1. Suppose a delivery robot must carry out a number of delivery activities, a, b, c, d, and e. Suppose that each activity happens at any of times 1, 2, 3, or 4. Let A be the variable reprsenting the time that activity a will occur, and similarly for the other activities. The variable domains, which represent possible times for each of the deliveries, are

$$dom(A) = \{1,2,3,4\}, \quad dom(B) = \{1,2,3,4\}, \quad dom(C) = \{1,2,3,4\},$$
$$dom(D) = \{1,2,3,4\}, \quad dom(E) = \{1,2,3,4\}.$$

Suppose the following constraints must be satisfied:

$$B \neq 3, C \neq 2, A \neq B, B \neq C, C < D, A = D,$$
$$E < A, E < B, E < C, E < D, B \neq D$$

The aim is the find an assignment of value to each activity, such that all the constraints are satisfied.

We define the evaluation function for any assignment by the number of constraints that it does NOT satisfy. E.g.,

- The assignment $(A = 2, B = 2, C = 3, D = 1, E = 1)$ has evaluation 4 as four constraints $A \neq B, B \neq D, A = D, C < D$ are not satisfied.
- The assignment $(A = 4, B = 2, C = 3, D = 4, E = 4)$ has evaluation 4 as four constraints $E < A, E < B, E < C, E < D$ are not satisfied.

We would like to employ genetic algorithm to solve the problem. Each candidate solution $(A = a, B = b, C = c, D = d, E = e)$ of the form can be encoded by a string $abcde$. E.g., $(A = 2, B = 2, C = 3, D = 1, E = 1)$ is encoded as 22311. Answer the following questions

(a) Perform crossover over the two candidate solutions $(A = 2, B = 2, C = 3, D = 1, E = 1)$ and $(A = 4, B = 2, C = 3, D = 4, E = 4)$ on the crossing site 4. What is the outcome and its evaluation?

(b) Using examples, briefly discuss how genetic algorithm may help desirable “traits” of a candidate solution to be preserved in the population thereby improving the solution found.

2. In a machine learning scenario, suppose we are given a dataset

x_1	x_2	x_3	y
0	0	0	1
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

where x_1, x_2, x_3 are input features, and y is the output. For example, when $x_1 = 0, x_2 = 0$ and $x_3 = 1$, the output $y = 0$.

We would like to develop a function of the form

$$y = \begin{cases} 0 & w_1x_1 + w_2x_2 + w_3x_3 < 0 \\ 1 & \text{otherwise} \end{cases}$$

to capture the association between the input features and the output. We require that each w_i to be either $-1, 0$ or 1. Hence, a candidate solution specifies the values of w_1, w_2, w_3.

Given (w_1, w_2, w_3), to compute the evaluation: For each x_1, x_2, x_3

(a) First, compute the weighted sum $s = w_1x_1 + w_2x_2 + w_3x_3$; and

(b) Then determine $y_c = 0$ if $s < 0$ and $y_c = 1$ otherwise.

(c) Then compare y_c against y, the true output.

This produces a table. For example, if $w_1 = -1, w_2 = 0, w_3 = 1$

x_1	x_2	x_3	y_c	y	$y_c = y$?
0	0	0	1	1	yes
0	0	1	1	0	no
0	1	0	1	1	yes
0	1	1	1	0	no
1	0	0	0	1	no
1	0	1	1	1	yes
1	1	0	0	1	no
1	1	1	1	1	yes

The evaluation of the candidate solution (w_1, w_2, w_3) is the number of "no"s. For example, the evaluation of $(w_1 = -1, w_2 = 0, w_3 = 1)$ is 4.

Describe how you would apply genetic algorithm to solve this problem. Use an example run-thru to illustrate the procedures.