Final Review & Wrap-up

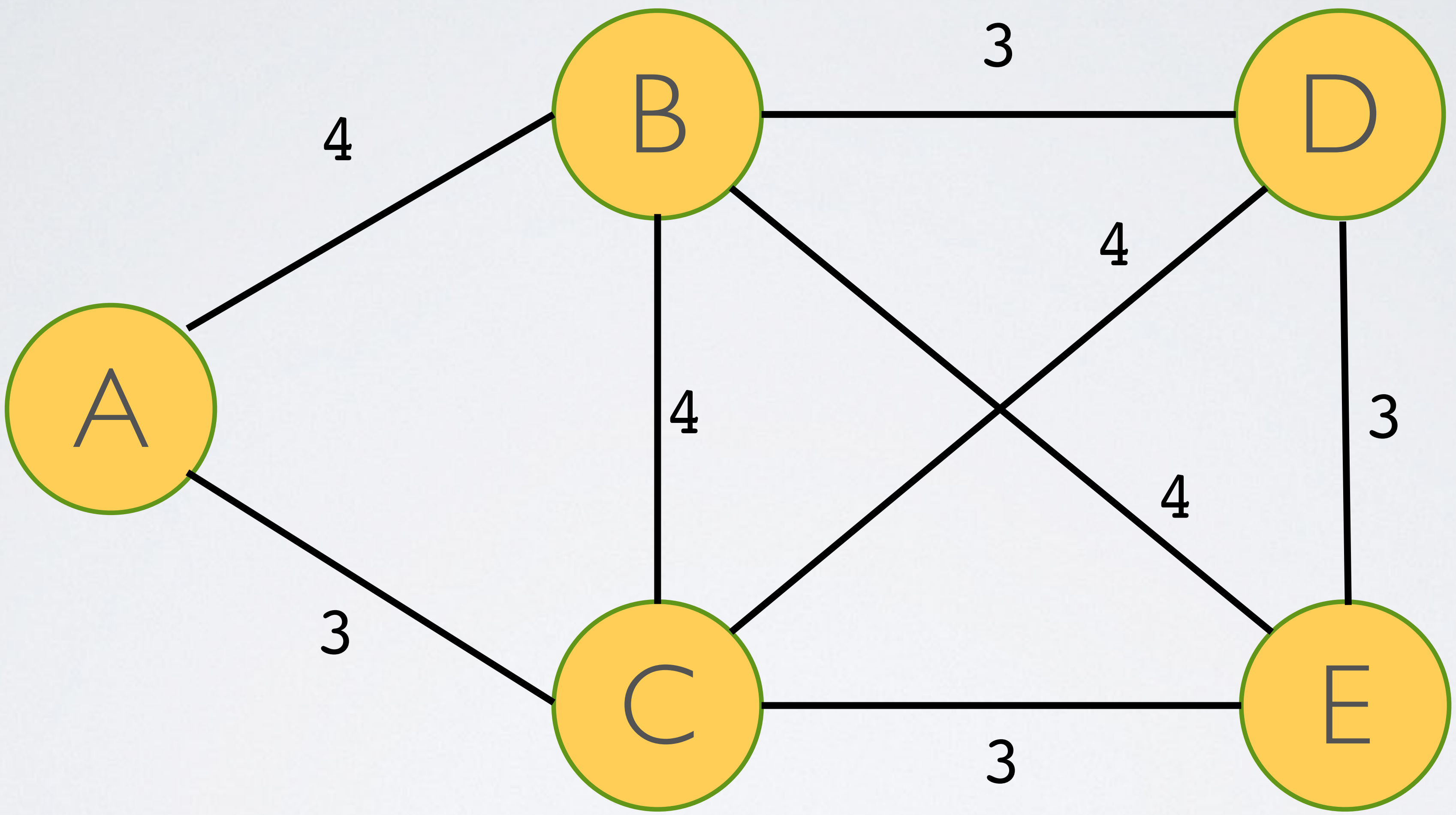
CS16: Introduction to Data Structures & Algorithms

Summer 2021

Shortest paths and MSTs

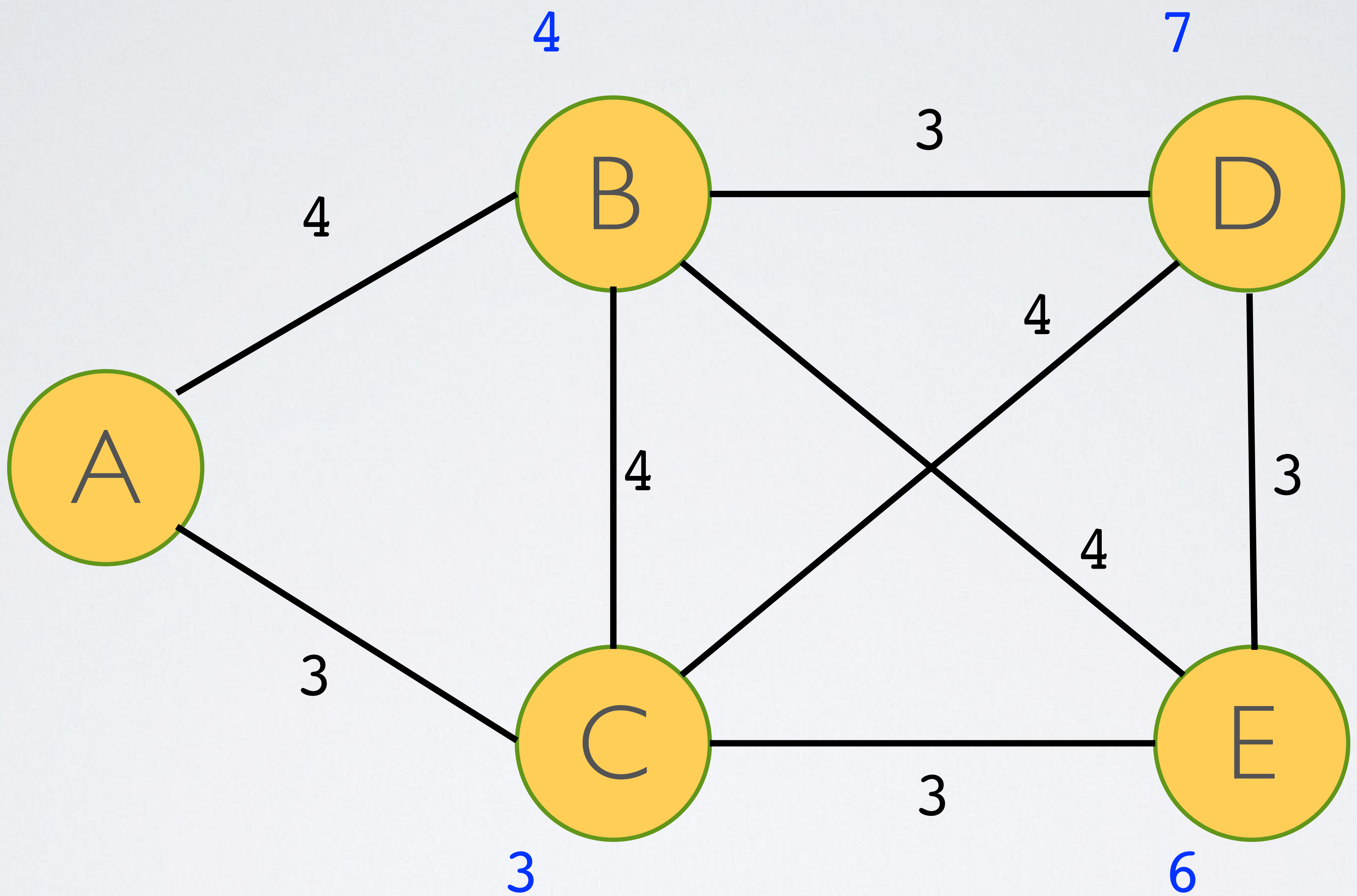
- What's a shortest path?
- What's a MST?
- How are they related?
- How are they different?

Single source shortest path

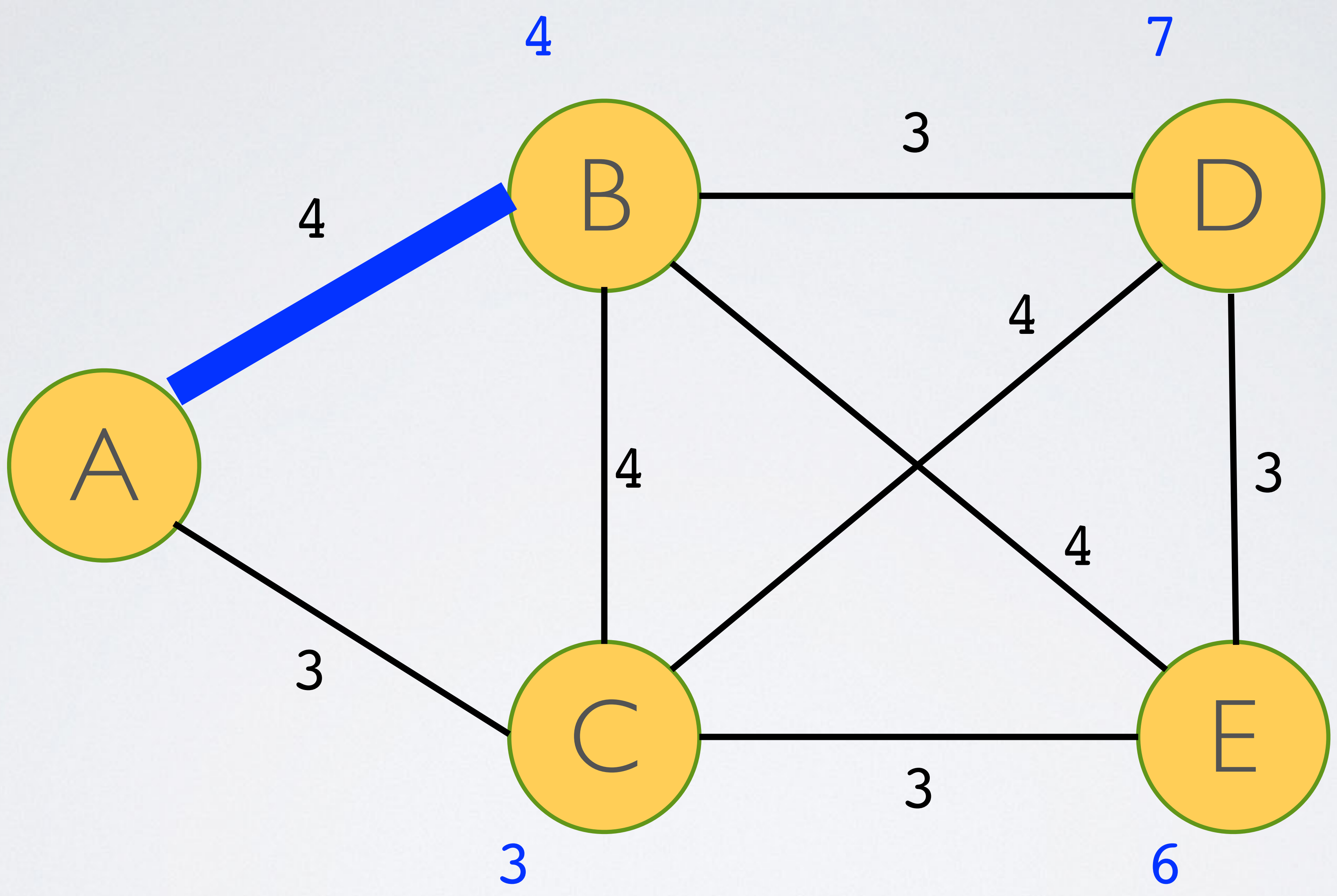


Draw next to each node the cost of the shortest path from A to that node

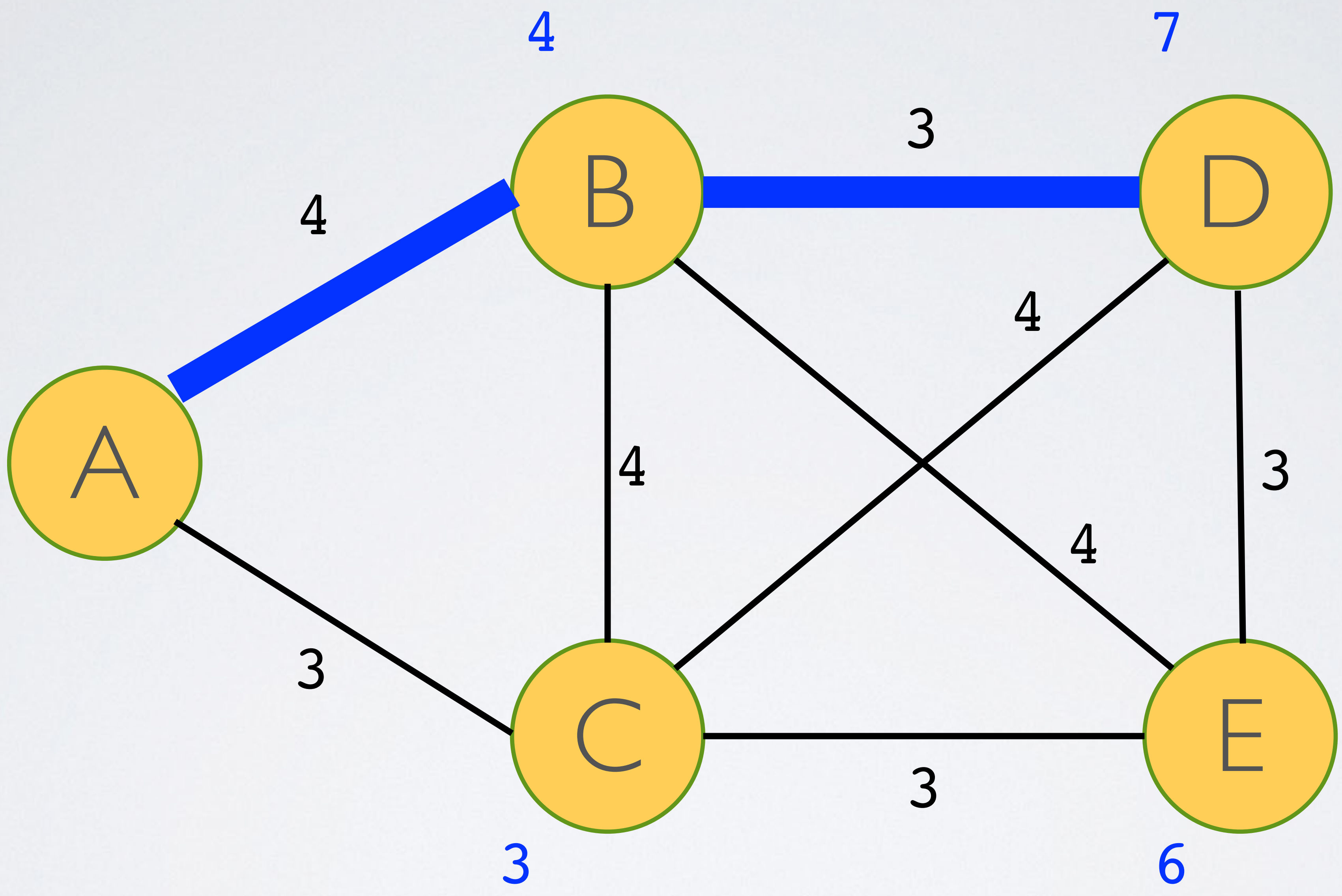
Shortest path



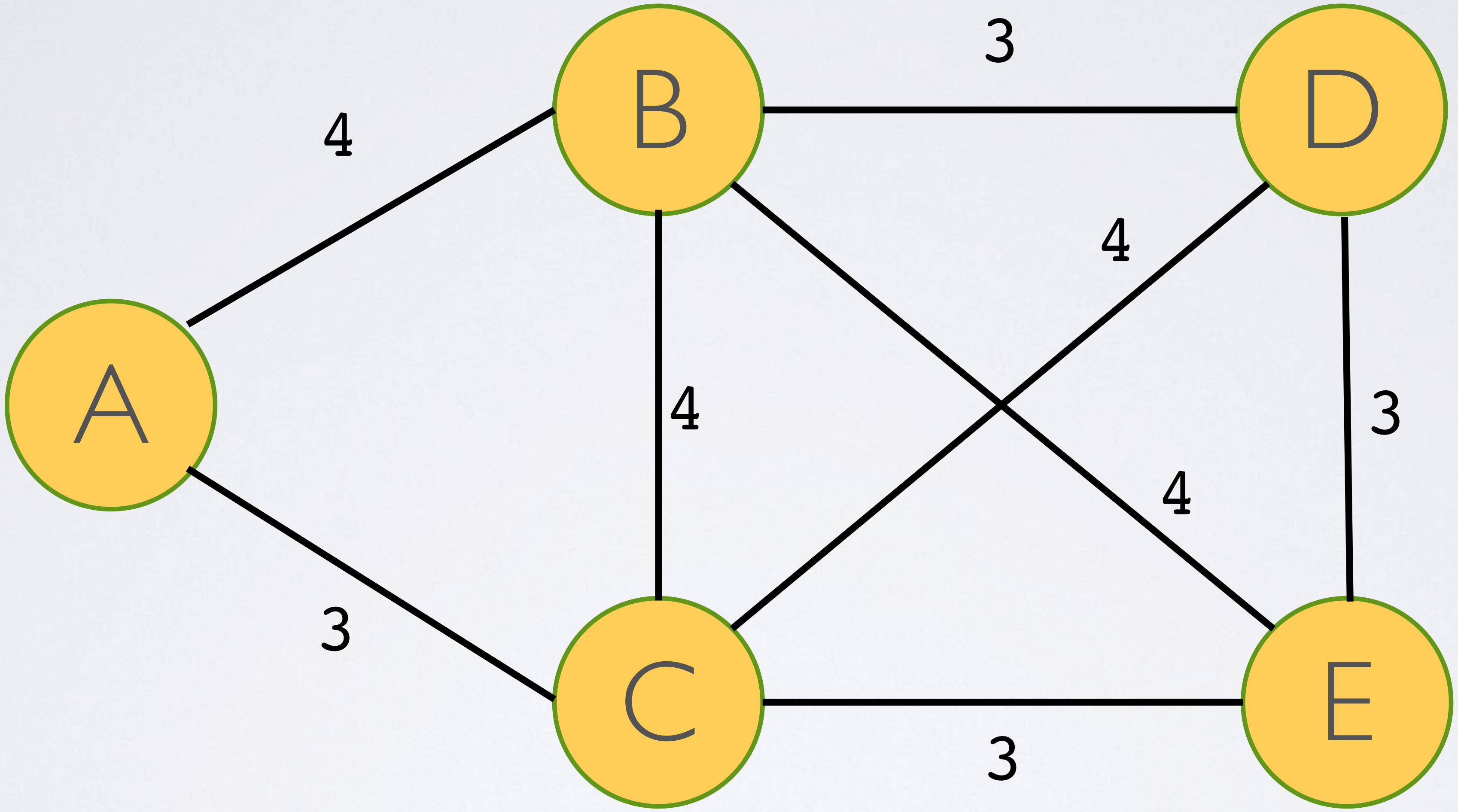
Shortest path



Shortest path

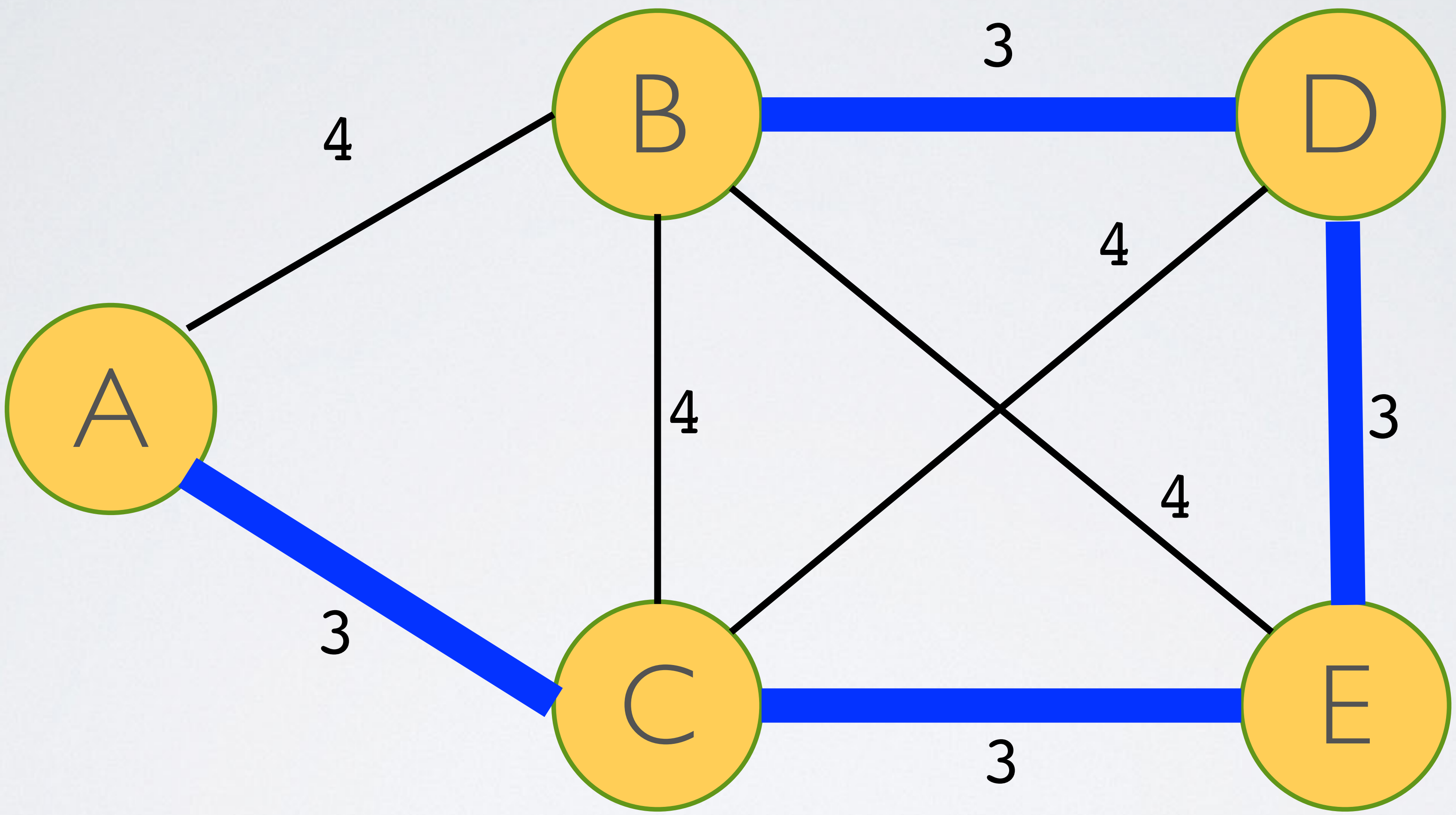


Minimum spanning tree



Draw the minimum spanning tree of this graph

Minimum spanning tree



Distance from A to B in MST?
Distance from A to D in MST?

Dijkstra Pseudo-Code

```
function dijkstra(G, s):
   // Input: graph G with vertices V, and source s
   // Output: Nothing
   // Purpose: Decorate nodes with shortest distance from s
   for v in V:
     v.dist = infinity  // Initialize distance decorations
     v.prev = null      // Initialize previous pointers to null
   s.dist = 0         // Set distance to start to 0

   PQ = PriorityQueue(V)    // Use v.dist as priorities
   while PQ not empty:
      u = PQ.removeMin()
      for all edges (u, v):  //each edge coming out of u
         if u.dist + cost(u, v) < v.dist: // cost() is weight
            v.dist = u.dist + cost(u,v)   // Replace as necessary
            v.prev = u        // Maintain pointers for path
            PQ.decreaseKey(v, v.dist)
```

Prim-Jarnik Pseudo-code

```
function prim(G):
   // Input: weighted, undirected graph G with vertices V
   // Output: list of edges in MST
   for all v in V:
      v.cost = ∞
      v.prev = null
   s = a random v in V // pick a random source s
   s.cost = 0
   MST = []
   PQ = PriorityQueue(V) // priorities will be v.cost values
   while PQ is not empty:
      v = PQ.removeMin()
      if v.prev != null:
         MST.append((v, v.prev))
      for all incident edges (v,u) of v such that u is in PQ:
         if u.cost > (v,u).weight:
            u.cost = (v,u).weight
            u.prev = v
            PQ.decreaseKey(u, u.cost)
  return MST
```

For the final…

- To study: look over homeworks, notes
- Rewrite definitions *in your own words*
- In answering questions:
  - Be explicit and clear
  - Convince us you understand!

What we’ve done this semester

- Analysis
  - Big-O
  - Worst-case analysis
  - Amortized analysis
  - Average-case analysis
  - Social responsibility

What we’ve done this semester

- Data structures
  - Dynamic stacks, queues, lists
  - Hash tables
  - Trees
    - BSTs
    - Heaps
  - Graphs

What we've done this semester

- Algorithms
  - Recursive
  - Dynamic programming
  - Searching trees and graphs
  - Sorting
  - Shortest paths
  - MSTs
  - Topological sort

What we've done this semester

- Other stuff
  - Basics of machine learning
  - Functional programming
  - Hardness
  - Program verification

Some advice

- Sometimes performance doesn’t matter
  - Programs that will run once on small data
  - Cases where n is always small
- When it does, focus on big-O first
- Then on smaller things (constant factors, language choice, etc.)

Some advice

- Social responsibility: be prepared
- If you go on in CS (but really, regardless of what you do) at some point you'll have to make a choice
  - Your boss asks you to implement something ethically questionable
  - You get a job offer from a company whose work conflicts with your values
- Worth spending some time thinking about what you'll do

Some advice

- One reason to learn data structures and algorithms: try not to reinvent the wheel
- You're looking at a problem (for an independent class project, for work, for research, etc.)
  - Can this problem be represented as a graph?
  - Would a priority queue be useful?
  - Is this problem amenable to dynamic programming?
  - Is this problem NP-complete?
- You might not remember the details of Dijkstra's algorithm after this semester
  - But you'll know it's there when you need it!