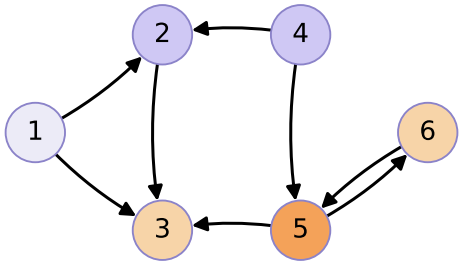

current in queue done not seen

Now: take **5** — 3 already seen, add 6

`queue:` `[3, 6]`

`visited:` `{4, 2, 5, 3, 6}`

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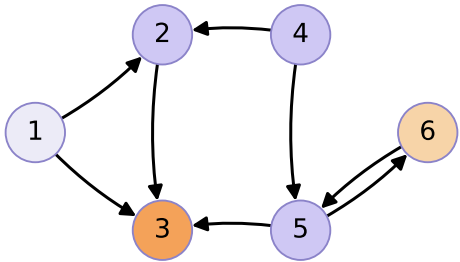

current in queue done not seen

Now: take **3** — `G[3] = []`, nothing to add

queue: `[6]`

visited: `{4, 2, 5, 3, 6}`

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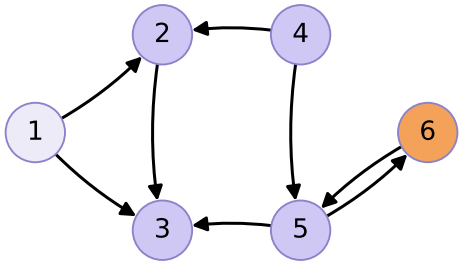

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Now: take **6** — 5 already seen

`queue:` `[]`

`visited:` `{4, 2, 5, 3, 6}`

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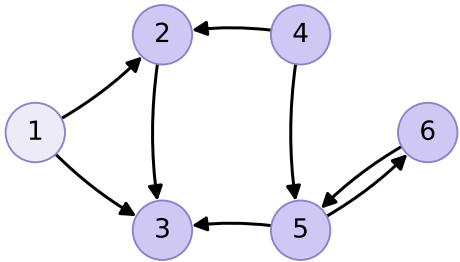

current in queue done not seen

Now: queue empty → done!

queue: `[]`

visited: `{4, 2, 5, 3, 6}`

Let's implement BFS

Reachability again — but breadth-first

```
def connected(source, target, G):
```

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def connected(source, target, G):
    visited = {}
    queue = deque([source])    # start with just the source
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            visited[y] = True
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    return False
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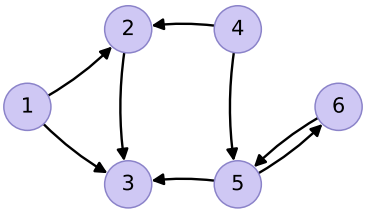
    return False
```

No recursion — the nodes still to visit sit in a `queue` we can see.

Does it work?



Discuss:

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print(connected(1, 5, g_adj))
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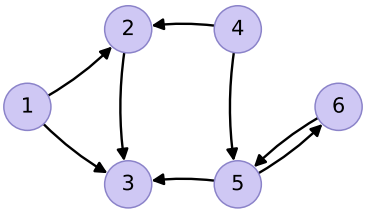

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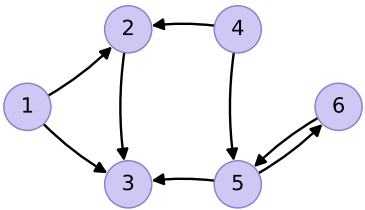

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print(connected(4, 6, g_adj))
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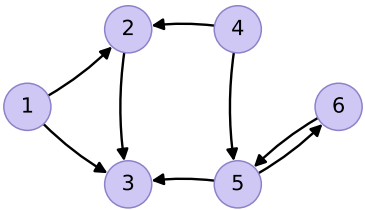

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From searching to traversing

Drop the `target`, print on the way out — BFS now **visits everything** it can reach:

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def bfs(visited, graph, node):
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Drop the `target`, print on the way out — BFS now **visits everything** it can reach:

```
def bfs(visited, graph, node):
  queue = deque([node])     # the only node we know
  visited[node] = True
```

From searching to traversing

Drop the `target`, print on the way out — BFS now **visits everything** it can reach:

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Same arguments as `dfs(visited, graph, node)` — swap one for the other in any program.

Running it from every node

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# g_adj = {1: [2, 3], 2: [3], 3: [],
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3
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3
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3
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4
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5
3
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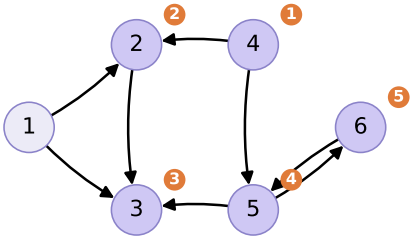
DFS vs. BFS: the same graph, from 4

DFS dive, then backtrack



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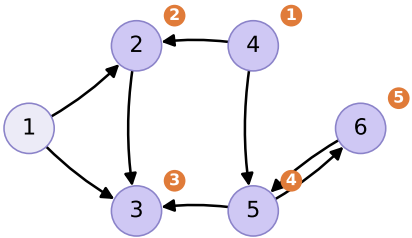

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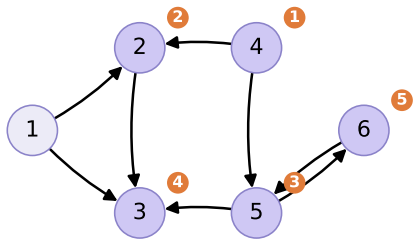
BFS level by level



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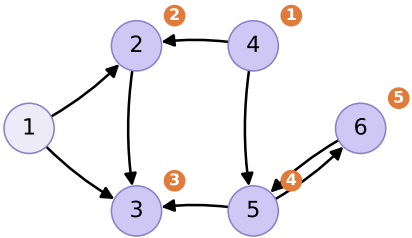

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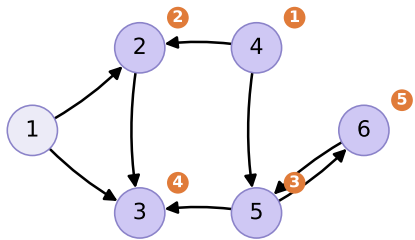

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*Same graph, same five nodes — the **order** is the whole difference.*

One data structure apart

DFS

```
def dfs(visited, graph, node):
    visited[node] = True
    print(node)
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The **call stack** holds what's left to do — newest first

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*DFS lets **recursion** remember what's left — BFS has **no recursion**, just a queue.*

BFS time complexity

Discuss: How many times does BFS put each vertex **into** the queue? How many times does it **look at** each edge?

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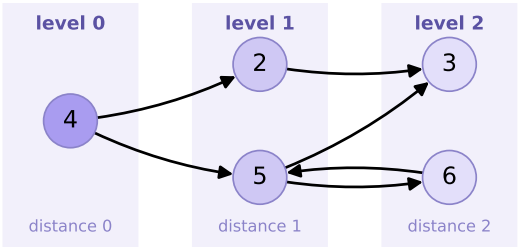
*Exactly the same as DFS. Choosing between them is never about speed — it is about the **order** you want.*

Why BFS: shortest paths



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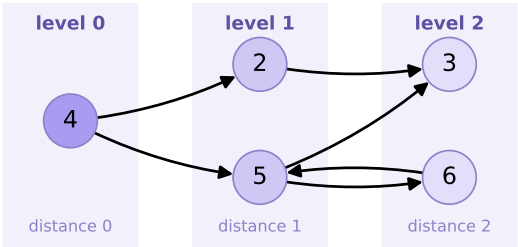

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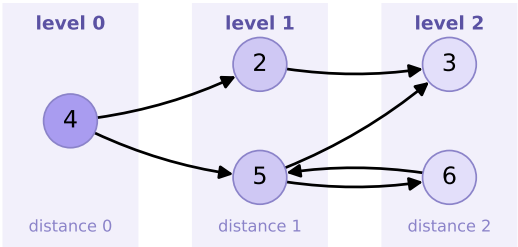

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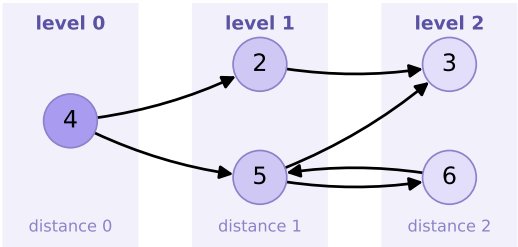

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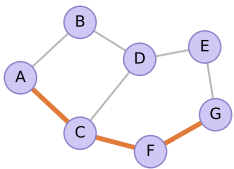
*BFS finds the **shortest path** (in number of edges) from the start to every node it reaches. DFS does **not**.*

Applications of BFS

Fewest stops



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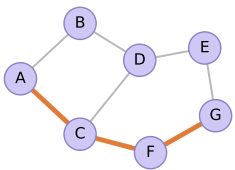

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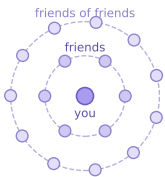

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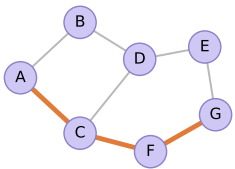

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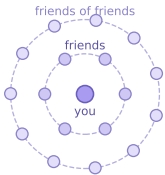

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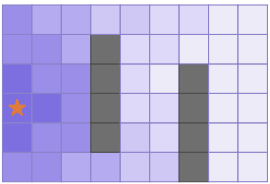

The paint bucket, pixel by pixel

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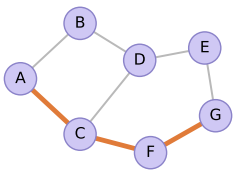

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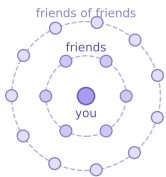

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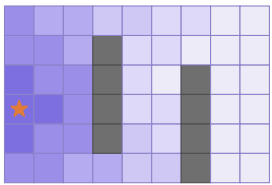

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Also **web crawling**, and **broadcasting**: how many hops to reach everyone?

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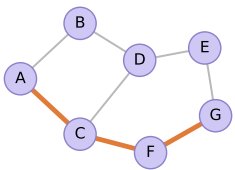

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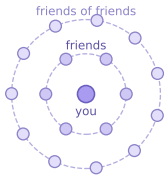

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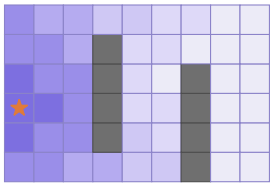

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Also **web crawling**, and **broadcasting**: how many hops to reach everyone?

*Whenever "**how far**" or "**how few steps**" is part of the question, reach for BFS.*

So which one should I use?

	DFS	**BFS**
Explores	deep along one branch	level by level
To-do list	the call stack — recursion keeps it **for you**	a `deque` you keep **yourself**
Shortest path?	no	yes (fewest edges)
Memory	one *path* at a time — usually far less	one whole *level* at a time — can be huge
Finds a target	sooner if it is **far** away	sooner if it is **near**
Good for	backtracking; cycles in a *directed* graph	distances, "how few steps", nearest match

Beyond DFS and BFS

For DFS and BFS, every edge counts the same: **one step**. Change how you pick the *next* node, and you get a whole family:

- **Dijkstra's algorithm** — edges have *lengths*; always take the **closest** node next (a **priority queue** instead of a queue)

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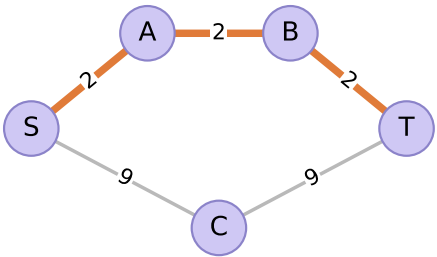
Stack → deep. Queue → level by level. Priority queue → nearest by distance. Same skeleton every time.

Dijkstra's algorithm: when steps have a *length*



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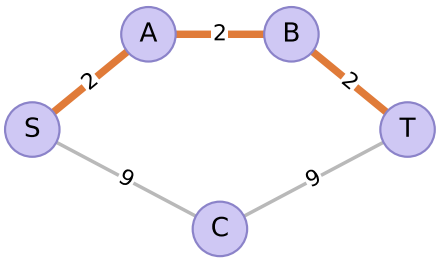

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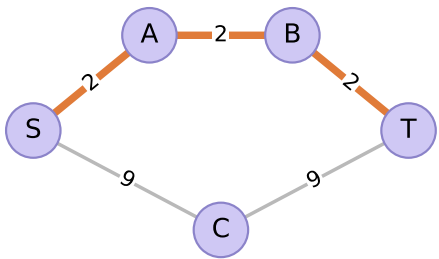

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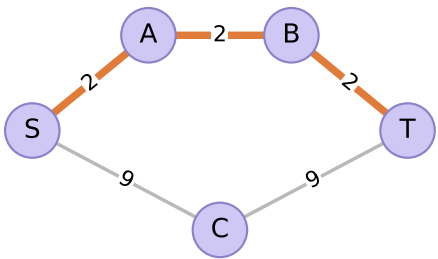

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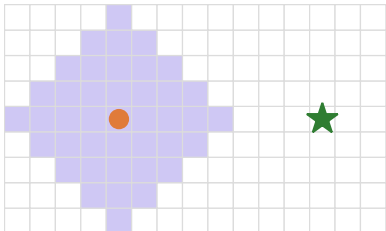
BFS is Dijkstra for the special case where every edge has length 1.

A* search: point the search at the goal

Dijkstra: spreads out in every direction



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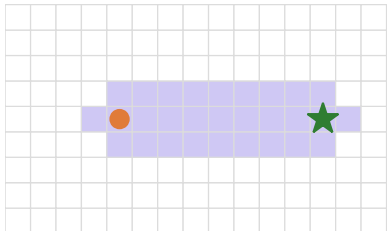

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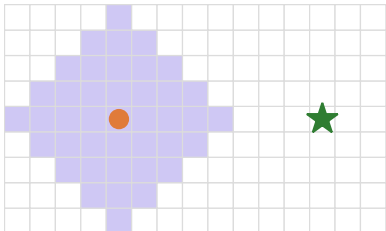

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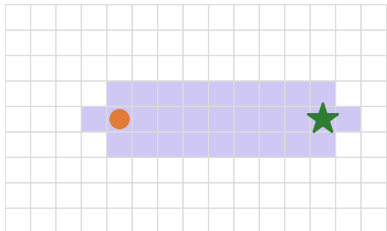

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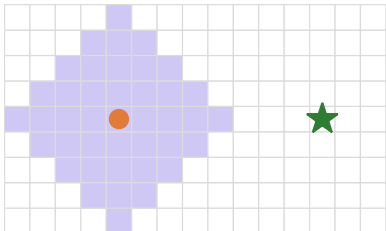

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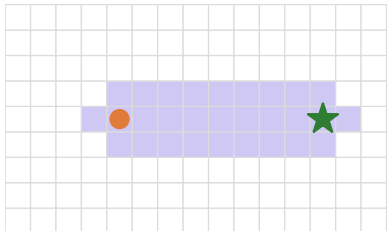

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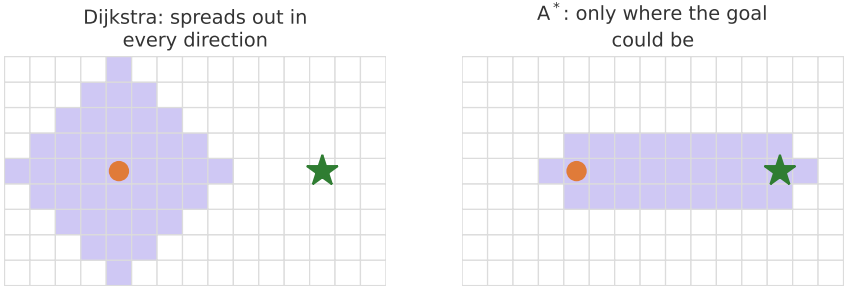

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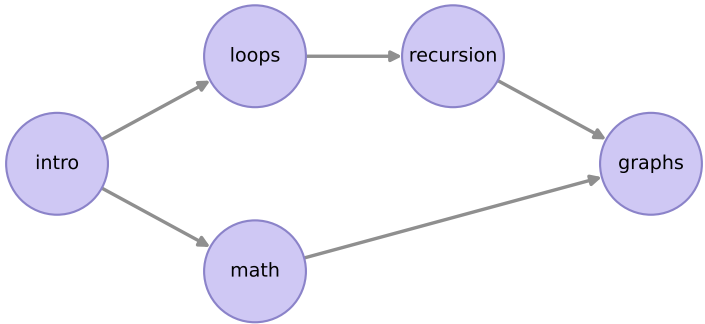
Same answer, far less searching — this is what a map app is really doing.

Topological sort: what order can I do things in?



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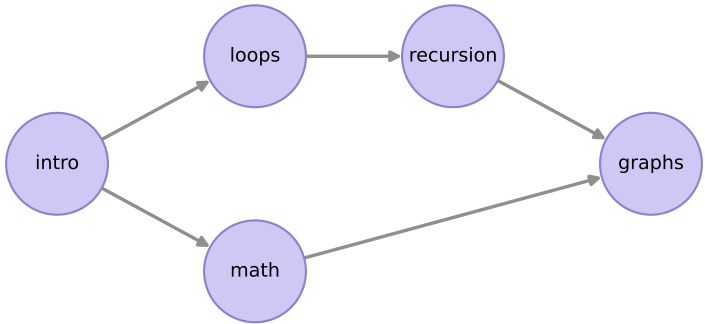
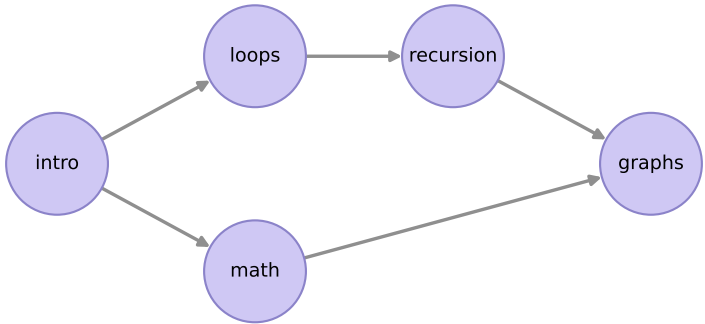


- An arrow means "**must come before**" — you cannot do `graphs` before `math` and `recursion`

Topological sort: what order can I do things in?



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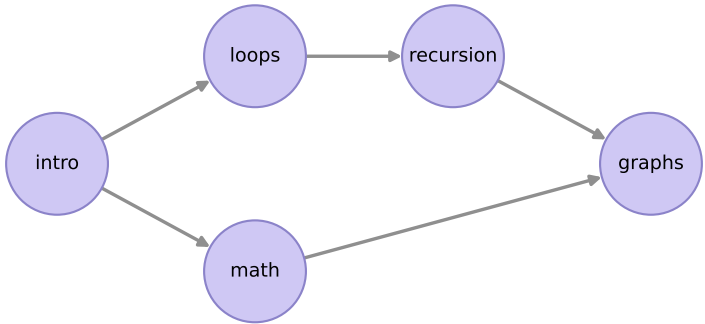

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  `intro` → `loops` → `math` → `recursion` → `graphs`
- Built on **DFS** — and it only exists if the graph has **no cycle**

Wrapping up

This afternoon:

- BFS explores **level by level** — nearest nodes first
- A **queue** replaces the call stack: `popleft()` instead of recursion
- Same $O(V + E)$ as DFS — but BFS gives you **shortest paths**

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Thank you — see you tomorrow!