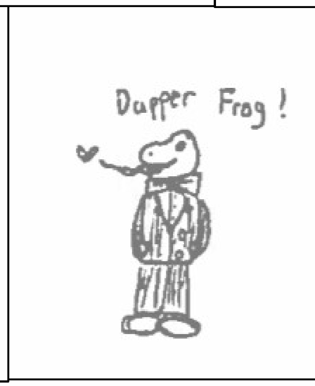
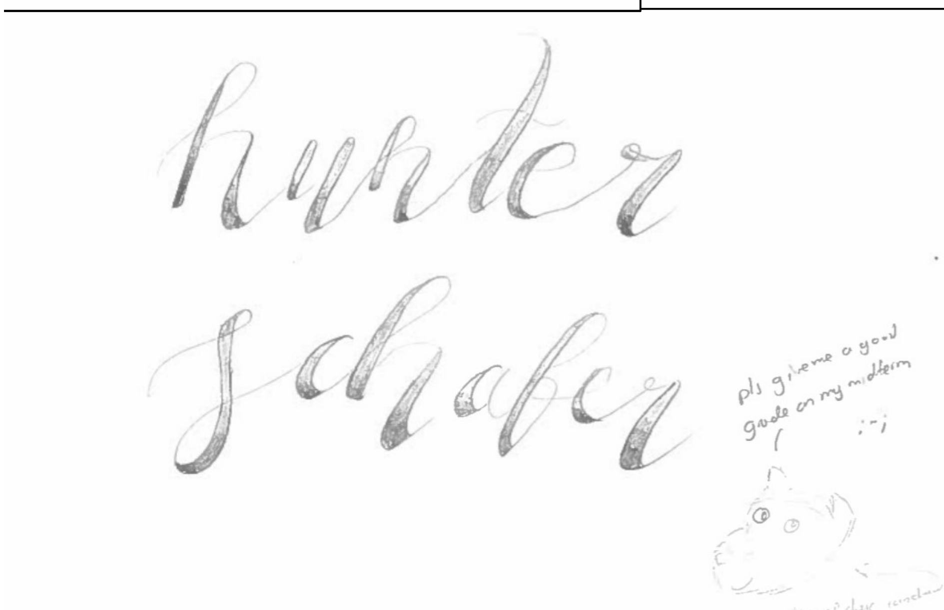

Recursion


AA
AC


A good boi


Dapper Frog!


Hunter w/ a Husky


hunter schafer
pls give me a good grade on my midterm
;-;


My parents bought my dog a hoodie


"bbbb"
"baaa"
"baba"
"bbba"
"baab"
"abbb"
"aaaa"
"aaab"
"bbab"

Exercise: Dice roll sum

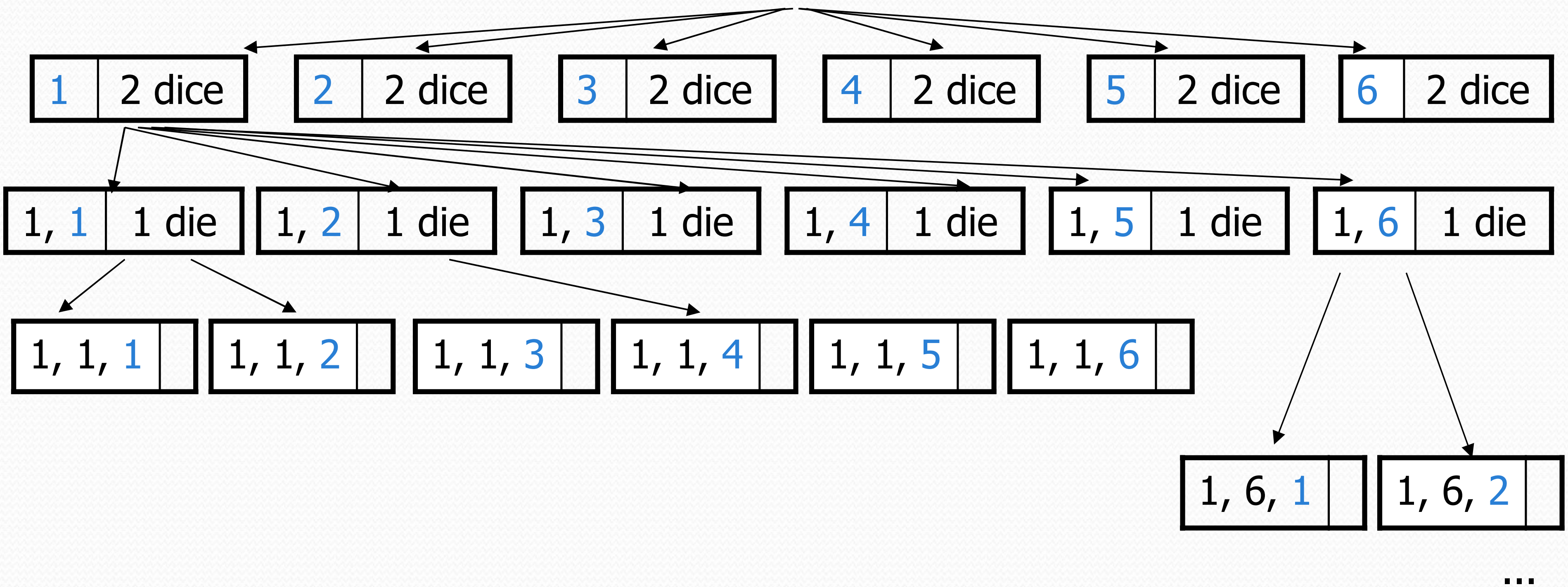
- Write a method `diceSum` similar to `diceRoll`, but it also accepts a desired sum and prints only arrangements that add up to exactly that sum.

```
diceSum(2, 7);

    [1, 6]
    [2, 5]
    [3, 4]
    [4, 3]
    [5, 2]
    [6, 1]
```

```
diceSum(3, 7);

    [1, 1, 5]
    [1, 2, 4]
    [1, 3, 3]
    [1, 4, 2]
    [1, 5, 1]
    [2, 1, 4]
    [2, 2, 3]
    [2, 3, 2]
    [2, 4, 1]
    [3, 1, 3]
    [3, 2, 2]
    [3, 3, 1]
    [4, 1, 2]
    [4, 2, 1]
    [5, 1, 1]
```

Consider all paths?

chosen	available	desired sum
-	3 dice	5



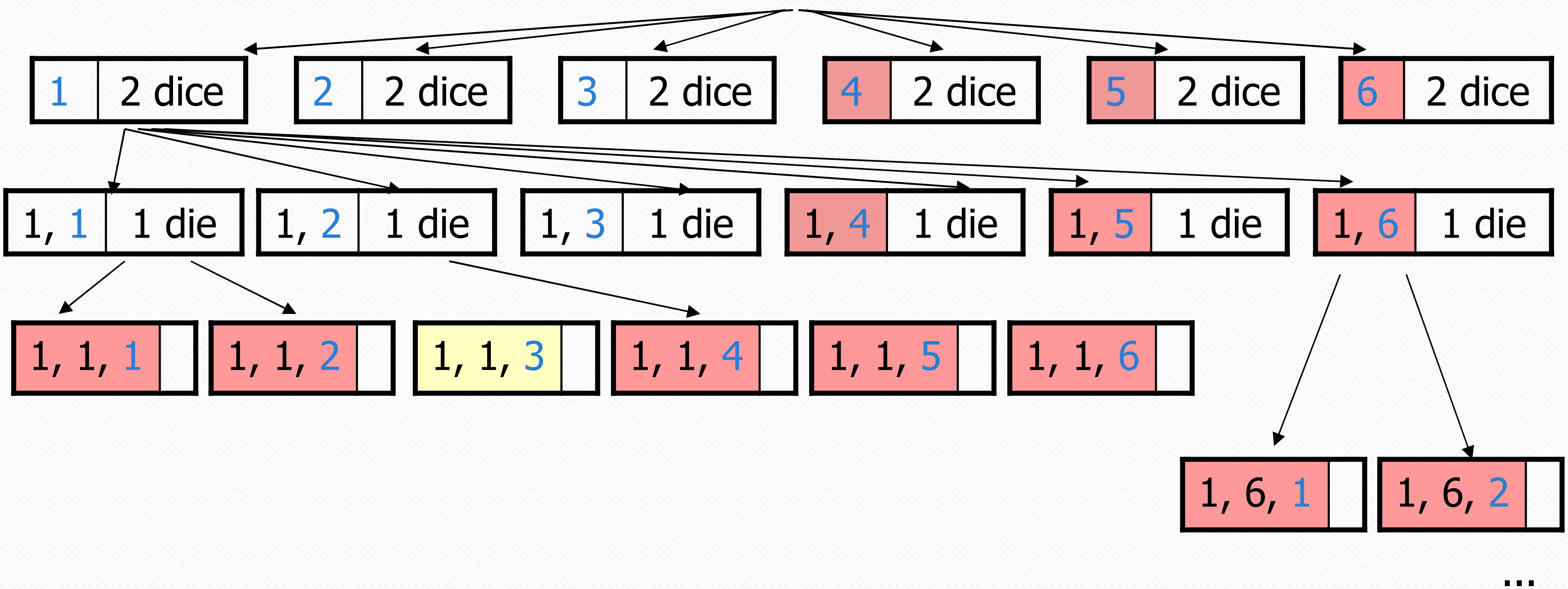
Optimizations

- We need not visit every branch of the decision tree.
  - Some branches are clearly not going to lead to success.
  - We can preemptively stop, or **prune**, these branches.

- Inefficiencies in our dice sum algorithm:
  - Sometimes the current sum is already too high.
    - (Even rolling 1 for all remaining dice would exceed the sum.)
  - Sometimes the current sum is already too low.
    - (Even rolling 6 for all remaining dice would not reach the sum.)
  - When finished, the code must compute the sum every time.
    - (1+1+1 = ..., 1+1+2 = ..., 1+1+3 = ..., 1+1+4 = ..., ...)

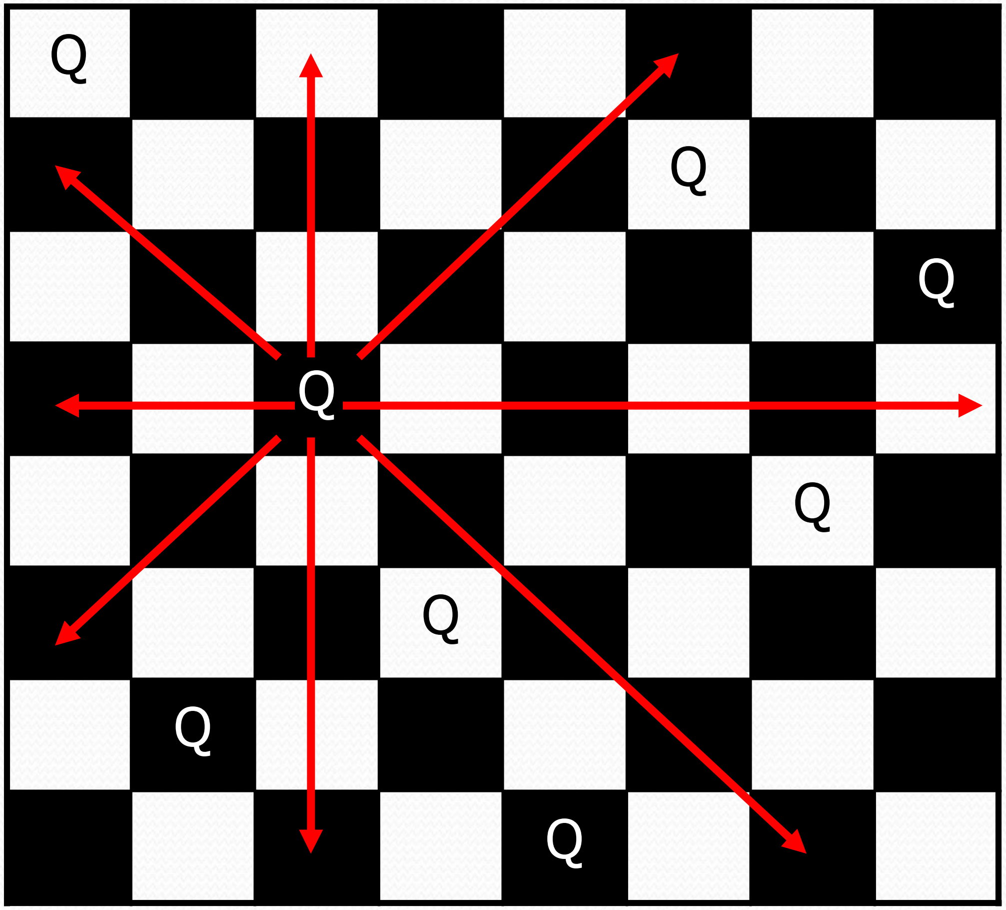
New decision tree

chosen	available	desired sum
-	3 dice	5



The "8 Queens" problem

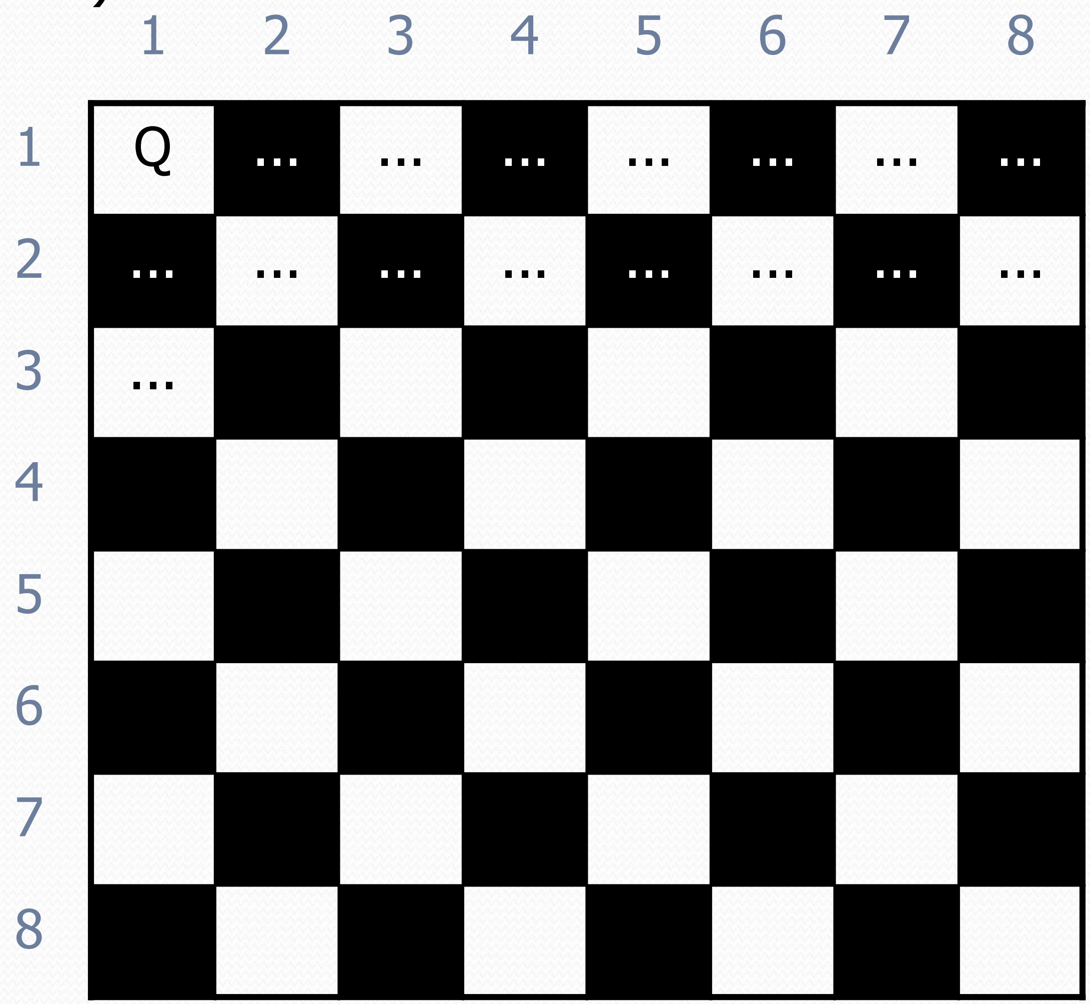
- Consider the problem of trying to place 8 queens on a chess board such that no queen can attack another queen.
  - What are the "choices"?
  - How do we "make" or "un-make" a choice?
  - How do we know when to stop?



Naive algorithm

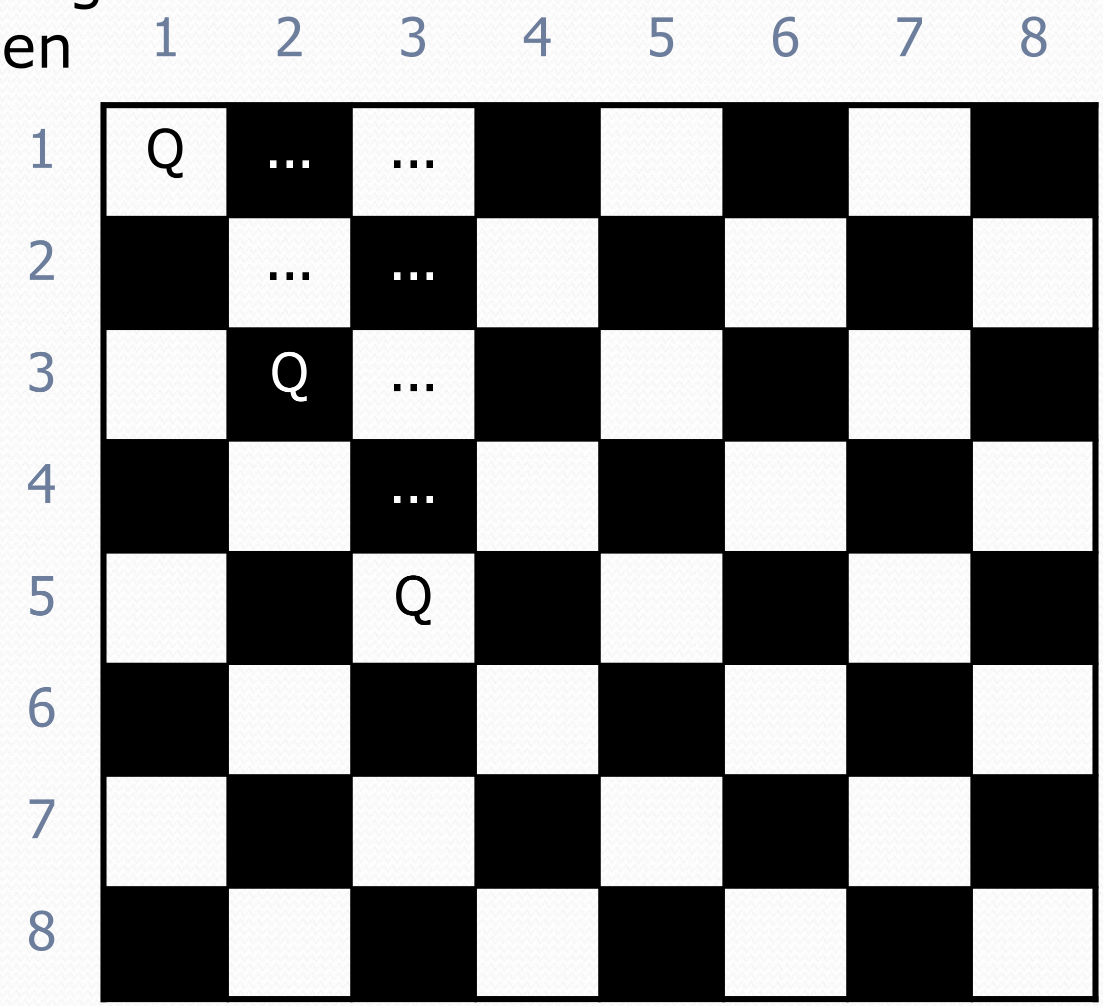
- for (each square on board):
  - Place a queen there.
  - Try to place the rest of the queens.
  - Un-place the queen.

  - 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 * ...



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

- 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.