YEAH A4

Recursive Backtracking

Logistics

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- Once again, you **are** allowed to work in pairs on this assignment. We think this one's pretty tricky, so be sure to start early!

Part 1: Warmups

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- In the first one, you'll be examining **The Towers of Hanoi**, a famous recursive problem. You'll be responsible for stepping through the recursive function and reporting back various info to us. Here are the helpful steps in the debugger:

- Stepping **over** a recursive call can be helpful when thinking holistically. A recursive call is simply a "magic" black box that completely handles the smaller subproblem.
- Stepping **into** a recursive call allows you to trace the nitty-gritty details of moving from an outer recursive call to the inner call.
- Stepping **out** of a recursive call allows you to follow along with the action when backtracking from an inner recursive call to the outer one.

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- In the second warmup, you'll be examining a **buggy** implementation of code that finds permutations. It'll be your job to figure out the little error that causes the bug, and after, you'll need to reflect as to *why* the that bug was so catastrophic.

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- In the second warmup, you'll be examining a **buggy** implementation of code that finds permutations. It'll be your job to figure out the little error that causes the bug, and after, you'll need to reflect as to *why* the that bug was so catastrophic.
    - We designed these warmups specifically because we've seen these error come up many times in the past! If you have a good understanding of why the permutations code doesn't work, you'll have a much better understanding of recursion / backtracking!

Let's hop into the code!

Poster for the 2015 film "Backtrack." Critics gave it a paltry 30% on Rotten Tomatoes, citing "not enough recursion."

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Stanford AI in Healthcare

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- A growing application of CS is in the field of Healthcare.
- Let's utilize the recursion skill we have practiced so far to solve a cool problem!

Stanford AI in Healthcare

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Name of doctor

List of patients matched

Part 2: Doctors Without Orders

- Let’s walk through a quick example (low animation budget ahead!)

Strategy 1: Grab-n-Go!

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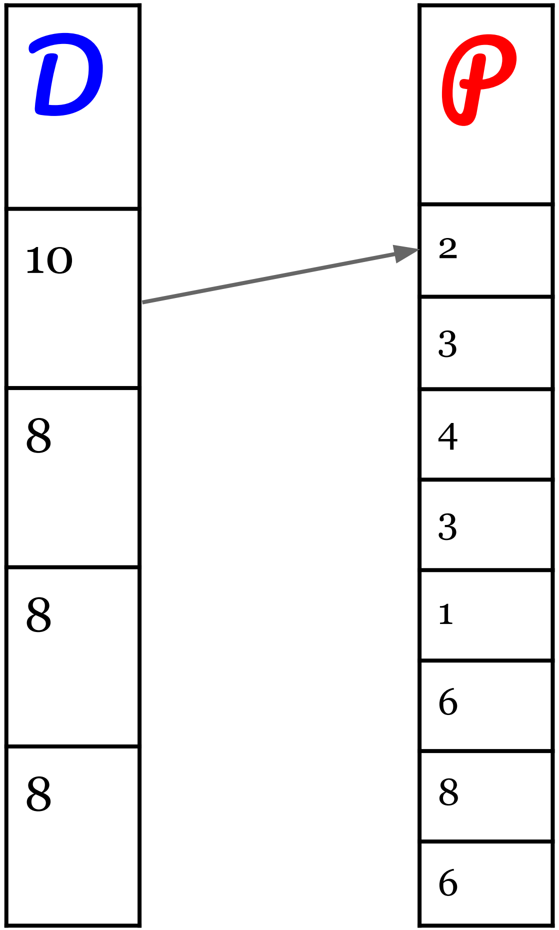

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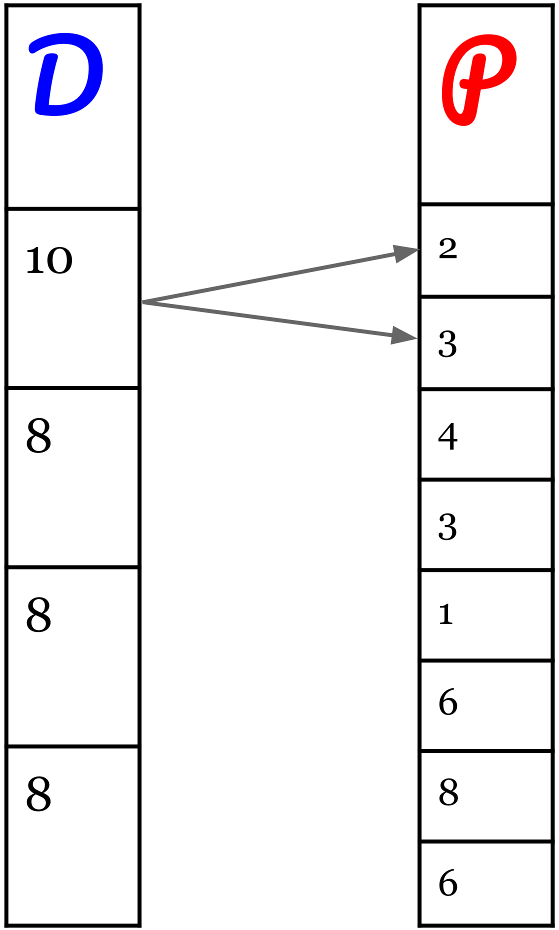

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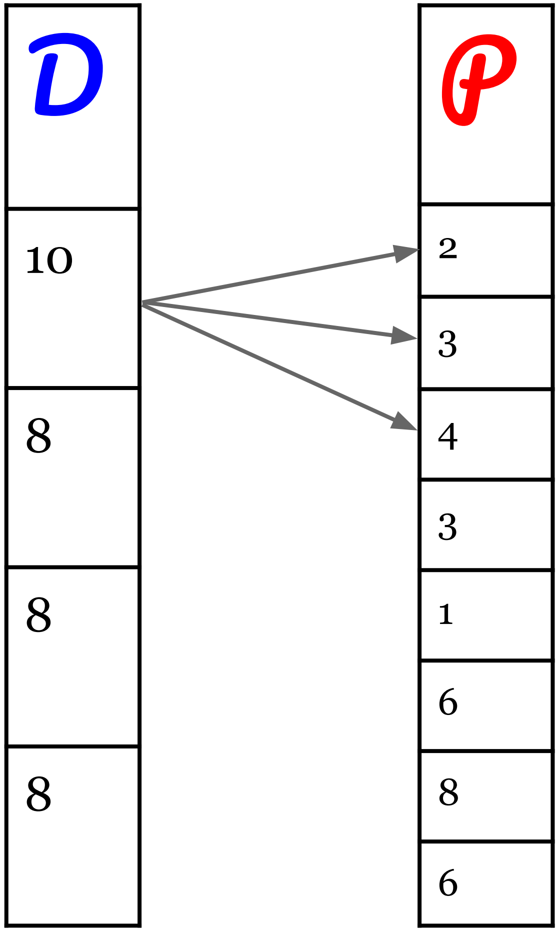

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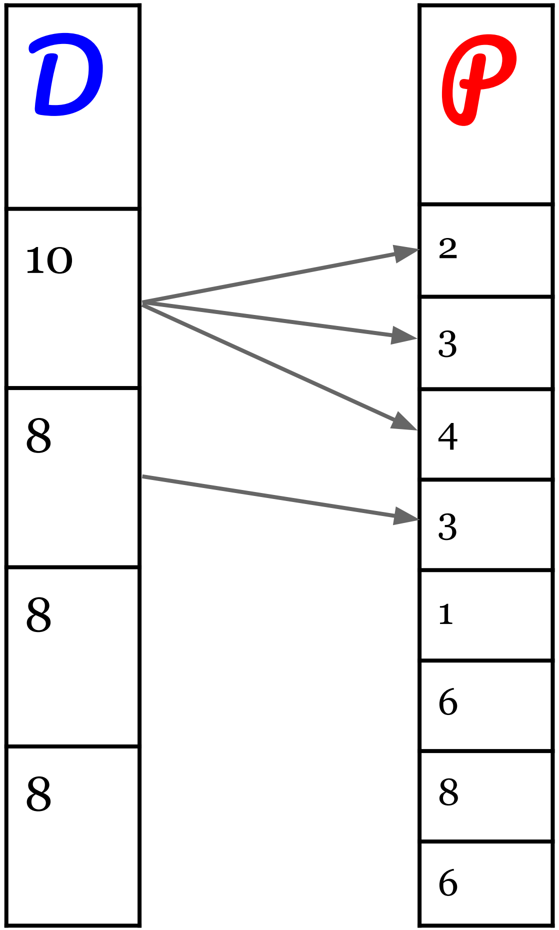

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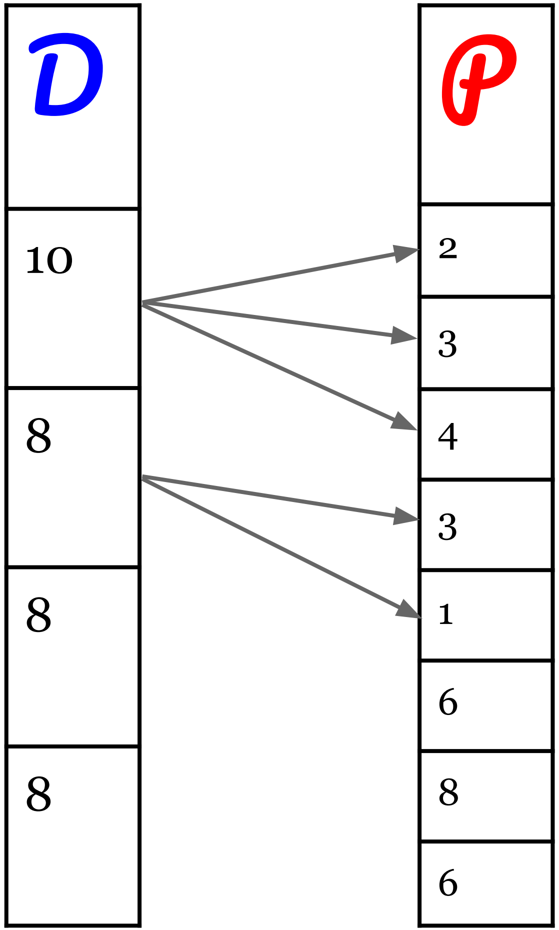

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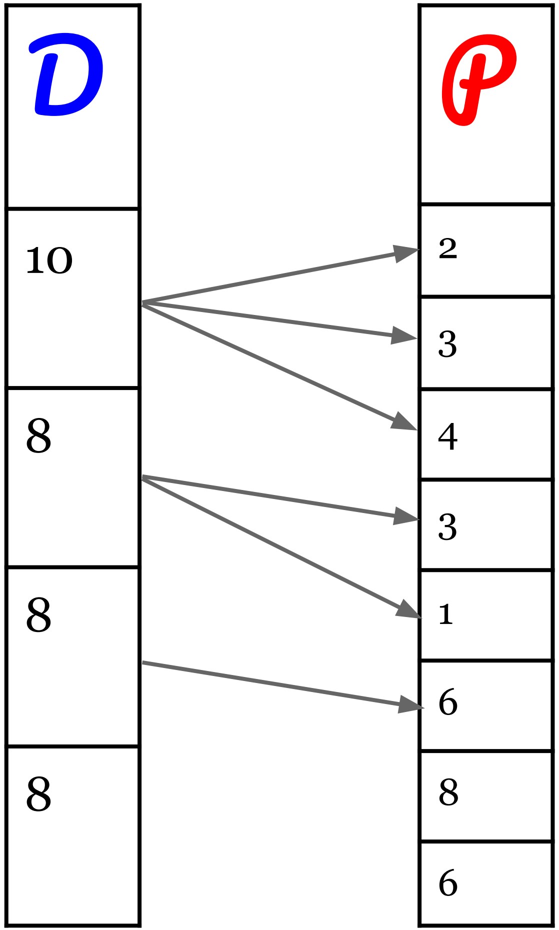

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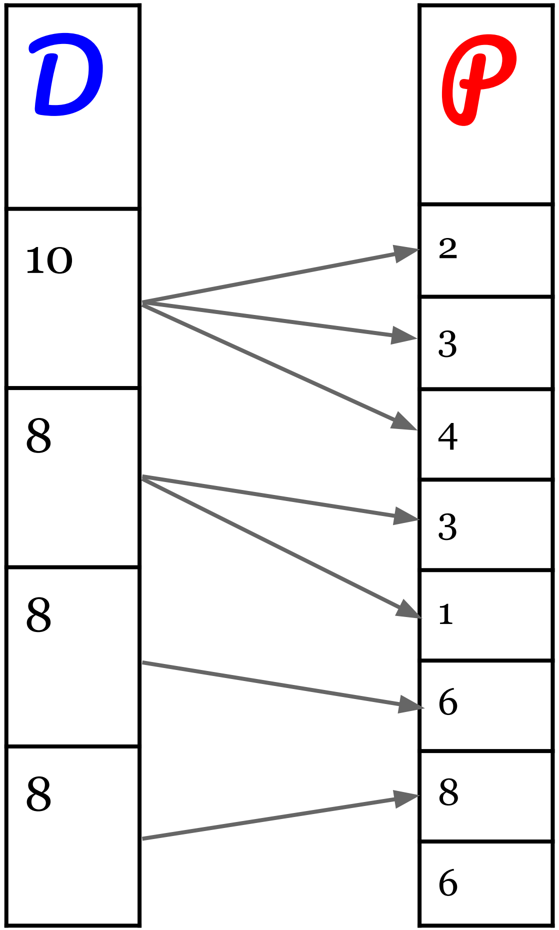

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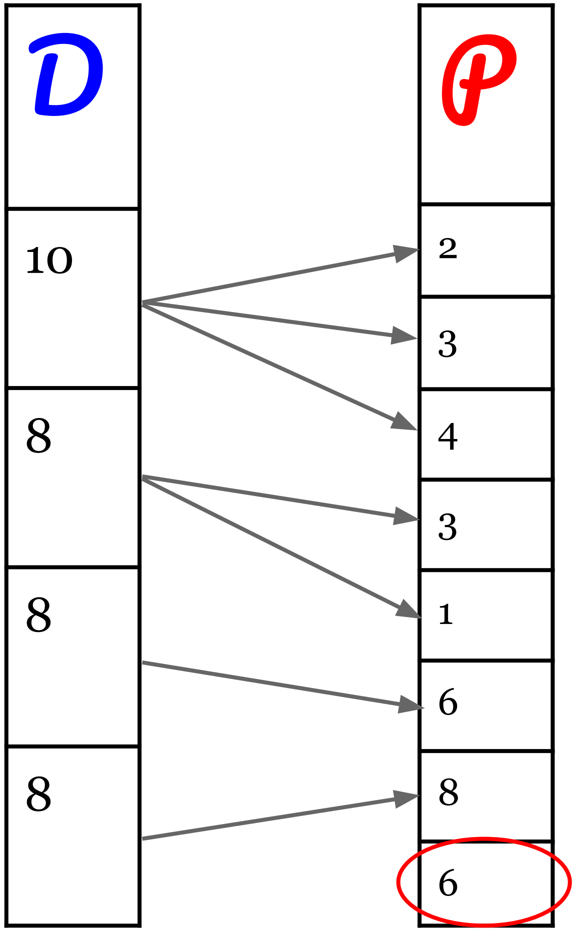
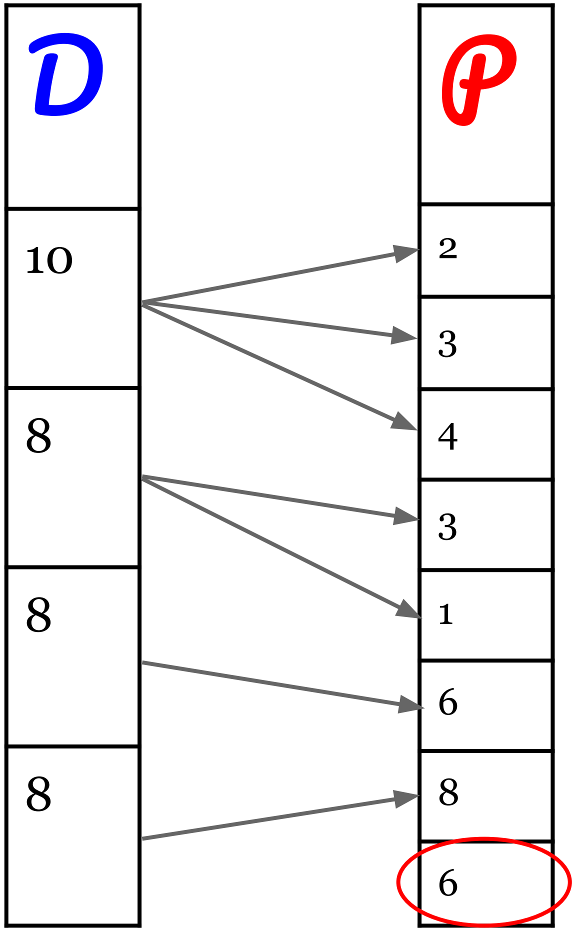


Strategy 1: Grab-n-Go!

Surprise! That's didn't work!



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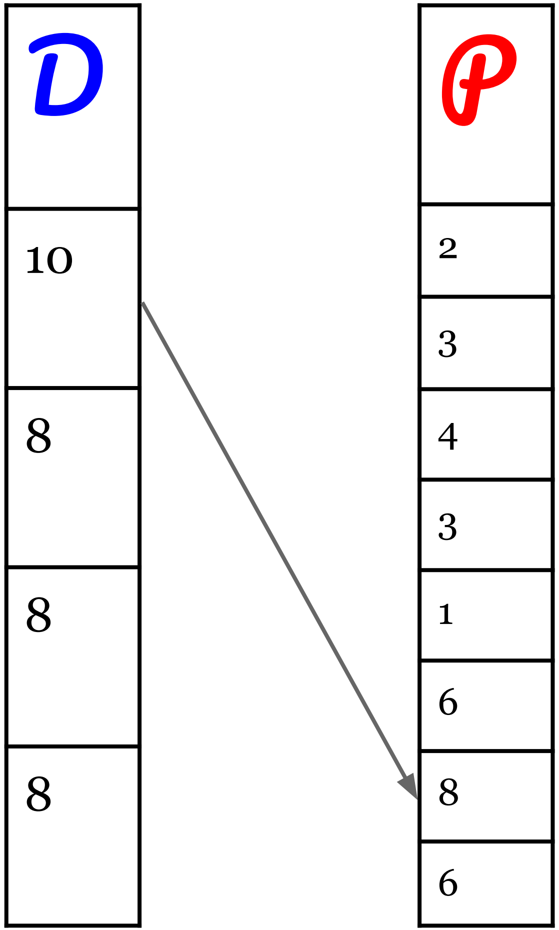

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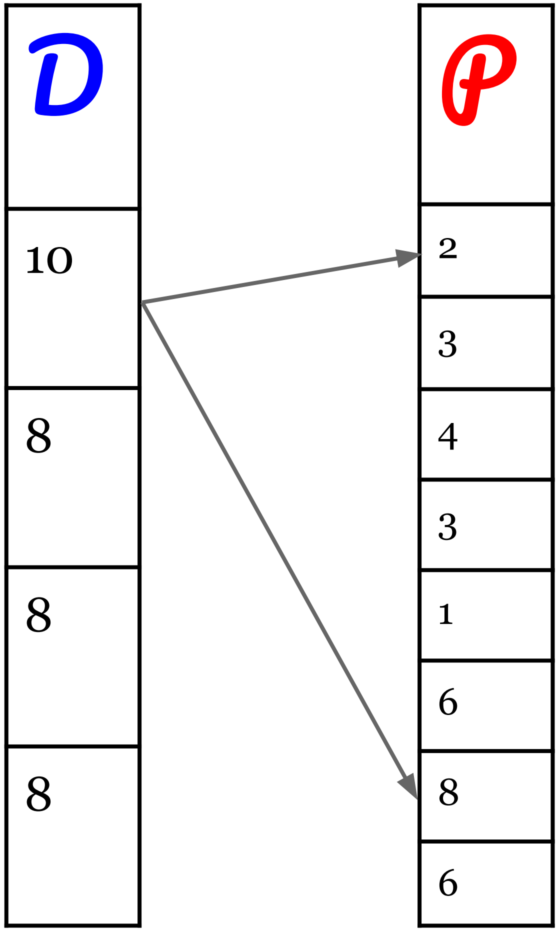

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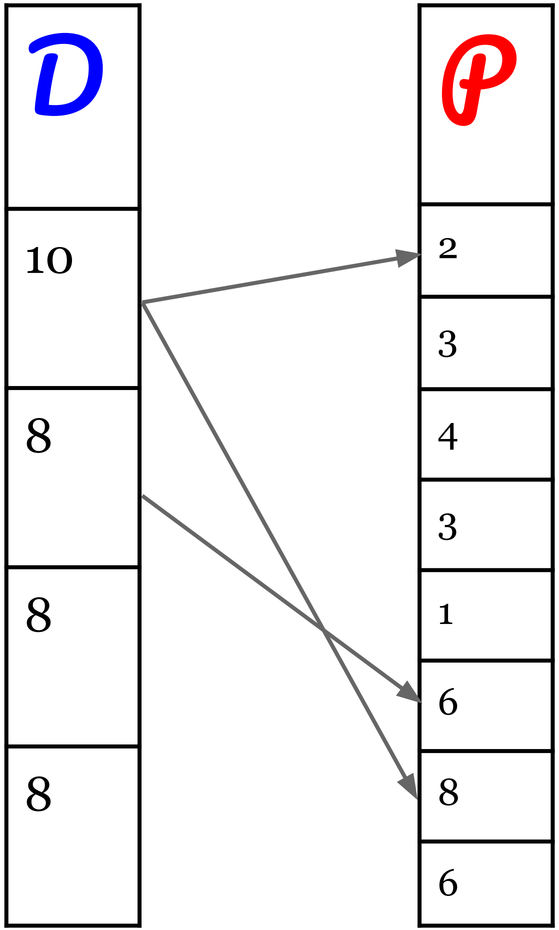

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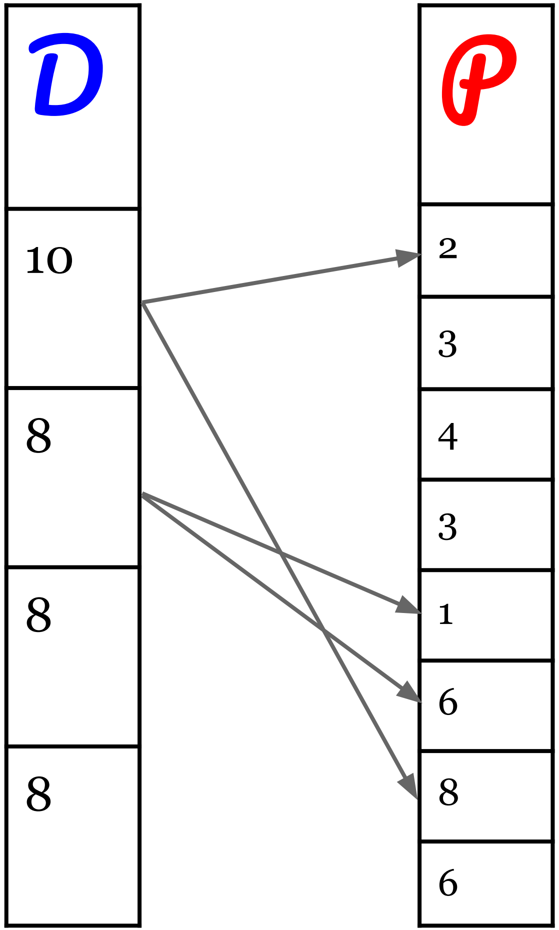

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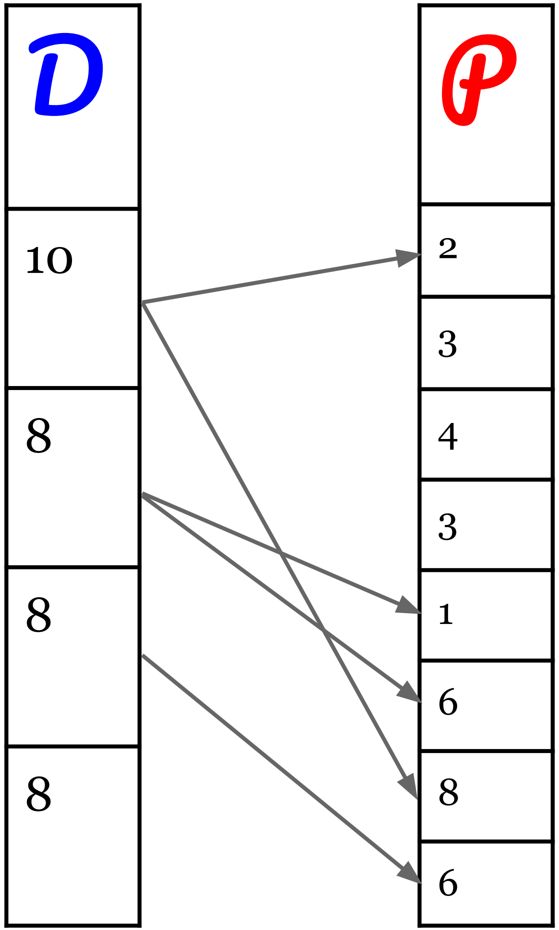

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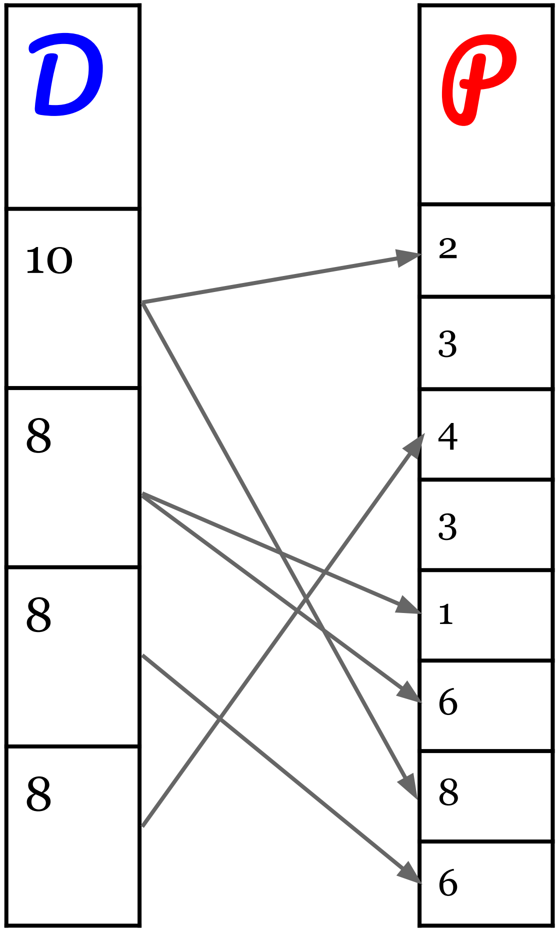

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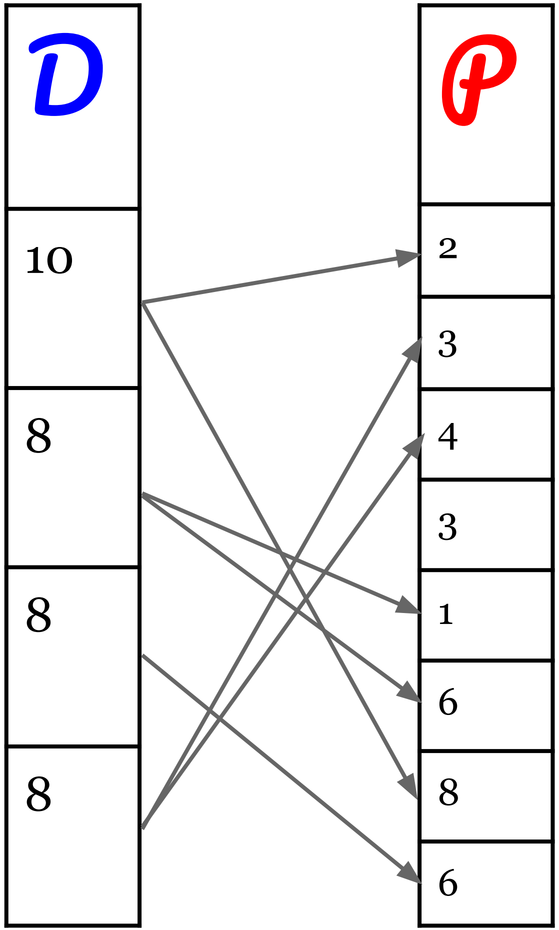

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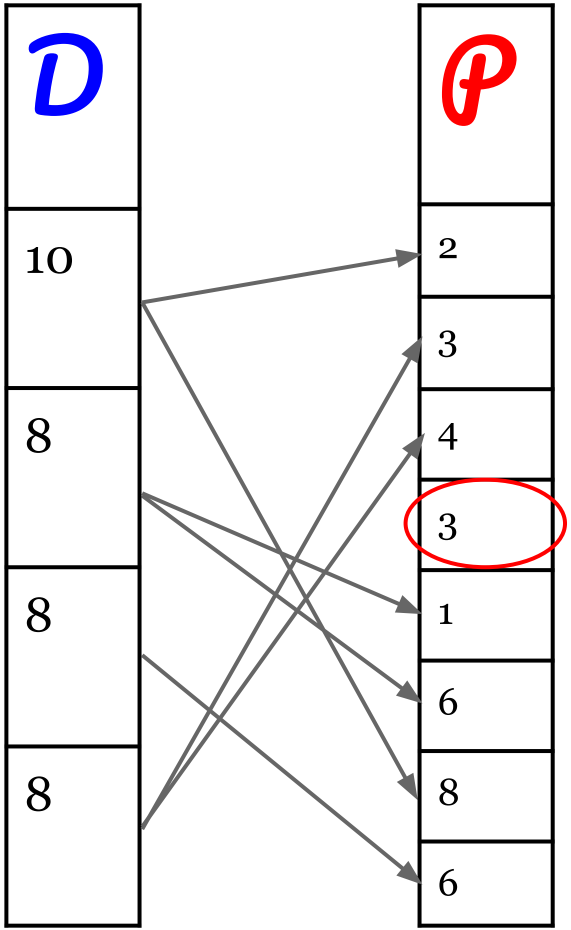

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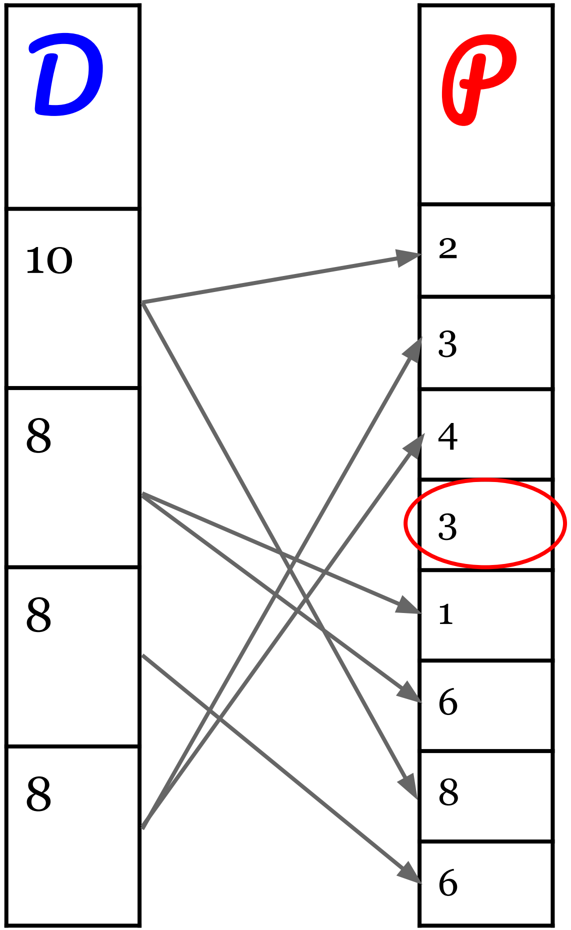

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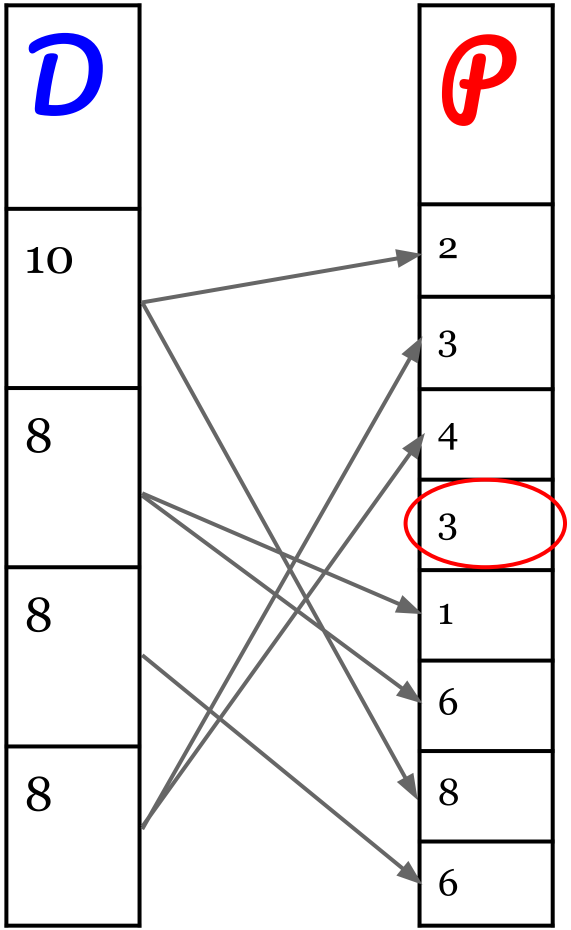
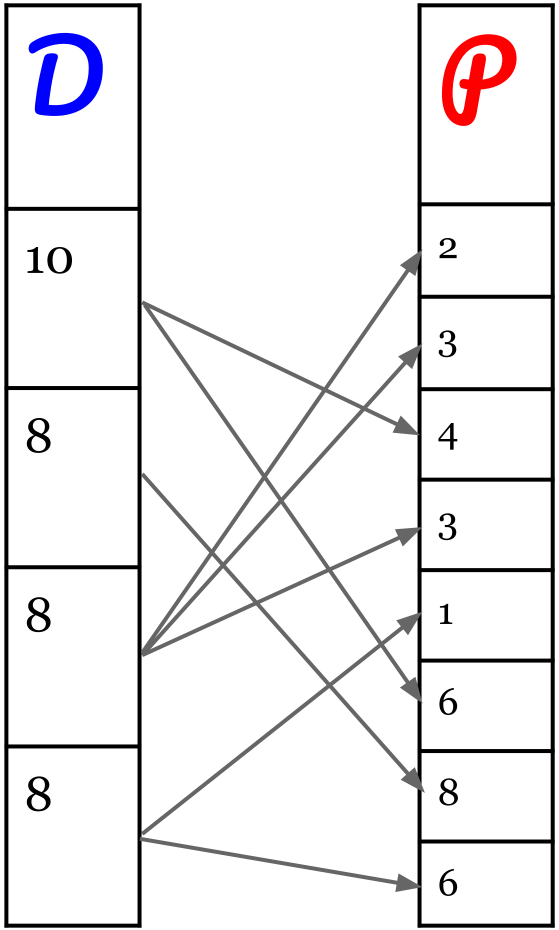
Note: This is provable! Take CS 161 to find out :)



“Strategy” 3: Oracle

There is indeed a solution here.



Part 2: Doctors Without Orders

- Some notes:
  - Each patient can only be assigned to ONE doctor.

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bool canAllPatientsBeSeen(const Map<string, int>& doctors,
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    - Each patient can only be assigned to ONE doctor.
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  - Doctors don’t have to use up all of their hours.
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  - We don’t care what “schedule” contains if not matching is possible.
    - Although we imagine that you don’t have to explicitly address this case.

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    - **`map.firstKey()`** can give you a “random” key from the map.
    - Not the first priority, but make sure your code is efficient (there is a stress test).
        - Don’t make repeated schedules.
        - Don’t go down impossible paths (like intentionally ignoring a patient).

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Questions?

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- A few limitations:
    - Limited supplies: We can't afford to stockpile **all** cities, so we can only pick a **strict subset** of the vulnerable cities to cover.
    - Need for proximity: A city cannot react to a disaster fast enough if the closest emergency supply is too far away.

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- A region is represented by a set of cities, and each pair of cities can be optionally connected by a road.
    - `Map<string, Set<string>>& roadNetwork;`

Name of city

List of cities it is connect to

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    - `Map<string, Set<string>>& roadNetwork;`
- There are only a limited number of cities we can directly supply.
    - `int numCities;`
- We would like to know, if possible, what cities should be supplied so, for every city in the region, it is either directly supplied, or adjacent to a city that is directly supplied.
    - `Set<string> supplyLocations;`

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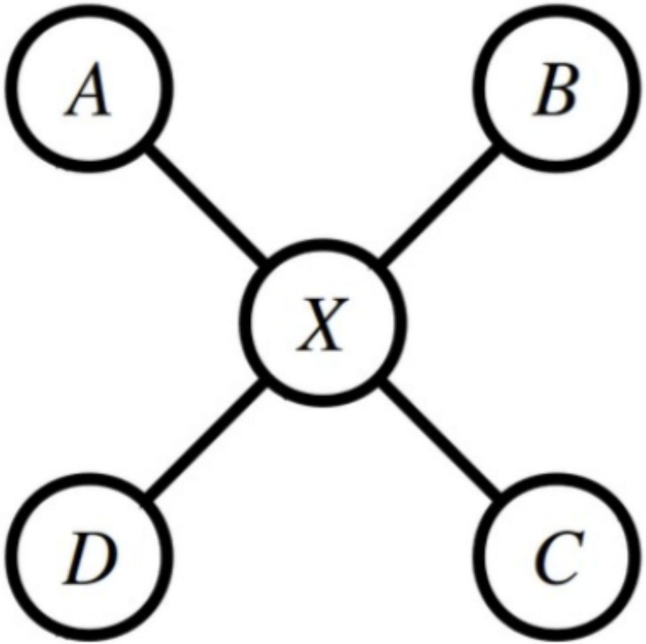

Say we have 5 Cities, A, B, X, D and C!

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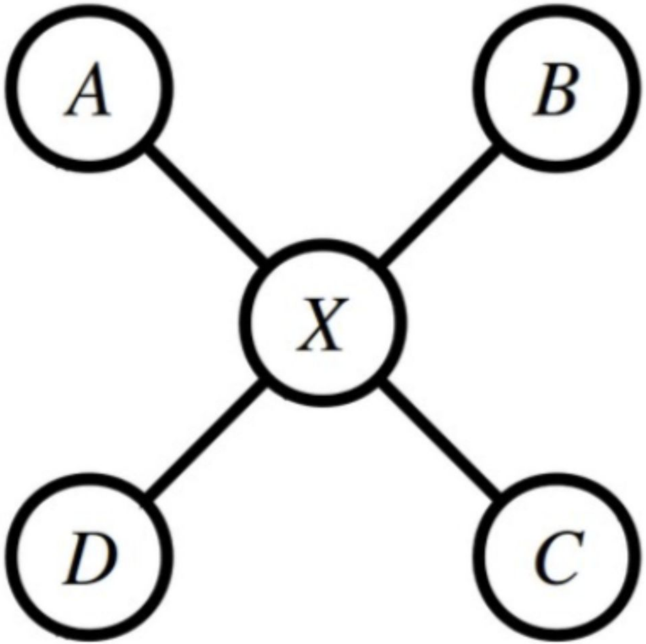

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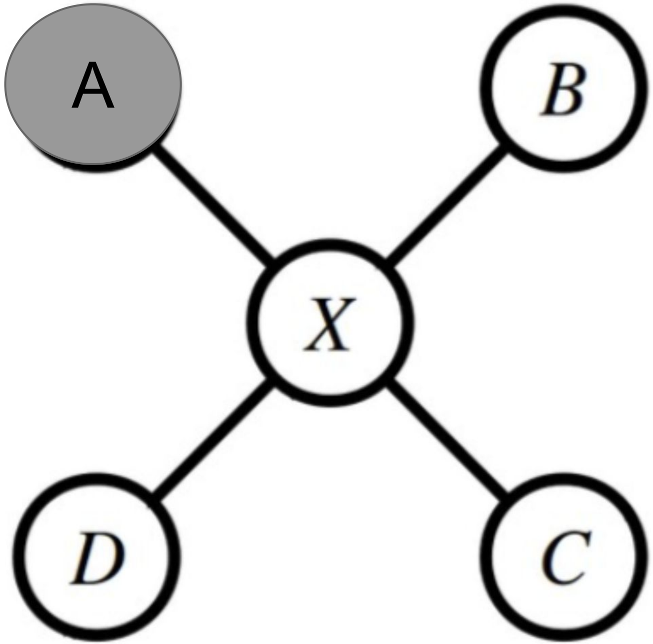

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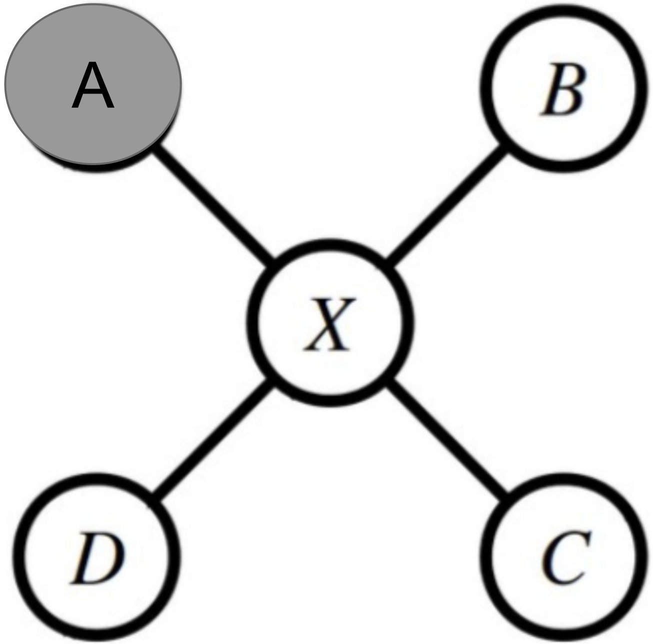

City A is now stocked up and safe, but because city A is neighbors with city X, city X is also covered due to its proximity!

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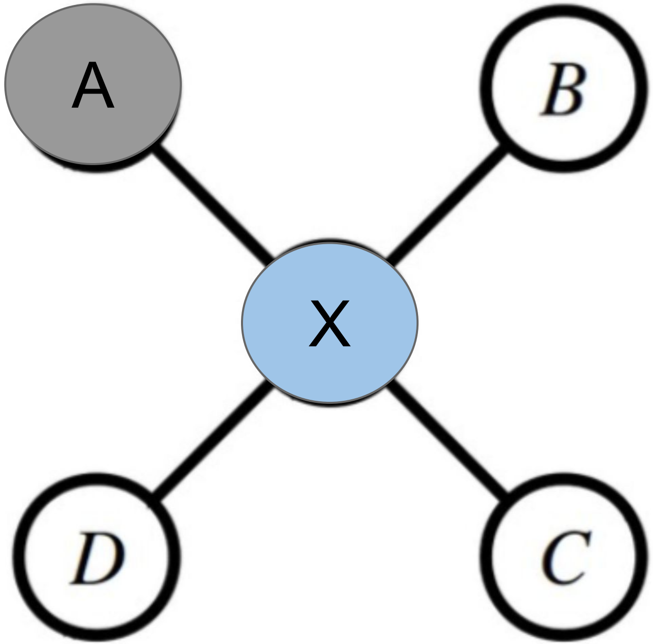

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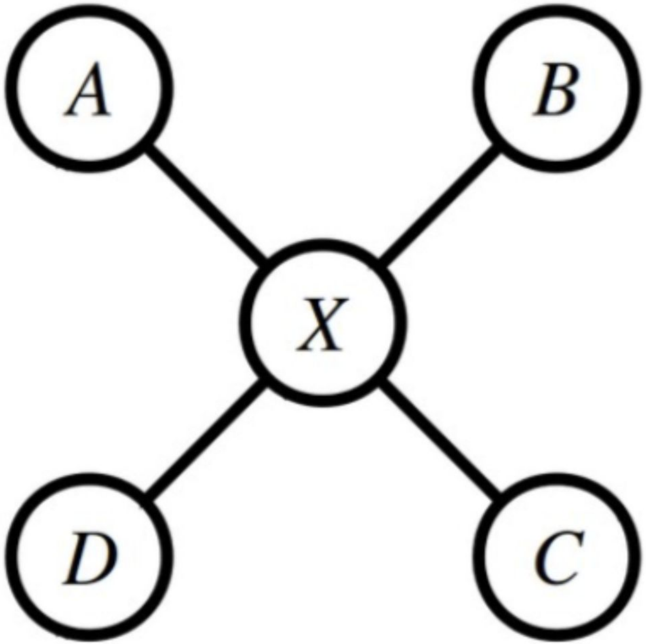

Question, what's the minimum number of cities we need to supply to "cover" all cities in this region?

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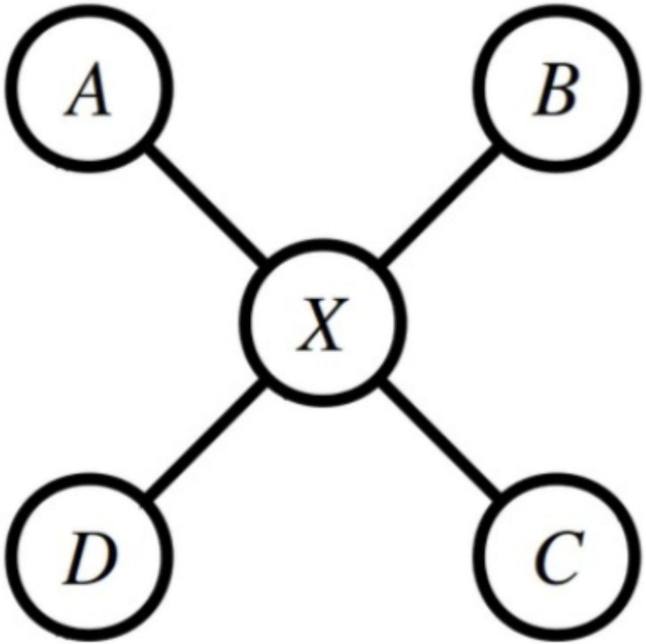

One! City X!

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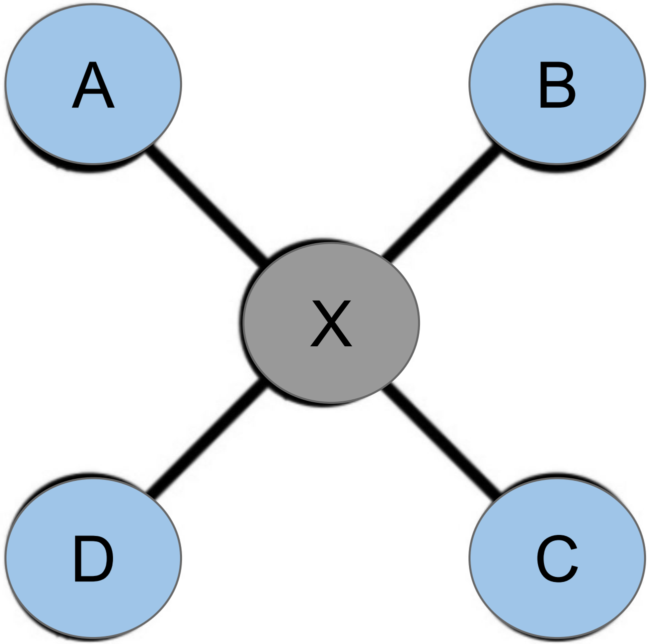

Remember that cities can be covered by their neighbors! This will come in handy in this assignment!

Part 3: Disaster Planning

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                            Set<string>& supplyLocations);
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Let’s go over the algorithm to solve this problem:

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Let’s go over the algorithm to solve this problem:

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2. For each way that it can be covered (i.e. covering the city or ANY of its neighbors), try covering that option, and then see whether the result of covering it returns **true**. If so, then covering that option was the correct choice, and you can return **true**. If all choices return false, then there's no way to cover that city, meaning that you cannot cover all cities -- you should return **false.**

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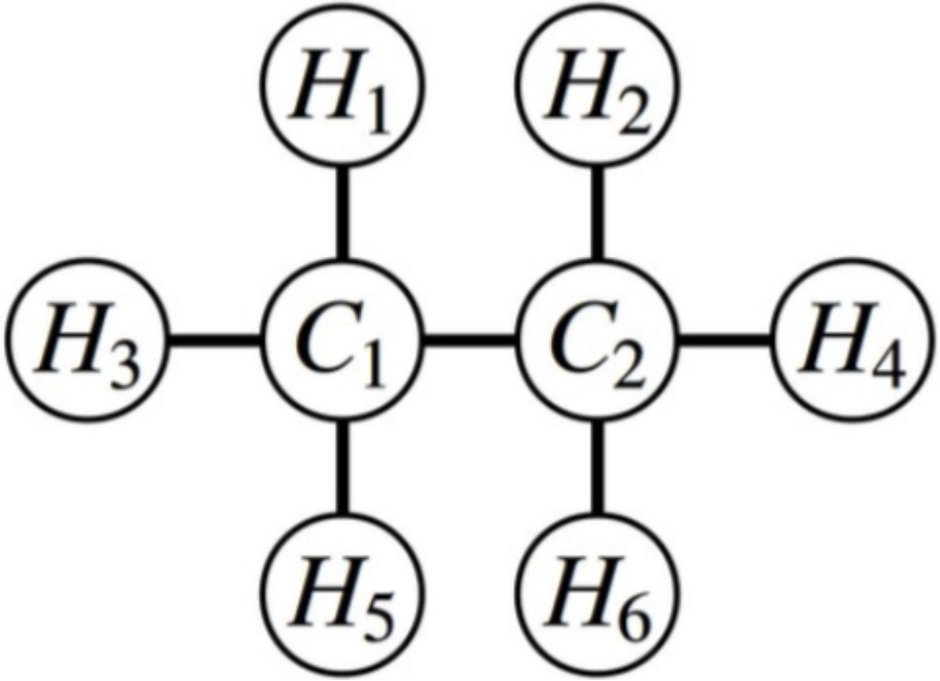
Part 3: Disaster Planning

Let's see some brief examples of this:



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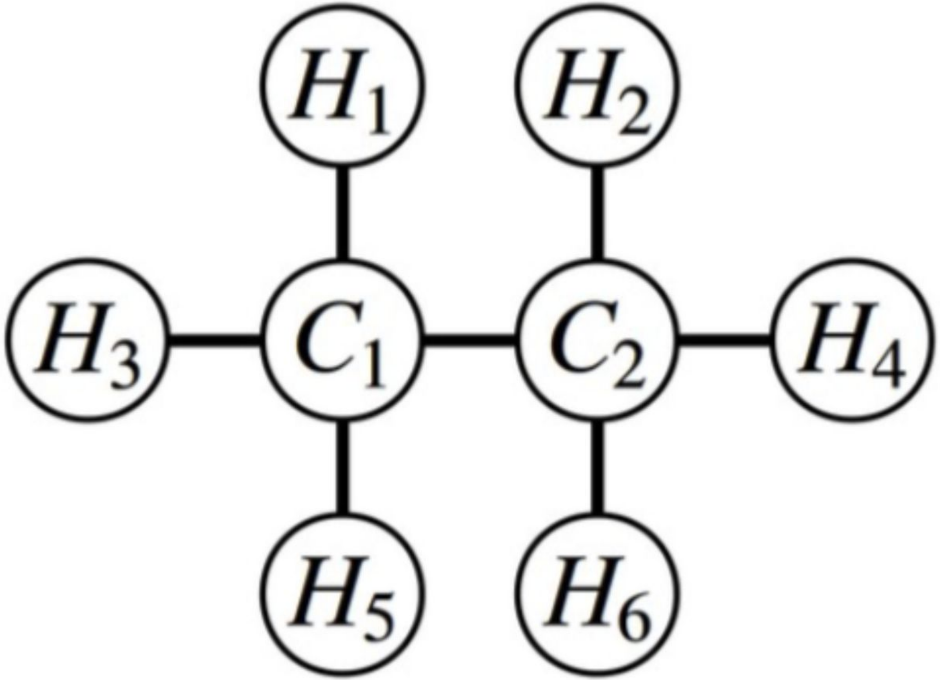

Let’s pick an uncovered city, say, H1

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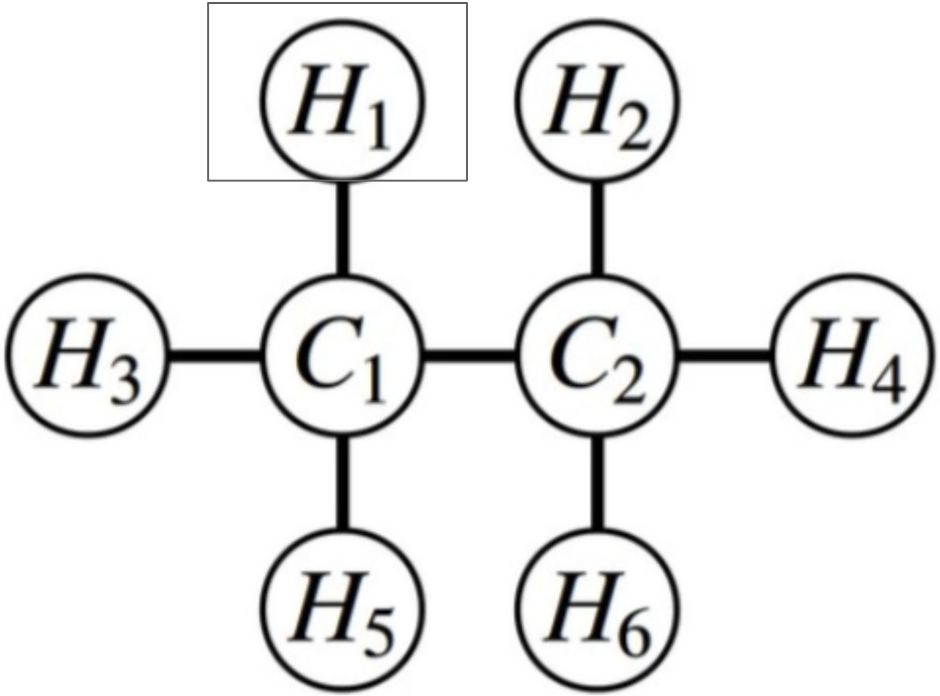

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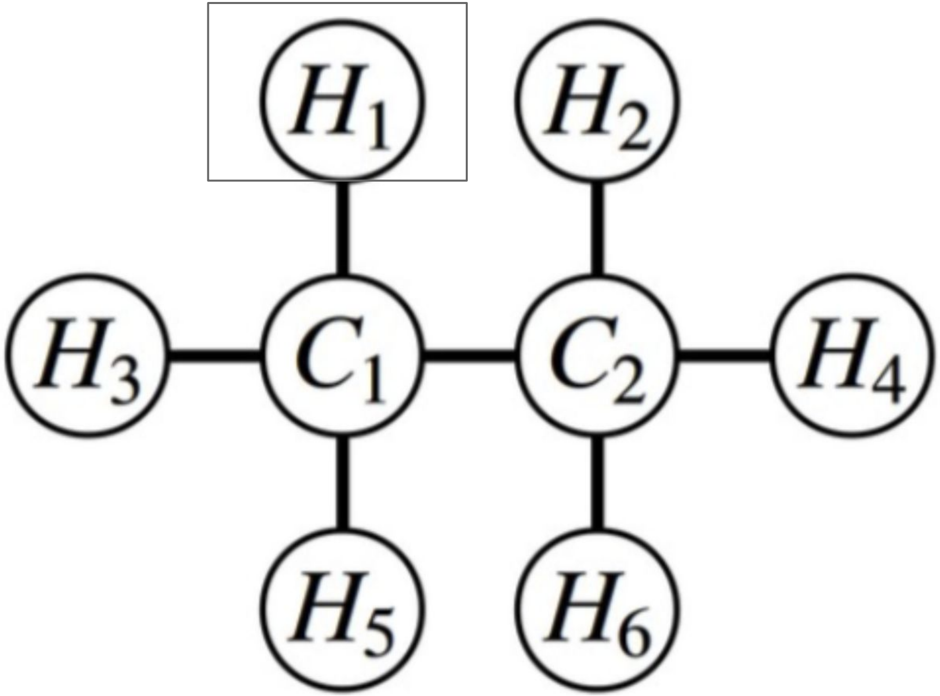

How many ways can we cover H1?

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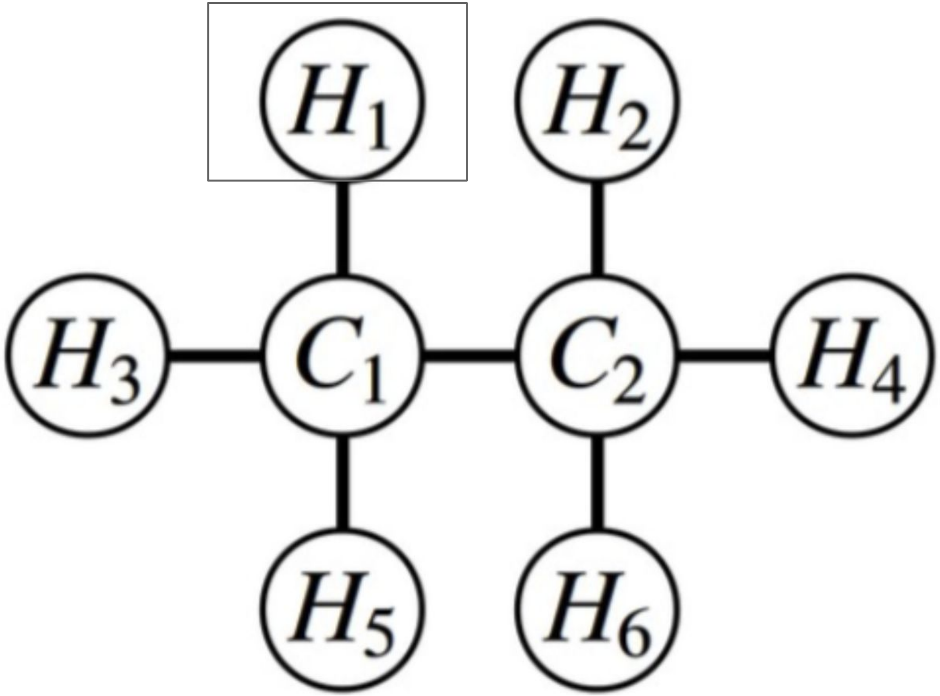

Only 2 ways: either by covering H1 or by covering C1

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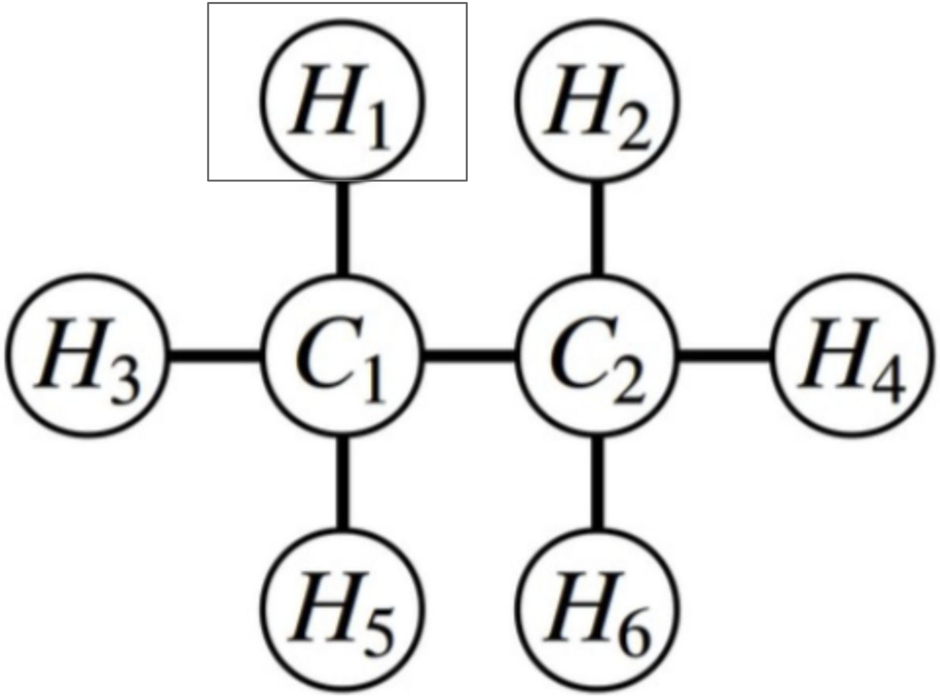

Let's say that we first try covering C1:

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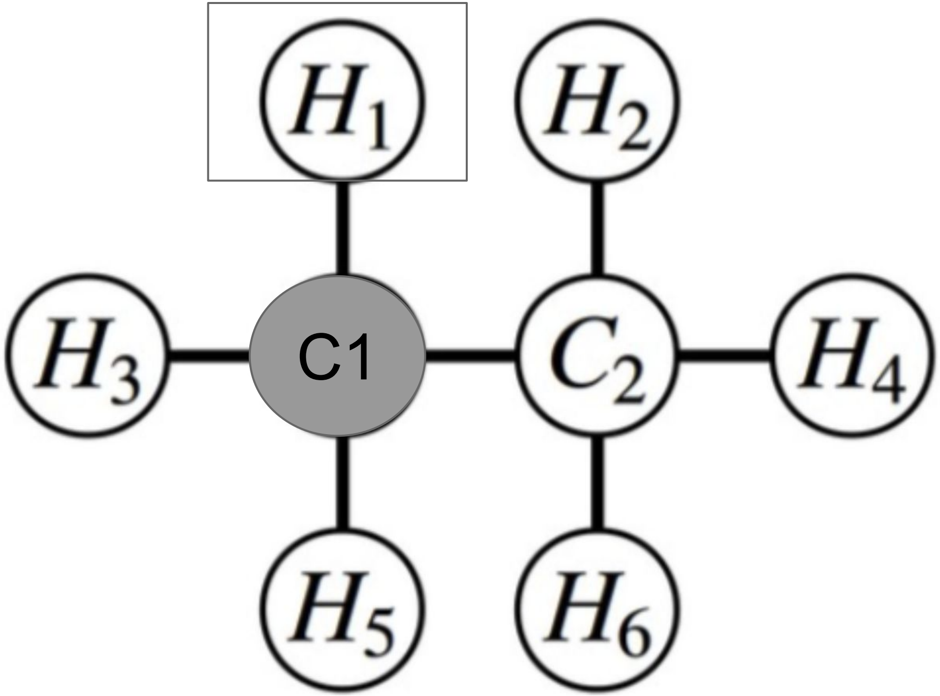

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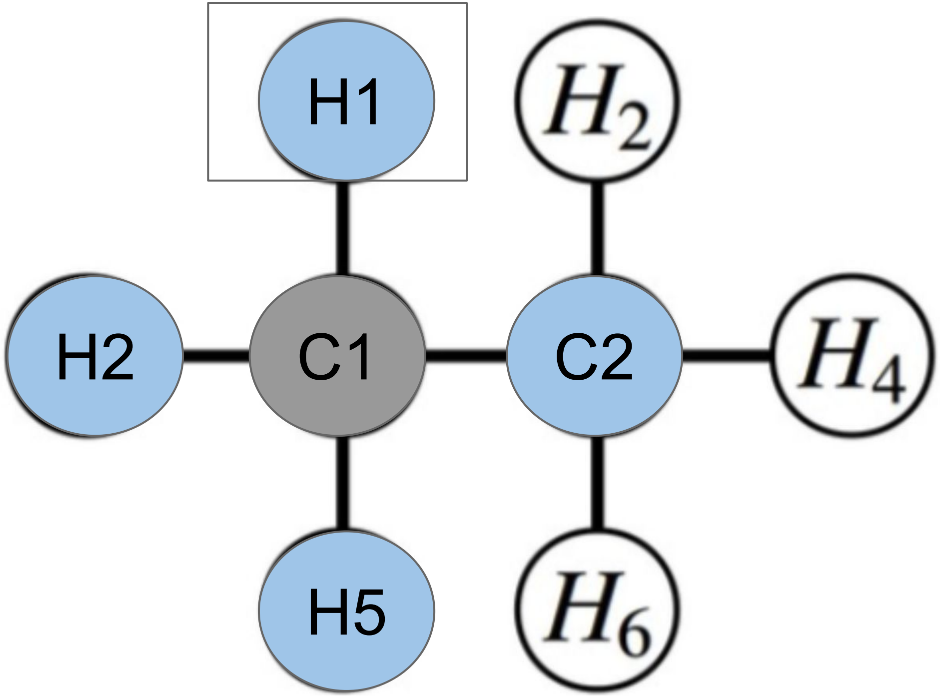

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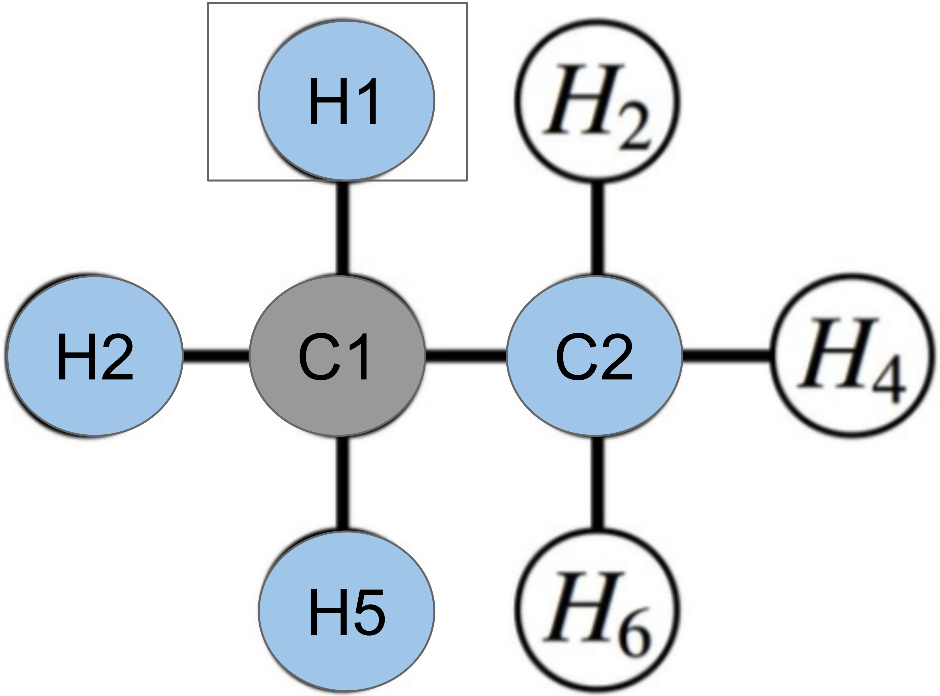

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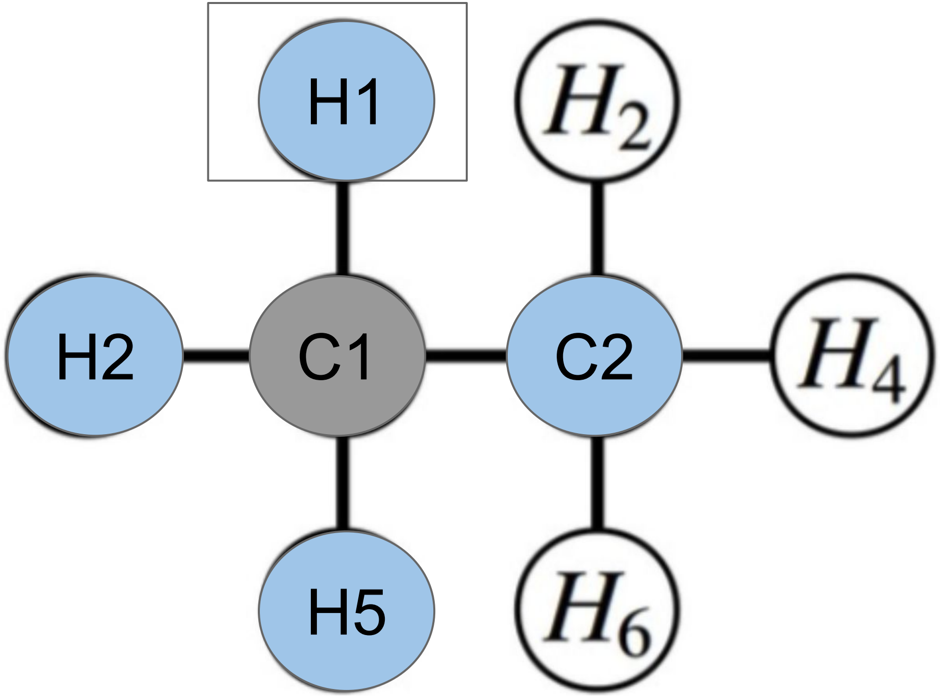

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In technical terms, by covering some city **C**, you can remove **roadNetwork[C]** (all of **C's** neighbors) from the set of uncovered cities, including C

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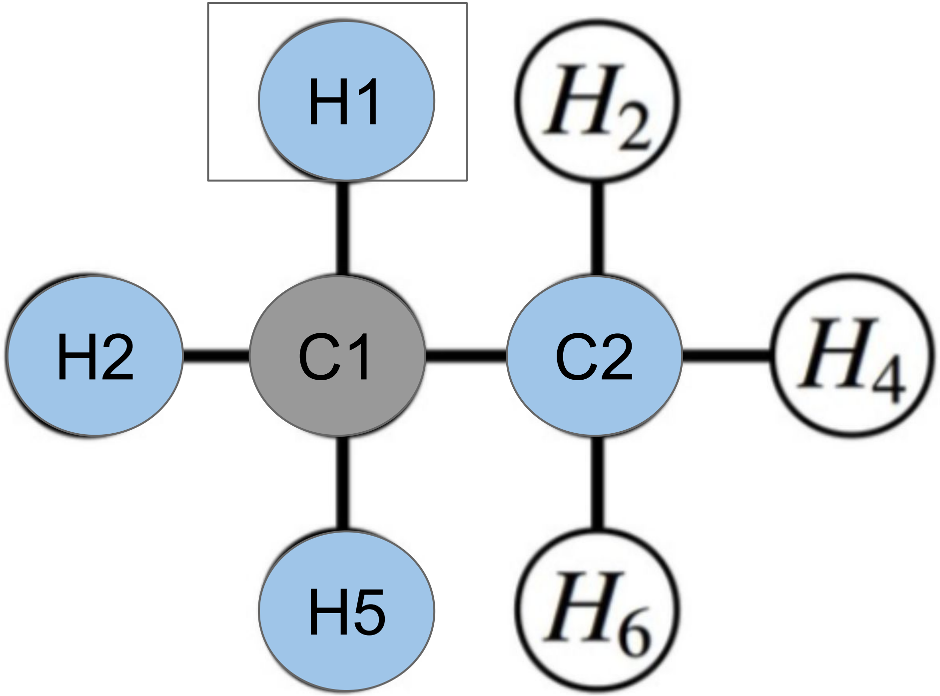

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Be sure to account for these changes in every recursive call!

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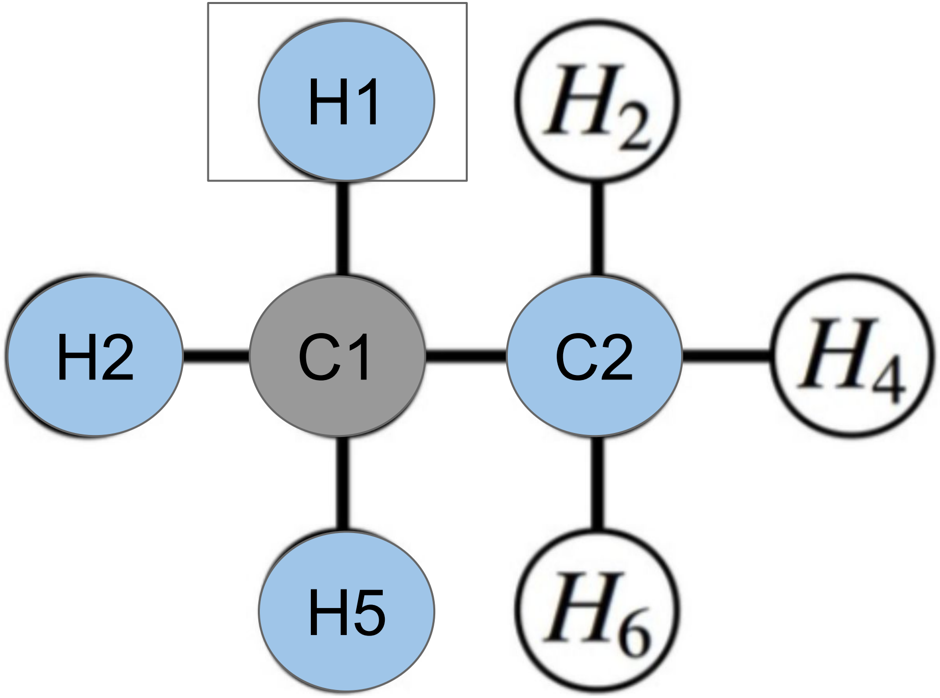

What's the next optimal choice to cover all cities?

Part 3: Disaster Planning

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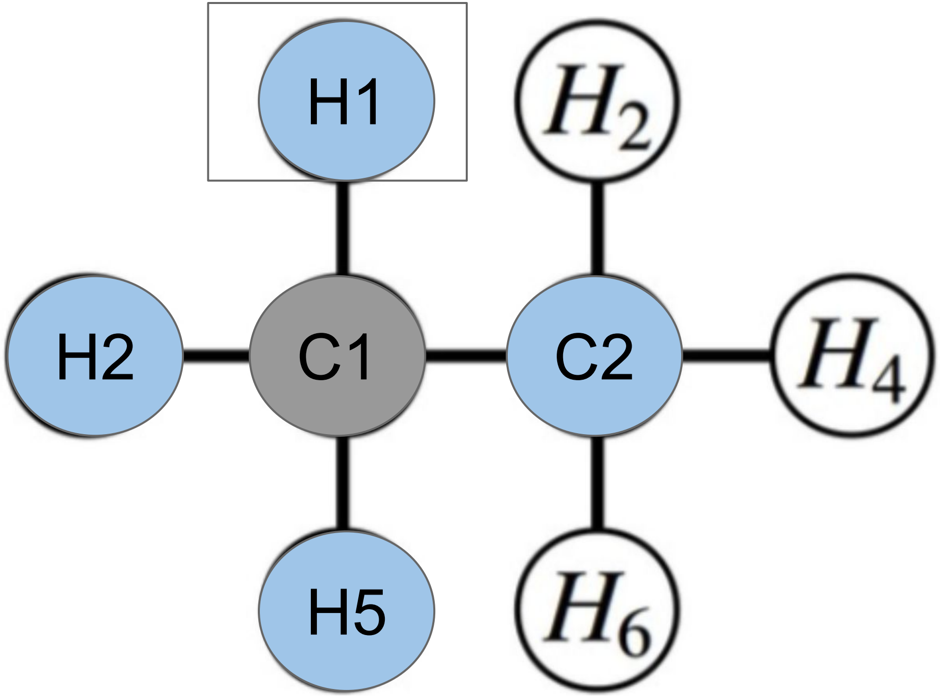

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C2! Even though it's already "covered," it is worth stockpiling the city because it will cover the last 3 uncovered cities!

Part 3: Disaster Planning

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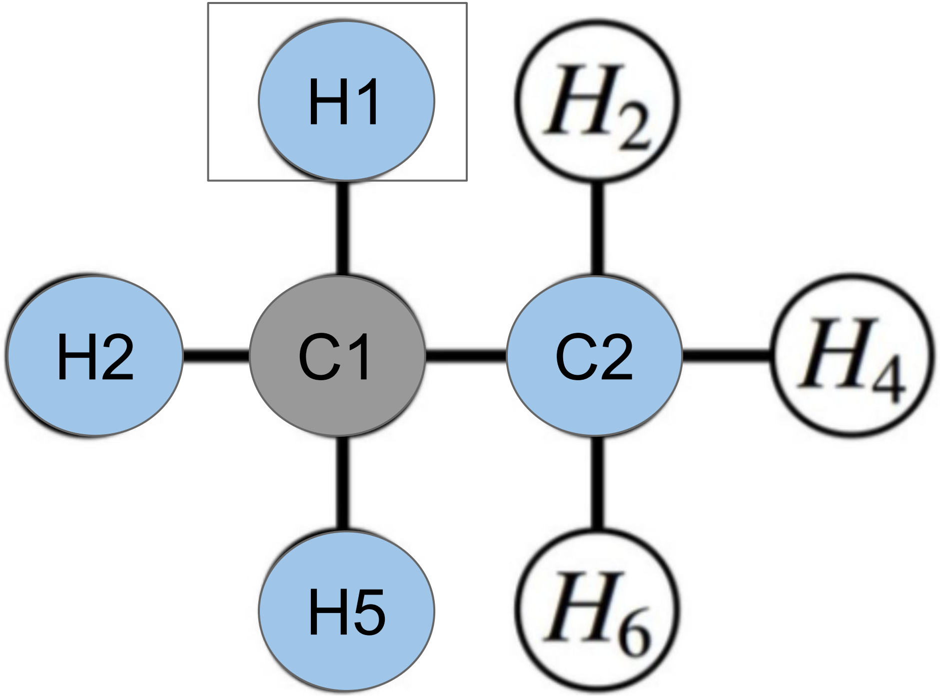

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Your computer won't be able to analyze the diagrams, so it needs to try all options :p

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  - **`numCities`** can be zero, but you should raise an **`error()`** if it’s negative.
  - Keith recommends getting the return statement correct before filling the outparameter **`supplyLocations`**. Once you’ve gotten the functionality correct that determines whether a region can be supplied, *then* you can start working on the outparameter.

```
bool canBeMadeDisasterReady(const Map<string, Set<string>>& roadNetwork,
                            int numCities,
                            Set<string>& supplyLocations);
```

Questions?