

### Complete Linkage

max

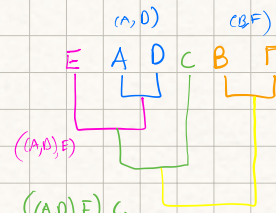
	A	B	C	D	E	F
A	0	4	3	2	4	11
B		0	20	8	6	3
C			0	6	5	18
D				0	3	13
E					0	8
F						0

	AD	B	C	E	F
A,D	0	8	6	4	13
B		0	20	6	3
C			0	5	18
E				0	8
F					0

$$\frac{4+8}{2} \quad \frac{2+6}{2} \quad \frac{4+3}{2} \quad \frac{11+13}{2}$$

dist from (A,D) to C

	A,D	B,F	C	E
A,D	0	13	6	4
B,F		0	20	8
C			0	5
E				0



$((A,D),E),C,(B,F)$

$((((A,D),E),C),(B,F))$


$((A,D),E),C$	$B,F$	
$((A,D),E),C$	0	20
$B,F$		0

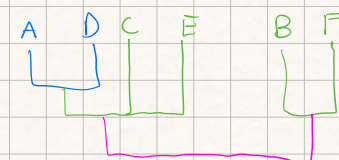
### Single Tree Linkage

min

	A	B	C	D	E	F
A	0	4	3	2	4	11
B		0	20	8	6	3
C			0	6	5	18
D				0	3	13
E					0	8
F						0

	A,D	B	C	E	F
A,D	0	4	3	3	11
B		0	20	6	3
C			0	5	18
E				0	8
F					0

		(A,D),C,E	B,F
(A,D),C,E	0	4	
B,F		0	



$((((A,D),C,E),(B,F)))$

$$\begin{array}{r} \text{HLW} / 80 \\ \text{Midpoint} / 20 \\ \text{Final} / 80 \end{array}$$

# UPGMA / Average Linkage

A	B	C	D	E	F
A	0	4	3	0	4
B		0	20	6	3
C			0	6	5
D				0	3
E					0
F					

A,D	B	C	E	F
A,D	0	6	4.5	3.5
B		0	20	6
C			0	5
E				0
F				

A,D	B,F	C	E
A,D	0	9	4.5
B,F		0	19
C			0
E			

(A,D),E	B,F	C
(A,D),E	0	8
B,F		0
C		

((A,D),E),C	B,F
((A,D),E),C	0
B,F	

number of unrooted trees

n sequences

u = n-1 trees

v = 2n-3 branches

distinct trees = (n-1)(2n-3)

$$\prod_{i=3}^n (2i-5)$$

rooted = unrooted - 1

Gamma dist correct Zveloff 245

Poisson - end of phylo slides

Linkage methods -> Zveloff 665

# Final Exam

③

A	C	A	G	A	G	$f_{1,A} = 0.5$
A	G	T	G	A	G	$f_{1,T} = 0.5$
T	A	T	C	A	G	
T	A	T	C	A	A	

$$\sum f_{C,A} \log_2 f_{C,A} = 1$$

④  $I_C = \log_2 4 - H_C = 3.3214$

$$I_A = 0.5 \times 3.32 = 1.6610$$

$$I_A = 0.5(\log_2(4) - 1) = 0.5$$

①

a:	A	T	T	C
b:	A	-	C	A
c:	A	-	-	C

a:	A	T	T	C
b:	A	-	C	A
	10	-5	-1	-1
	3			

a:	A	T	T	C
c:	A	-	-	C
	10	-5	-5	10
	10			

b:	A	-	C	A
c:	A	-	-	C
	10	-5	-5	-1
	-5			
	-6			

Sum all Pairs = 7

Conc



②

a: A T T C  
b: A - C A  
10 -5 -1 -1  
3

a: A T T C  
c: A - - C  
10 -5 -1 10  
14

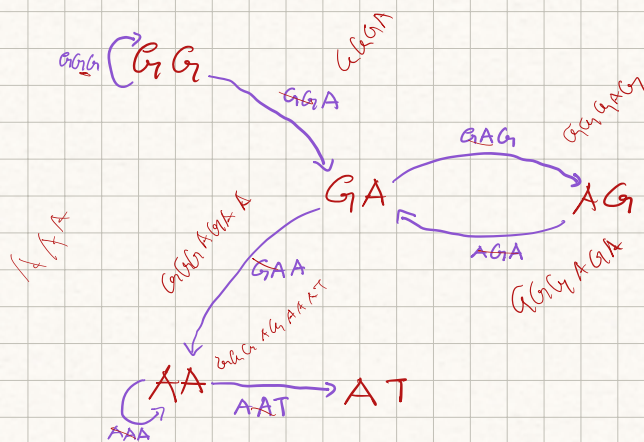
b: A - C A  
c: A - - C  
10 -5 -1 -1  
-5  
-2

affine

Sum all pairs = 15

⑤

AAA AAT AGA GAA GAG GGA GGG  
AA AA AA AT AG GA AA AG GG GA GG GG



⑥

GGGAGAAAT

⑦



list of arguments

```
for i in range(N-1)
```

for  $j$  in range  $(i+1, N)$

