

Find the **global alignment** between GATCGTT and TCTGAT with the δ values from the table below. As a reminder the recursive formula for global alignment is given.

| | | | | | |
|----------|-------|-------|-------|-------|-----------|
| δ | A | C | T | G | - |
| A | 1.5 | -1 | -0.75 | -1 | -0.5 |
| C | -1 | 1.5 | -1 | -0.75 | -0.5 |
| T | -0.75 | -1 | 1.5 | -1 | -0.5 |
| G | -1 | -0.75 | -1 | 1.5 | -0.5 |
| - | -0.5 | -0.5 | -0.5 | -0.5 | $-\infty$ |

$$V(i, j) = \max \begin{cases} V(i-1, j-1) + \delta(S[i], T[j]) & \text{match/mismatch} \\ V(i-1, j) + \delta(S[i], -) & \text{delete} \\ V(i, j-1) + \delta(-, T[j]) & \text{insert} \end{cases}$$

| | | T | C | T | G | A | T | |
|---------------------------------|---|-----------|-------------|--------------|------------|------------|-------------|-----------|
| G A T C G T T | G | 0 L | -0.5 L | -1 L | -1.5 L | -2 L | -2.5 L | -3 L |
| | A | -0.5 U | -1 D/L/U | -1.25 D | -1.75 L | 0 D | -0.5 L | -1 L |
| | T | -1 U | -1.25 D | -1.75 L/U | -2 D | -0.5 U | 1.5 D | 1 L |
| | C | -1.5 U | 0.5 D | 0 L | -0.25 D | -0.75 L | 1 U | 3 D |
| | G | -2 U | 0 U | 2 D | 1.5 L | 1 L | 0.5 L/U | 2.5 U |
| | T | -2.5 U | -0.5 U | 1.5 U | 1 D/L/U | 3 D | 2.5 L | 2 L/U |
| | T | -3 U | -1 D/U | 1 U | 3 D | 2.5 L/U | 2.25 D | 4 D |
| | T | -3.5 U | -1.5 D/U | 0.5 U | 2.5 D/U | 2 D/L/U | 1.75 D/U | 3.75 D |

Best score: _____ 3.75

Best alignment:

GATC-GAT

--TCTGTT

| | | | |
|-------|-------|-----|-------|
| (0,0) | (1,0) | ... | (n,0) |
| (0,1) | (1,1) | ... | (n,1) |
| : | : | | : |
| (0,m) | (1,m) | ... | (n,m) |

Find the **local alignment** between CACTUS and REACTSBAD with the σ values that follow the rules below. As a reminder the recursive formula for global alignment is given.

$$V(i, j) = \max \begin{cases} 0 & \text{align empty strings} \\ V(i-1, j-1) + \delta(S[i], T[j]) & \text{match/mismatch} \\ V(i-1, j) + \delta(S[i], -) & \text{delete} \\ V(i, j-1) + \delta(-, T[j]) & \text{insert} \end{cases}$$

$$\begin{aligned} \delta(-, x) &= -1 \text{ for } x \in \Sigma \\ \delta(x, -) &= -1 \text{ for } x \in \Sigma \\ \delta(x, y) &= 2 \text{ for } y = x \\ \delta(x, y) &= -1 \text{ for } y \neq x \end{aligned}$$

| | | R | E | A | C | T | S | B | A | D |
|----------------------------|---|---|---|---|---|---|---|---|---|---|
| C A C T U S | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | S | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 |
| | S | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 2 |
| | S | 0 | 0 | 0 | 1 | 4 | 3 | 2 | 1 | 1 |
| | S | 0 | 0 | 0 | 0 | 3 | 6 | 5 | 4 | 3 |
| | S | 0 | 0 | 0 | 0 | 2 | 5 | 5 | 4 | 3 |
| | S | 0 | 0 | 0 | 0 | 1 | 4 | 7 | 6 | 5 |

Best score: _____7

Best alignment:

ACTUS

ACT-S

| | | | |
|-------|-------|-----|-------|
| (0,0) | (1,0) | ... | (n,0) |
| (0,1) | (1,1) | ... | (n,1) |
| : | : | | : |
| (0,m) | (1,m) | ... | (n,m) |

Find the **global alignment with affine gap costs** between AGGC and ATTGGGC with the scores. As a reminder the recursive formula for global alignment is given.

$$F(i, j) = \max \begin{cases} F(i-1, j) - b \\ G(i-1, j) - f_{a,b}(1) \end{cases}$$

$$f_{a,b}(i) = \alpha + \beta \cdot i$$

$$E(i, j) = \max \begin{cases} E(i, j-1) - b \\ G(i, j-1) - f_{a,b}(1) \end{cases}$$

$$G(i, j) = \max \begin{cases} G(i-1, j-1) + \delta(S[i], T[j]) \\ E(i, j) \\ F(i, j) \end{cases}$$

| F | A | T | T | G | G | G | C | |
|---|-----------|-----------|-----------|-------------|----------|-----------|----------|------------|
| | $-\infty$ | -2.5 L | -3 L | -3.5 L | -4 L | -4.5 L | -5 L | -5.5 L |
| A | $-\infty$ | -5 O | 2.5 O | 2.0 L | 1.5 L | 1 L | 0.5 L | 0 L |
| G | $-\infty$ | -5.5 O | 0 O | 1.5 O | 1 L | 4.5 O | 4 O/L | 3.5 O/L |
| G | $-\infty$ | -6 O | -0.5 O | -1 O | 0.5 O | 4 O | 9.5 O | 9 O/L |
| C | $-\infty$ | -6.5 O | -1 O | -1.5 O/L | -2 L | 1.5 O | 7 O | 8.5 O |

$$\delta(x, y) = 5 \text{ for } y = x$$

$$\delta(x, y) = -1 \text{ for } y \neq x$$

$$\alpha = 2$$

$$\beta = 0.5$$

Best score: _____ 16.5

Best alignment:

A---GGC
ATTGGGC

| G | A | T | T | G | G | G | C | |
|---|-----------|-----------|------------|------------|----------|-----------|-----------|-----------|
| | 0 | -2.5 L | -3 L | -3.5 L | -4 L | -4.5 L | -5 L | -5.5 L |
| A | -2.5 U | 5 D | 2.5 F | 2 F | 1.5 F | 1 F | 0.5 F | 0 F |
| G | -3 U | 2.5 E | 4 D | 1.5 D/F | 7 D | 6.5 D | 6 D | 3.5 F |
| G | -3.5 U | 2 E | 1.5 D/E | 3 D | 6.5 D | 12 D | 11.5 D | 9 F |
| C | -4 U | 1.5 E | 1 D/E | 0.5 D/E | 4 E | 9.5 E | 11 D | 16.5 D |

| E | A | T | T | G | G | G | C | |
|---|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | $-\infty$ | $-\infty$ | $-\infty$ | $-\infty$ | $-\infty$ | $-\infty$ | $-\infty$ | |
| A | -2.5 U | -5 O | -5.5 O | -6 O | -6.5 O | -7 O | -7.5 O | -8 O |
| G | -3 U | 2.5 O | 0 O | -0.5 O | -1 O | -1.5 O | -2 O | -2.5 O |
| G | -3.5 U | 2 U | 1.5 O | -1 O/U | 4.5 O | 4 O | 3.5 O | 1 O |
| C | -4 U | 1.5 U | 1 U | 0.5 O | 4 O/U | 9.5 O | 9 O | 6.5 O |

| | | | |
|-------|-------|-----|-------|
| (0,0) | (1,0) | ... | (n,0) |
| (0,1) | (1,1) | ... | (n,1) |
| : | : | | : |
| (0,m) | (1,m) | ... | (n,m) |

Find the **edit distance** between **BASEBALL** and **BALLCAP**. As a reminder the recursive formula for global alignment is given.

$$V[i, j] := \min \begin{cases} V[i-1, j-1] & \text{if } s_1[i] = s_2[j] \\ V[i-1, j-1] + 1 & \text{if } s_1[i] \neq s_2[j] \\ V[i, j-1] + 1 \\ V[i-1, j] + 1 \end{cases}$$

| | | B | A | L | L | C | A | P |
|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| B | 1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| A | 2 | 1 | 0 | 1 | 2 | 3 | 4 | 5 |
| S | 3 | 2 | 1 | 1 | 2 | 3 | 4 | 5 |
| E | 4 | 3 | 2 | 2 | 2 | 3 | 4 | 5 |
| B | 5 | 4 | 3 | 3 | 3 | 3 | 4 | 5 |
| A | 6 | 5 | 4 | 4 | 4 | 4 | 3 | 4 |
| L | 7 | 6 | 5 | 4 | 4 | 5 | 4 | 4 |
| L | 8 | 7 | 6 | 5 | 4 | 5 | 6 | 5 |

Edit Distance: _____ 5

| | | | |
|-------|-------|-----|-------|
| (0,0) | (1,0) | ... | (n,0) |
| (0,1) | (1,1) | ... | (n,1) |
| : | : | | : |
| (0,m) | (1,m) | ... | (n,m) |

Build the **Suffix Tree** for the string `MISSISSIPPI` using Ukkonen's algorithm. Without edge compression or suffix links. When you have completed the implicit tree for a given value, circle it in the table below.

| | | | | | | | | | | | | |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|---|
| | | | | | | | | | | 1 | 1 | 1 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | |
| M | I | S | S | I | S | S | I | P | P | I | \$ | |

