

Minimum Genetic Mutation

This problem is a shortest path search in an unweighted graph:

- Nodes: Gene strings (8-char)
- Edges: Two nodes are connected if they differ by exactly one character.
- Goal: Find the minimum mutations (edges) to reach end Gene from start Gene using only valid genes from bank.

Key Insights:

1. Bank as allowed nodes:
 - Only genes in bank (plus start Gene) are valid to traverse.
 - If end Gene is not in bank, return -1 (no valid path!).
2. One-character mutation rule:
 - Two genes are neighbors if they differ by exactly one character.
3. Use BFS (Breadth-First Search):
 - BFS ensures minimum steps in an unweighted graph.
 - At each step, mutate one character and check if it's in bank and not visited.

Algorithm Steps:

1. Put bank into a set for $O(1)$ lookups.
2. Initialize BFS queue with start Gene.
3. At each step:
 - For each gene in the queue, generate all valid 1-char mutations.
 - If mutation is end Gene, return current steps + 1.
 - Mark visited to avoid loops.
4. If BFS ends without finding end Gene, return -1.

Complexity:

Time: up to bank.length * gene.length * 4 $\rightarrow O(10^8 * 4) = O(320)$ worst-case (very small).

Space: $O(\text{bank.length})$ for visited set.