CSE 143
Lecture 16

More Recursive Backtracking

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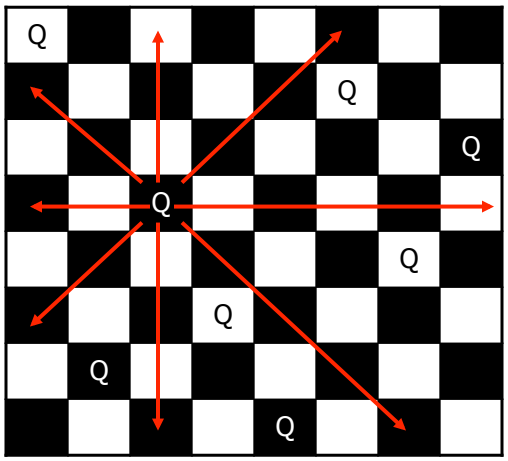
http://www.cs.washington.edu/143/

The "8 Queens" problem

- Consider the problem of trying to place 8 queens on a chess board such that no queen can attack another queen.
  - What are the "choices"?
  - How do we "make" or "un-make" a choice?
  - How do we know when to stop?



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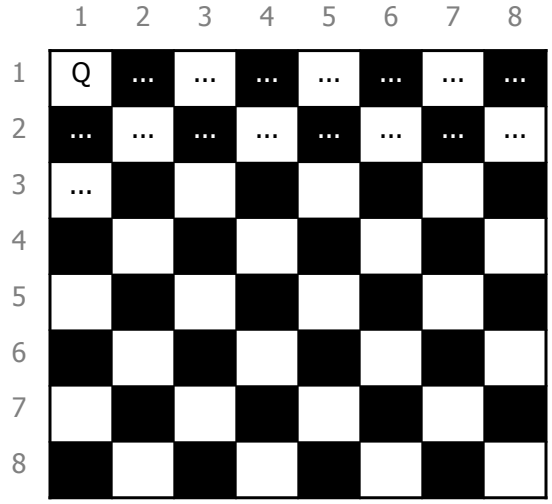
Naive algorithm

- for (each square on board):
  - Place a queen there.
  - Try to place the rest of the queens.
  - Un-place the queen.
  - How large is the solution space for this algorithm?
    - 64 * 63 * 62 * ...



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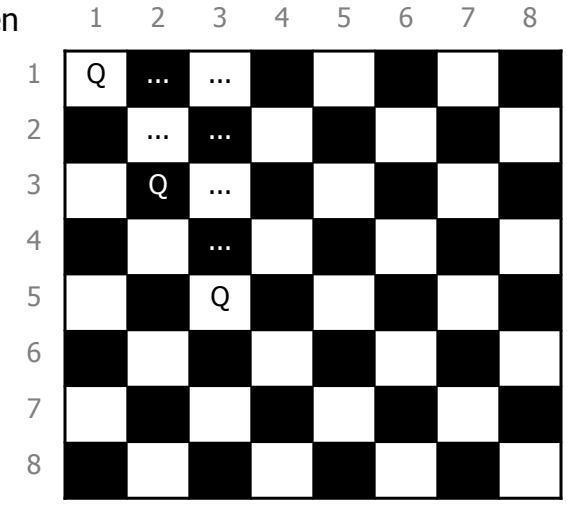
Better algorithm idea

- Observation: In a working solution, exactly 1 queen must appear in each row and in each column.
  - Redefine a "choice" to be valid placement of a queen in a particular column.
  - How large is the solution space now?
    - 8 * 8 * 8 * ...



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Exercise

- Suppose we have a `Board` class with the following methods:

Method/Constructor	Description
`public` **`Board`**`(int size)`	construct empty board
`public boolean` **`isSafe`**`(int row, int column)`	`true` if queen can be safely placed here
`public void` **`place`**`(int row, int column)`	place queen here
`public void` **`remove`**`(int row, int column)`	remove queen from here
`public String` **`toString`**`()`	text display of board

- Write a method `solveQueens` that accepts a `Board` as a parameter and tries to place 8 queens on it safely.
  - Your method should stop exploring if it finds a solution.

Exercise solution

```
// Searches for a solution to the 8 queens problem
// with this board, reporting the first result found.
public static void solveQueens(Board board) {
    if (!explore(board, 1)) {
        System.out.println("No solution found.");
    } else {
        System.out.println("One solution is as follows:");
        System.out.println(board);
    }
}

...
```

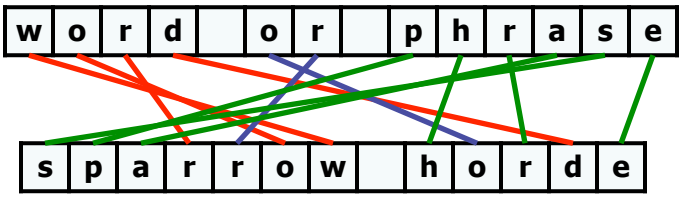
Exercise solution, cont'd.

```
// Recursively searches for a solution to 8 queens on this
// board, starting with the given column, returning true if a
// solution is found and storing that solution in the board.
// PRE: queens have been safely placed in columns 1 to (col-1)
public static boolean explore(Board board, int col) {
    if (col > board.size()) {
        return true;   // base case: all columns are placed
    } else {
        // recursive case: place a queen in this column
        for (int row = 1; row <= board.size(); row++) {
            if (board.isSafe(row, col)) {
                board.place(row, col);           // choose
                if (explore(board, col + 1)) {   // explore
                    return true;   // solution found
                }
                b.remove(row, col);              // un-choose
            }
        }
        return false;   // no solution found
    }
}
```


Anagrams

- **anagram:** a rearrangement of the letters from a word or phrase to form another word or phrase

- Consider the phrase "word or phrase"
  - one anagram of "word or phrase" is "sparrow horde"



AnagramSolver

- Consider the phrase "Ada Lovelace"
- Some anagrams of "Ada Lovelace" are:
  - "ace dale oval"
  - "coda lava eel"
  - "lace lava ode"
- We could think of each anagram as a list of words:
  - "ace dale oval" → [ace, dale, oval]
  - "coda lava eel" → [coda, lava, eel]
  - "lace lava ode" → [lace, lava, ode]

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AnagramSolver

- Consider also the following dictionary:

ail	gnat	run
alga	lace	rung
angular	lain	tag
ant	lava	tail
coda	love	tan
eel	lunar	tang
gal	nag	tin
gala	natural	up
giant	nit	urn
gin	ruin	

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AnagramSolver

- Which is the first word in this list that *could* be part of an anagram of "Ada Lovelace"
  - ail
    - no: "Ada Lovelace" doesn't contain an "i"
  - alga
    - no: "Ada Lovelace" doesn't contain a "g"
  - angular
    - no: "Ada Lovelace" doesn't contain an "n", a "g", a "u", or an "r"
  - ant
    - no: "Ada Lovelace" doesn't contain an "n" or a "t"
  - coda
    - yes: "Ada Lovelace" contains all the letters in "coda"

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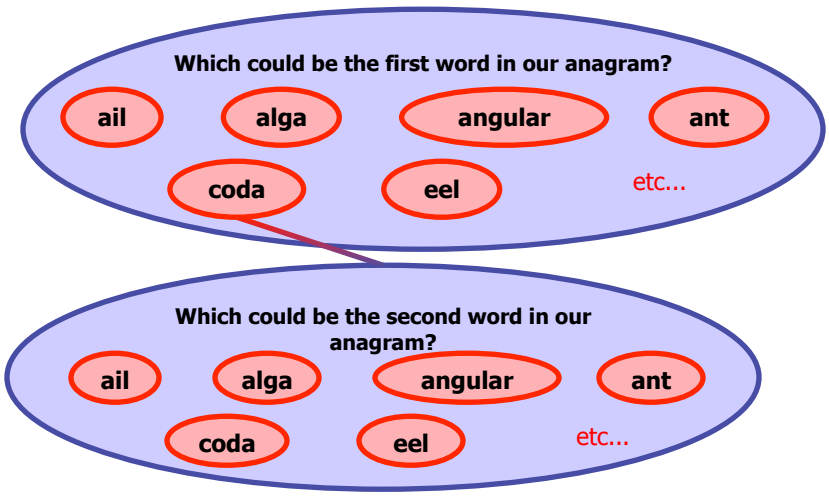
AnagramSolver

- This is just like making a choice in recursive backtracking:



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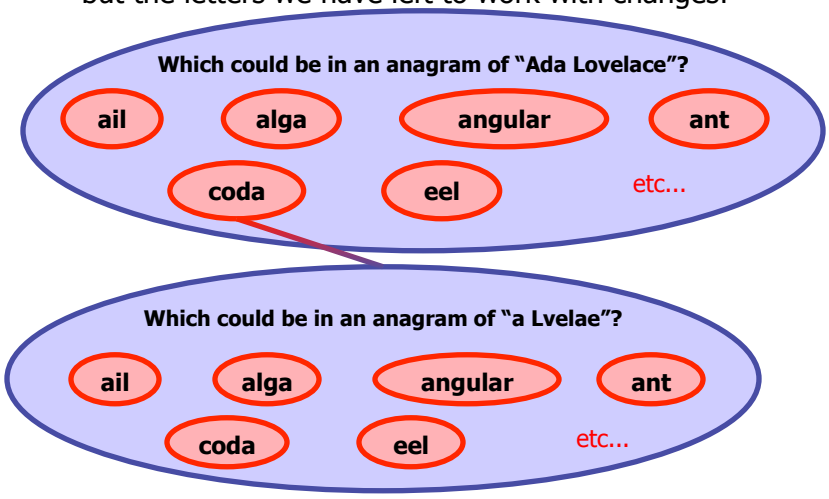
AnagramSolver

- At each level, we go through all possible words
  - but the letters we have left to work with changes!



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Low-Level Details

- There are some low level details here in deciding whether one phrase contains the same letters as another
- Just like 8 Queens had the Board class for its low-level details, we'll have a class that handles the low-level details of **`AnagramSolver`**
- This low-level detail class is called **`LetterInventory`**
  - Now where have I seen that before…

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AnagramSolver

- Key questions to ask yourself on this assignment:
  - When am I done?
    - for 8 Queens, we were done when we reached column 9
  - If I'm not done, what are my options?
    - for 8 Queens, the options were the possible rows for this column
  - How do I make and un-make choices?
    - for 8 Queens, this was placing and removing queens

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AnagramSolver

- You must include two optimizations in your assignment
  - because backtracking is inefficient, we need to gain some speed where we can
- You must preprocess the dictionary into `LetterInventory`s
  - you'll store these in a Map
    - specifically, in a HashMap, which is slightly faster than a TreeMap
- You must prune the dictionary before starting the recursion
  - by "prune," we mean remove all the words that couldn't possibly be in an anagram of the given phrase
  - you need do this only once (before starting the recursion)

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