Genetic Algorithm Problem: "Evolve the Target String"

Problem Statement

Create a genetic algorithm that evolves a population of random strings to match a target phrase: **"HELLO WORLD"**

Your program should start with completely random strings (like "XKQP ZMRTB") and gradually evolve them through generations until one perfectly matches the target.

Learning Objectives

You'll implement the core components of a genetic algorithm:

1. **Population** - A group of candidate solutions

2. **Fitness Function** - Measures how close each candidate is to the solution

3. **Selection** - Chooses the best candidates to reproduce

4. **Crossover** - Combines two parents to create offspring

5. **Mutation** - Introduces random changes for diversity

Implementation Requirements

1. Initialize Population

- Create 100 random strings, each 11 characters long

- Use uppercase letters and spaces (A-Z + space)

- Example: `["ABCDE FGHIJ", "ZMQRT PQWXL", ...]`

2. Fitness Function

Calculate how many characters match the target in the correct position.

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Example:

Target: "HELLO WORLD"

Candidate: "HXLLP WPRLD"

Fitness: 7/11 (H, L, L, space, W, R, L, D match)
```

3. Selection

Choose parents for the next generation:

- **Tournament Selection**: Pick 5 random individuals, select the best one

- Or **Roulette Wheel**: Probability proportional to fitness

4. Crossover

Combine two parents to create offspring:

- **Single-point crossover**: Split at random position

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Parent 1: "HELLO WORLD"

Parent 2: "ABCDE FGHIJ"

Split at position 6

Child: "HELLO FGHIJ"
```

5. Mutation

With a small probability (2-5%), randomly change a character:

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Before: "HELLO WORLD"

After: "HELLO WQRLD" (O → Q)
```

6. Evolution Loop

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1. Evaluate fitness of all individuals

2. If any individual has perfect fitness → DONE!

3. Create next generation:

- Keep top 10% (elitism)

- Fill rest with offspring from crossover + mutation

4. Repeat
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Sample Output

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Generation 1: Best: "XKQP ZMRTB" (Fitness: 1/11)

Generation 5: Best: "HELAO WPRND" (Fitness: 6/11)

Generation 12: Best: "HELLO WDRLD" (Fitness: 9/11)

Generation 18: Best: "HELLO WORLD" (Fitness: 11/11) 
```

```
Evolved in 18 generations!
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Questions to Explore

1. **What happens if you increase/decrease mutation rate?**

2. **How does population size affect convergence speed?**

3. **What if you remove elitism?**

4. **Try different target strings - are some harder to evolve?**