

**Phylogenetic Trees: Neighbor Joining**

You are given the dissimilarity map  $\delta$  below for the samples  $\mathcal{X} = \{A, B, C, D, E\}$ . Fill in the steps below to create the Neighbor-Joining tree for  $\mathcal{X}$ . First, in the space to the right of  $\delta$ , draw the initialization of the NJ tree and let (lowercase)  $c$  be the center node. Write out  $N_c$  and  $|N_c|$ . To start, we let  $d = \delta$ .

$\delta$	A	B	C	D	E
A	0	1	3	6	6
B		0	2	5	5
C			0	5	5
D				0	2
E					0

- (a) The tables below show  $S$  and  $Q$  for the first iteration. Verify that  $S_C$  and  $Q(D, E)$  are correct.

$i$	A	B	C	D	E
$S_i$	16	13	15	18	18

$Q$	B	C	D	E
A	-26	-22	-16	-16
B		-22	-16	-16
C			-18	-18
D				-30

- (b) Join  $D$  and  $E$  at internal vertex  $v$  and draw the new tree. Then calculate:
  - $d(D, v) =$
  - $d(E, v) =$

- (c) Fill in the updated  $d$  matrix:

$d$	A	B	C	v
A	0	1	3	
B		0	2	
C			0	
v				0

2. (a) Second iteration: verify  $S_v$ ,  $Q(A, B)$ , and  $Q(C, v)$ .

$i$	A	B	C	v
$S_i$	9	7	9	13

$Q$	B	C	v
A	-14	-12	-12
B		-12	-12
C			-14

(b) We will arbitrarily choose  $A$  and  $B$  to join at vertex  $w$ . Draw the new tree and calculate:

- $d(A, w) =$
- $d(B, w) =$

(c) Fill in the updated  $d$  matrix:

$d$	w	C	v
w	0		
C		0	4
v			0

3. (a) Third iteration: fill in the tables below.

$i$	w	C	v
$S_i$			

$Q$	C	v
w		
C		

(b) We will arbitrarily choose  $w$  and  $C$  to combine, but we don't change the topology since they are already joined at center vertex  $c$ . We do need to fill in the remaining edge weights:

- $d(w, c) =$
- $d(C, c) =$

(c) To fill in the last edge weight we update the distance matrix  $d$ :

$d$	c	v
c	0	3
v		0