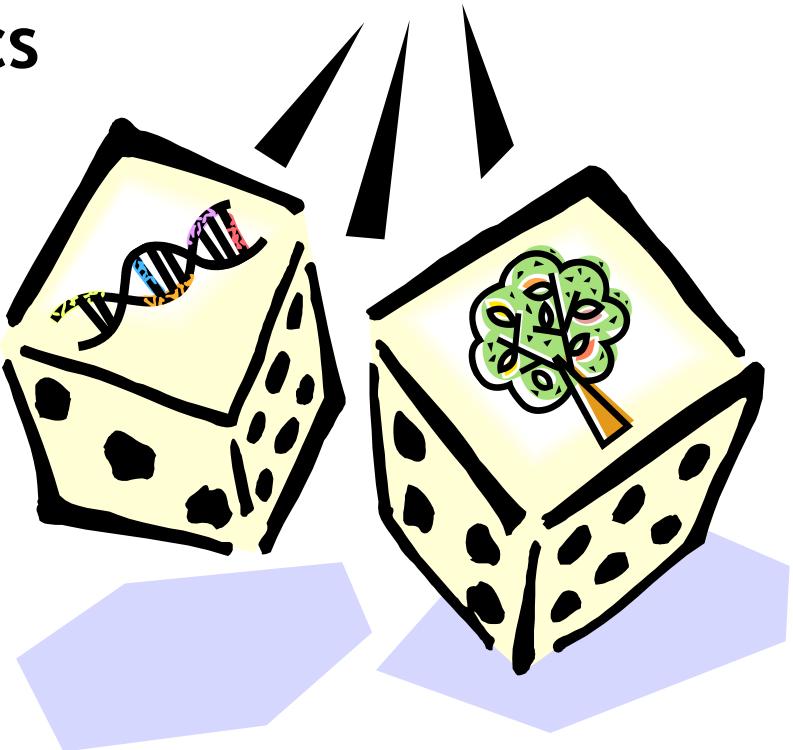
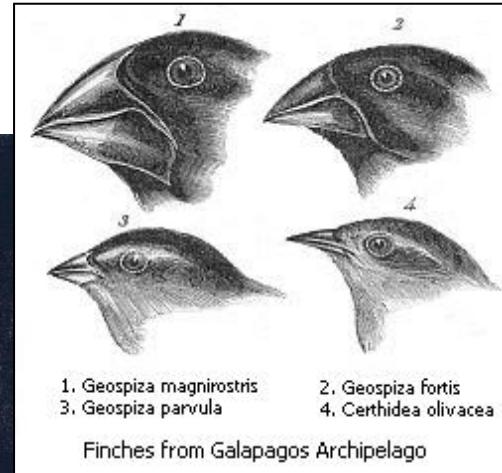


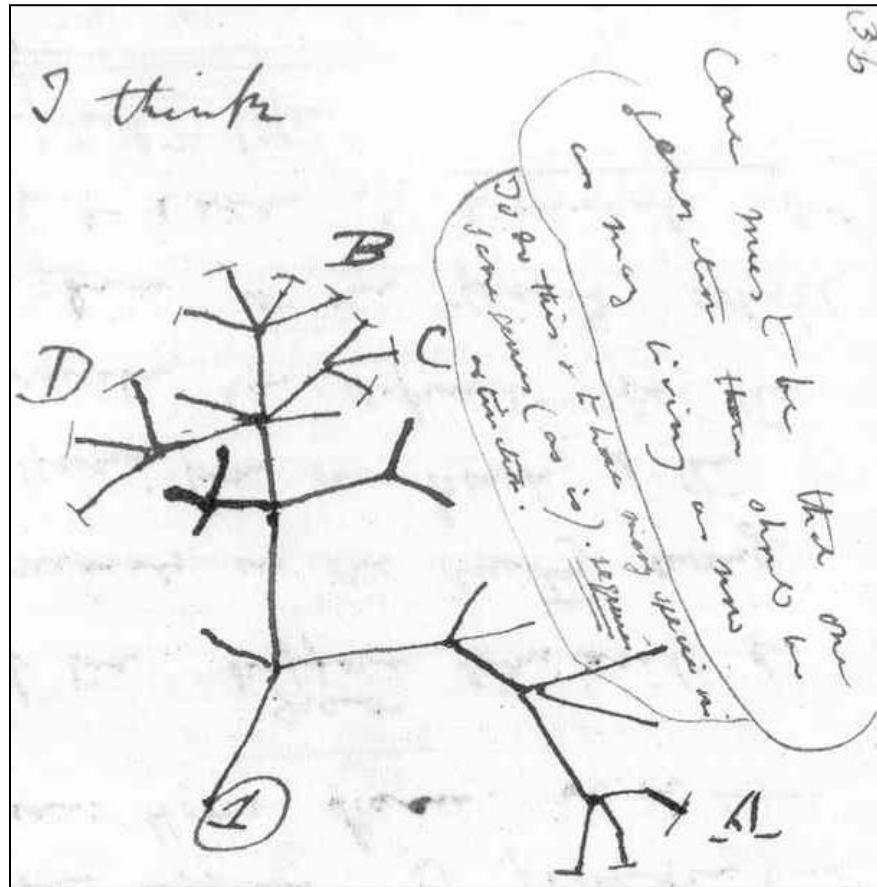
MATH 833: Stochastic Processes in Evolution and Genetics



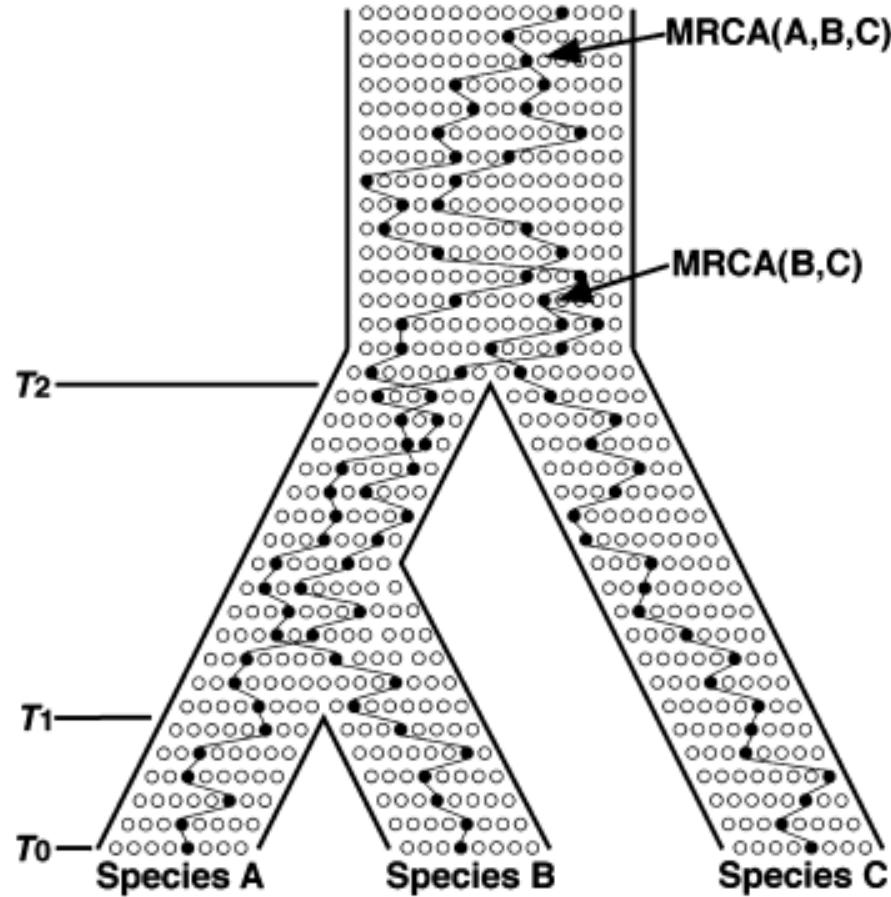
Darwin's finches



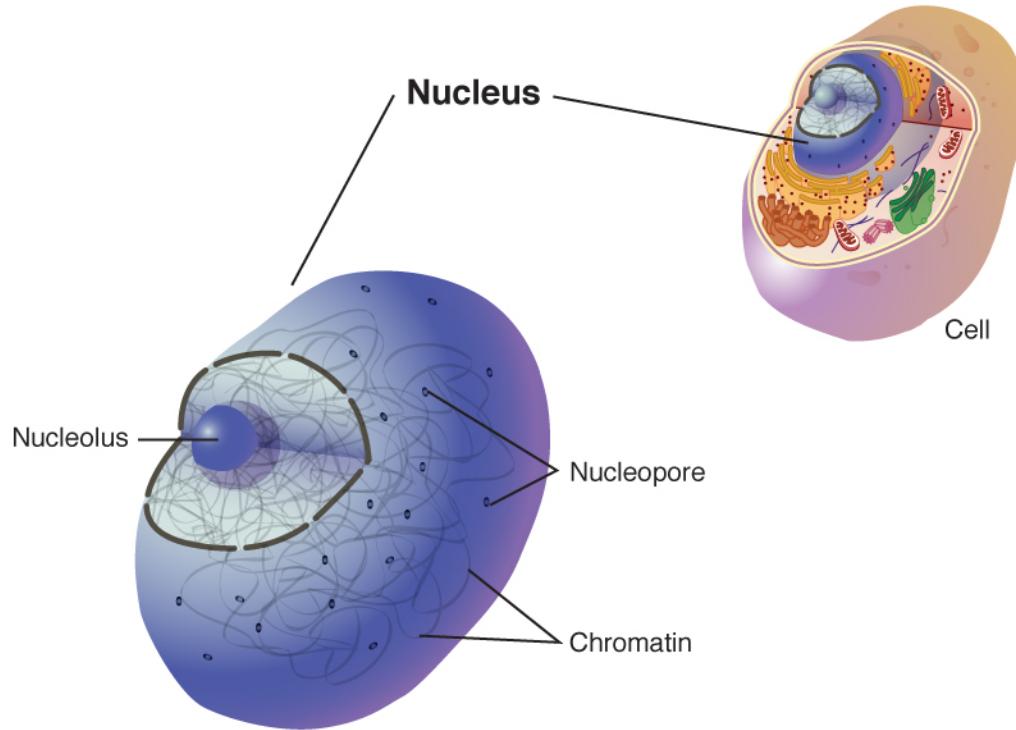
evolutionary tree



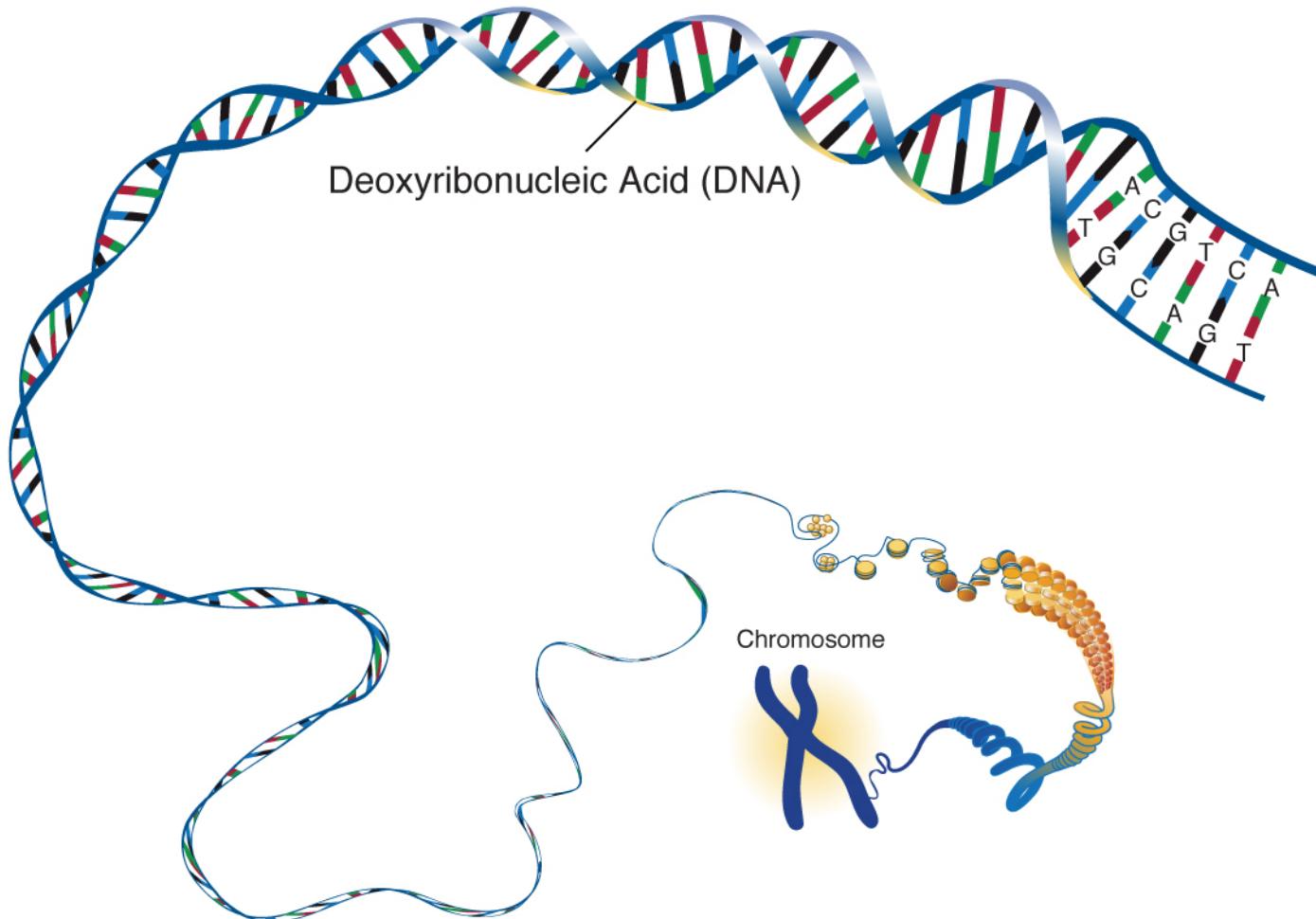
zooming in on populations



Nucleus



DNA (Deoxyribonucleic Acid)



Talking Glossary of Genetic Terms

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Illustration by Darryl Leja, NHGRI



Genetic Code



RNA codon table

1st position	2nd position				3rd position
	U	C	A	G	
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	stop	stop	A
	Leu	Ser	stop	Trp	G
	Leu	Pro	His	Arg	U
C	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
	Leu	Pro	Gln	Arg	
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
	Val	Ala	Asp	Gly	U
G	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G
	Val	Ala	Glu	Gly	
Amino Acids					

Ala: Alanine
Arg: Arginine
Asn: Asparagine
Asp: Aspartic acid
Cys: Cysteine
Gln: Glutamine
Glu: Glutamic acid
Gly: Glycine
His: Histidine
Ile: Isoleucine
Leu: Leucine
Lys: Lysine
Met: Methionine
Phe: Phenylalanine
Pro: Proline
Ser: Serine
Thr: Threonine
Trp: Tryptophane
Tyr: Tyrosine
Val: Valine

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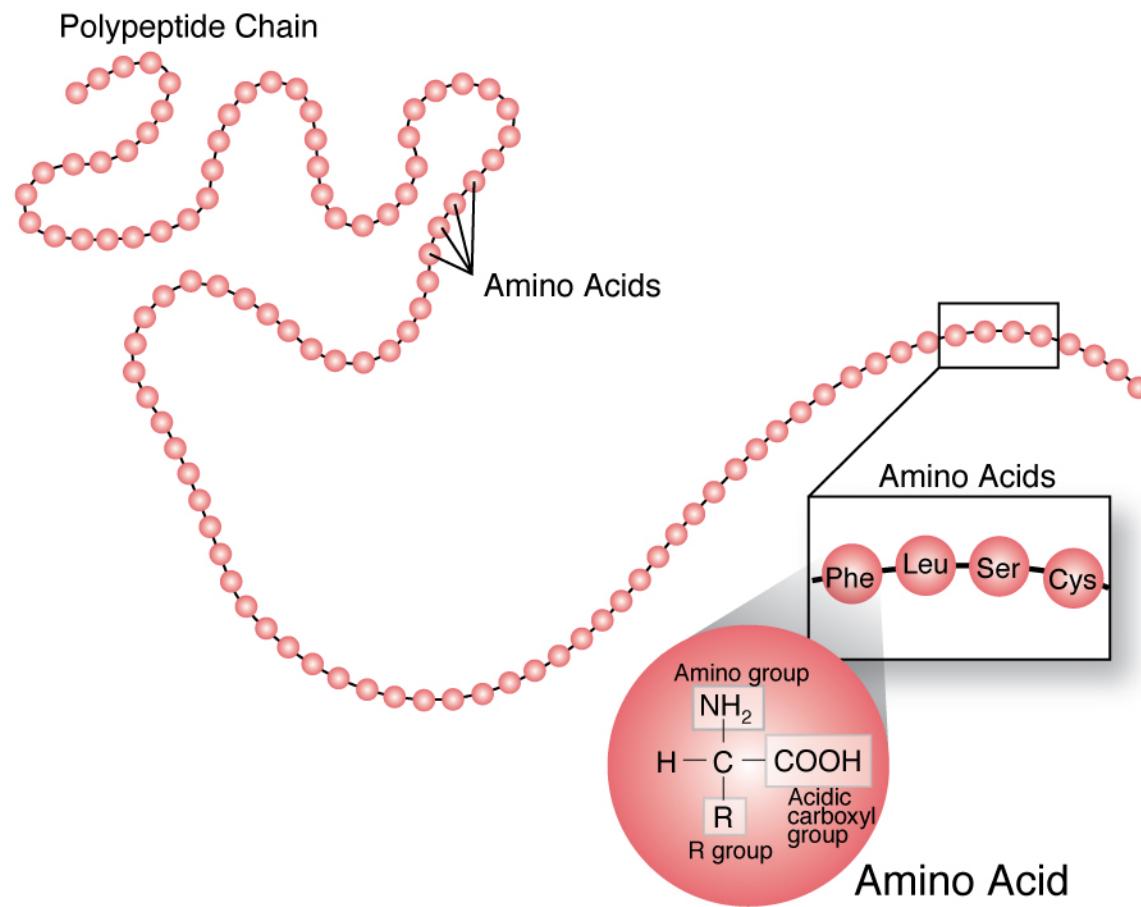
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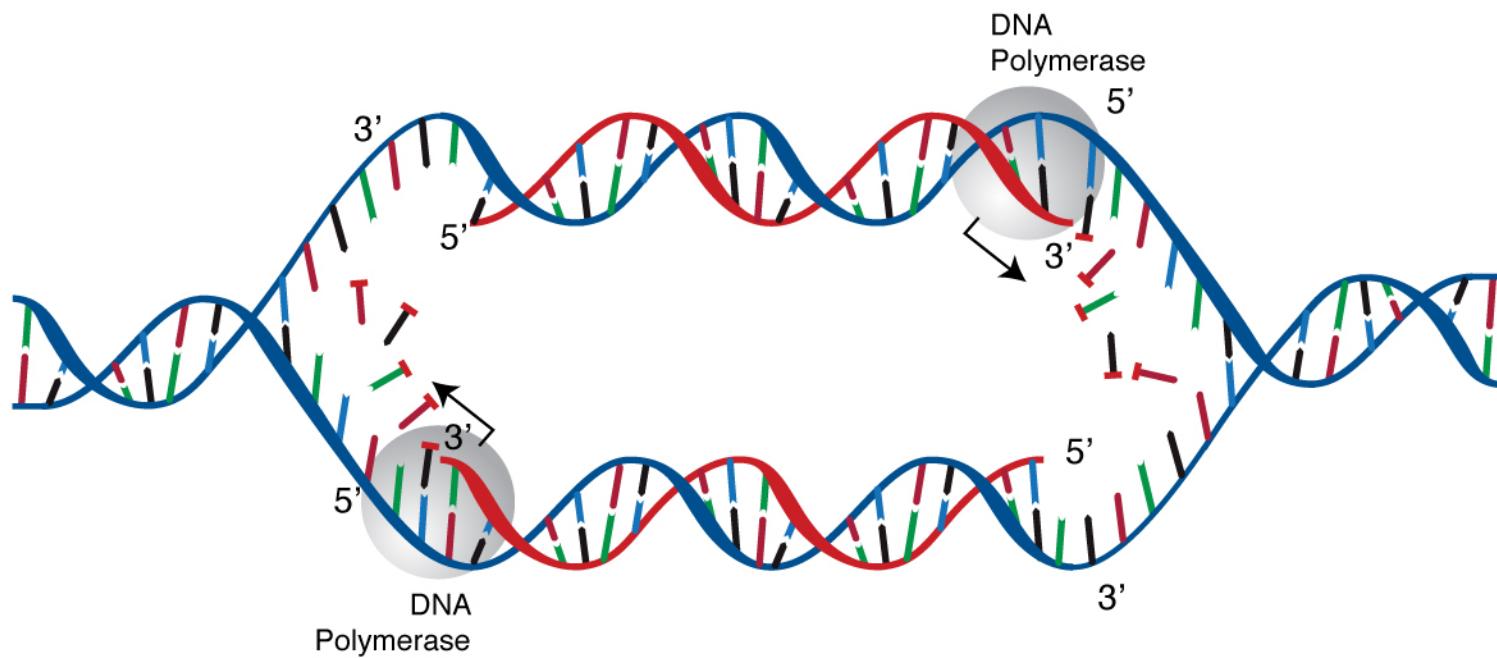
Illustration by Darryl Leja, NHGRI



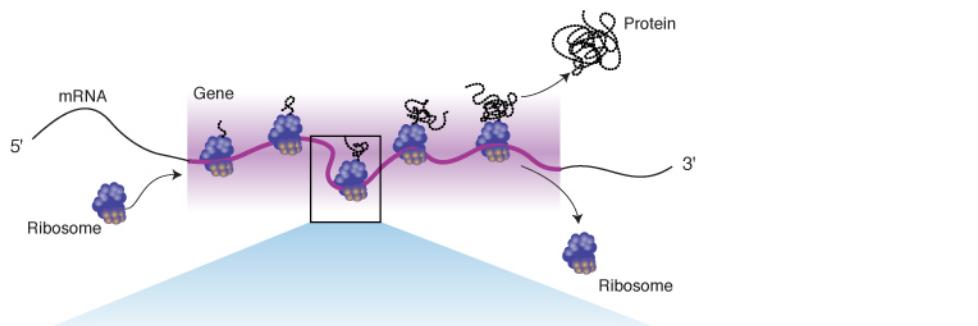
Amino Acid



DNA Replication



Point mutation



Normal

Amino Acids — Ala Ile Arg Leu Gly Tyr Ser Ala Cys Ile His Val Ala Ile Arg ...
tRNA —
anticodon — ...CGAUUAUCCGAUCCA AUGUCACGUACGU AUGUGCAUCGAU AUGCG...
mRNA — ...GCUAUAAGGCUAGGUUACAGUGCAUGDAUACACGUAGCUAUACGC...
5' codons 3'



Protein

Missense mutation

Amino Acids — Ala Ile Arg Leu **Ala** Tyr Ser Ala Cys Ile His Val Ala Ile Arg ...
tRNA —
anticodon — ...CGAUUAUCCGAUCCGAU AUGUCACGUACGU AUGUGCAUCGAU AUGCG...
mRNA — ...GCUAUAAGGCUAG**GUUACAGUGCAUGD**AUACACGUAGCUAUACGC...
5' codons 3'



Protein

Missense mutation

Nonsense mutation

Amino Acids — Ala Ile Arg Leu Gly Tyr Ser Ala Cys **stop** ...
tRNA —
anticodon — ...CGAUUAUCCGAUCCA AUGUCACGUACGU AUU
mRNA — ...GCUAUAAGGCUAGGUUACAGUGCAUG**GUAA**AACGUAGCUAUACGC...
5' codons 3'



Protein

Nonsense mutation

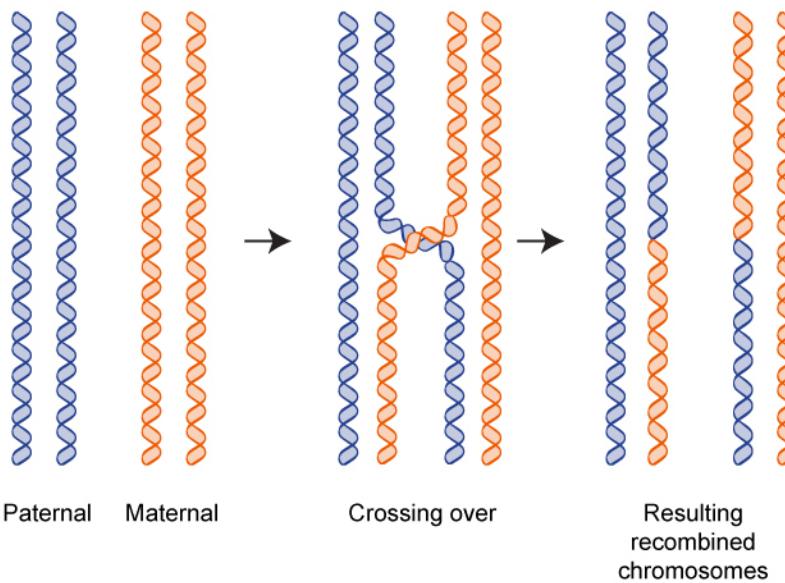
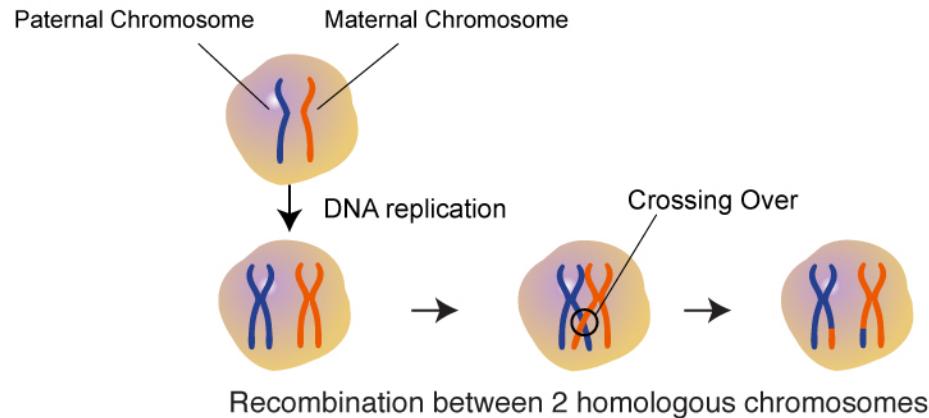
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Homologous recombination



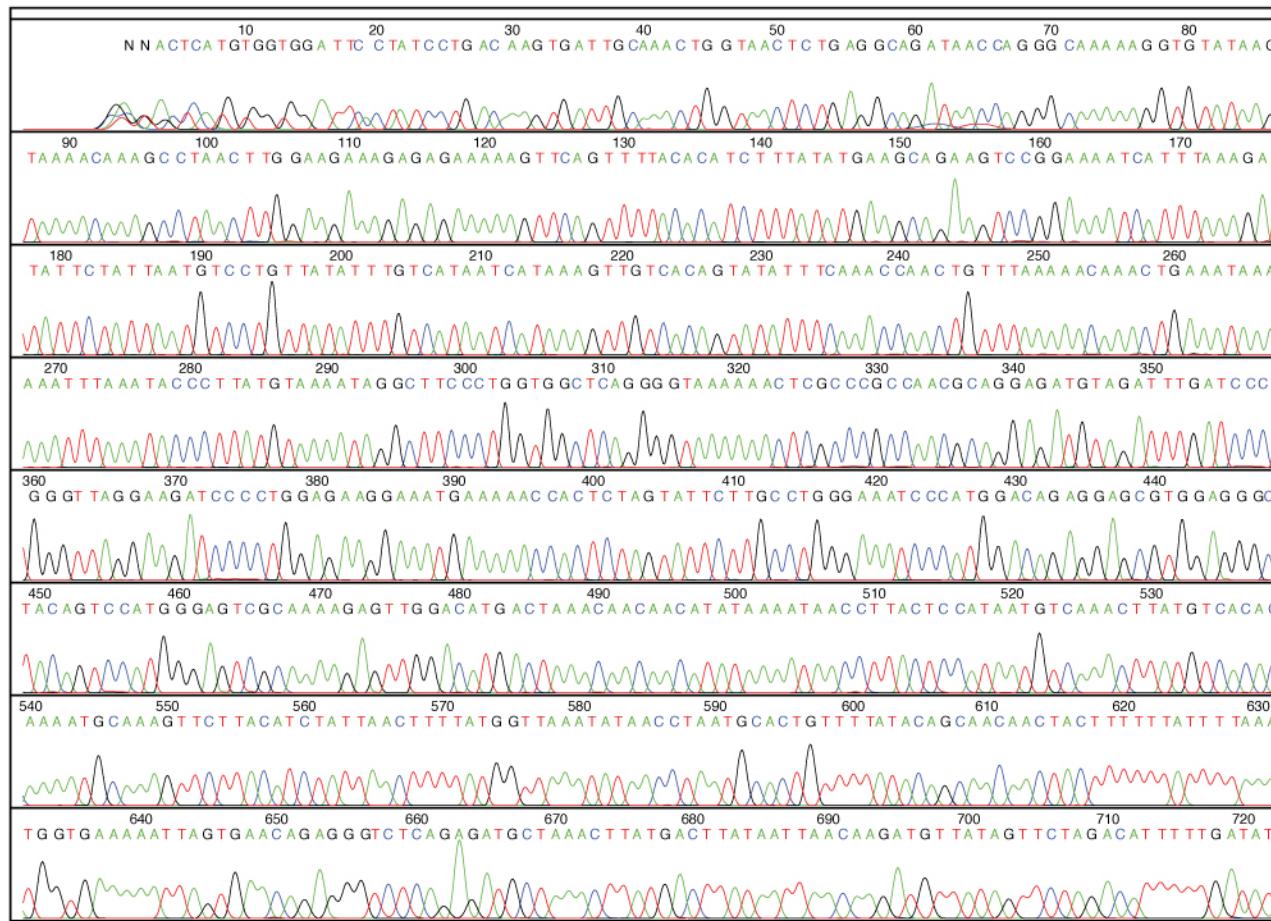
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DNA Sequencing



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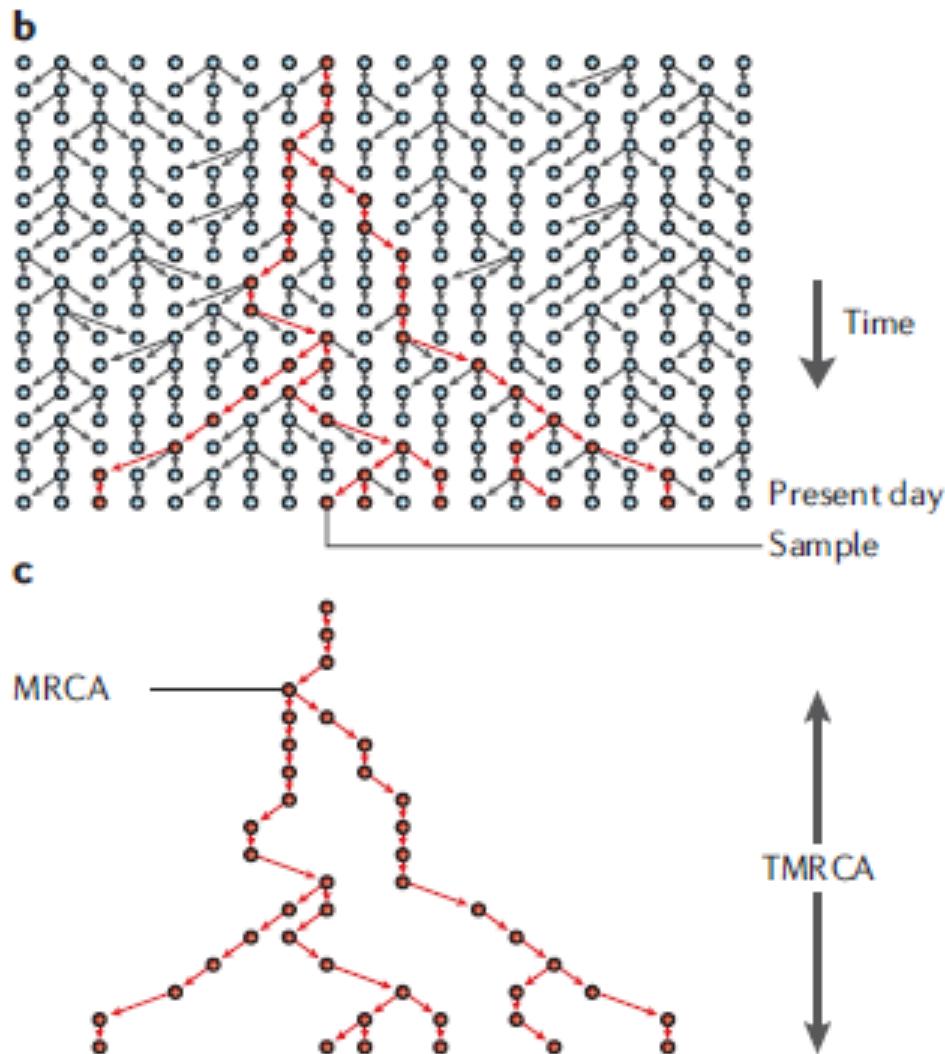
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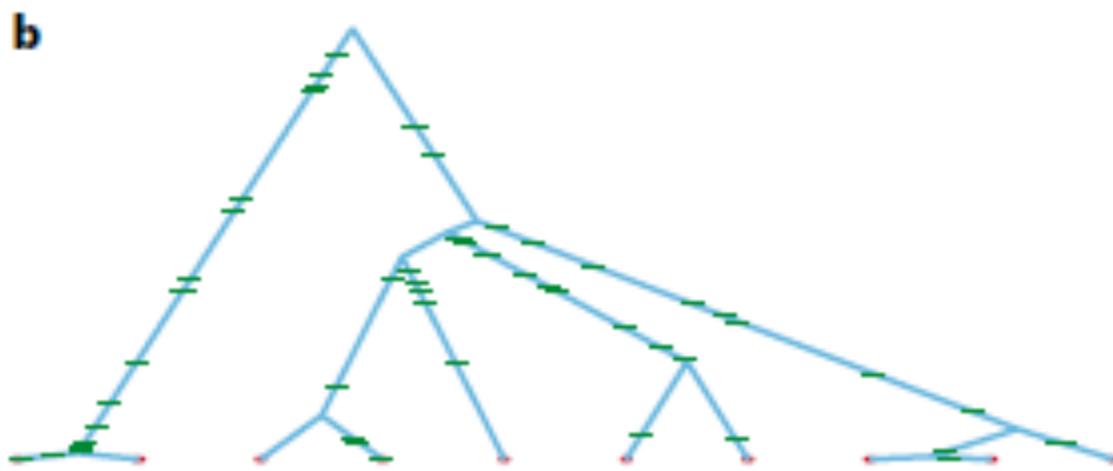
genetic variation

		Nucleotide position in the control region																																																			
		1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3																			
ID:		6	8	9	0	2	4	6	6	9	9	0	1	3	4	5	5	6	7	7	9	0	0	0	1	3	4	9	8	1	6	4	9	2	6	0	4	0	9	3	7	1	5	7	1	5	6	1	2	4	9	9	4
1	C	A	.	T	.	.	.	T								
2	A	.	T	T								
3	T	.	.	T	.	.	.	T								
4	T	.	.	T	.	.	.	T								
5	.	T	.	A	.	.	T	.	.	T	.	.	.	T	.	T	.	A	.	.	A	.	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.									
6	.	T	.	A	.	.	.	T	A	.	.	.	A	.	.	A	.	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.									
7	C	T	.	A	.	.	.	T	.	.	T	.	.	.	T	.	A	.	.	A	.	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.										
8	.	T	.	A	.	.	.	T	.	.	T	.	.	.	T	.	A	.	.	A	.	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.										
9	C	T	T	.	.	T	.	.	.	T	.	A	.	.	A	.	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.										
10	.	T	T	.	.	T	.	.	.	T	.	A	.	.	A	.	.	.	C	G	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.									
11	.	T	T	.	.	T	.	.	.	T	.	A	.	.	A	.	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.										
12	.	T	T	T	.	A	.	.	A	.	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.								
13	.	T	A	T	.	A	.	.	A	.	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.								
14	.	T	T	T	T	.	A	.	.	A	.	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.							
15	.	T	T	T	T	.	A	C	.	A	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.							
16	T	T	T	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.							
17	T	.	.	T	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.							
18	.	.	.	T	.	.	.	T	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.							
19	.	.	T	T	T	.	C	.	C	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.									
20	C	.	.	T	.	.	A	.	.	.	A	.	.	C	.	C	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.									
21	T	.	.	T	C	.	C	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.									
22	C	T	.	.	T	C	.	C	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.									
23	T	T	C	.	C	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.										
24	T	C	.	C	T	.	C	.	C	T	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.										
25	T	T	C	.	C	T	C	.	C	T	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.										
26	T	C	.	C	T	C	.	C	T	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.										
27	C	C	C	C	.	T							
28	C	C	.	T	C	C	T							

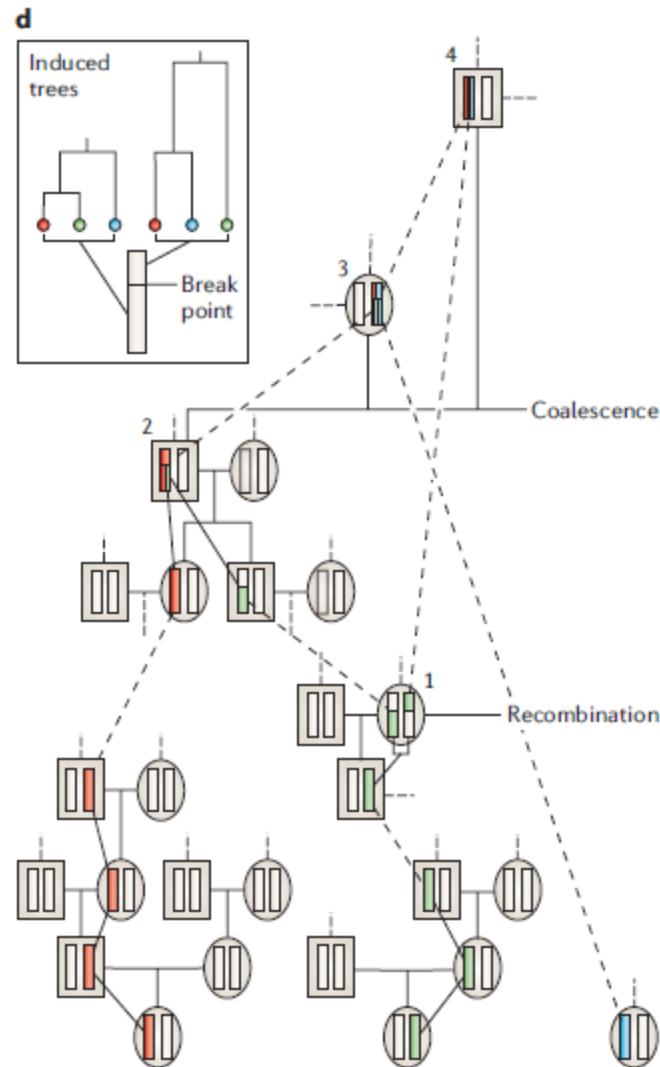
looking backwards in time



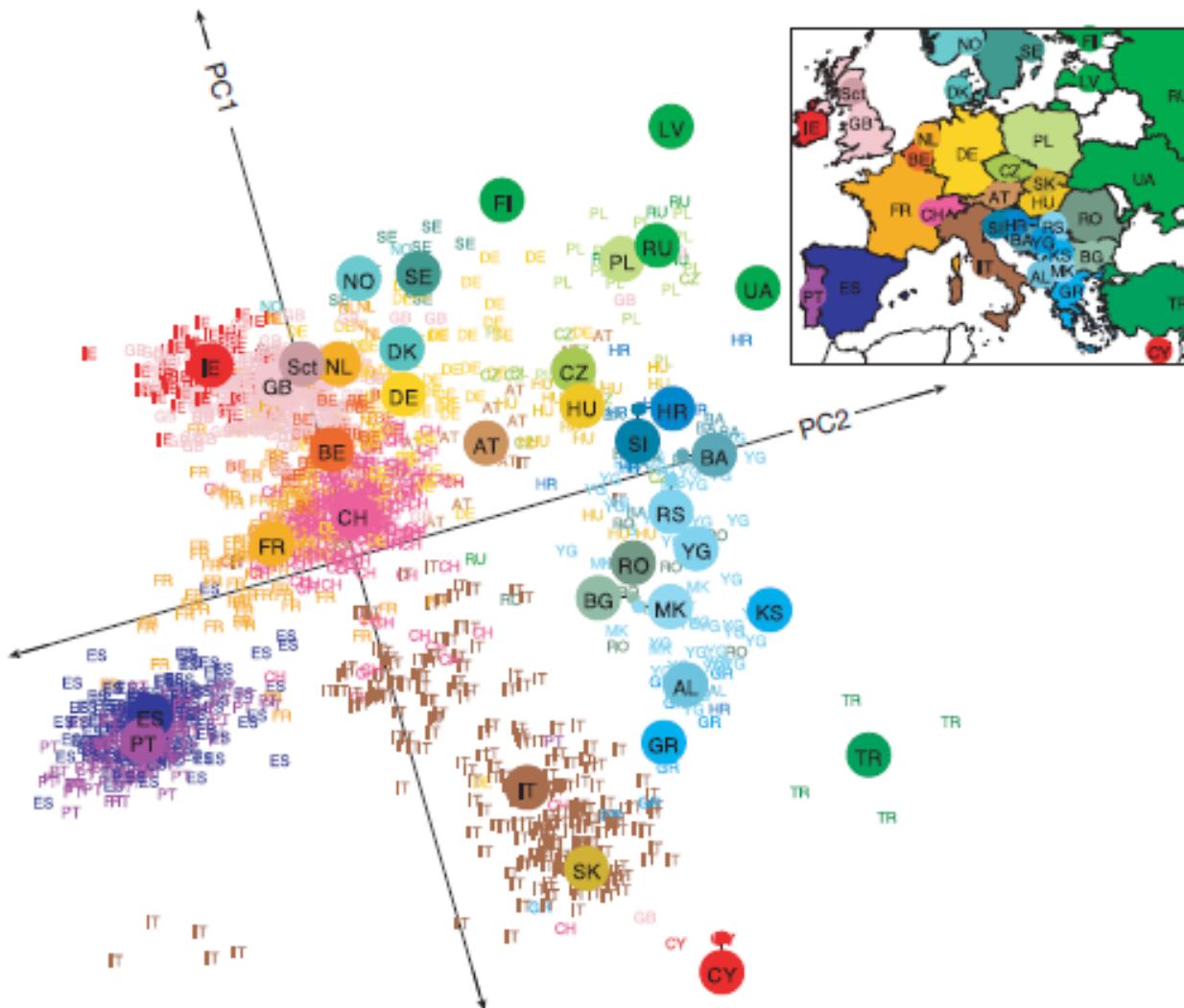
mutations



ancestral recombination graph

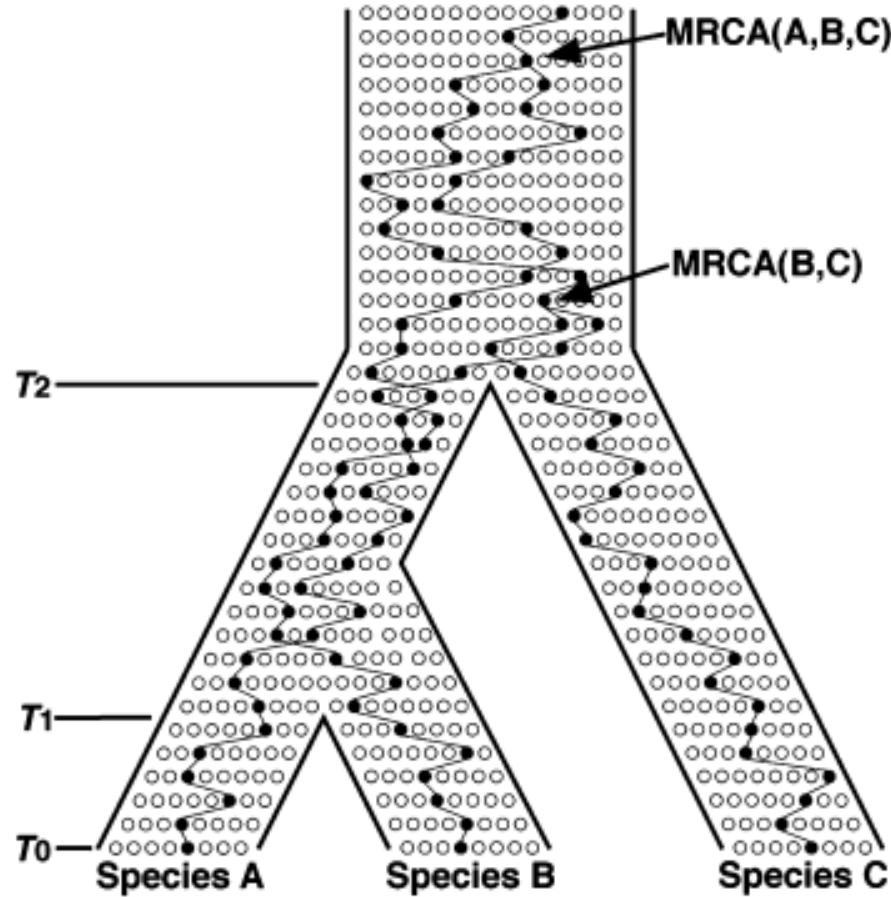


population genomics



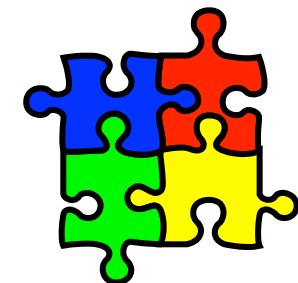
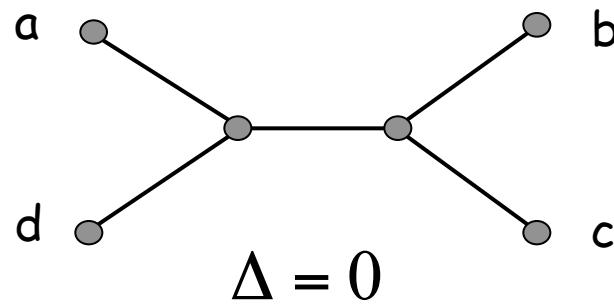
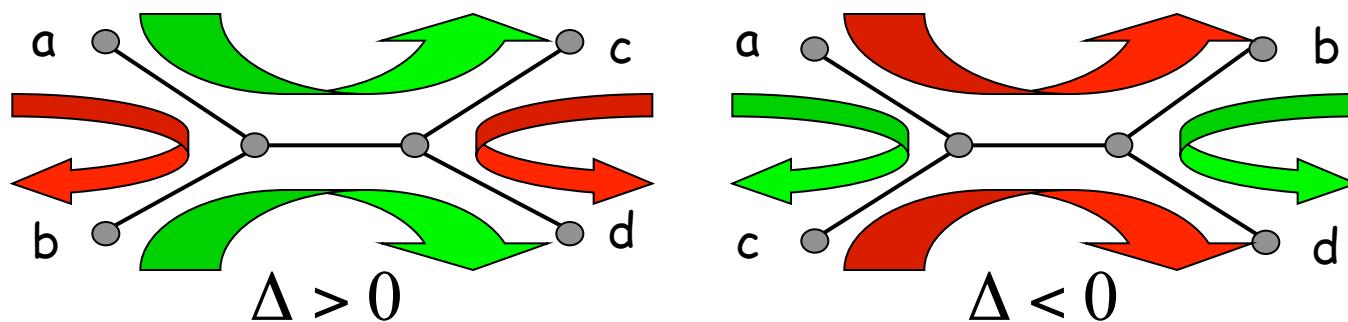
Novembre et al., *Nature* (2008)

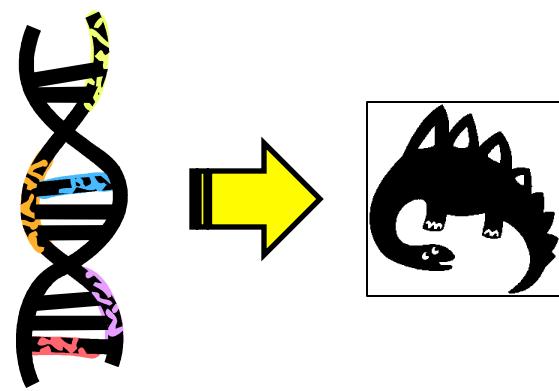
at the inter-species level



evolutionary distance

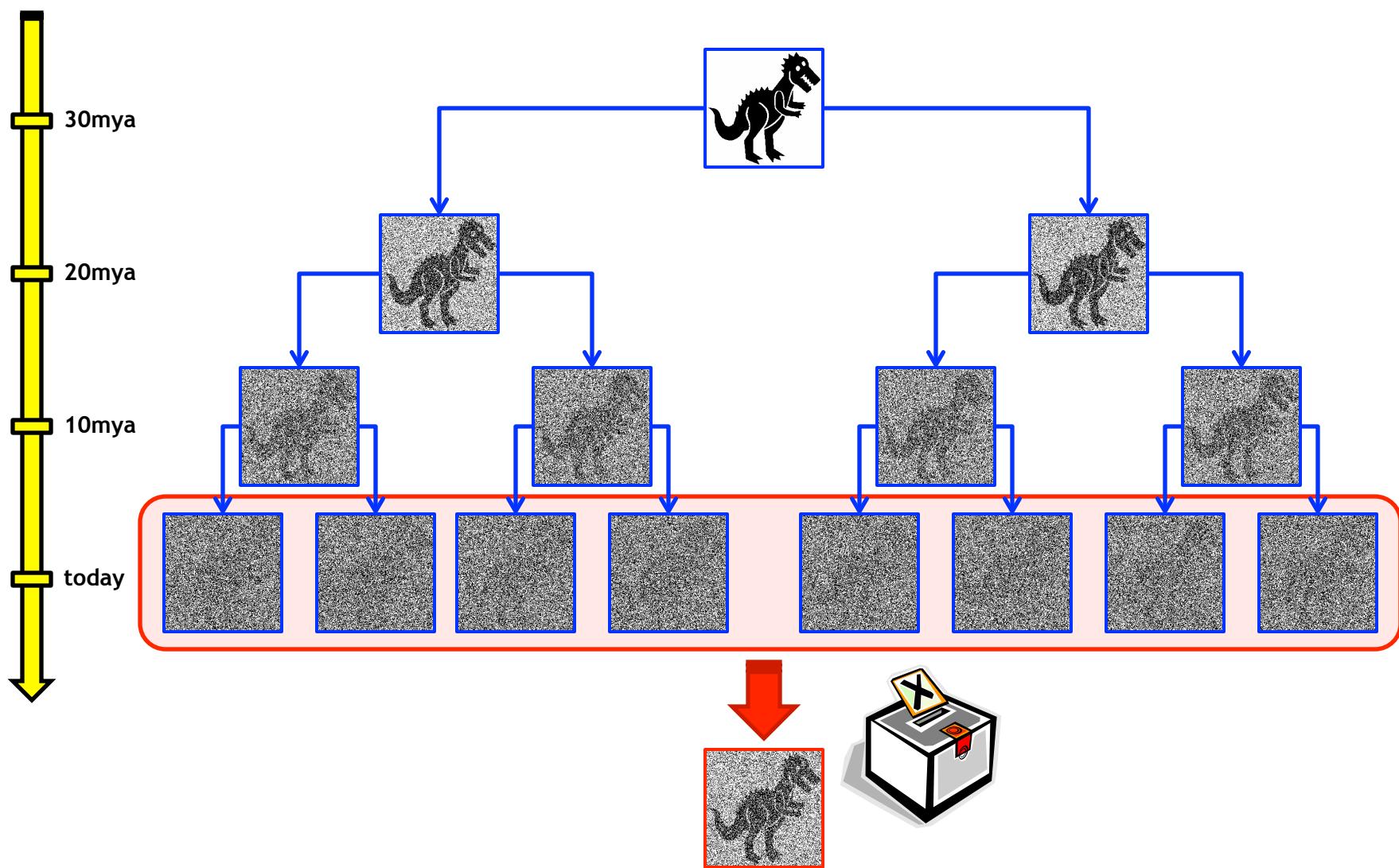
$$\Delta = D'(a,c) + D'(b,d) - D'(a,b) - D'(c,d)$$

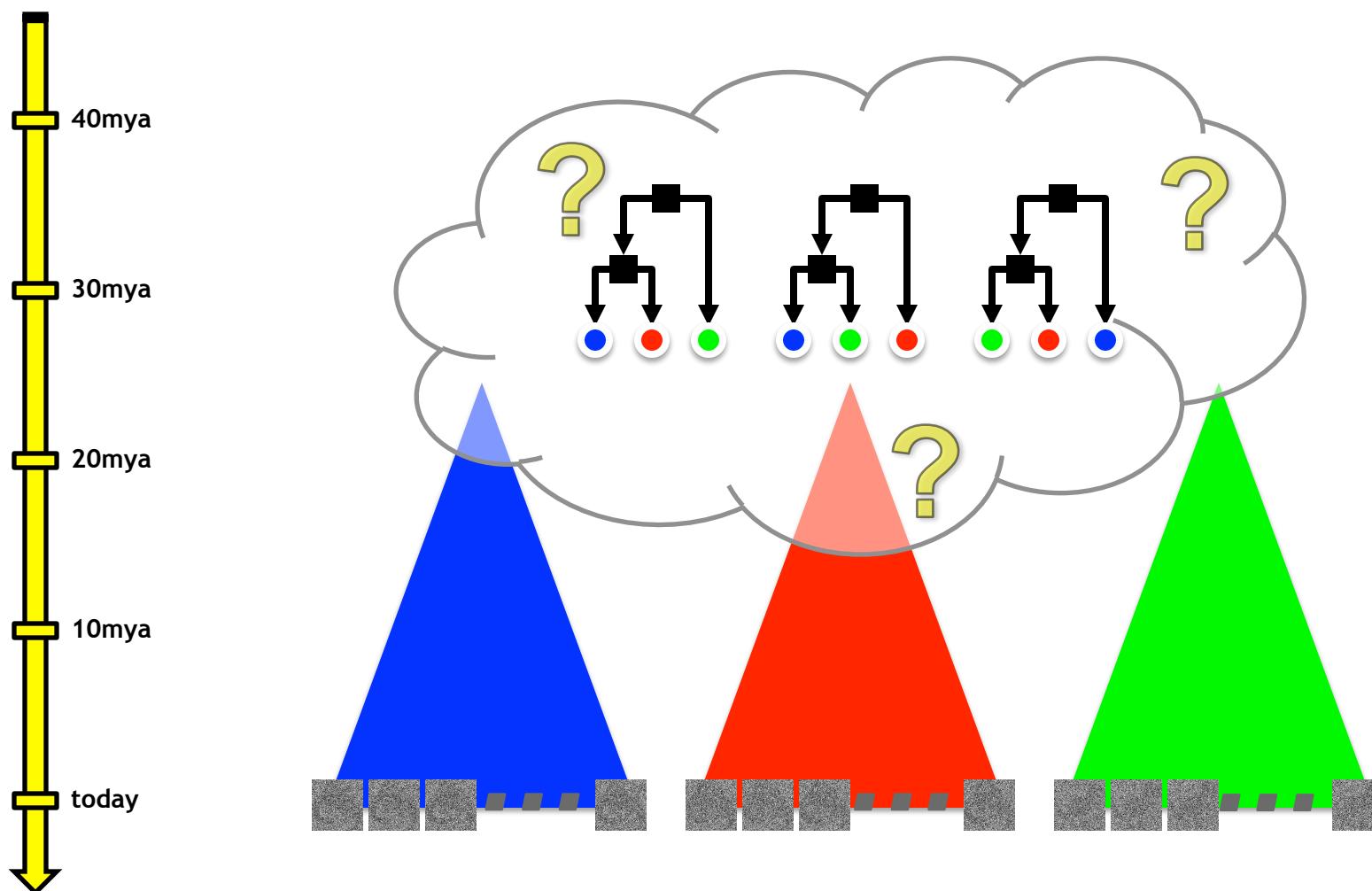


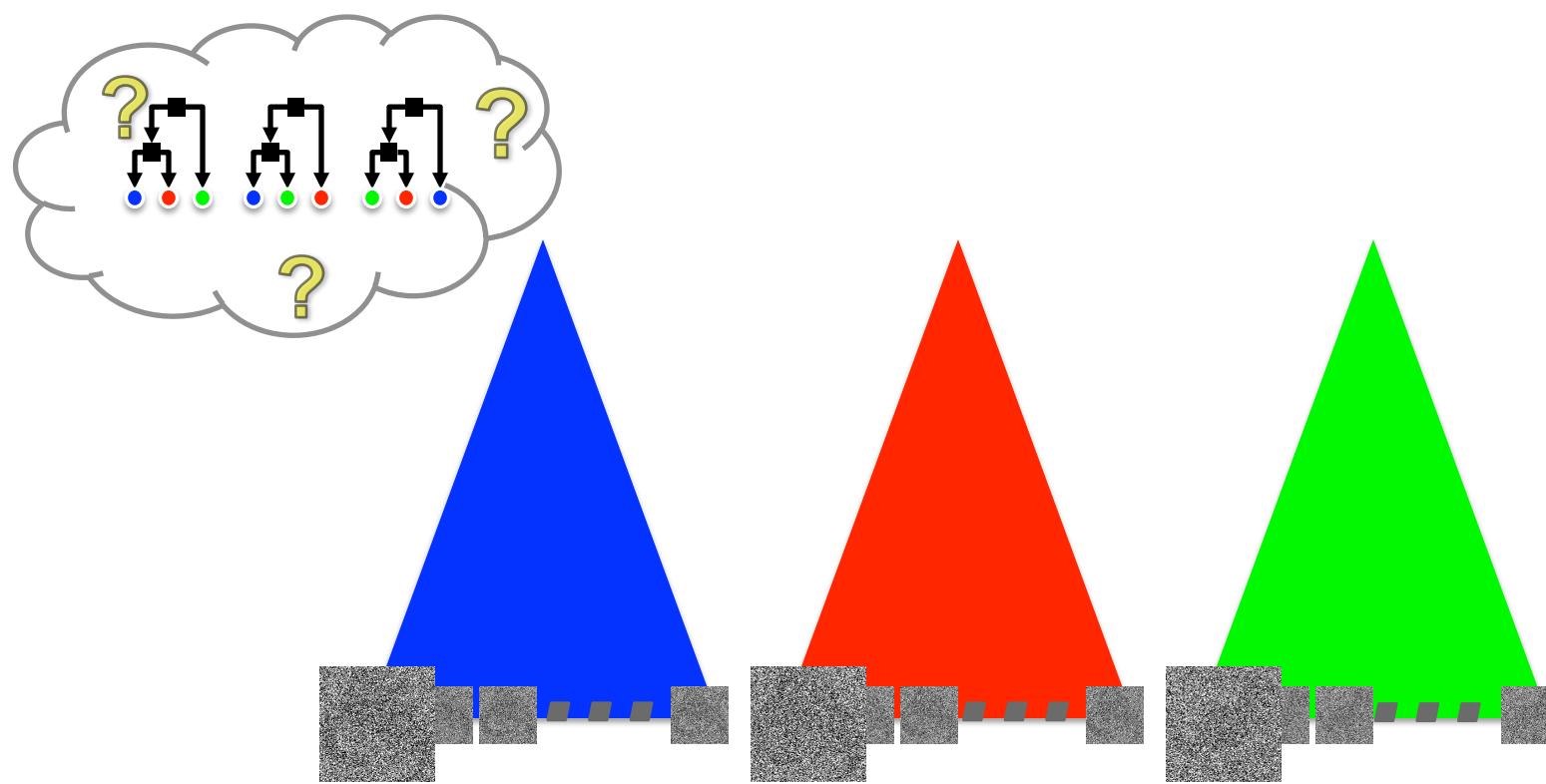


Daskalakis & Roch, *Microsoft TechFest* (2009)



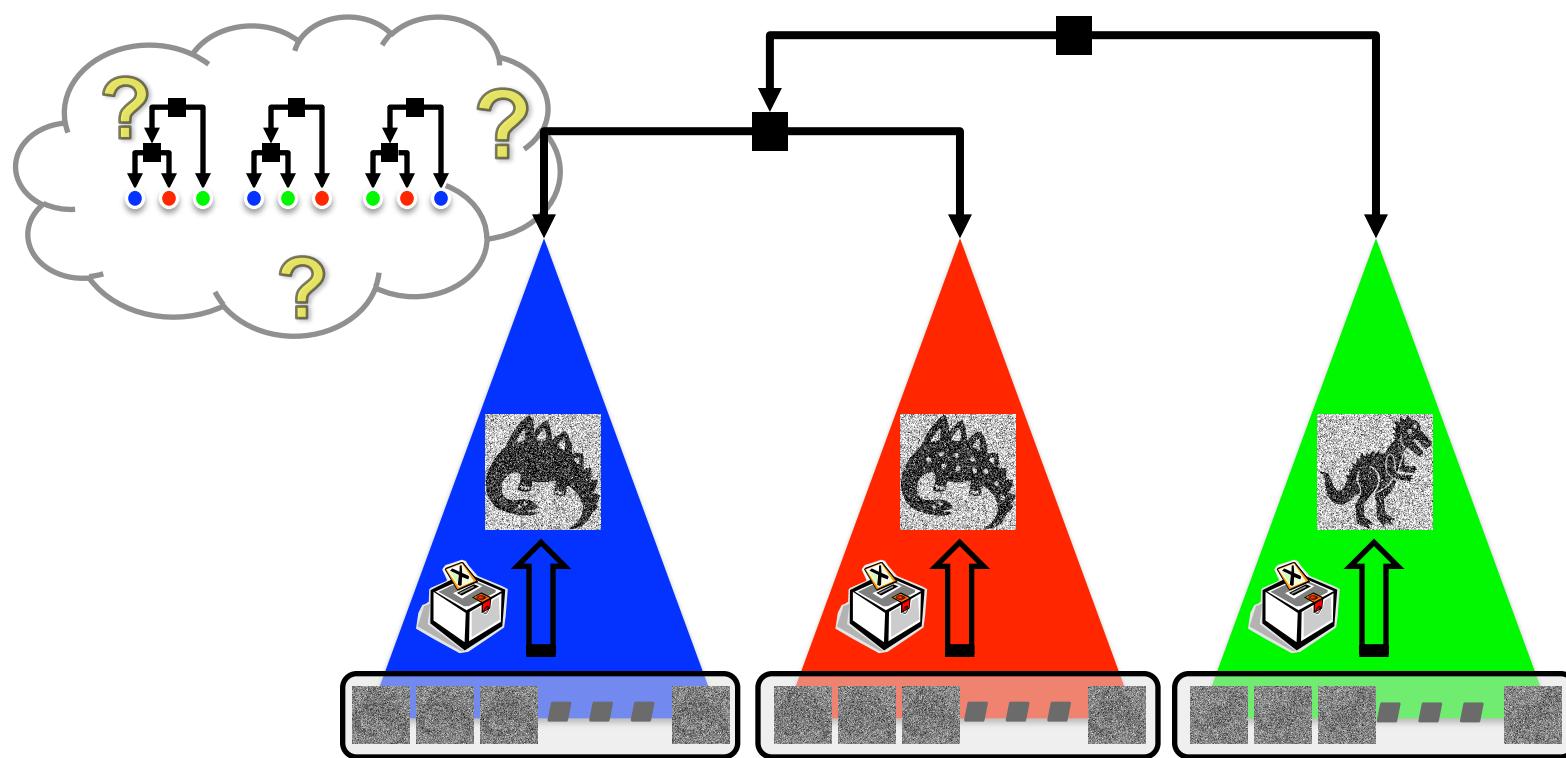






$$\begin{array}{c} \triangle \oplus \triangle = \square \\ \triangle \oplus \triangle = \square \\ \triangle \oplus \triangle = \square \end{array}$$

?



New	Old
$\triangle \oplus \triangle =$	
$\triangle \oplus \triangle =$	
$\triangle \oplus \triangle =$	

A large yellow question mark is positioned to the right of the third row of equations.

back to Darwin's finches

