

Quiz 1

Last Lecture

Friday 11/20 at Yale

Monday 11/23 at Harvard

CS50 EXPO

FRIDAY, NOVEMBER 20TH

3PM - 4:30PM

STERLING MEMORIAL LIBRARY

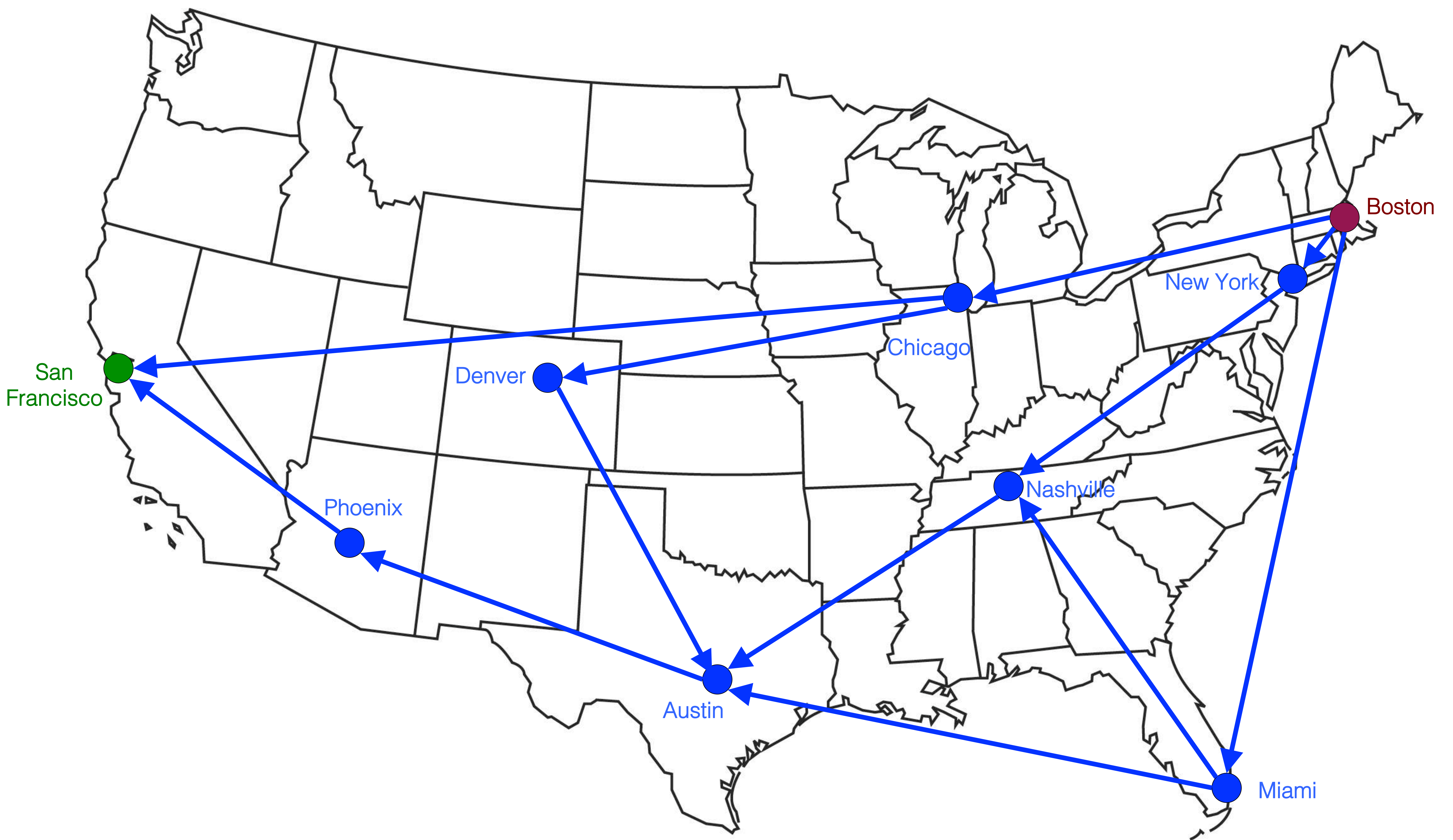
Research projects, student groups,
and startups from Yale and Harvard all
related to engineering and science.
Learn about how you can get involved!

Search

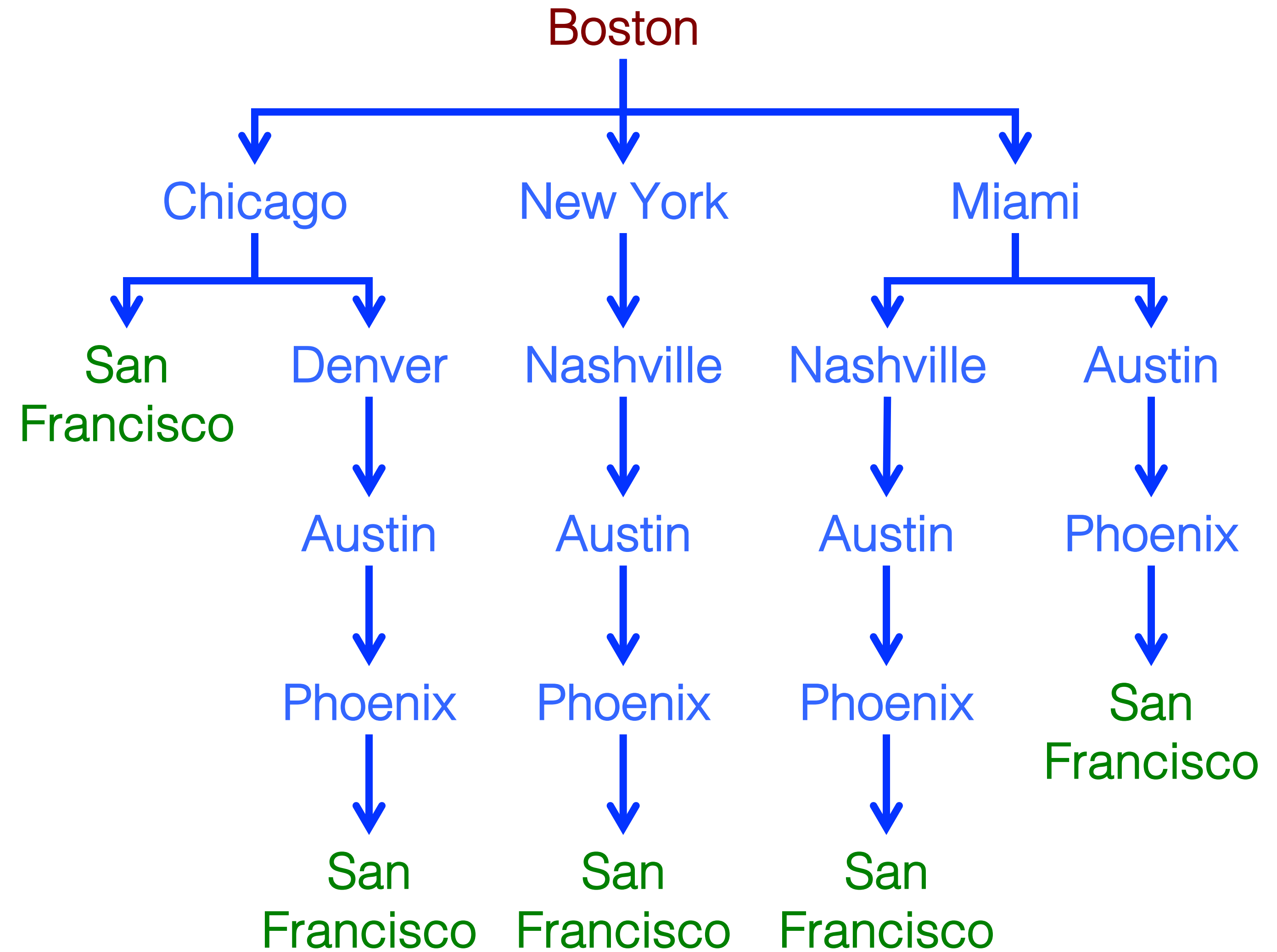
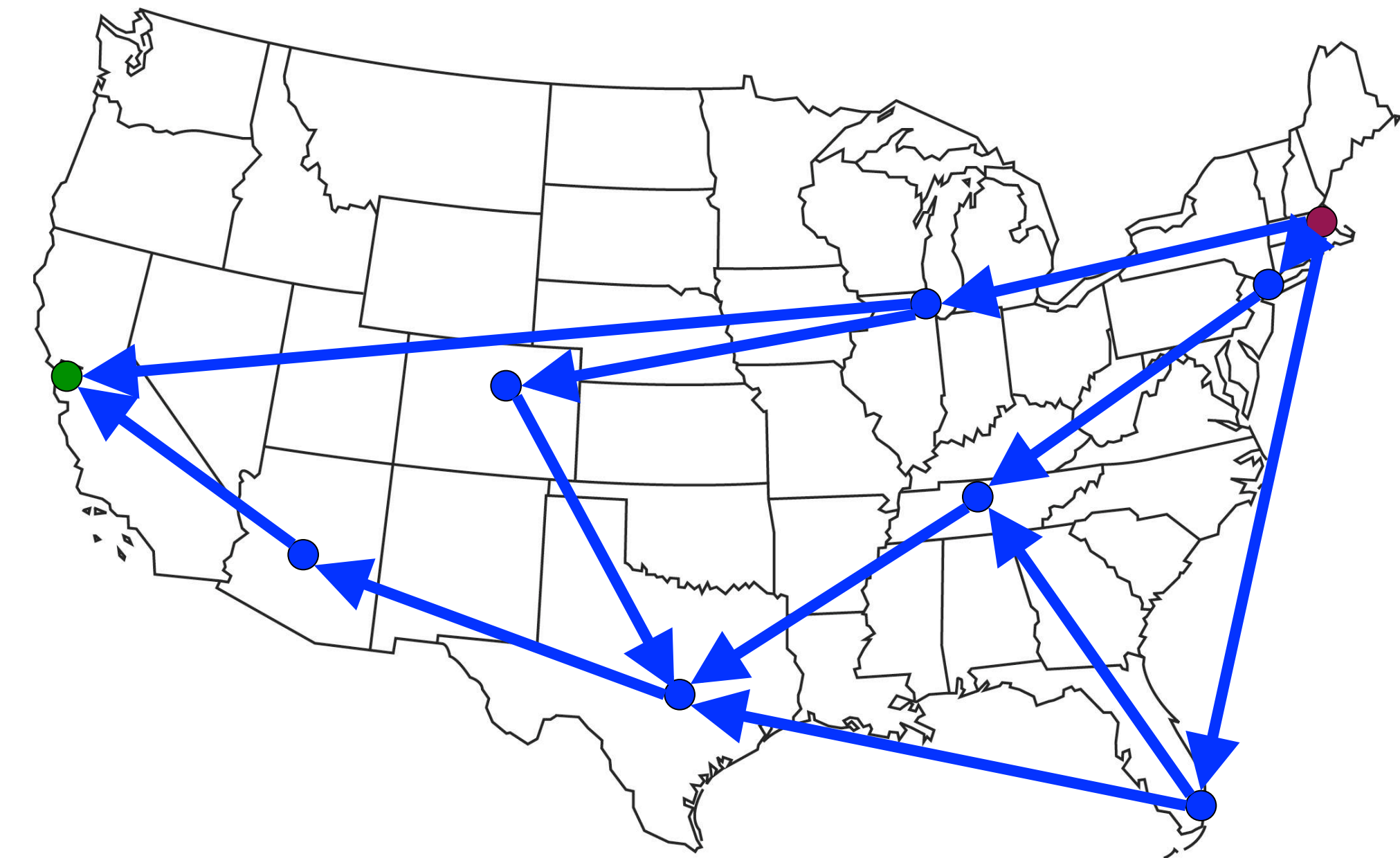
(Solving problems with brute-force approaches)





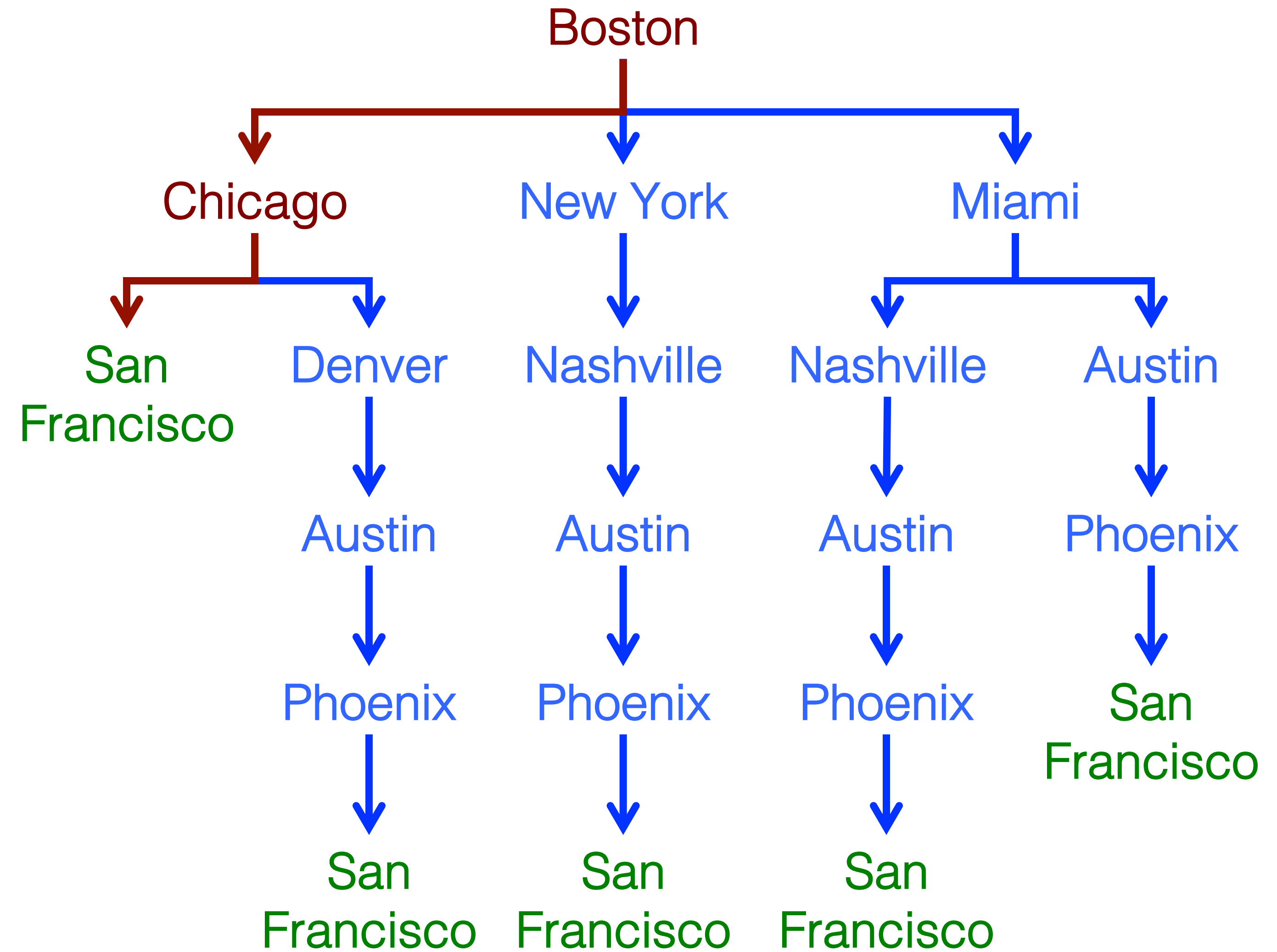
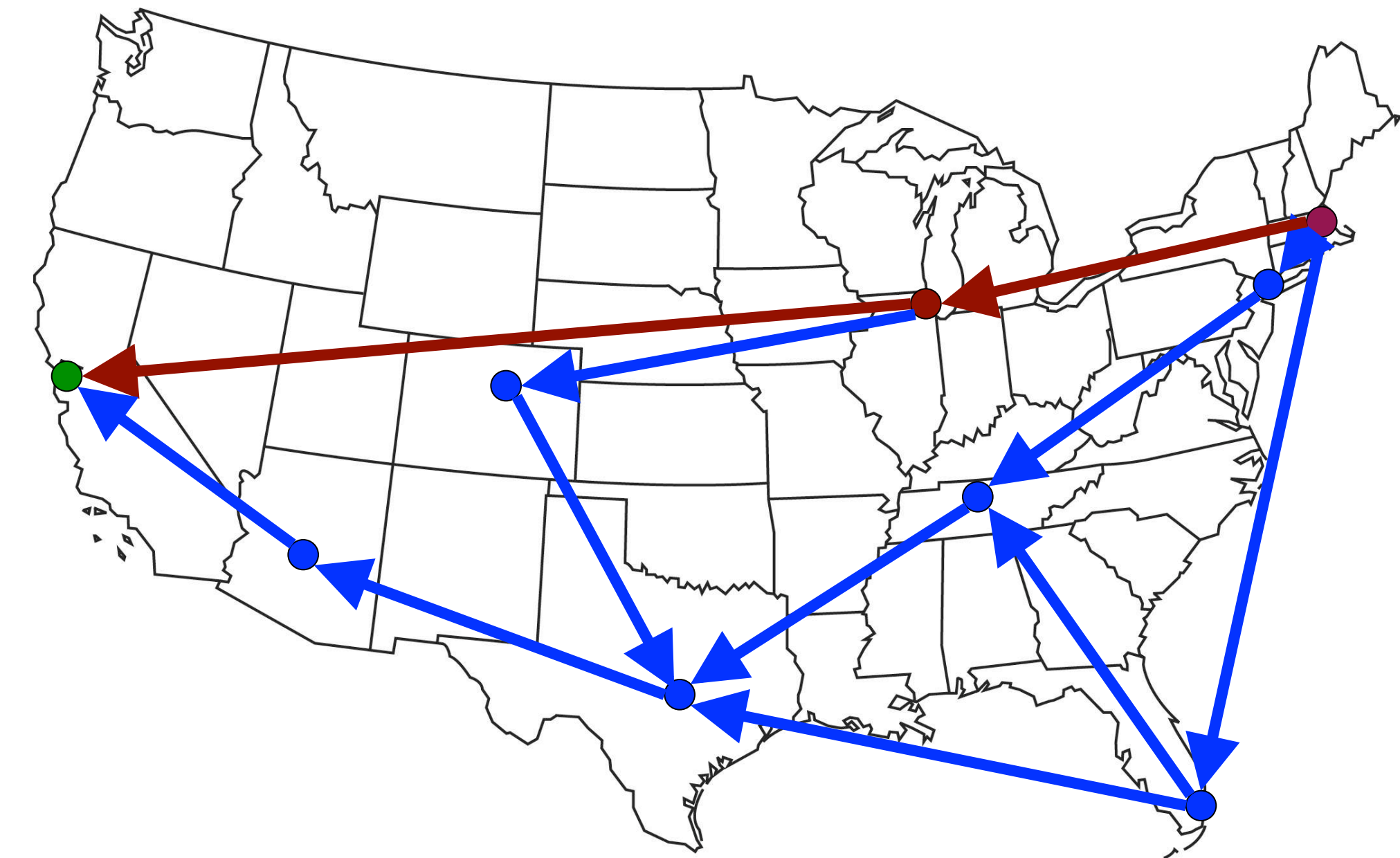


Search Trees



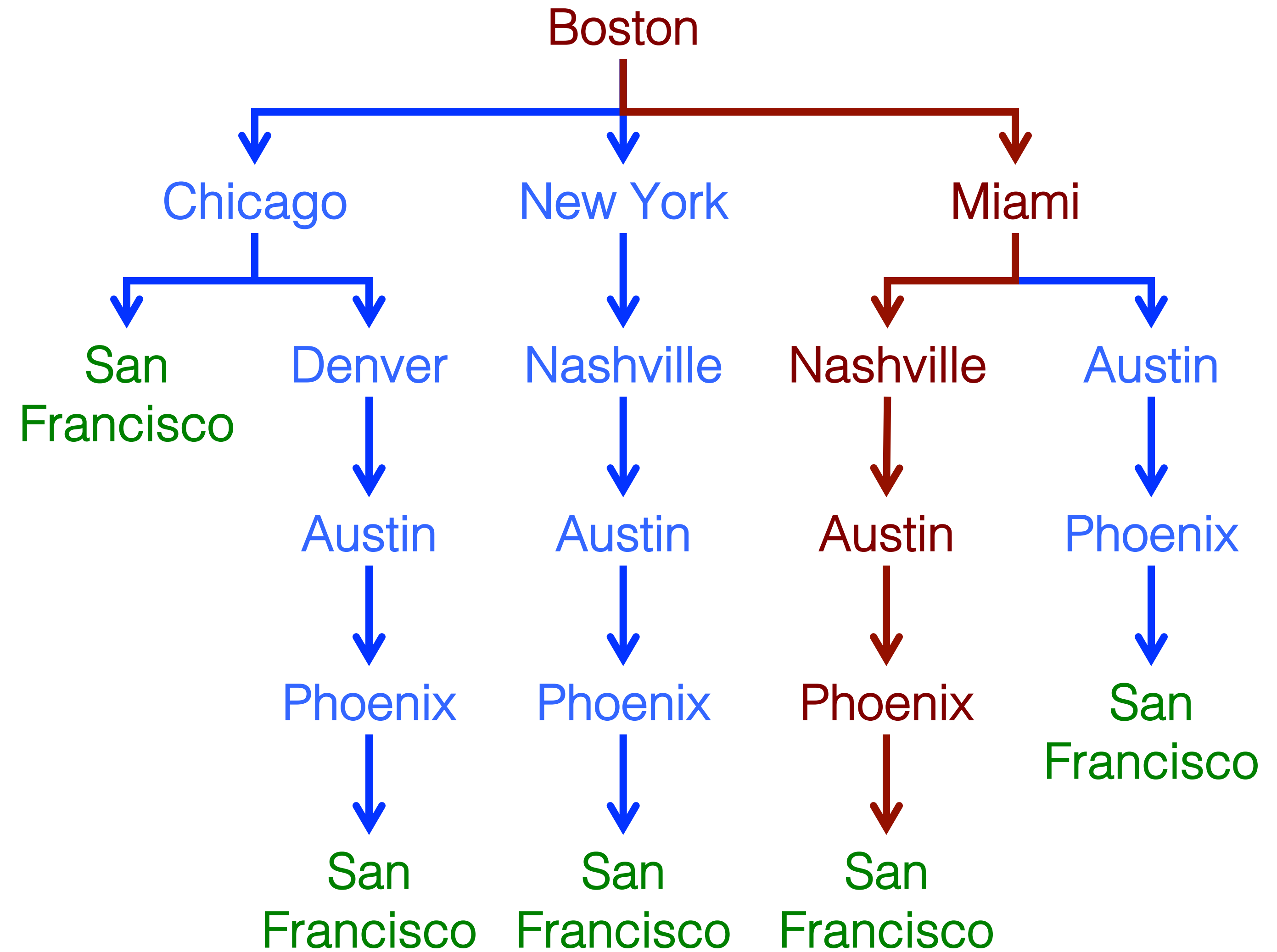
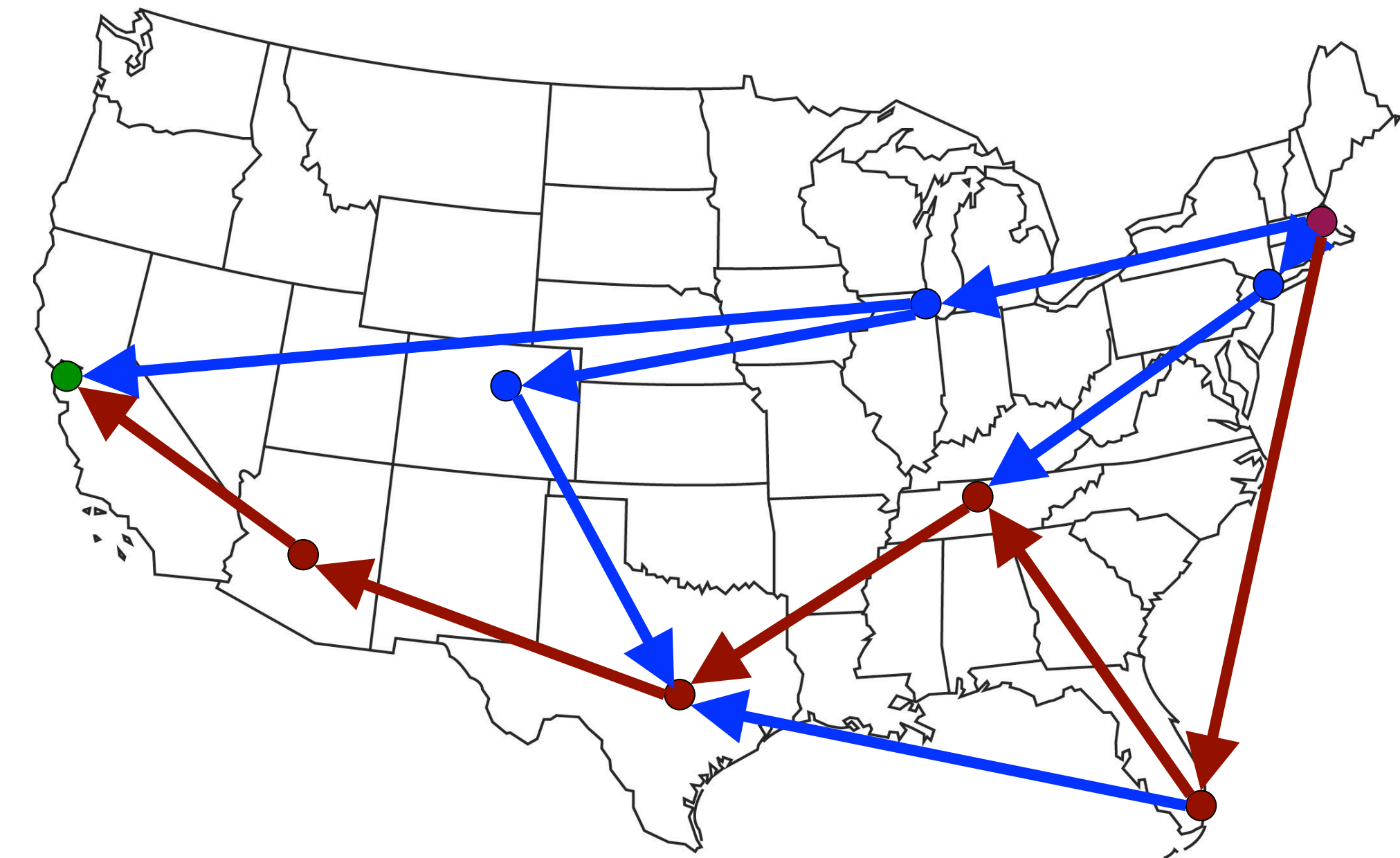
Search Trees

Metric: Distance



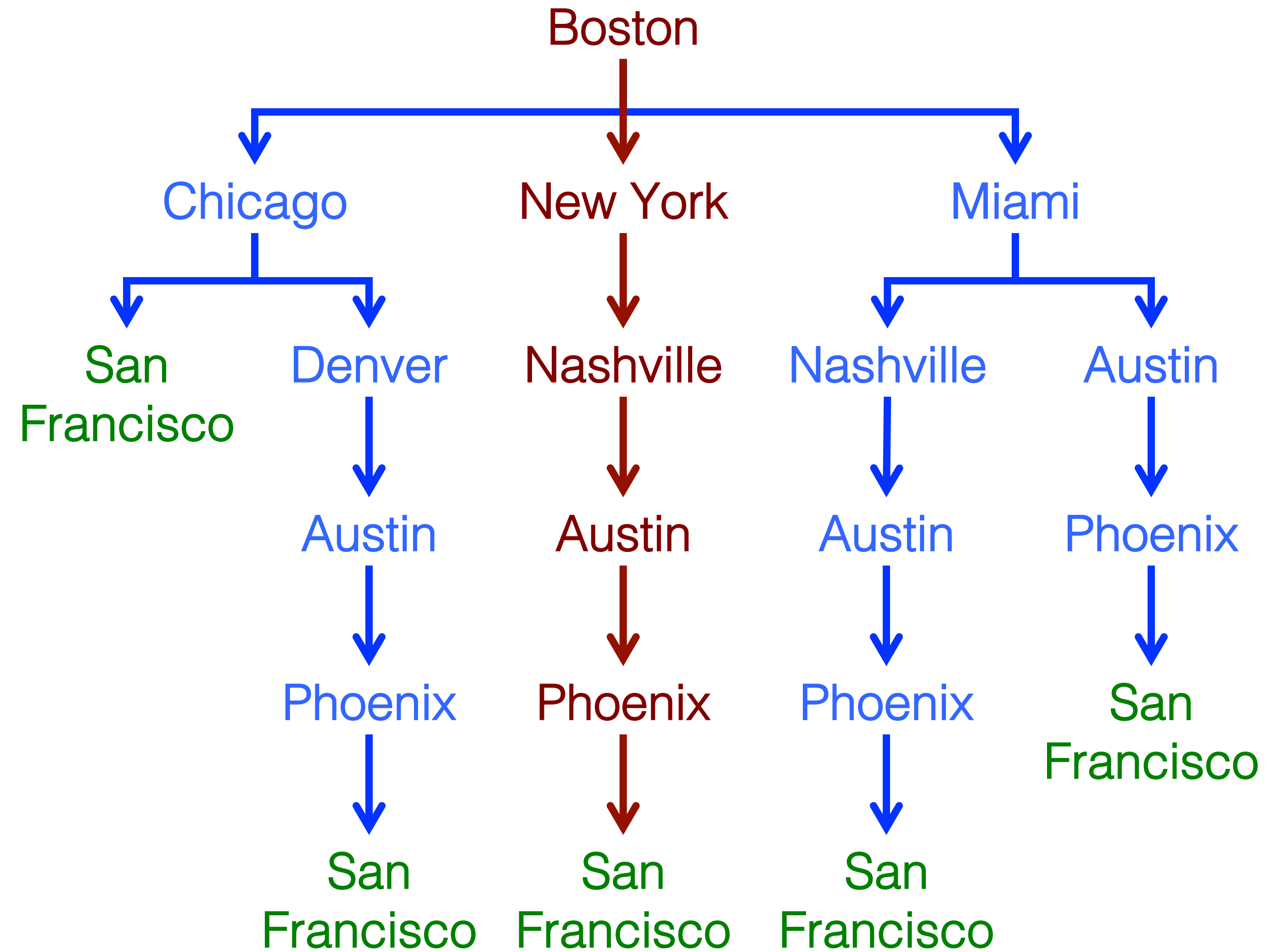
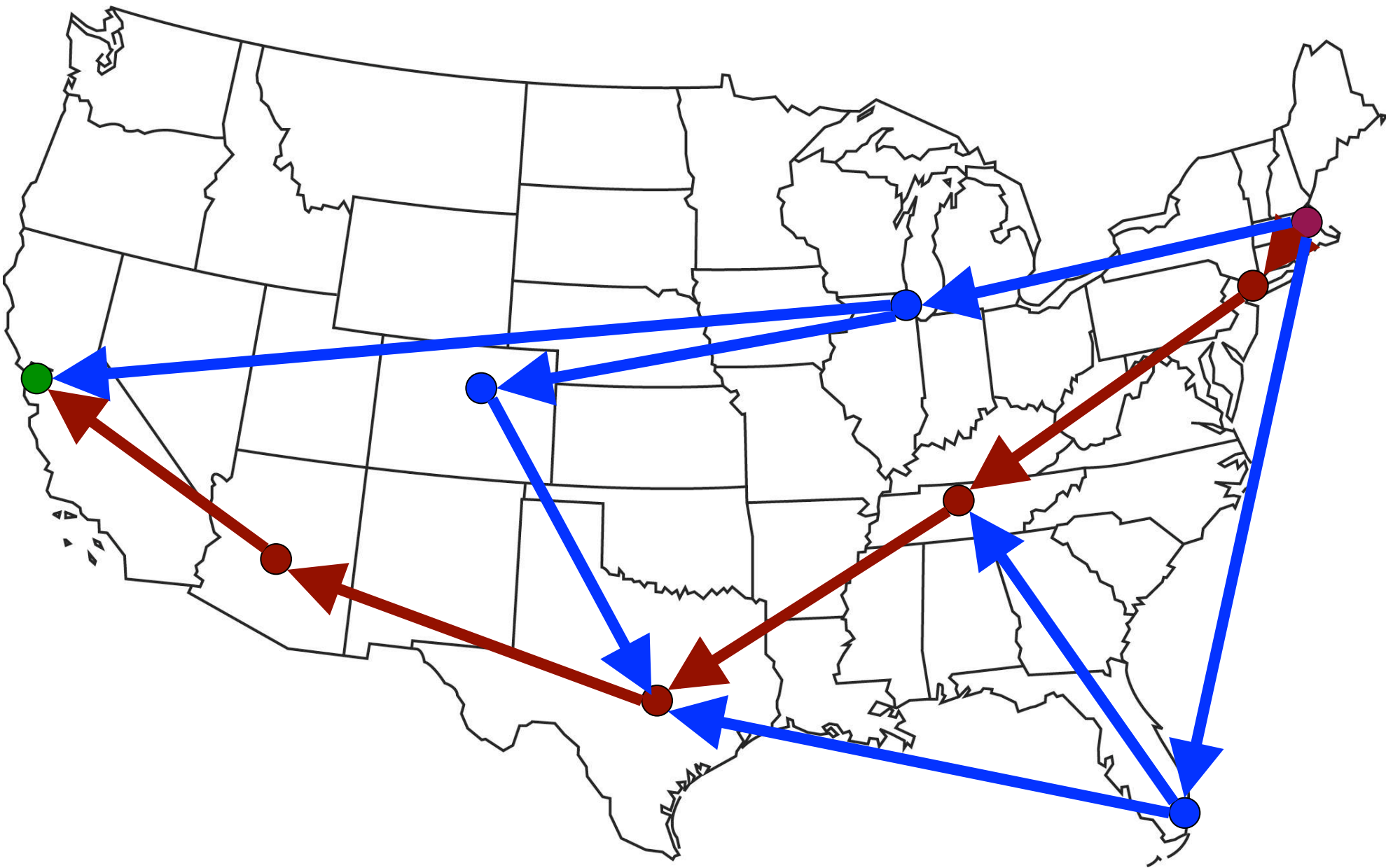
Search Trees

Metric: Cost



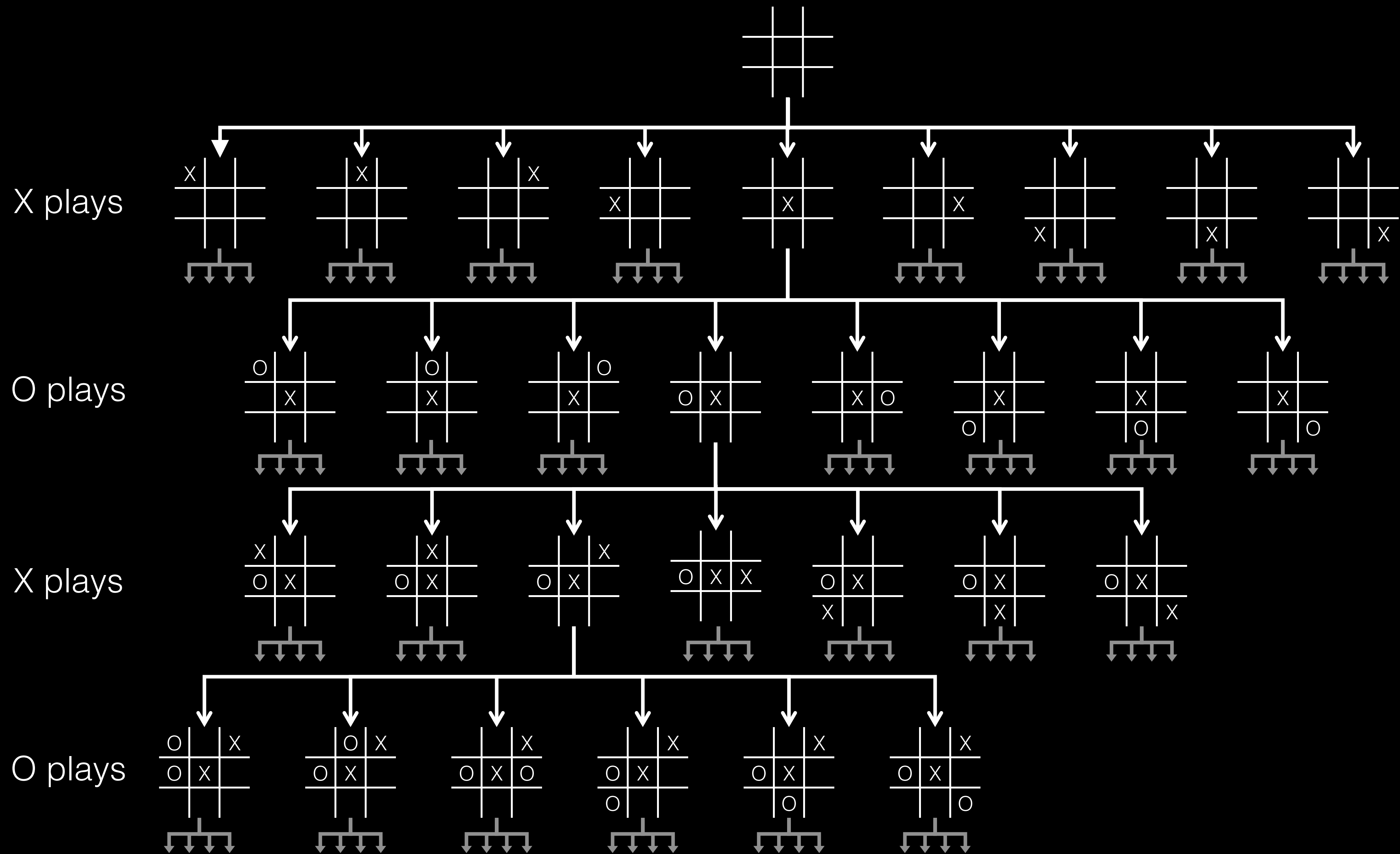
Search Trees

Metric: Best Food Options



Adversarial Search

(how to play games and make it look like research)



Minimax Strategy:

Choose the move which leaves your opponent with the worst set of possibilities

Minimax Algorithm

Generate the entire game tree

Evaluate each terminal node (high values are good for your side)

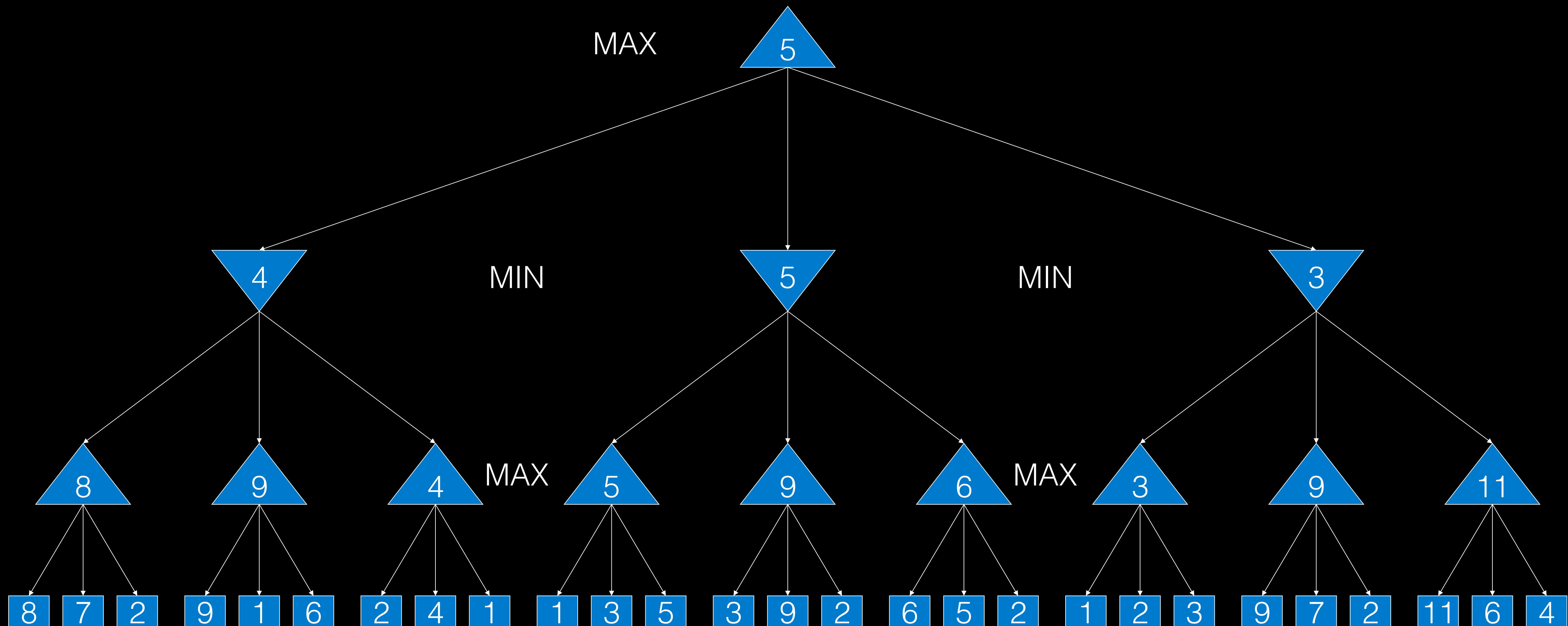
Filter values from the terminal nodes up through the tree:

At nodes controlled by your opponent, choose the **minimum** value of the children

At nodes controlled by you, choose the **maximum** value of the children

When you reach the top of the tree, you have an optimal solution

Minimax



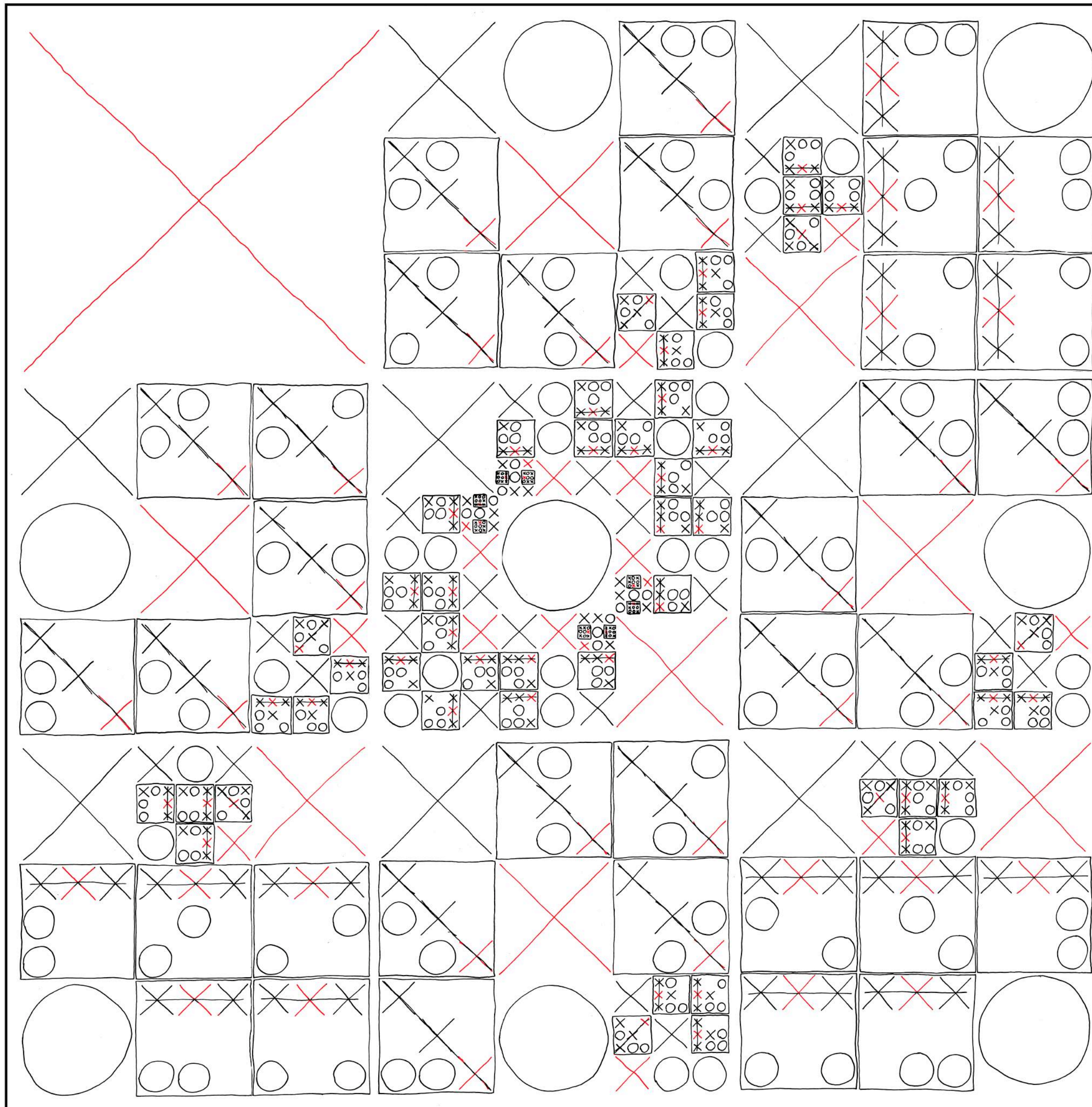
Tic-Tac-Toe

COMPLETE MAP OF OPTIMAL TIC-TAC-TOE MOVES

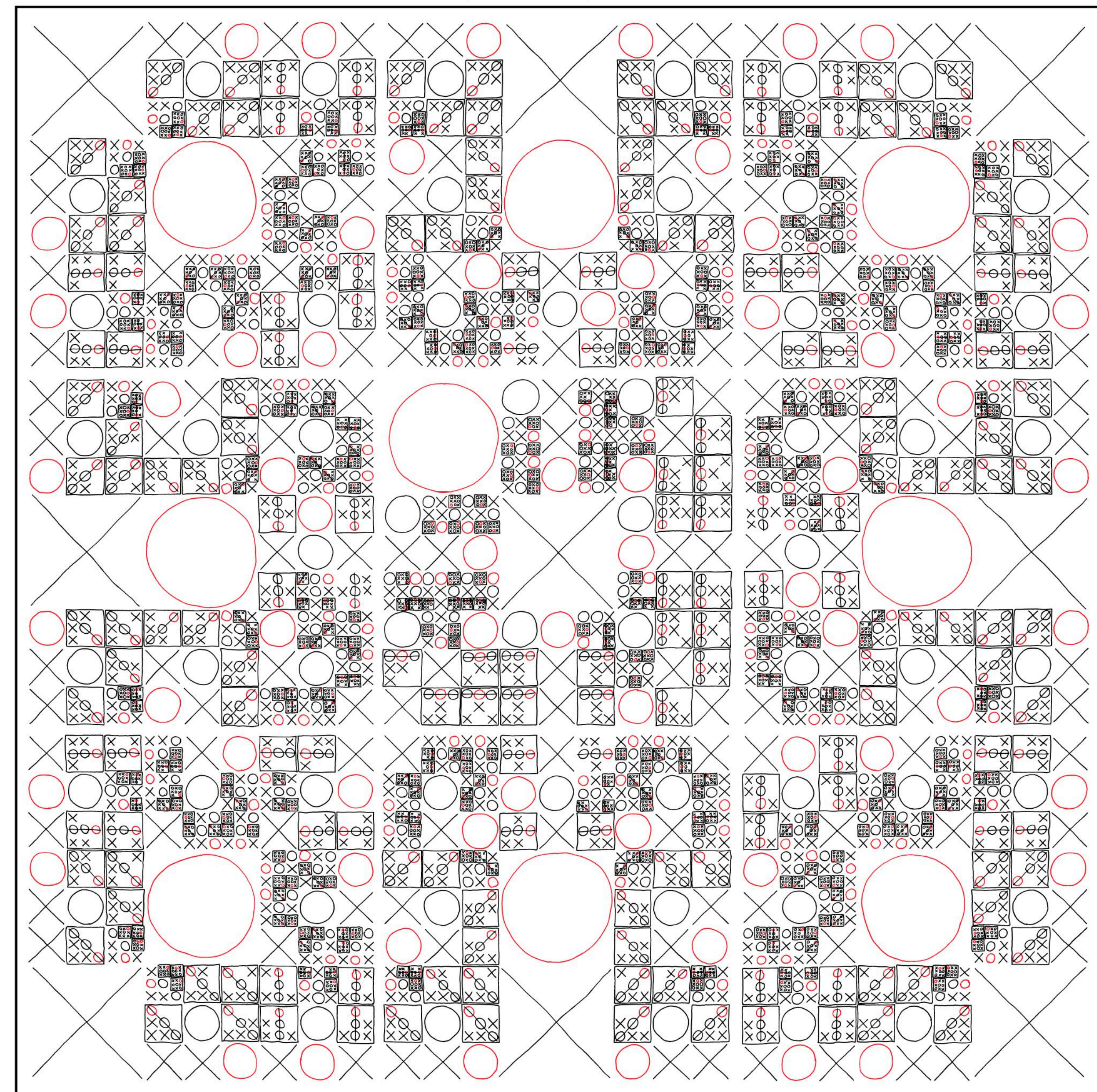
<https://xkcd.com/832/>

YOUR MOVE IS GIVEN BY THE POSITION OF THE LARGEST RED SYMBOL ON THE GRID. WHEN YOUR OPPONENT PICKS A MOVE, ZOOM IN ON THE REGION OF THE GRID WHERE THEY WENT. REPEAT.

MAP FOR X:



MAP FOR O:



What happens when we cannot
compute the complete tree?

Evaluation Function

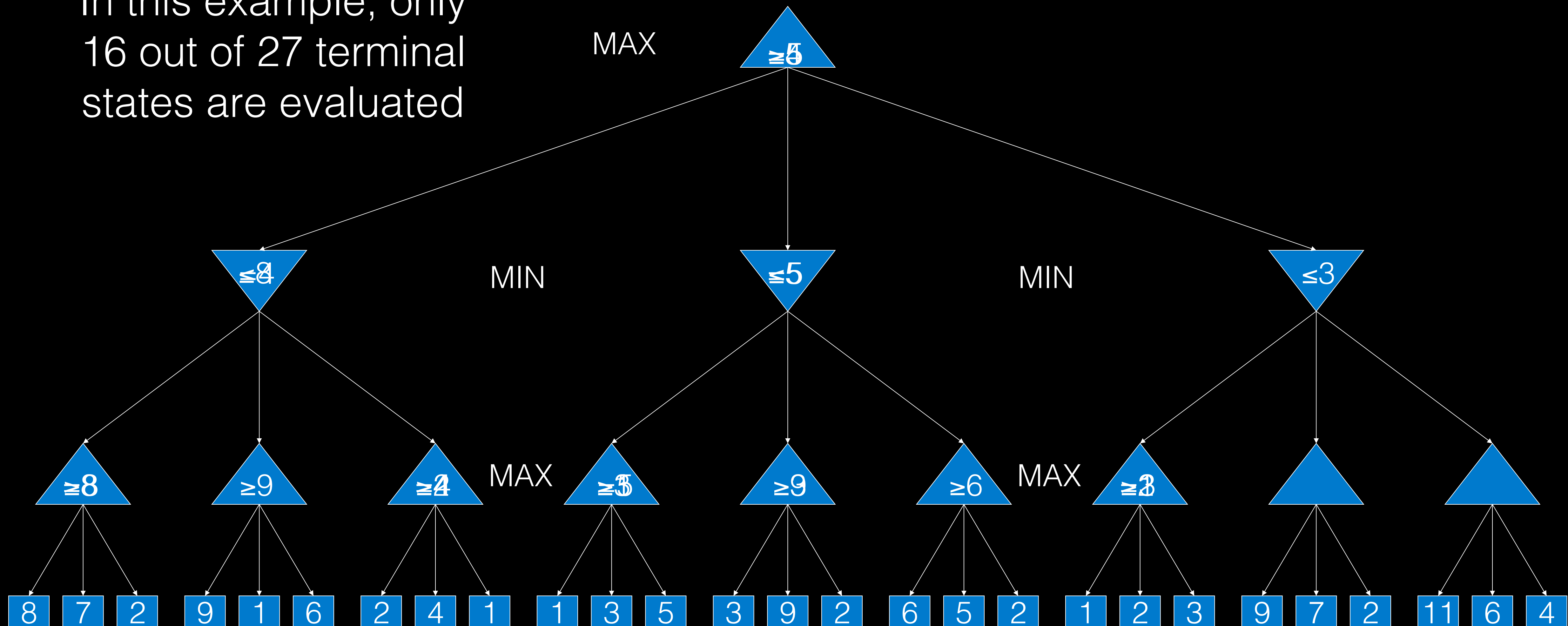


The alpha-beta principle

If you have an idea that is **bad**,
don't waste time seeing how truly **awful** it is

Minimax with Alpha-Beta

In this example, only
16 out of 27 terminal
states are evaluated



Game Complexity

	Board Size	Branching Factor	Number of Leaves	First Machine Champion
Tic-Tac-Toe	3x3	4	10^5	-- trivial --
Connect-4	6x7	4	10^{21}	-- solved --
Checkers	8x8 (halved)	2.8	10^{31}	Chinook defeats Marion Tinsley (1992)
Chess	8x8	35	10^{123}	Deep Blue defeats Garry Kasparov (1995)
Go	19x19	250	10^{360}	none

Traditional Board Games

Perfect information

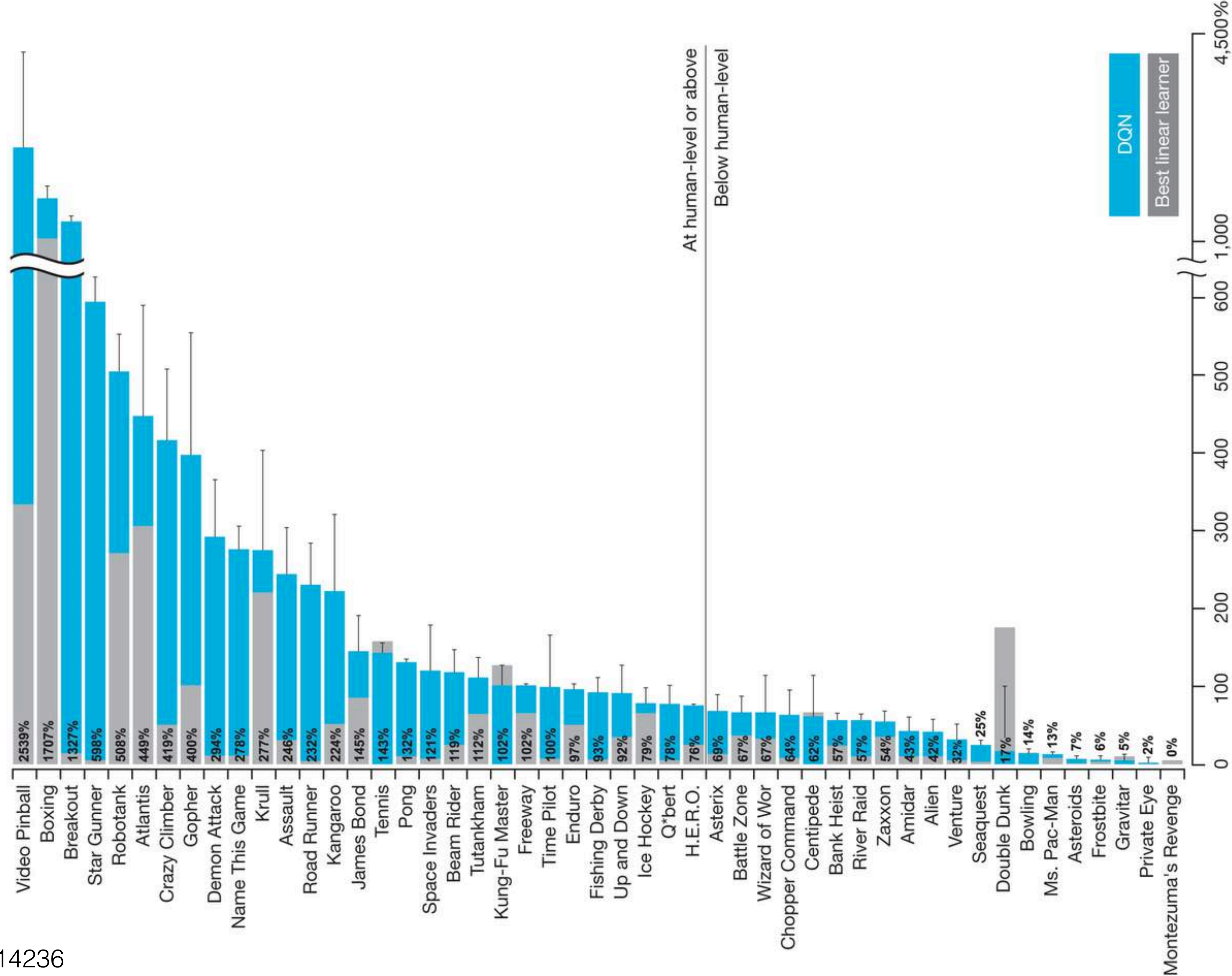
Static environment

Discrete action space

Deterministic actions

Beyond Board Games





Modern AI Opponents



4X Computer Games

Limited information

Dynamic environment

Discrete action space

Deterministic actions



First-Person Computer Games

Limited information

Dynamic environment

Continuous action space

Sometimes Stochastic actions

Robotics

Limited information

Dynamic environment

Continuous action space

Stochastic actions

Robotics & Game Playing Agent Architectures

Baxter