3 Exercise solutions – Extension of global alignment

1. **DP with score matrix**

   Use the score matrix below with gap penalty g =1 and answer the following questions.

	C	G	A	T
C	1	0	0	0
G		1	1	0
A			1	0
T				1

   (a) Calculate the alignment score.

   - Alignment 1

```
q: ATGCT
d: CA--T
```

     Solution: -1

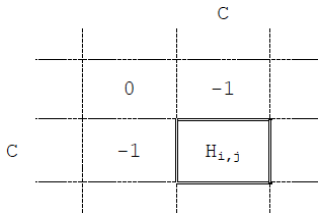
   - Alignment 2

```
q: CAGCT
d: C-A-T
```

     Solution: 1

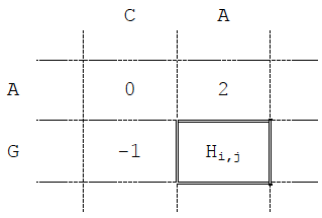
   (b) Calculate the score of $H_{i,j}$.

   - Table A



     Solution: 1

   - Table B



     Solution: 1

(c) Fill the empty cells with appropriate scores in the DP table. What is the optimal alignment score?

q\d		C	A	T
	0	-1	-2	-3
C	-1		0	-1
A	-2	0	2	1
G	-3	-1		2
C	-4	-2		1
T	-5	-3	-1	

Solution: 1

(d) There are two different alignments that give the same optimal score in the solution above. Specify both of them.

Solution:

```
q: CAGCT
d: CA--T

q: CAGCT
d: C-A-T
```

2. **Affine gap penalty**

Affine gap penalties are often preferable ways to calculate gap scores than linear penalties. A gap with length l can be calculated as: $g_l = g_{open} + (l-1) * g_{extend}$.

Use the following scoring scheme and gap penalties to answer the questions.

Scoring scheme:
$R_{ab} = 1$ for a = b
$R_{ab} = 0$ for a $\neq$ b
$g_{open} = 1$, $g_{extend} = 0.1$

(a) What is the gap penalty when $l = 2$.

Solution: $g_{l=2} = 1 + (2-1) * 0.1 = 1.1$

(b) Calculate the scores of the alignments.

1.
```
q: CAGCT
d: CT--T
```

Solution: 0.9

2.
```
q: CAGCT
d: C-T-T
```

Solution: 0

3.
```
q: CCT--
d: ---CT
```

Solution: -2.3

3. **Affine gap with single DP table**

You need to check extra cells in addition to the adjacent cells of H when finding an optimal alignment with affine gap penalties.

Scoring scheme:
$R_{ab} = 1$ for a = b
$R_{ab} = 0$ for a $\neq$ b
$g_{open} = 1$, $g_{extend} = 0.1$

		C	G
	0	-1	-1.1
C	-1	1	0
A	-1.1	0	

Assume we want to update $H_{2,2}$ and answer the following questions.

(a) Calculate $H_{1,1} + R_{q_2,d_2}$.

Solution: $1 + 0 = 1$

(b) Calculate $max_{1 \leq l \leq 2}(H_{2,2-l} - g_l)$.

Solution: $max(H_{2,1} - g_{l=1}, H_{2,0} - g_{l=2}) = max(01, -1.11.1) = -1$

(c) Calculate $max_{1 \leq l \leq 2}(H_{2-l,2} - g_l)$.

Solution: $max(H_{1,2} - g_{l=1}, H_{0,2} - g_{l=2}) = max(01, -1.11.1) = -1$

(d) What is the score of $H_{2,2}$.

Solution: $max(1, 1, -1) = 1$

4. **Initializtion for affine gap penalty**

Initialize the following tables when $g_{open} = 10$ and $g_{extend} = 1$.

E

		T	G	C
	0	-10	-11	-12
A	-10			
A	-11			

F

		T	G	C
	0	-10	-11	-12
A	-11			
A	-12			

G

		T	G	C
	0	-10	-11	-12
A	-10			
A	-11			

5. **Affine gap with three DP tables**

Use the following scoring scheme and gap penalties to find the optimal alignment score of two sequences q = AG and d = GGGC.

Scoring scheme:

$R_{ab} = 1$ for a = b
$R_{ab} = 0$ for a $\neq$ b
$g_{open} = 1$, $g_{extend} = 0.1$

(a) Fill all blank cells in the DP tables E, F, and G.

E

		G	G	G	C
	0	-1	**-1.1**	**-1.2**	**-1.3**
A	-1	**-2**	-2.1	-2.2	-2.3
G	**-1.1**	-1	-2	**-2.1**	-2.2

F

		G	G	G	C
	0	-1	**-1.1**	**-1.2**	**-1.3**
A	-1	-2	-1	**-1.1**	-1.2
G	**-1.1**	**-2.1**	-1	0	-0.1

G

		G	G	G	C
	0	-1	**-1.1**	**-1.2**	**-1.3**
A	-1	0	-1	-1.1	-1.2
G	**-1.1**	0	1	0	**-1.1**

(b) What is the optimal score?

Solution: -0.1

6. **Backtrack with affine gap penalty**

Perform backtracking on E, F, and G tables to find the optimal alignment. The cells with double border should be visited during backtracking.

E

		A	C	G	T
C					
G					

F

		A	C	G	T
C					
G					

G

		A	C	G	T
C					
G					

(a) Write the optimal alignment.

Solution:

```
q: -CG-
d: ACGT
```

7. **Sequence distance with DP**

DP can be used to calculate the edit distance (Levenshtein distance) between two sequences.

Scoring scheme:

$R_{ab} = 0$ for a = b
R_{ab} = -1 for a $\neq$ b
$g = 1$

With the scoring scheme above, the edit distance d is calculated as $1 * T$ where T is the optimal score of the DP.

Find the edit distance between two sequences q = AG and d = ACG.

(a) Fill the DP table.

q\d		A	C	T
	0	-1	-2	-3
A	-1	0	-1	-2
G	-2	-1	-1	-2

(b) What is the edit distance between q and d?

Solution:

2