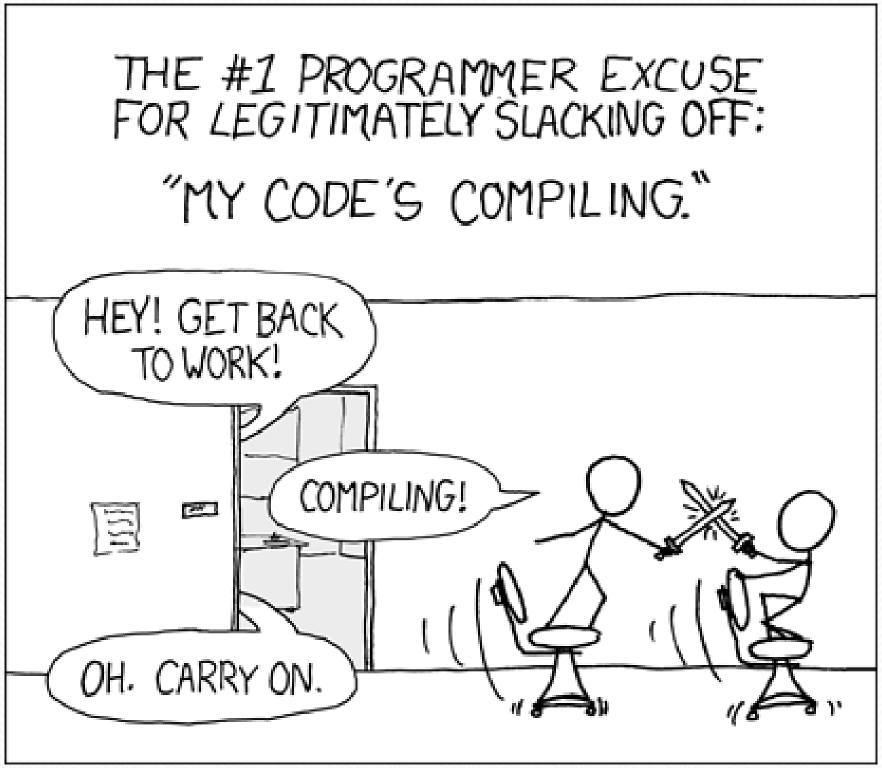
CSE 143

read: 12.5

Lecture 18: recursive backtracking

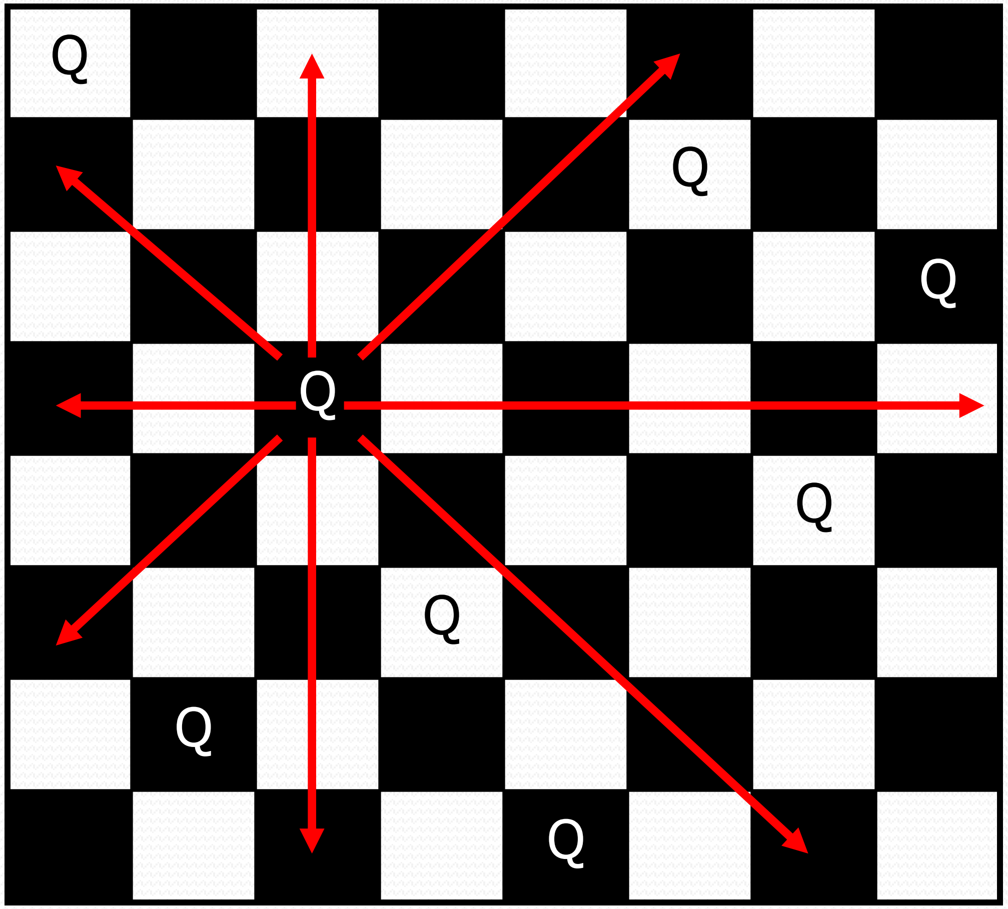


Backtracking strategies

- When solving a backtracking problem, ask these questions:
  - What are the "choices" in this problem?
    - What is the "base case"? (How do I know when I'm out of choices?)
  - How do I "make" a choice?
    - Do I need to create additional variables to remember my choices?
    - Do I need to modify the values of existing variables?
  - How do I explore the rest of the choices?
    - Do I need to remove the made choice from the list of choices?
  - Once I'm done exploring, what should I do?
  - How do I "un-make" a choice?

The "8 Queens" problem

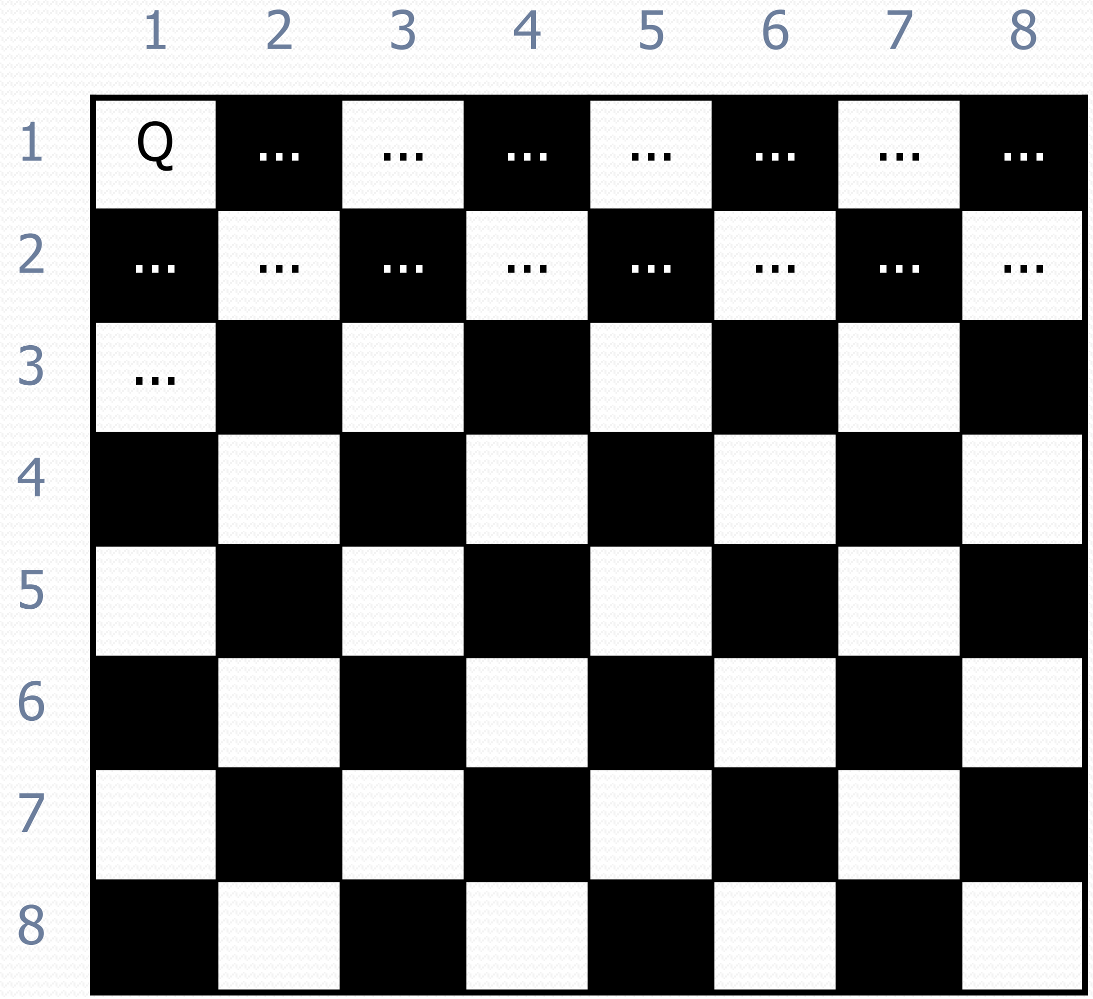
- Consider the problem of trying to place 8 queens on a chess board such that no queen can attack another queen.
  - What are the "choices"?
  - How do we "make" or "un-make" a choice?
  - How do we know when to stop?



Naive algorithm

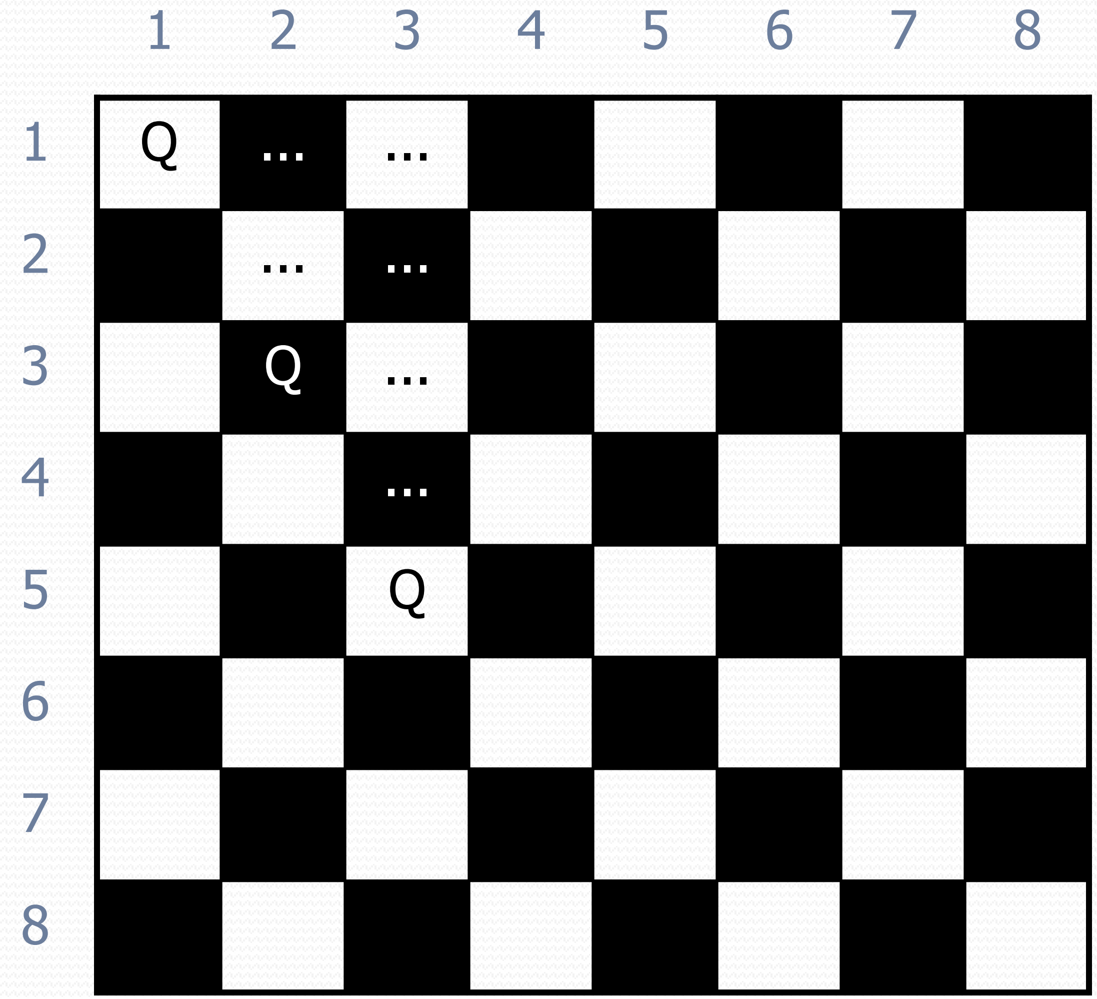
- for (each square on board):
  - Place a queen there.
  - Try to place the rest of the queens.
  - Un-place the queen.

  - How large is the solution space for this algorithm?
    - 64 * 63 * 62 * ...



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 * ...



Exercise

- Suppose we have a `Board` class with these 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.

Recall: Backtracking

A general pseudo-code algorithm for backtracking problems:

Explore(**choices**):

- if there are no more **choices** to make: stop.
- else, for each available choice **C**:
  - Choose **C**.
  - Explore the remaining **choices**.
  - Un-choose **C**, if necessary. (backtrack!)

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 (solveQueens(board, 1)) {
        System.out.println("One solution is as follows:");
        System.out.println(board);
    } else {
        System.out.println("No solution found.");
    }
}

...
```

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 solveQueens(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
    }
}
```