Heuristic Search

Ref: Chapter 4

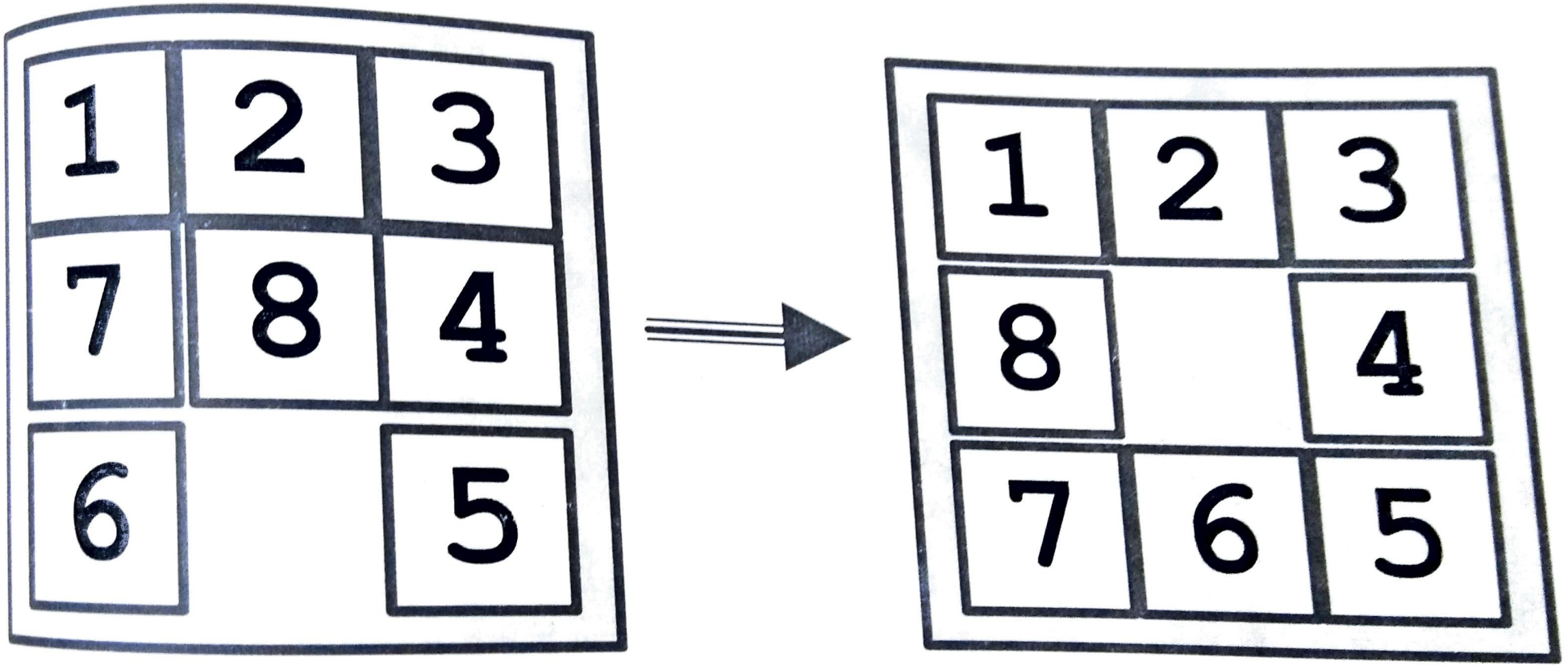
Heuristic Search Techniques

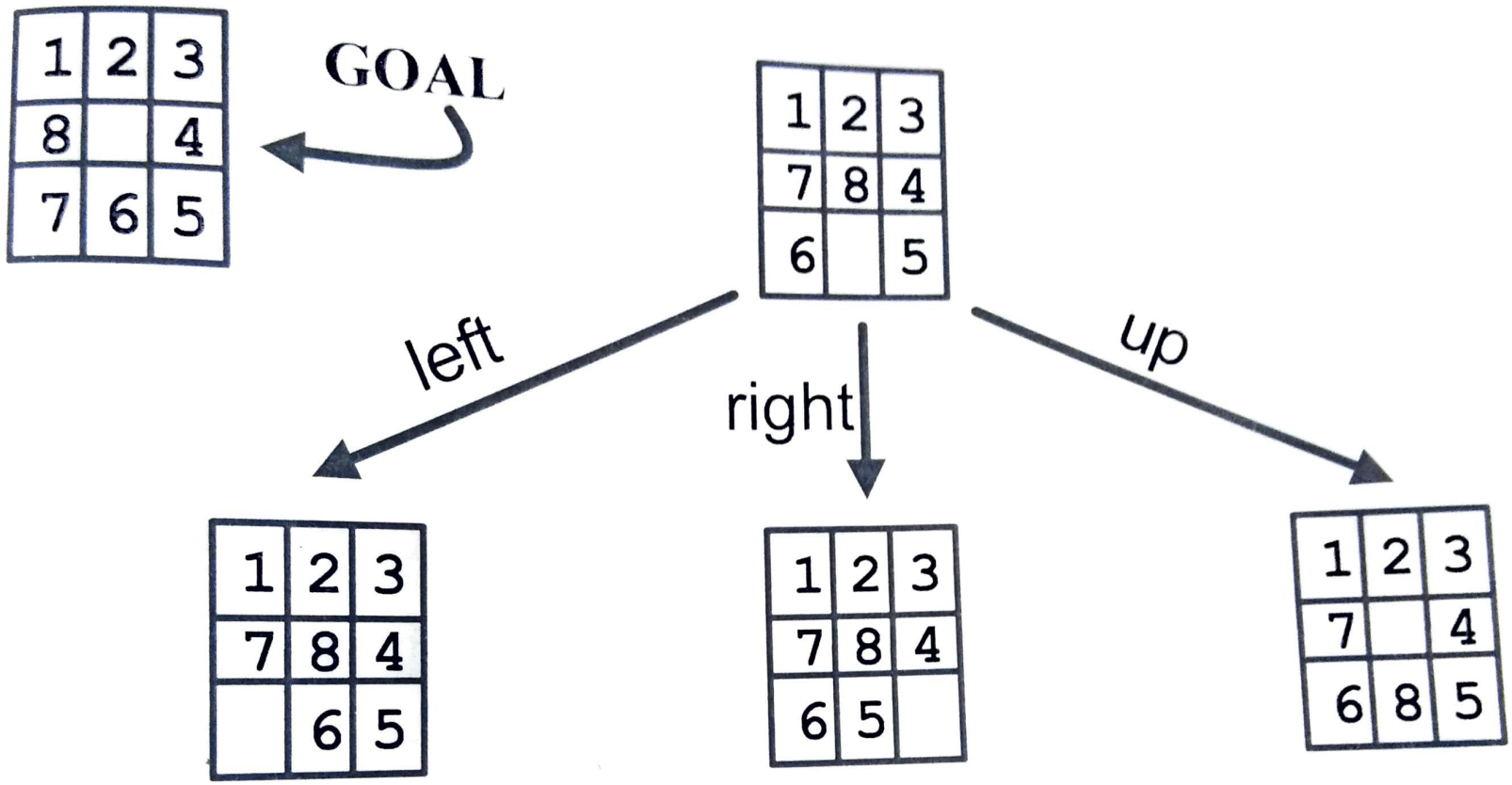
- *Direct* techniques (blind search) are not always possible (they require too much time or memory).

- *Weak* techniques can be effective if applied correctly on the right kinds of tasks.

  – Typically require domain specific information.

Example: 8 Puzzle





Which move is best?

8 Puzzle Heuristics

- Blind search techniques used an arbitrary ordering (priority) of operations.
- Heuristic search techniques make use of domain specific information - a heuristic.
- What heurisitic(s) can we use to decide which 8-puzzle move is "best" (worth considering first).

8 Puzzle Heuristics

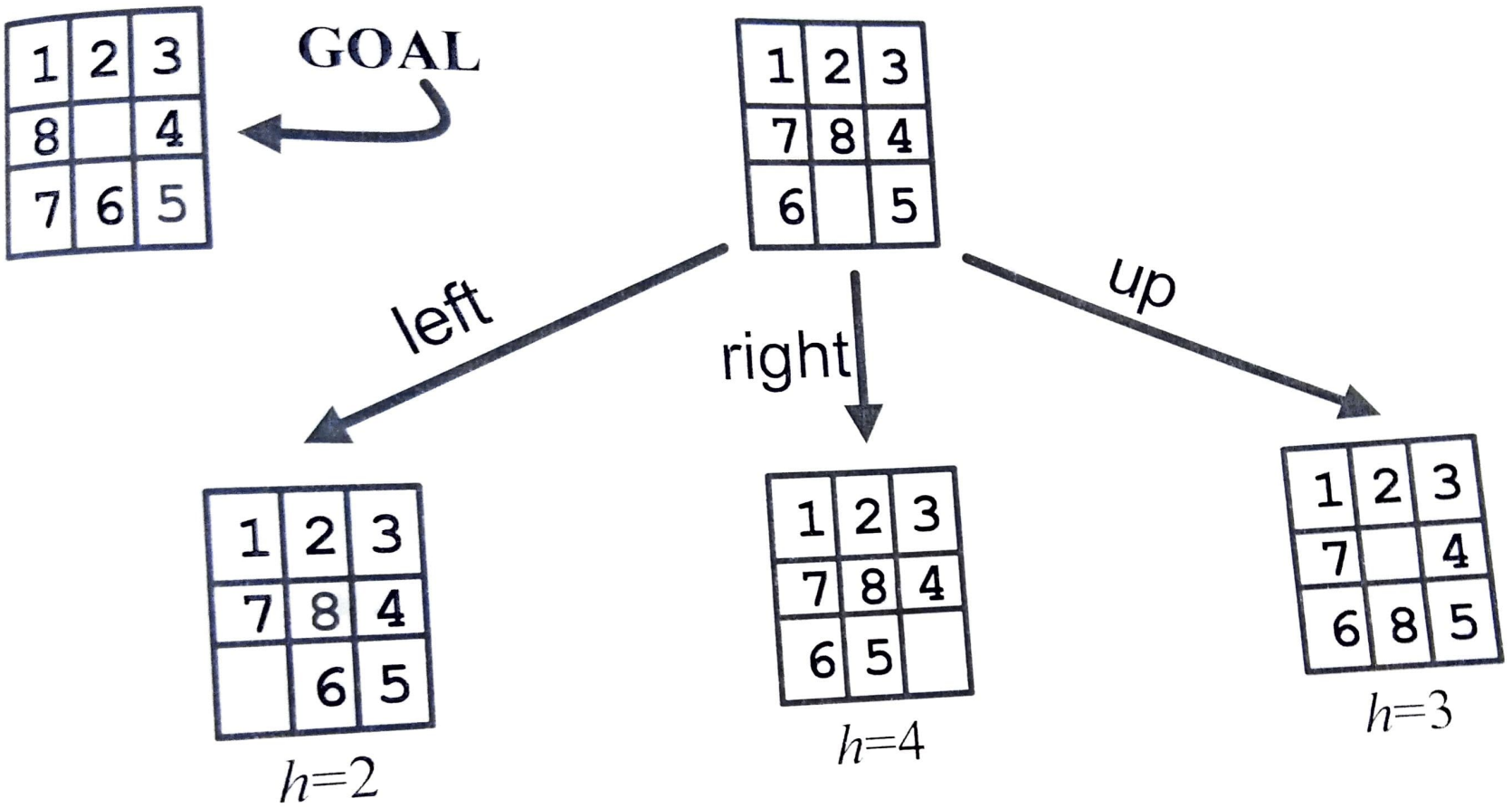
- For now - we just want to establish some ordering to the possible moves (the values of our heuristic does not matter as long as it ranks the moves).
- Later - we will worry about the actual values returned by the heuristic function.

A Simple 8-puzzle heuristic

- Number of tiles in the correct position.
  - The higher the number the better.
  - Easy to compute (fast and takes little memory).
  - Probably the simplest possible heuristic.

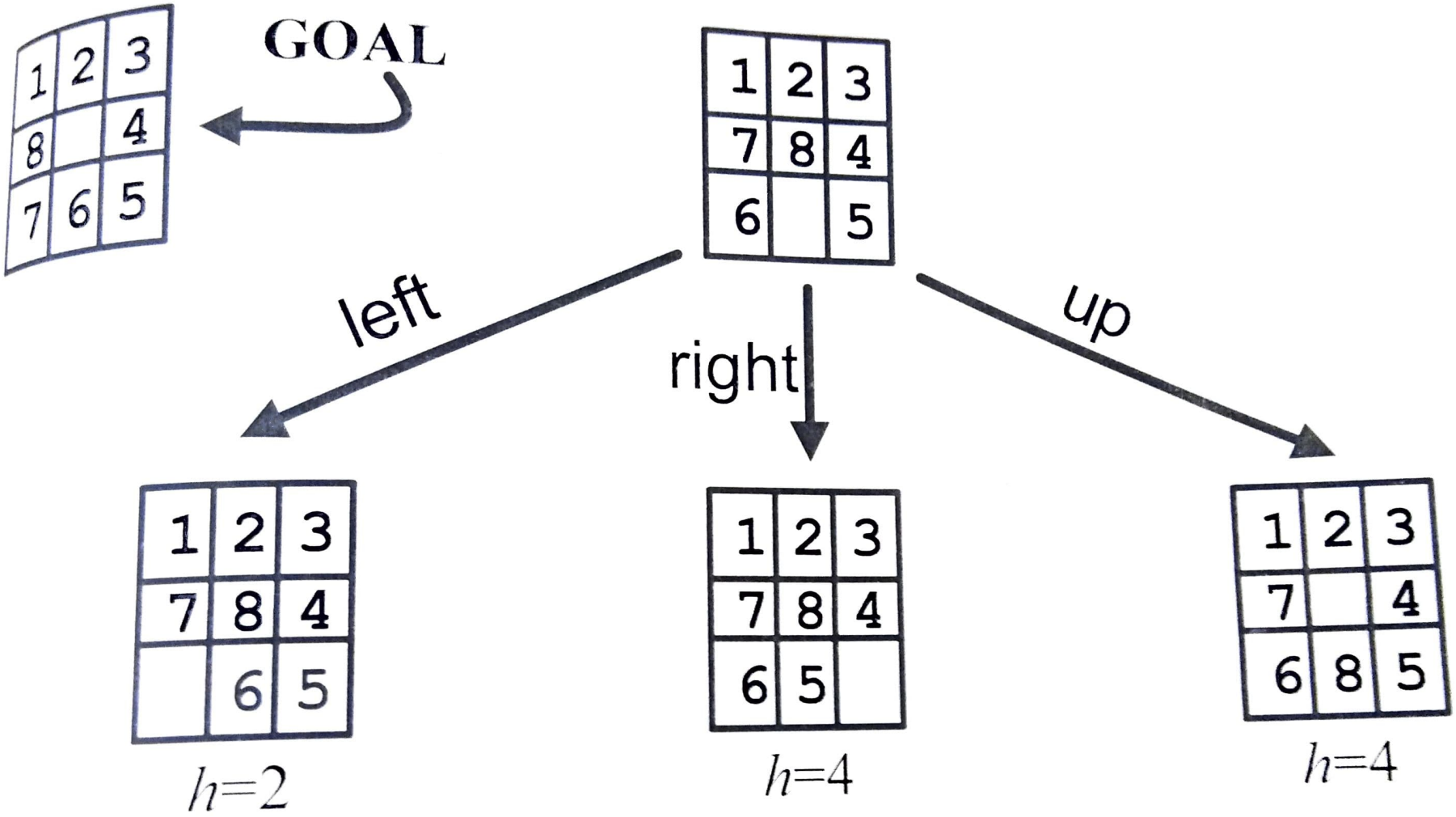
Another approach

- Number of tiles in the *incorrect* position.
  - This can also be considered a lower bound on the number of moves from a solution!
  - The "best" move is the one with the lowest number returned by the heuristic.
  - Is this heuristic more than a heuristic (is it always correct?).
    - Given any 2 states, does it always order them properly with respect to the minimum number of moves away from a solution?


GOAL
1 2 3
8 4
7 6 5
1 2 3
7 8 4
6 5
left
right
up
1 2 3
7 8 4
6 5
h=2
1 2 3
7 8 4
6 5
h=4
1 2 3
7 4
6 8 5
h=3

Another 8-puzzle heuristic

- Count how far away (how many tile movements) each tile is from it's correct position.
- Sum up this count over all the tiles.
- This is another estimate on the number of moves away from a solution.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Techniques

- There are a variety of search techniques that rely on the estimate provided by a heuristic function.
- In all cases - the quality (accuracy) of the heuristic is important in real-life application of the technique!

Generate-and-test

- Very simple strategy - just keep guessing.

```
do while goal not accomplished
   generate a possible solution
   test solution to see if it is a goal
```

- Heuristics may be used to determine the specific rules for solution generation.

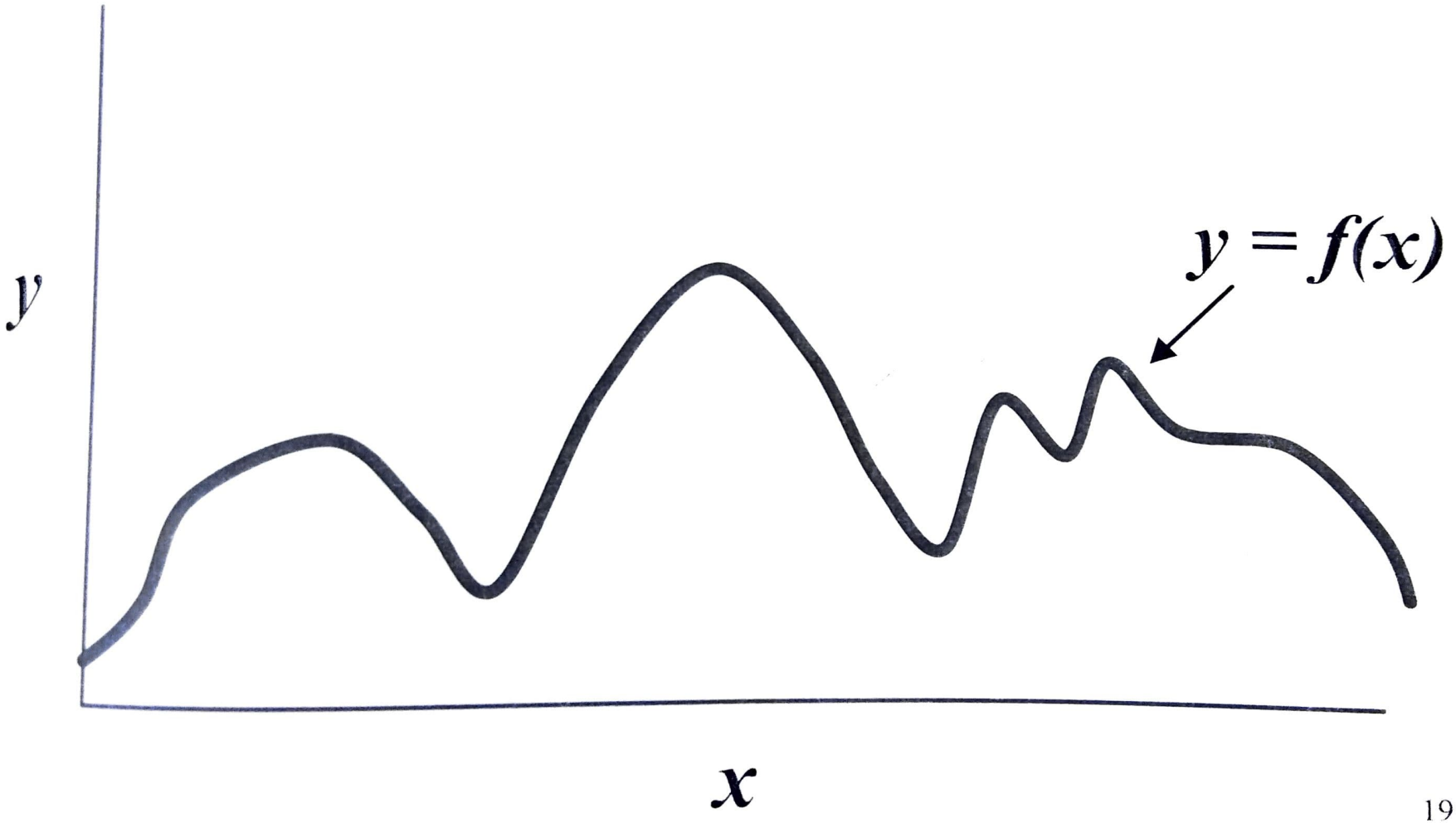
Hill Climbing

- Variation on generate-and-test:
  - *generation* of next state depends on feedback from the *test* procedure.
  - *Test* now includes a heuristic function that provides a guess as to how good each possible state is.
- There are a number of ways to use the information returned by the *test* procedure.

Simple Hill Climbing

- Use heuristic to move only to states that are *better* than the current state.
- Always move to better state when possible.
- The process ends when all operators have been applied and none of the resulting states are better than the current state.

Simple Hill Climbing Function Optimization



Potential Problems with Simple Hill Climbing

- Will terminate when at local optimum.
- The order of application of operators can make a big difference.
- Can't see past a single move in the state space.

Simple Hill Climbing Example

- TSP - define state space as the set of all possible tours.

- Operators exchange the position of adjacent cities within the current tour.

- Heuristic function is the length of a tour.

Steepest-Ascent Hill Climbing

- A variation on simple hill climbing.
- Instead of moving to the *first* state that is *better*, move to the best possible state that is one move away.
- The order of operators does not matter.

- Not just climbing to a better state, climbing up the *steepest* slope.

Hill Climbing Termination

- Local Optimum: all neighboring states are worse or the same.

- Plateau - all neighboring states are the same as the current state.

- Ridge - local optimum that is caused by inability to apply 2 operators at once.

Heuristic Dependence

- Hill climbing is based on the value assigned to states by the heuristic function.
- The heuristic used by a hill climbing algorithm does not need to be a static function of a single state.
- The heuristic can look ahead many states, or can use other means to arrive at a value for a state.

A* Algorithm

1. Create a priority queue of search nodes (initially the start state). Priority is determined by the function f)
2. While queue not empty and goal not found:

   get best state x from the queue.

   If x is not goal state:

      generate all possible children of x (and save path information with each node).

      Apply f to each new node and add to queue.

      Remove duplicates from queue (using f to pick the best).

Best-First Search

- Combines the advantages of Breadth-First and Depth-First searchs.
  - DFS: follows a single path, don't need to generate all competing paths.
  - BFS: doesn't get caught in loops or dead-end-paths.
- Best First Search: explore the most promising path seen so far.

Best-First Search (cont.)

While goal not reached:

1. Generate all potential successor states and add to a list of states.
2. Pick the best state in the list and go to it.

- Similar to steepest-ascent, but don't throw away states that are not chosen.