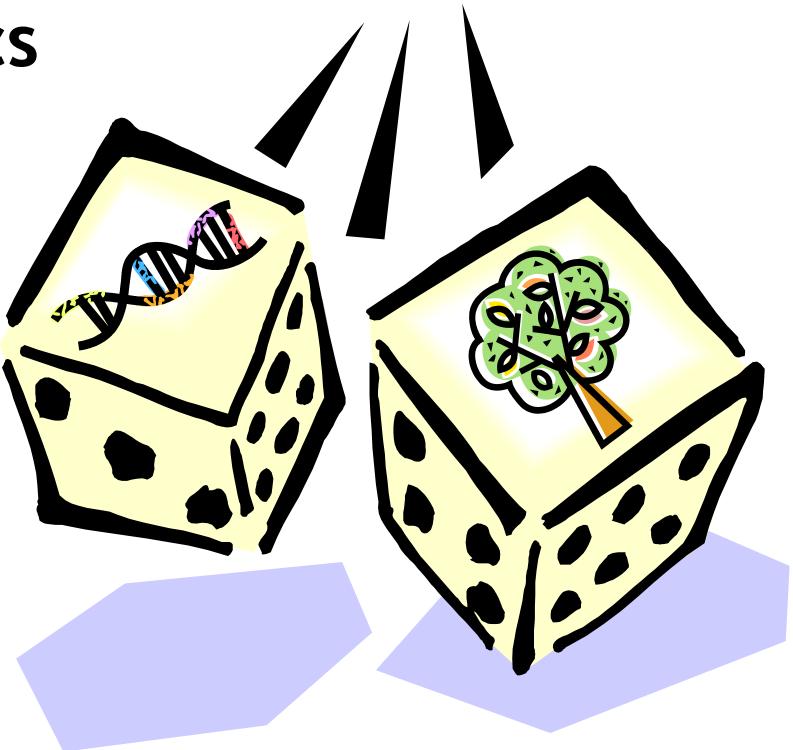
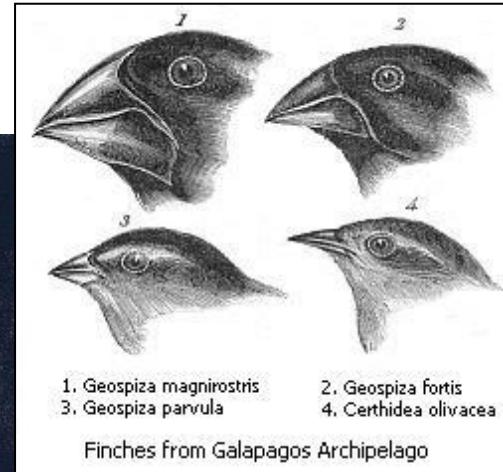


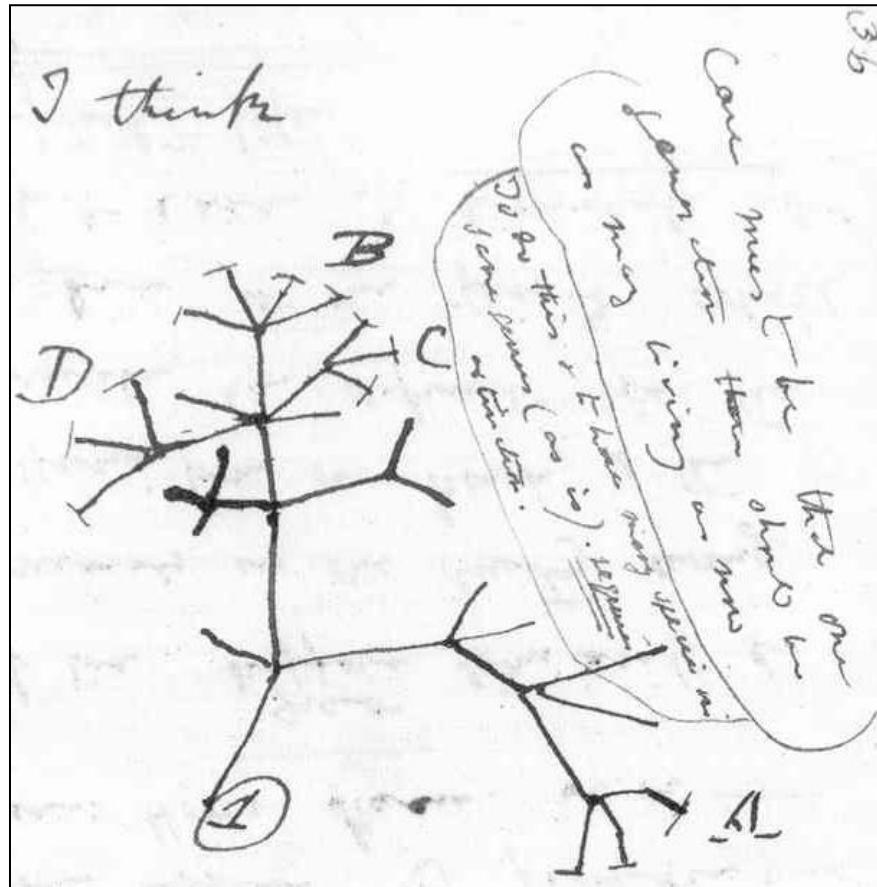
MATH285K: Stochastic Processes in Evolution and Genetics



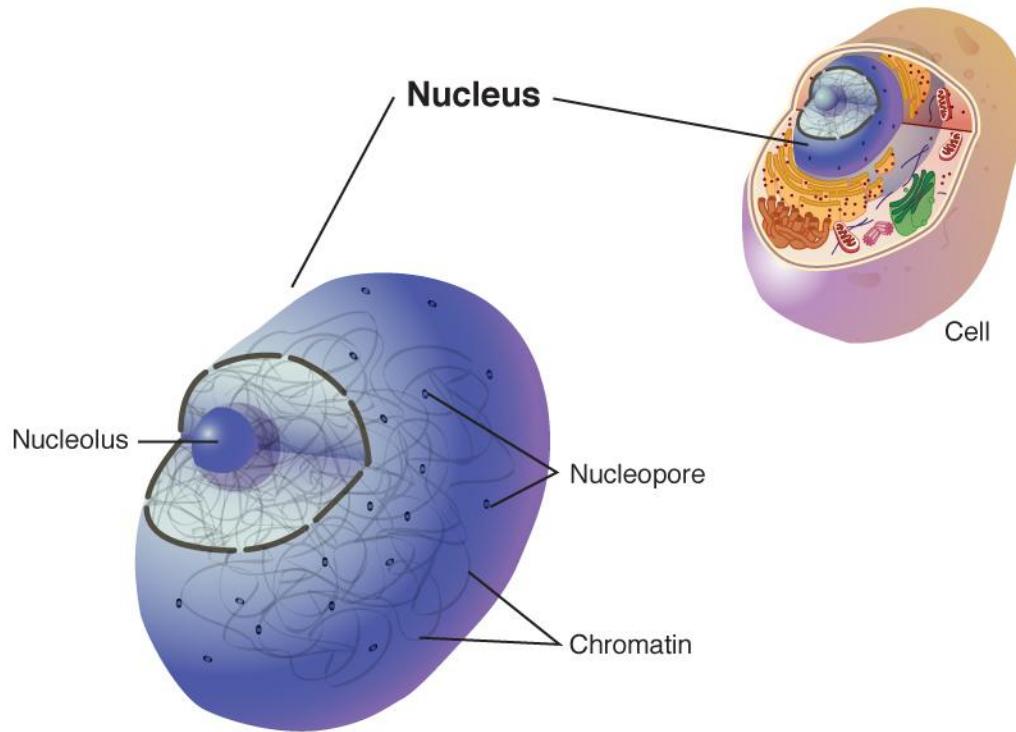
Darwin's finches



evolutionary tree



Nucleus



Talking Glossary of Genetic Terms

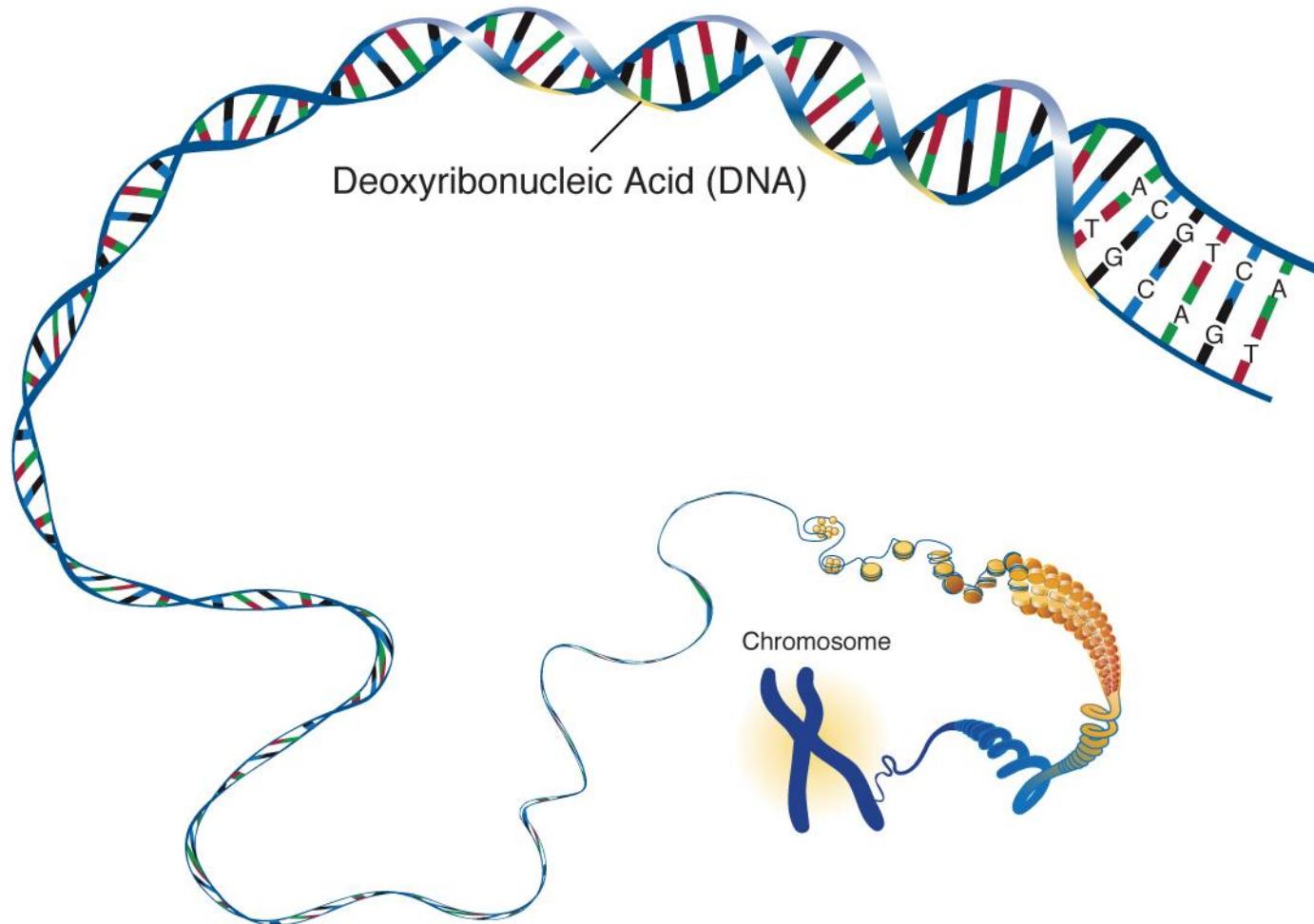
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Illustration by Darryl Leja, NHGRI



DNA (Deoxyribonucleic Acid)



Talking Glossary of Genetic Terms

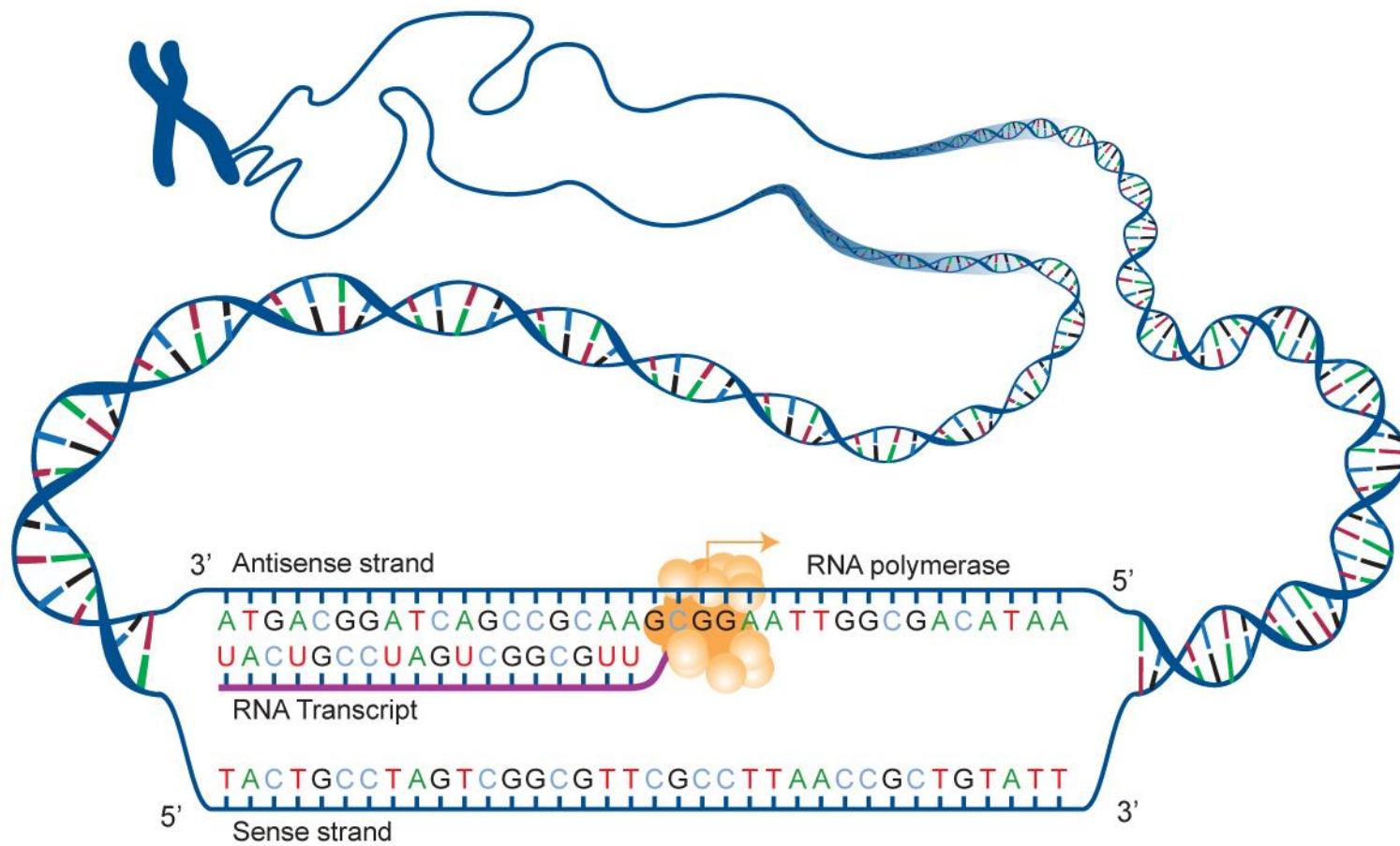
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Illustration by Darryl Leja, NHGRI



Transcription



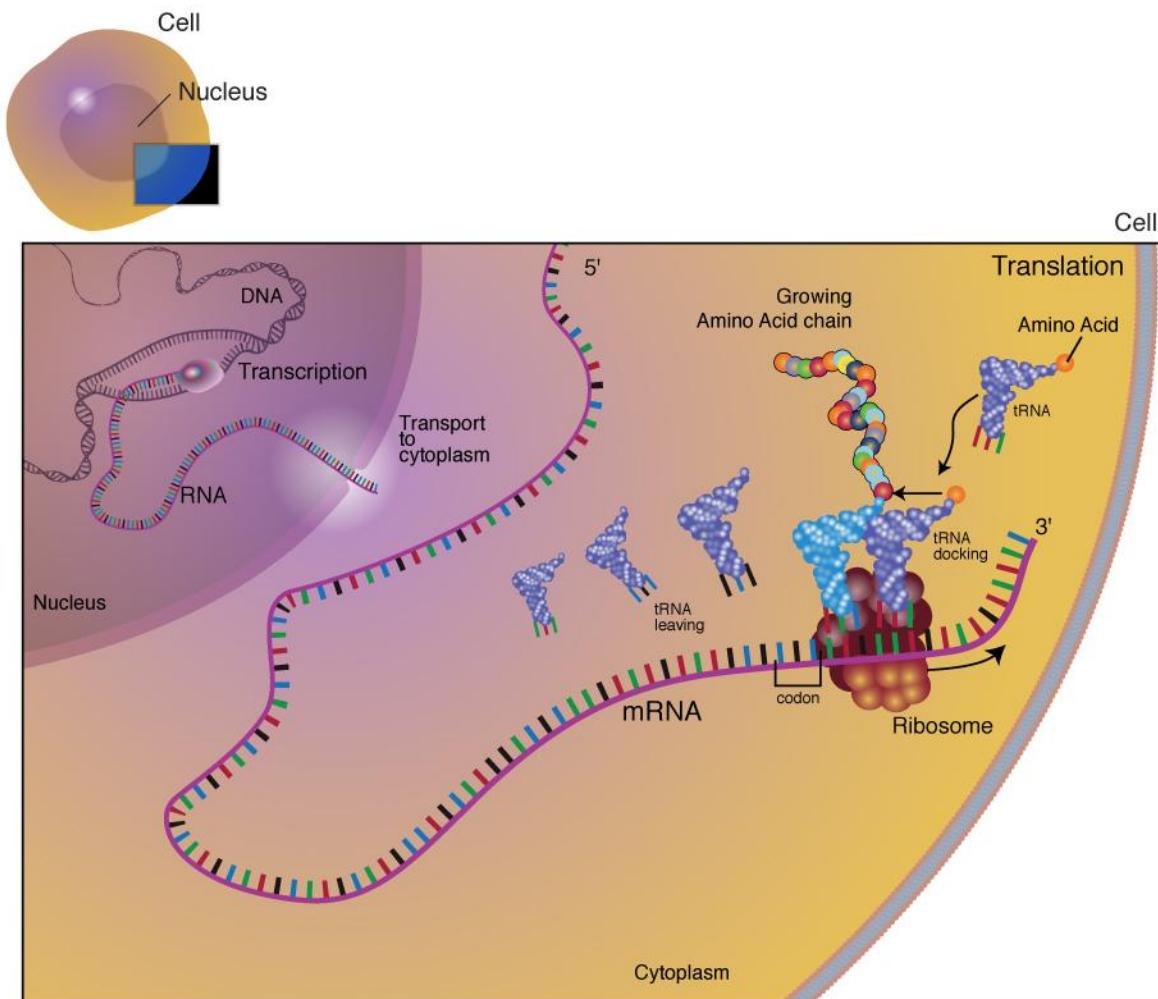
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Translation



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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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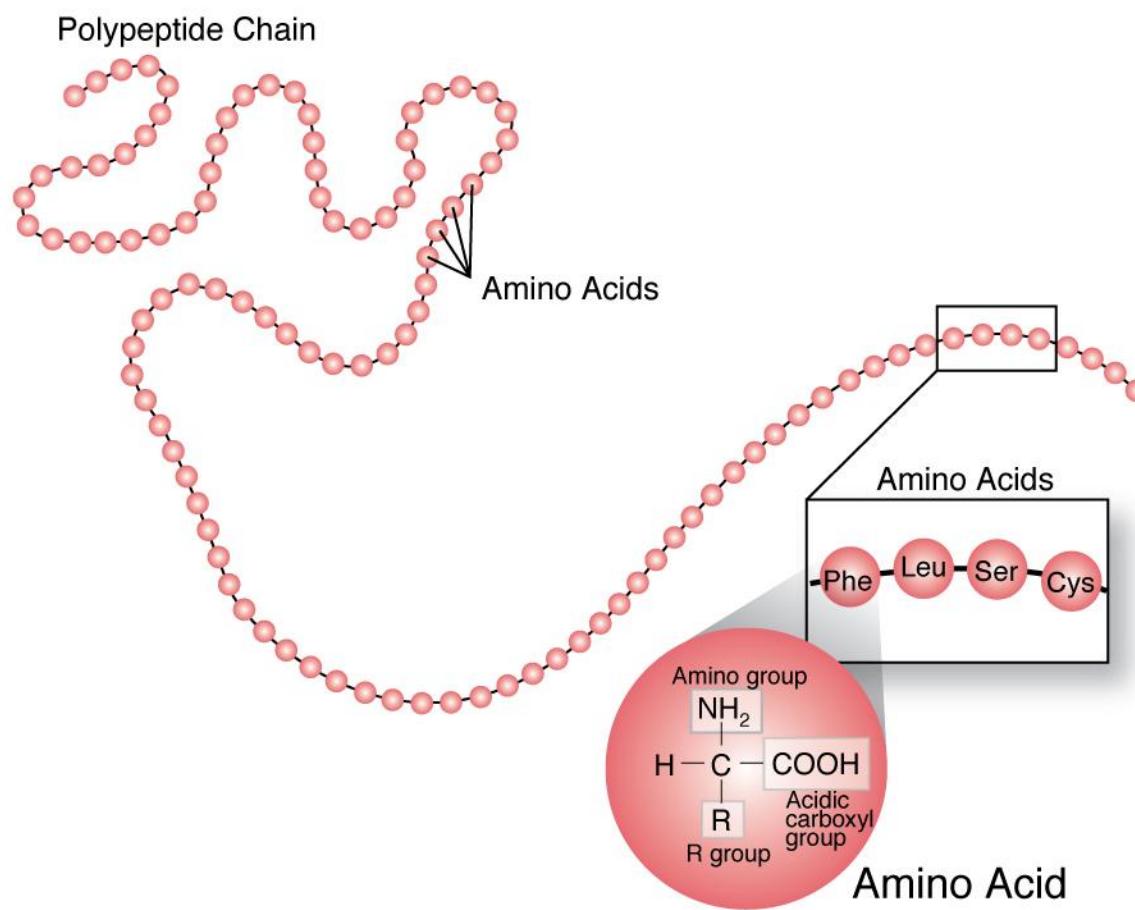
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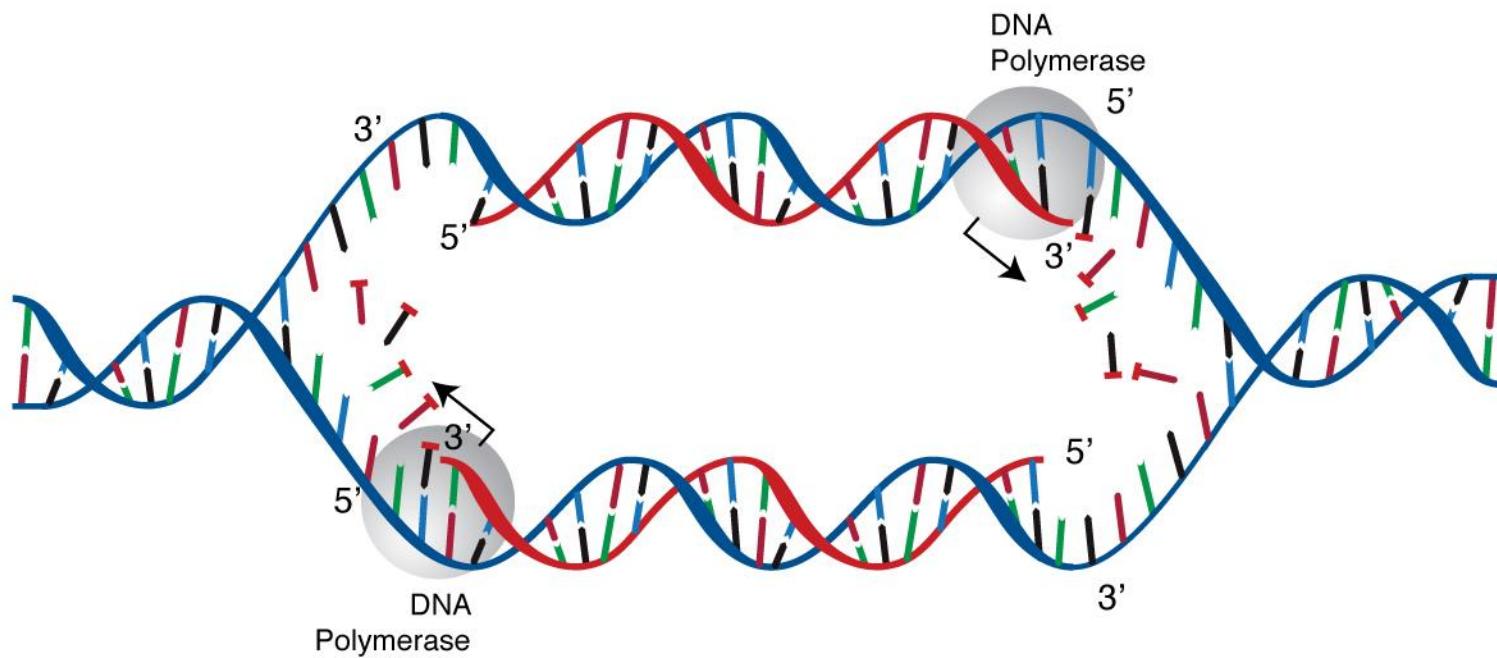
Illustration by Darryl Leja, NHGRI



Amino Acid



DNA Replication



Talking Glossary of Genetic Terms

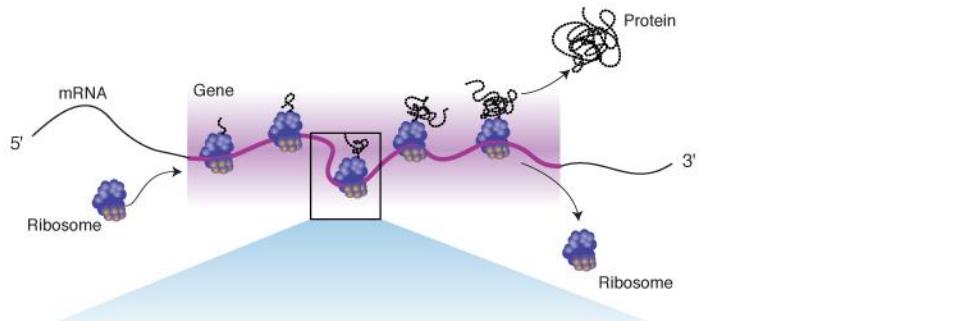
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Illustration by Darryl Leja, NHGRI



Point mutation



Normal

Amino Acids	— Ala Ile Arg Leu Gly Tyr Ser Ala Cys Ile His Val Ala Ile Arg —→
tRNA	—
anticodon	... CGAU AUU UCC GAA UCC AA AUG UCA UC GUA AC GUA AUG UG GCA UC GUA AU AUG CG ...
mRNA	... GCU AUU AGG CUAG GUAC AGU GCA UG GCA UAC AC CAG GUAG GCU AU AC CGC ...
5' codons	
3'	



Missense mutation

Amino Acids	— Ala Ile Arg Leu Ala Tyr Ser Ala Cys Ile His Val Ala Ile Arg —→
tRNA	—
anticodon	... CGAU AUU UCC GAA UCC AA AUG UCA UC GUA AC GUA AUG UG GCA UC GUA AU AUG CG ...
mRNA	... GCU AUU AGG CUAG GUAC UAC AGU GCA UG GCA UAC AC CAG GUAG GCU AU AC CGC ...
5' codons	
3'	



Missense mutation

Nonsense mutation

Amino Acids	— Ala Ile Arg Leu Gly Tyr Ser Ala Cys stop —→
tRNA	—
anticodon	... CGAU AUU UCC GAA UCC AA AUG UCA UC GUA AC GUA AUU
mRNA	... GCU AUU AGG CUAG GUAC AGU GCA UG GCA UAC AC CAG GUAG GCU AU AC CGC ...
5' codons	
3'	



Nonsense mutation

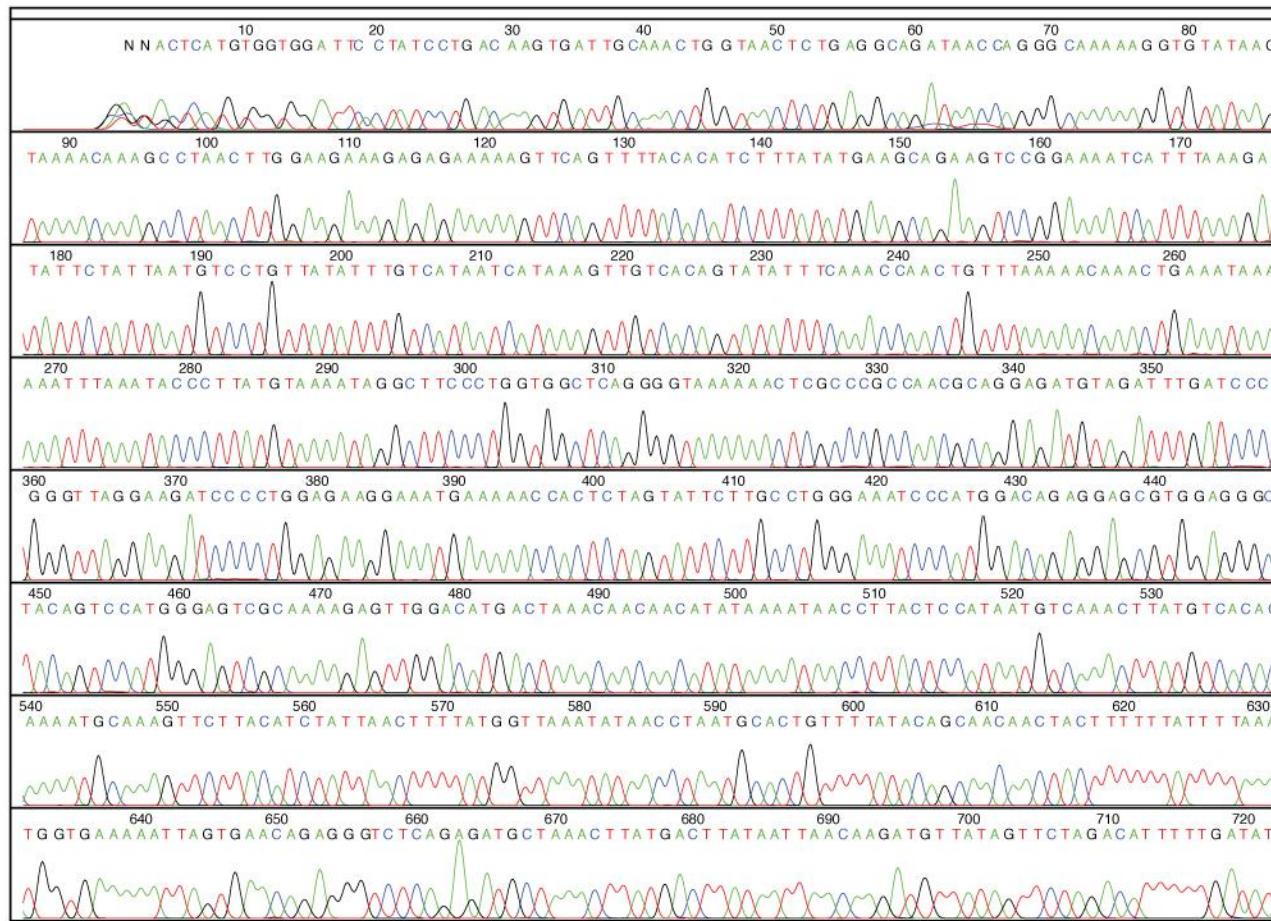
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DNA Sequencing

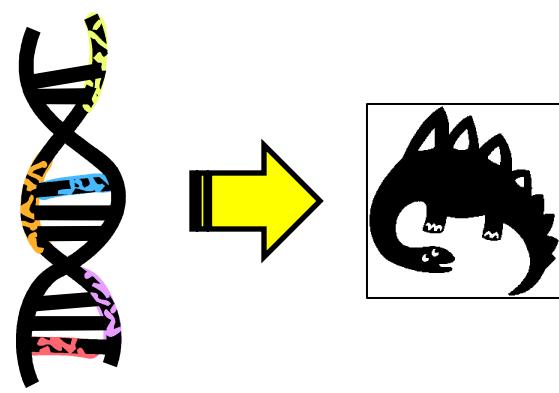


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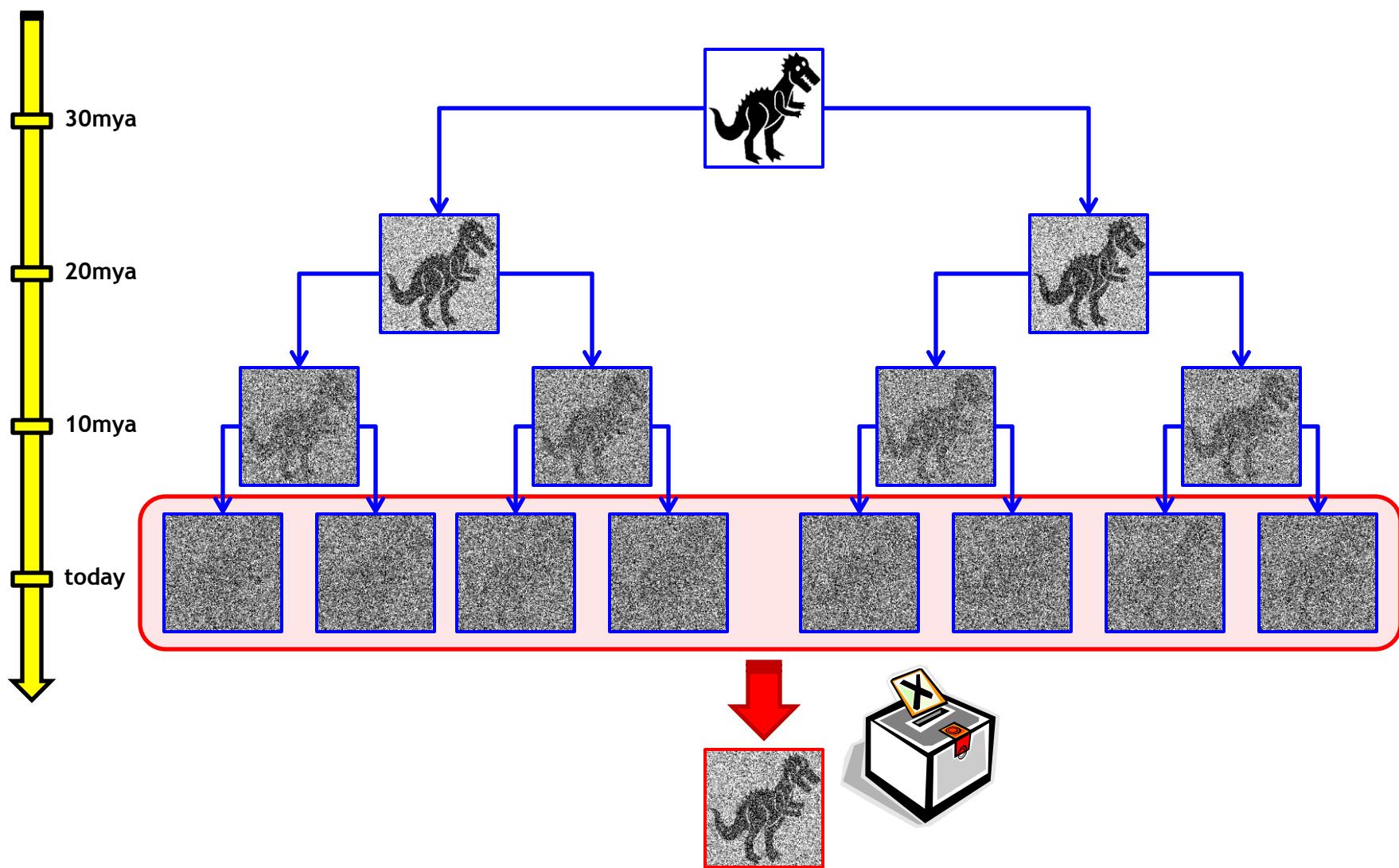
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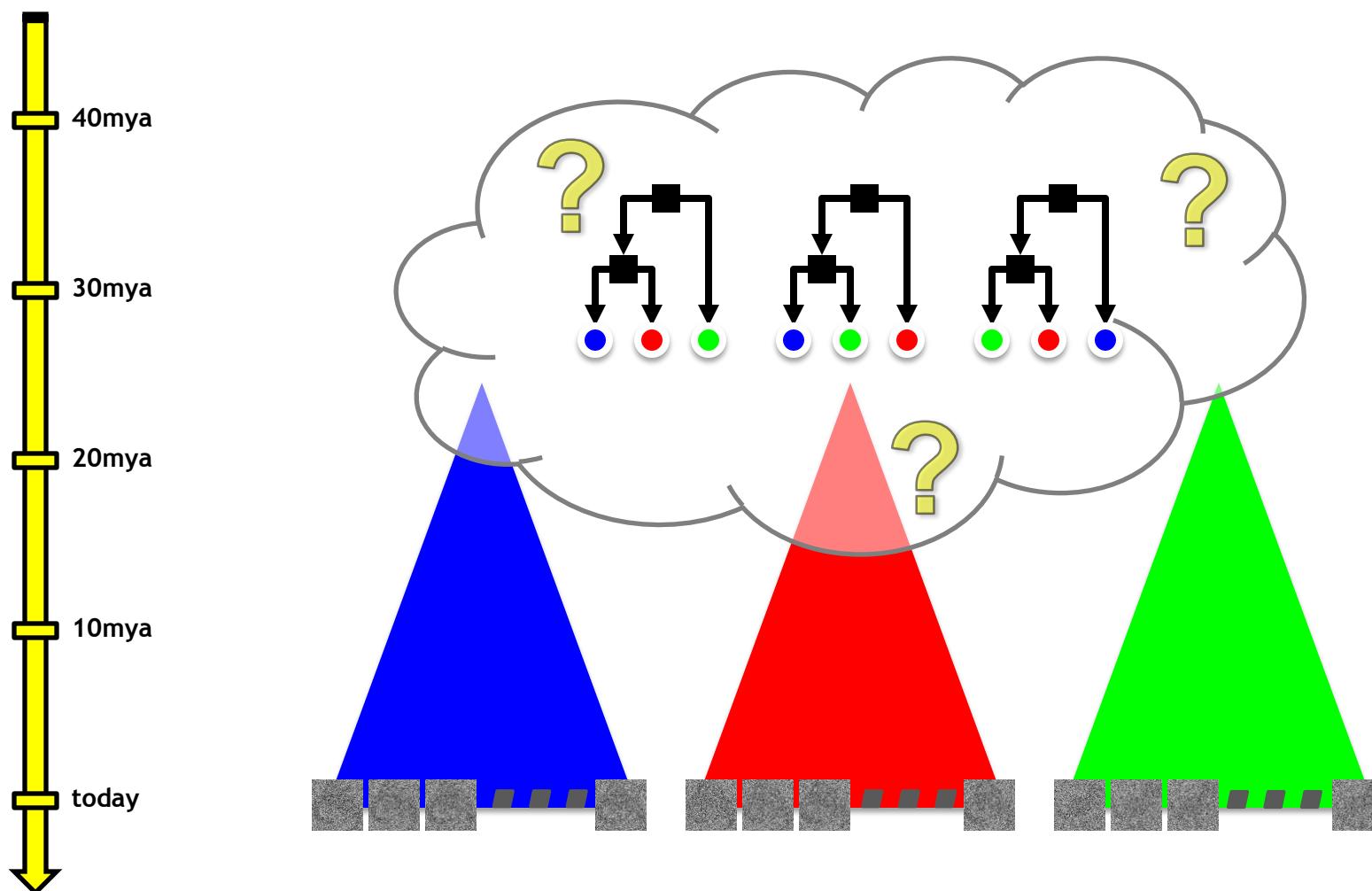
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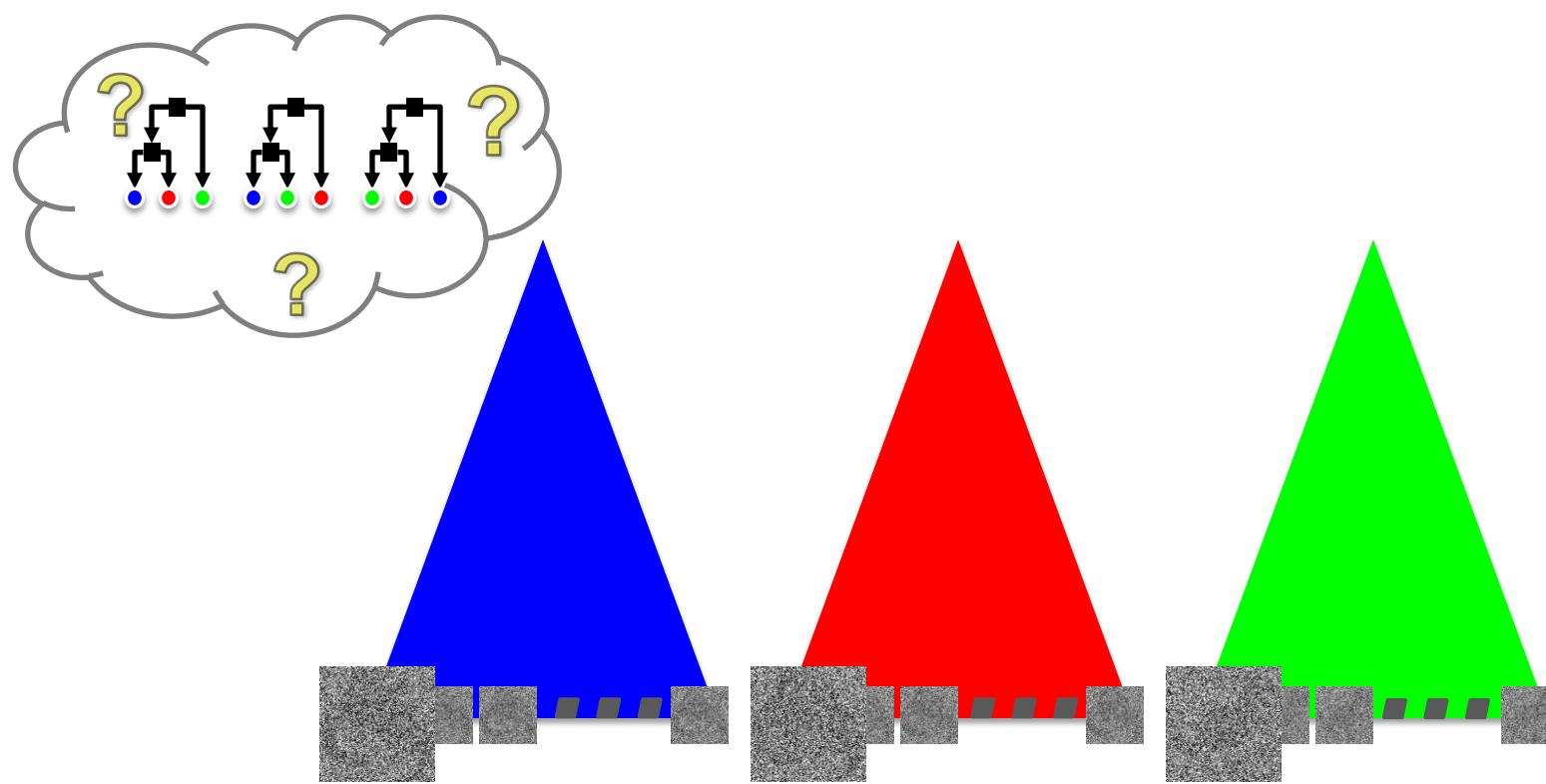








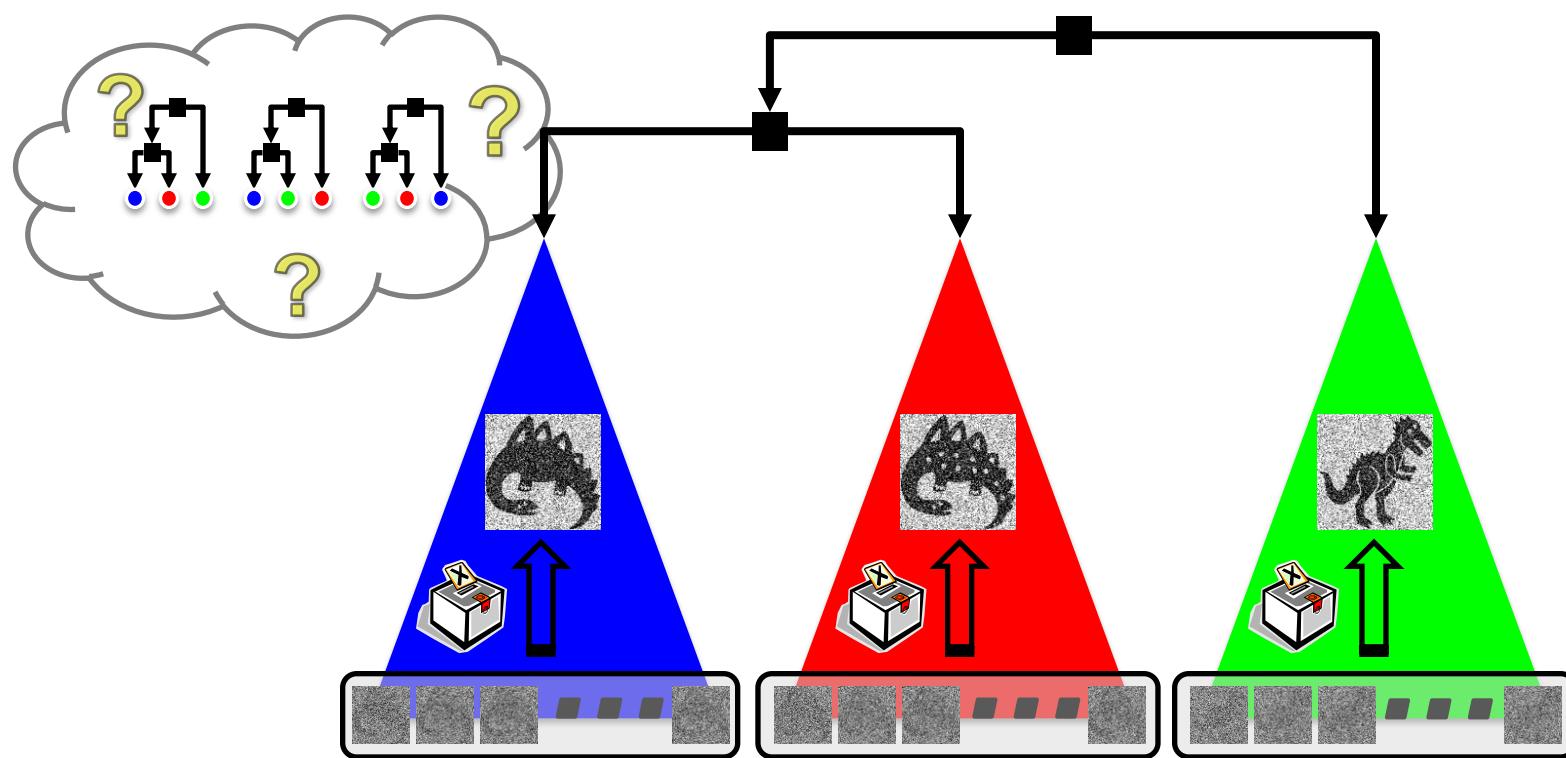




$$\begin{matrix} \text{Blue Triangle} & \oplus & \text{Red Triangle} \\ \end{matrix} = \boxed{\text{Grey Block}} \quad ?$$

$$\begin{matrix} \text{Blue Triangle} & \oplus & \text{Green Triangle} \\ \end{matrix} = \boxed{\text{Grey Block}} \quad ?$$

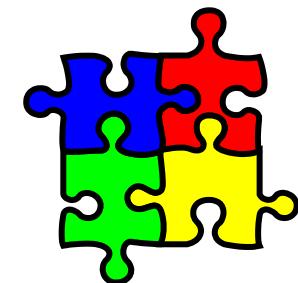
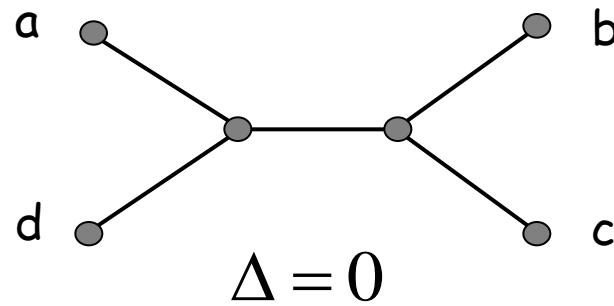
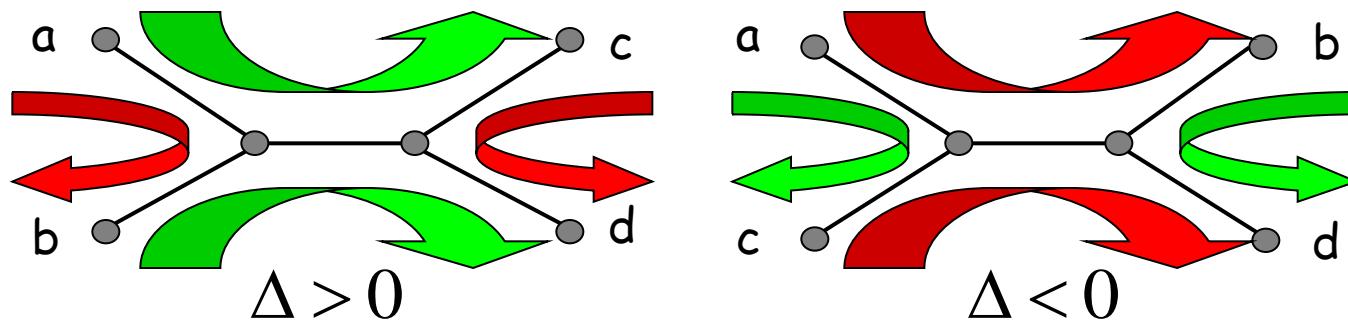
$$\begin{matrix} \text{Red Triangle} & \oplus & \text{Green Triangle} \\ \end{matrix} = \boxed{\text{Grey Block}}$$



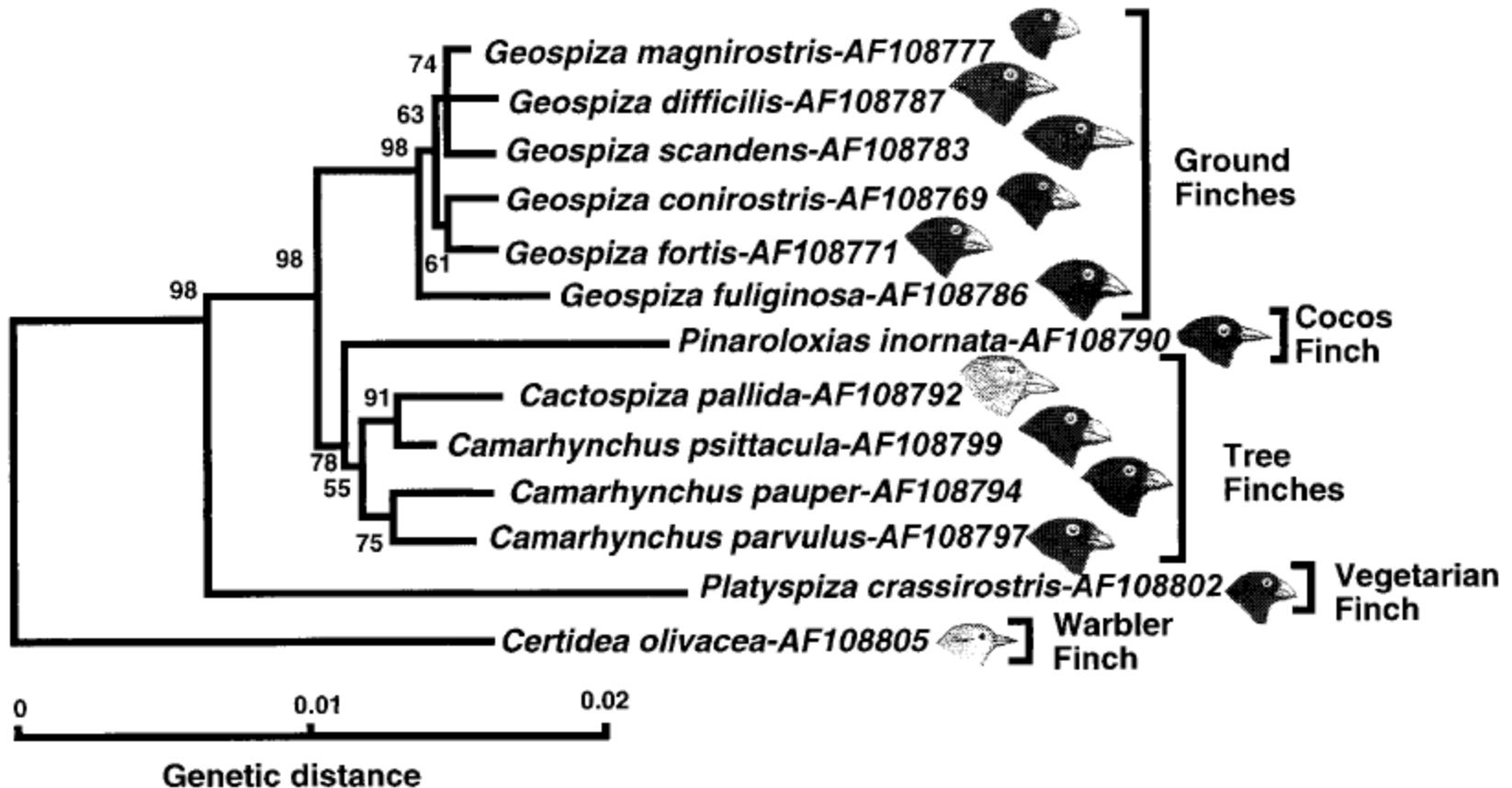
New	Old
$\triangle_{\text{Blue}} \oplus \triangle_{\text{Red}} =$	
$\triangle_{\text{Blue}} \oplus \triangle_{\text{Green}} =$	
$\triangle_{\text{Red}} \oplus \triangle_{\text{Green}} =$	

beyond the molecular clock

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



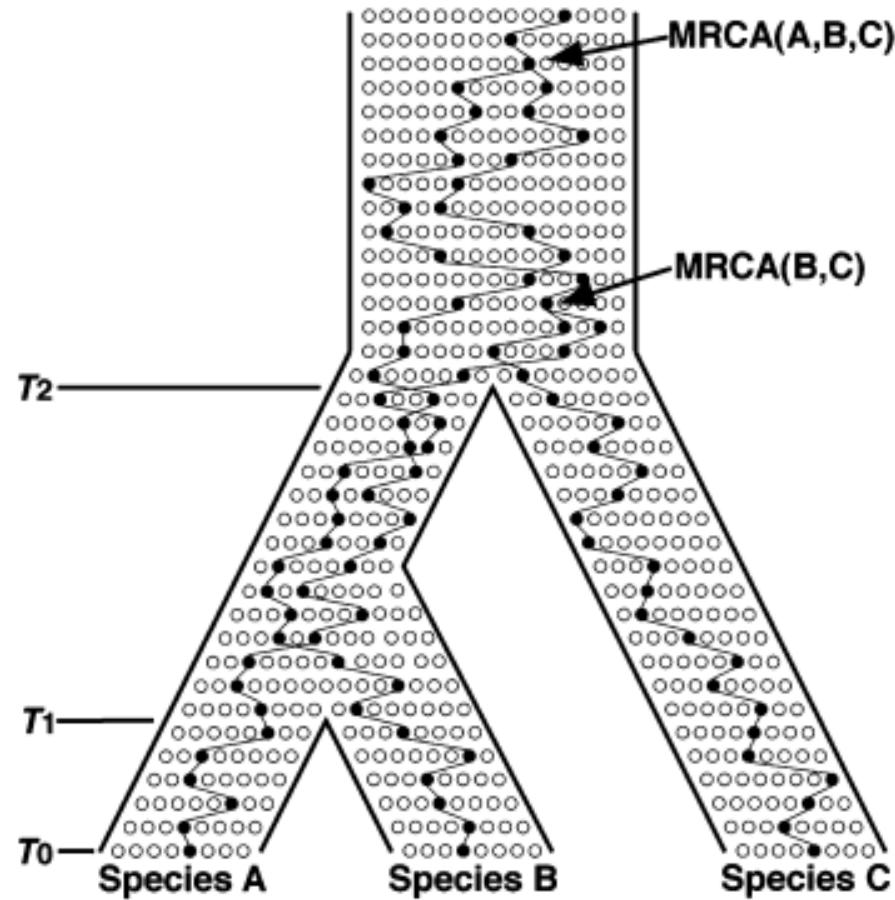
back to Darwin's finches



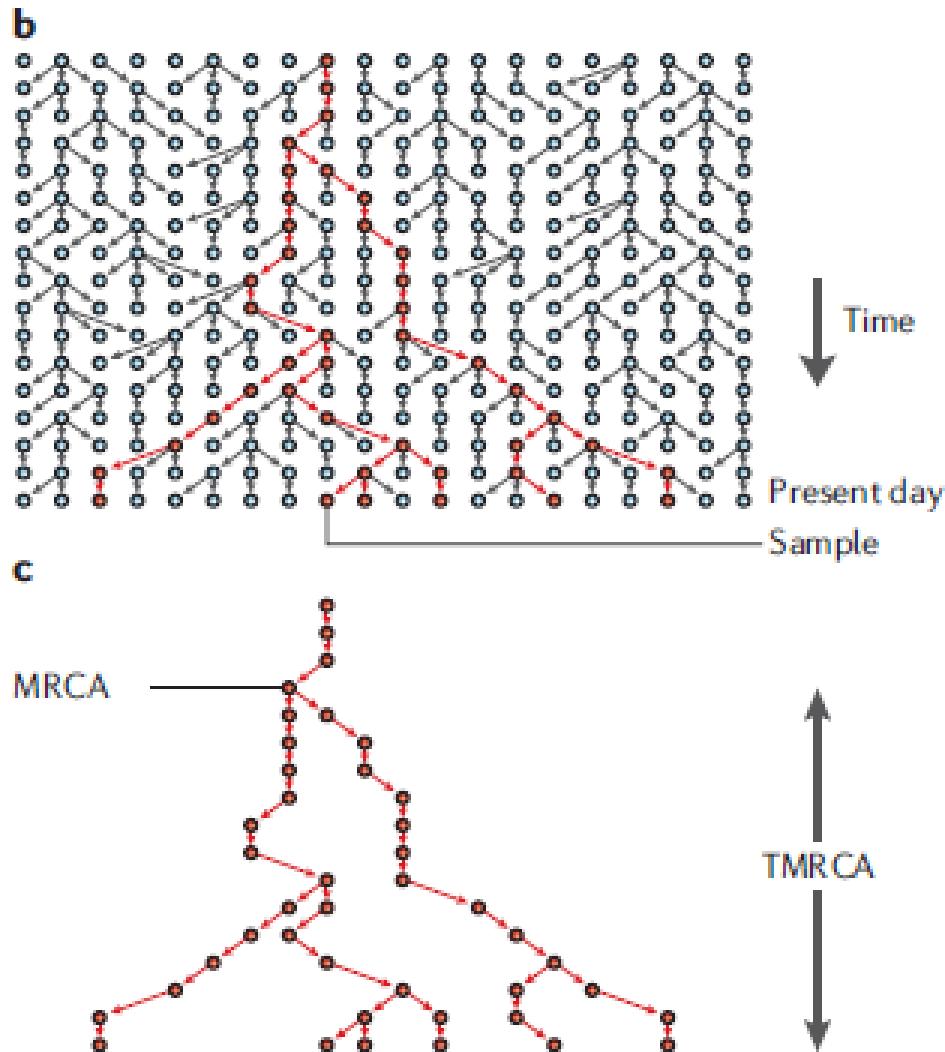
genetic variation

		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	2	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								
4	T	T								
5	.	T	.	A	.	.	T	.	.	T	T	.	A	.	.	A	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	.	C	.	C	.	C	.										
6	.	T	.	A	.	.	.	T	A	.	.	A	.	.	A	.	.	C	.	.	C	.	.	C	.	.	C	.	C	.	C	.	C	.	C	.											
7	C	T	.	A	.	.	.	T	.	.	T	.	.	.	T	.	A	.	A	.	A	.	C	.	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.											
8	.	T	.	A	.	.	.	T	T	.	A	.	A	.	A	.	C	.	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.											
9	C	T	T	T	.	A	.	A	.	A	.	C	.	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.											
10	.	T	T	T	.	A	.	A	.	A	.	C	G	.	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.										
11	.	T	T	T	.	A	.	A	.	A	.	C	.	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.											
12	.	T	T	T	.	A	.	A	.	A	.	C	.	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.											
13	.	T	A	T	.	A	.	A	.	A	.	C	.	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.											
14	.	T	T	T	T	.	A	.	A	.	A	.	C	.	.	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	.	C	.										
16	T	T	T	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.										
17	T	T	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.										
18	T	T	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.										
19	.	.	.	T	.	.	.	T	T	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.										
20	C	.	.	T	A	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.										
21	T	T	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.										
22	C	T	T	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.										
23	T	T	T	T	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.											
24	T	T	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.										
25	T	T	T	T	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.											
26	T	T	.	C	.	C	.	C	.	C	.	C	.	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.	C	.										
27	C	C	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.									
28	C	C	.	T	.	.	.	T	.	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.	C	C	.										

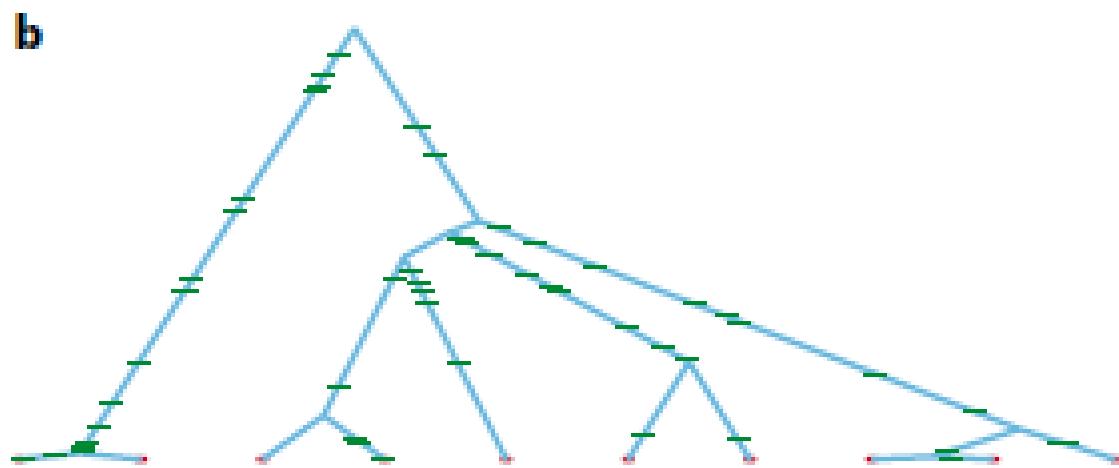
zooming in on populations



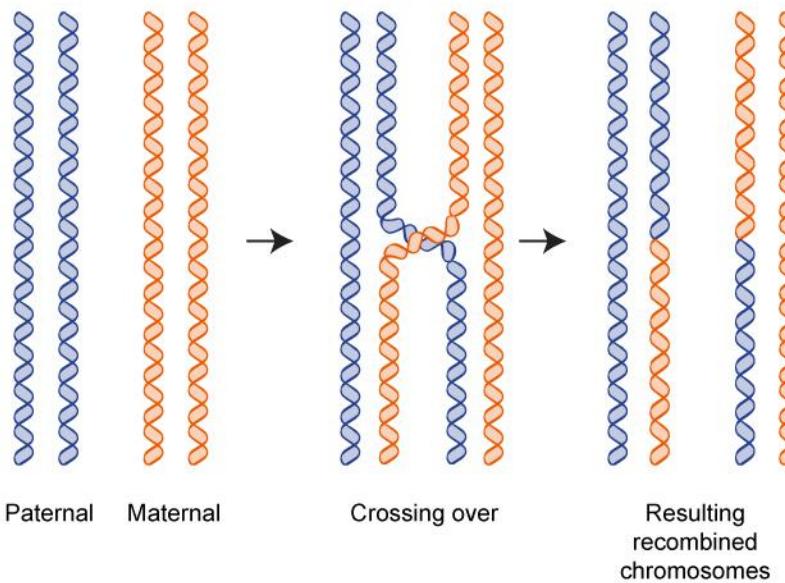
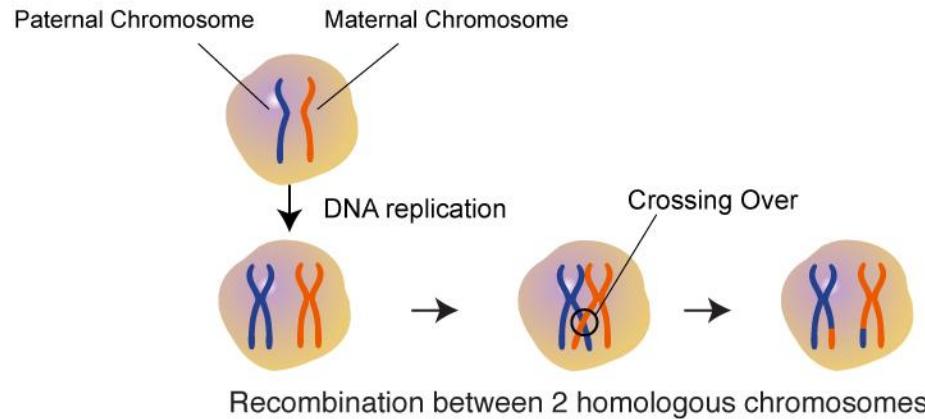
looking backwards in time



mutations



Homologous recombination



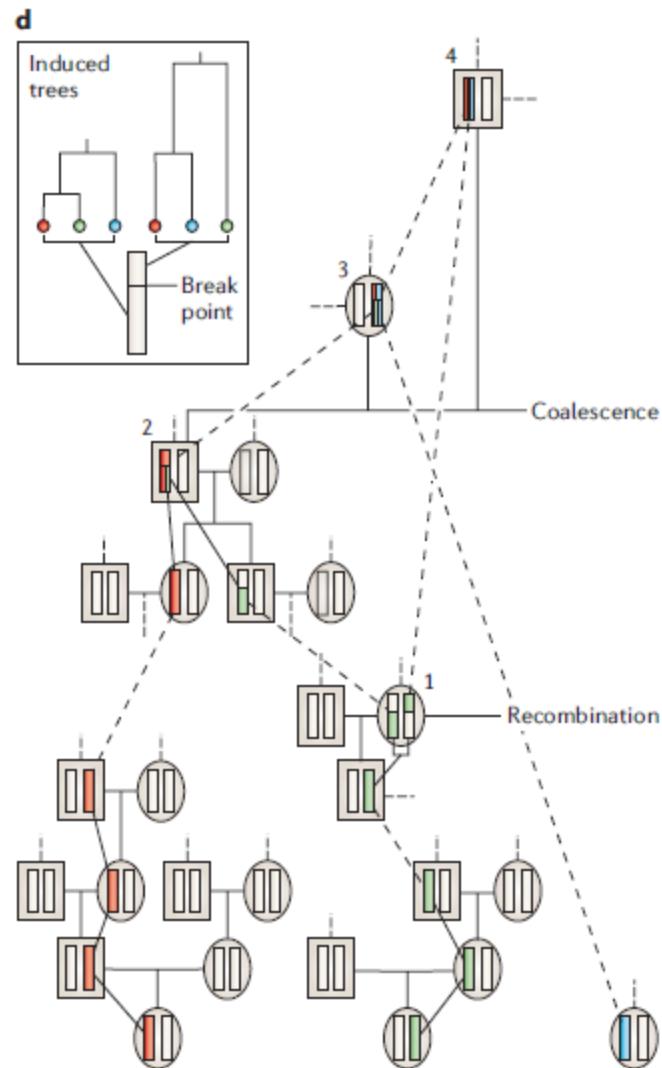
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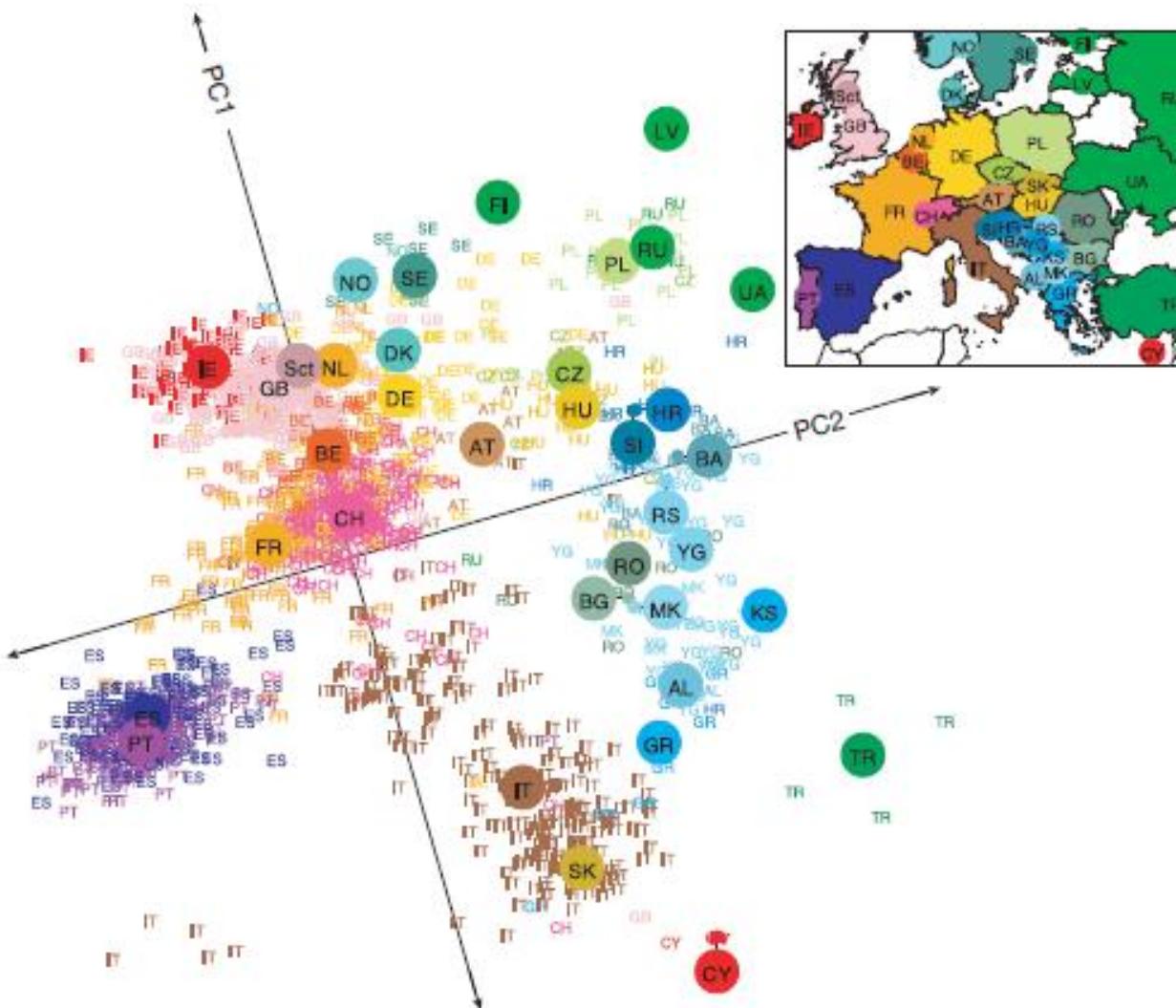
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ancestral recombination graph



population genomics



Novembre et al., *Nature* (2008)