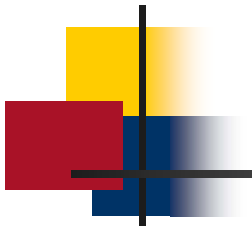
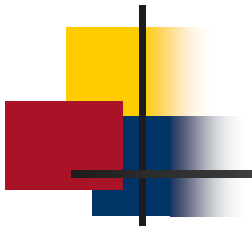


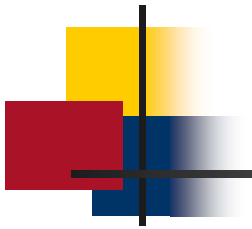
More Recursion: NQueens

- continuation of the recursion topic
  - notes on the *NQueens* problem
  - an extended example of a recursive solution



Recursion & Backtracking

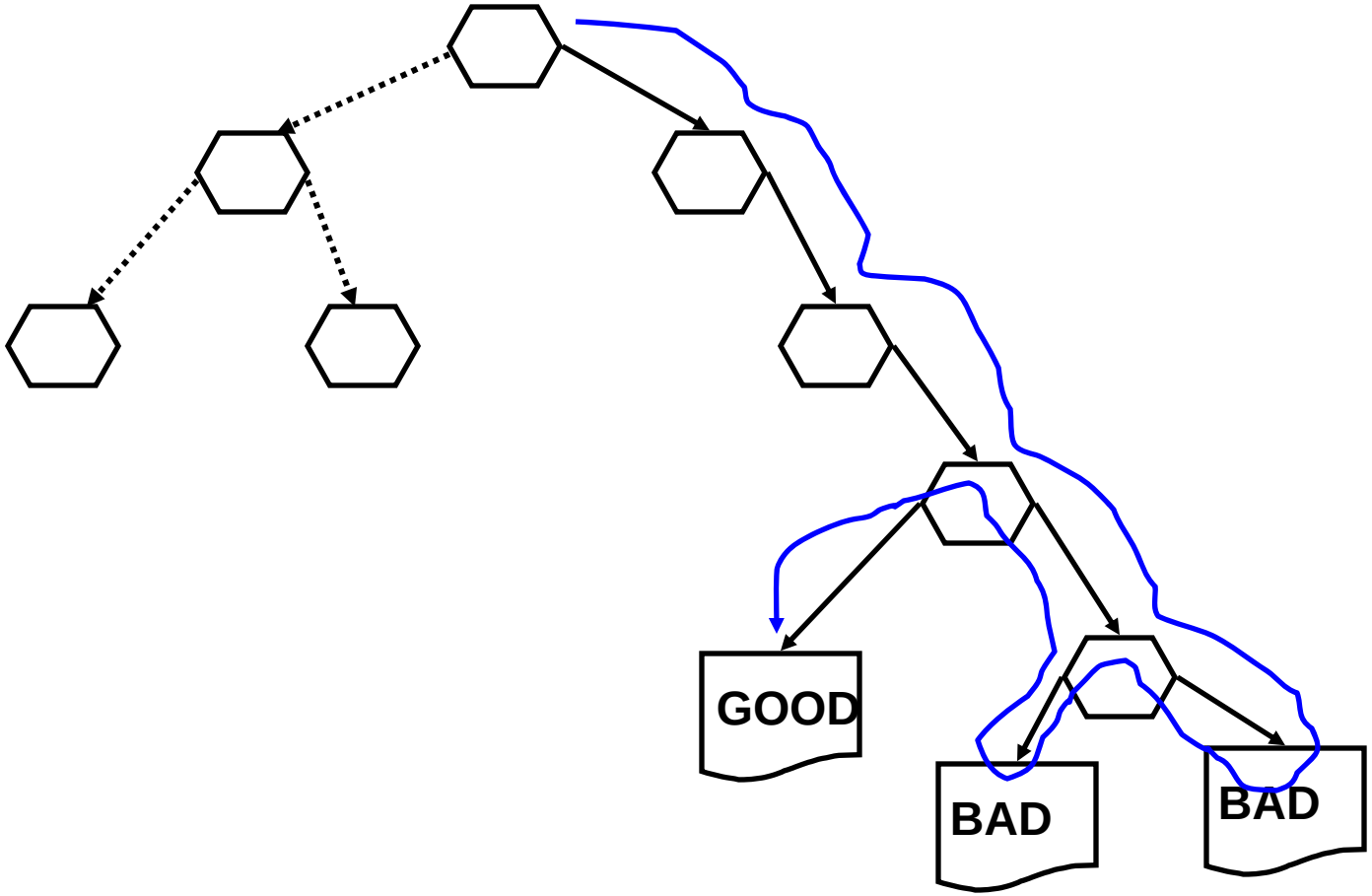
- backtracking
  - an algorithmic tool
  - used in artificial intelligence (& other) programs
- problems where a backtracking strategy works
  - when there are many different
    - possible solution paths
    - each consisting of a sequence of steps
      - from a start state to a solution state
    - & it is not known which path is optimal

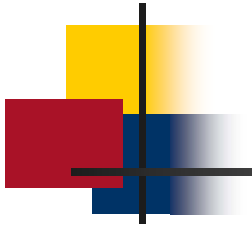


Recursion & Backtracking

- the backtracking strategy
  - systematically, recursively builds a path
    - out of a sequence of choices
  - if a solution cannot be found on the current path
    - then undo the last step: *backtrack*
    - & try an alternative path
  - note: the backtracking may
    - go all the way back to the *first* step in the process

Recursion & Backtracking



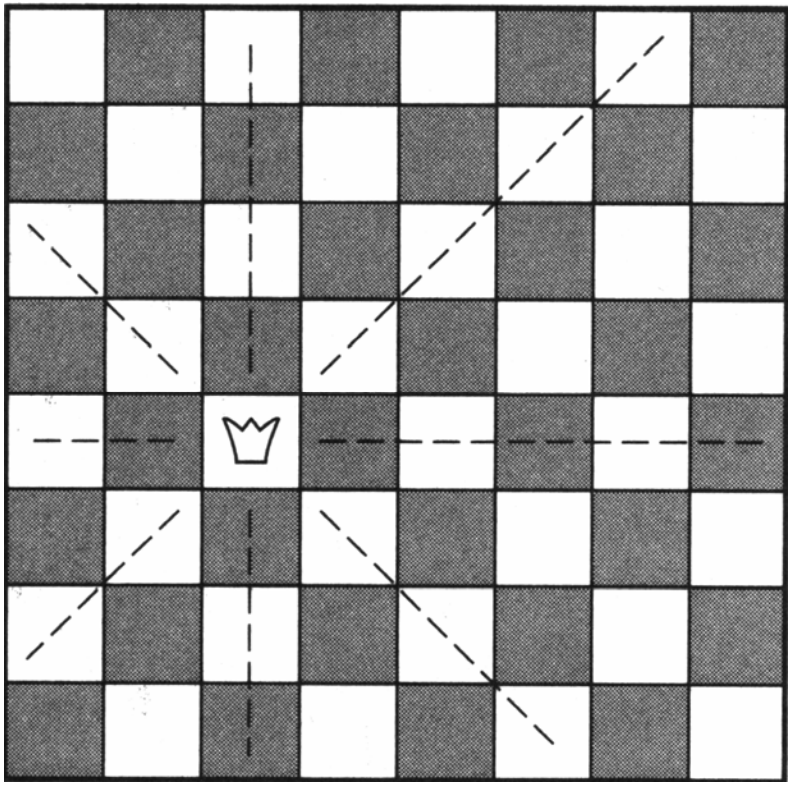


Recursion & Backtracking

- an example
  - the NQueens problem
  - a solution consists of:
    - placing n queens on an n x n chessboard
    - so that no queen "threatens" conflicts with any other
    - so, only 1 queen per column, row, & diagonal
  - recursive backtracking solution follows
    - recursion is a necessary part of such an algorithm
    - makes it much easier to write

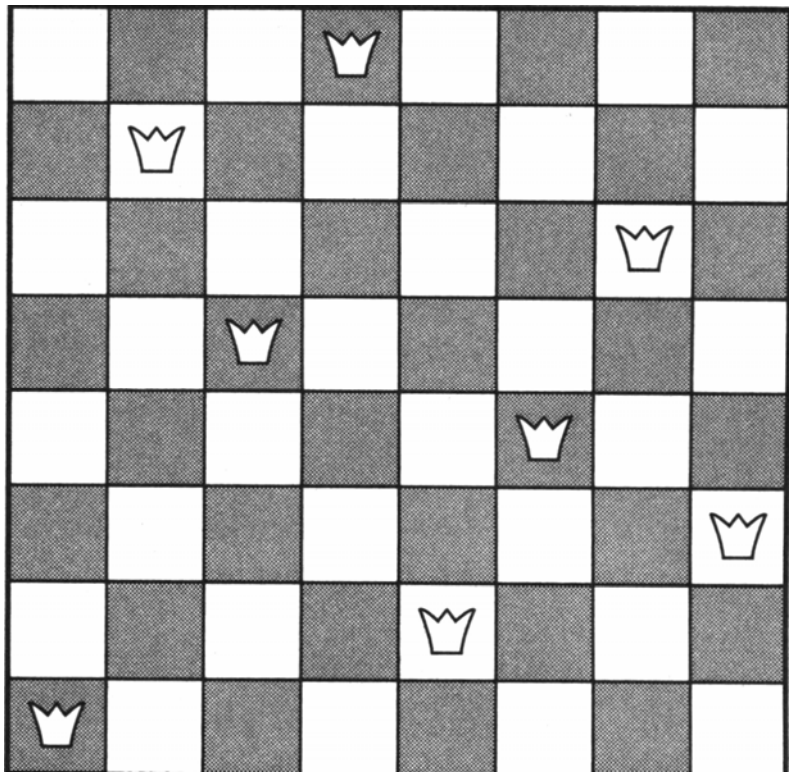
NQueens

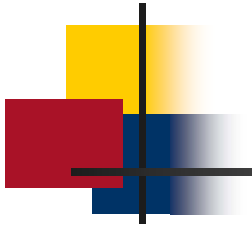
- constraint for the NQueens problem
  - each queen in a separate column, row & diagonal
- example: single Queen on 8x8 grid (chessboard)
  - & who she threatens, potential conflicts



NQueens

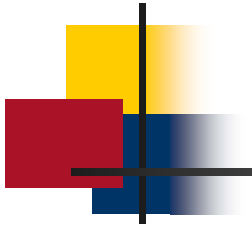
- one sample solution for the 8-Queens problem
  - on an 8x8 grid, no queen threatens another
    - how many solutions are there? what are they?





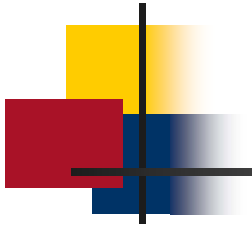
NQueens

- sample algorithm to find one solution
  - provided the problem has a solution
    - other algorithms might find all solutions
  - uses recursion & backtracking
  - it is relatively easy to solve this problem for small n
    - for the example using n=4, can show each step
    - break out to 4QueensDemo
  - watch for the backtracking!



NQueens

- solving the nqueens problem
  - number the rows & columns from zero
  - note that only one Queen can occupy each column
  - therefore each column *must* have a Queen
    - move across the grid, column by column
    - place a queen in each column
    - start from column zero & go to column n-1
      - place the queen for the current column in a row & diagonal
      - such that she doesn't threaten previously placed queens



NQueens

- solving the nqueens problem
  - pseudocode for a recursive method
    - assumes placing queens using a Board object
    - full code of the method on the next slide

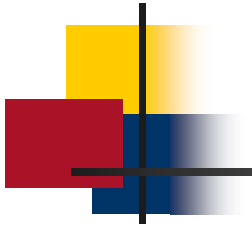
```
// board size n X n
boolean solveNQ (int col)
  if col >= size then all done!
  for row 0 to row n-1
    if (row, col) is a safe(non-threatened) position
      place a Queen at (row, col)
      if solveNQ (col + 1) is true then //recursive step
        return true
      else
        remove Queen from (row, col)    // backtracking step
  (Outside of loop:) return false
```

NQueens

```
public static boolean solveNQ(Board bd, int col) {
    // anchor/base case: successful solution
    if (col >= bd.getSize()) return true;

    // try putting a queen in each row of the current column
    for (int row = 0; row < bd.getSize(); row++) {
        if (safePosition(bd, row, col)) {
            bd.putQueen(row, col);
            if (solveNQ(bd, col+1))            //recursive step
                return true;
            else
                bd.removeQueen(row, col);      // backtrack step
        } // end if
    } // end for

    // anchor/base case: there is no solution
    return false;
} // end solveNQ
```



NQueens

- solving the nqueens problem
  - Board.java
    - a class used to represent an n x n board
      - fixed size (8) in the sample implementation
    - stores locations of queens
      - allows checking for occupied locations, board size
      - allows removal of a queen, display of board status
  - NQueenRecursive.java
    - the application program includes
    - the recursive backtracking solution method
    - a method to check for threats/conflicts
    - & uses a Board object to place queens, display result