Introduction to Bioengineering
BIOE/ENGR.80
Stanford University

Spring 2020 Class Slides

Day 22
27 May 2020

Week 7 reprise

PROJECT
SKILL

Impact versus effort mapping

Project topic selection

Communicating clearly

Storytelling for engagement

Performing for impact

Week 8 look ahead

CONCEPT
SKILL

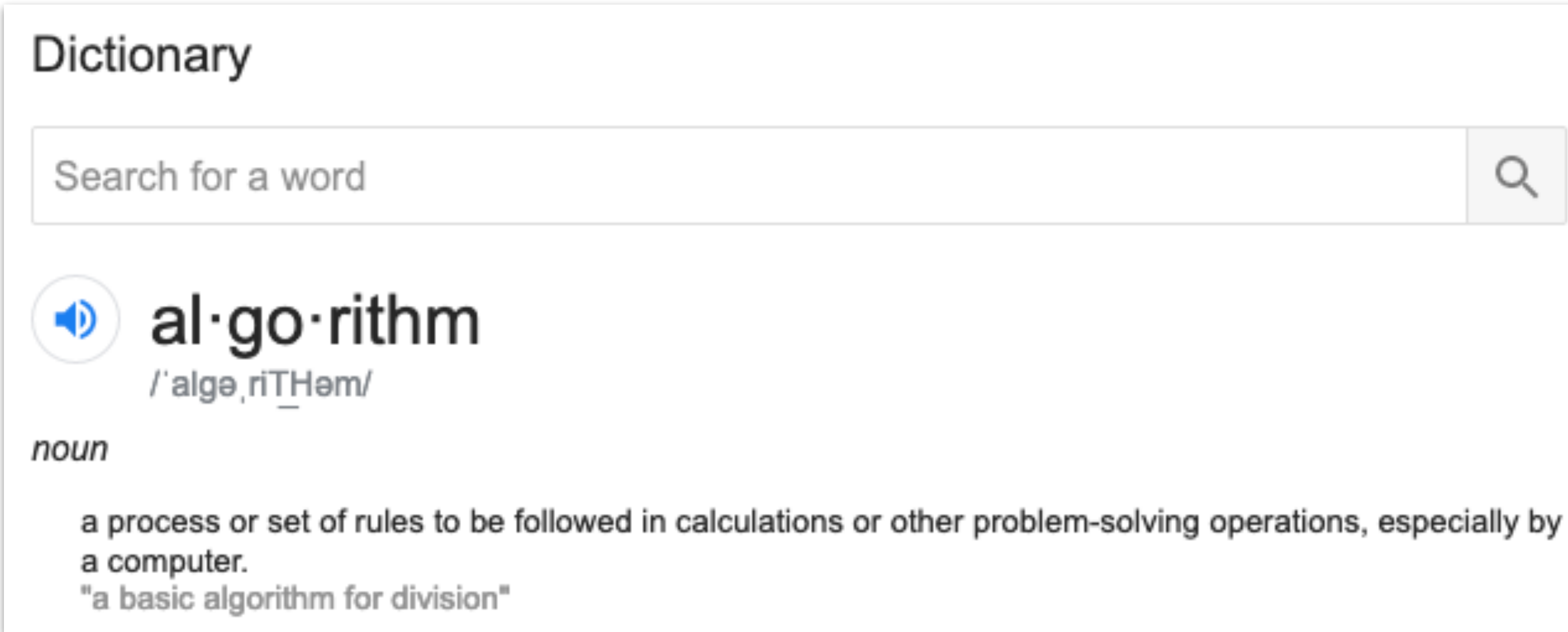
Evolution as algorithm

Evolution as service

Evolution 2.0?

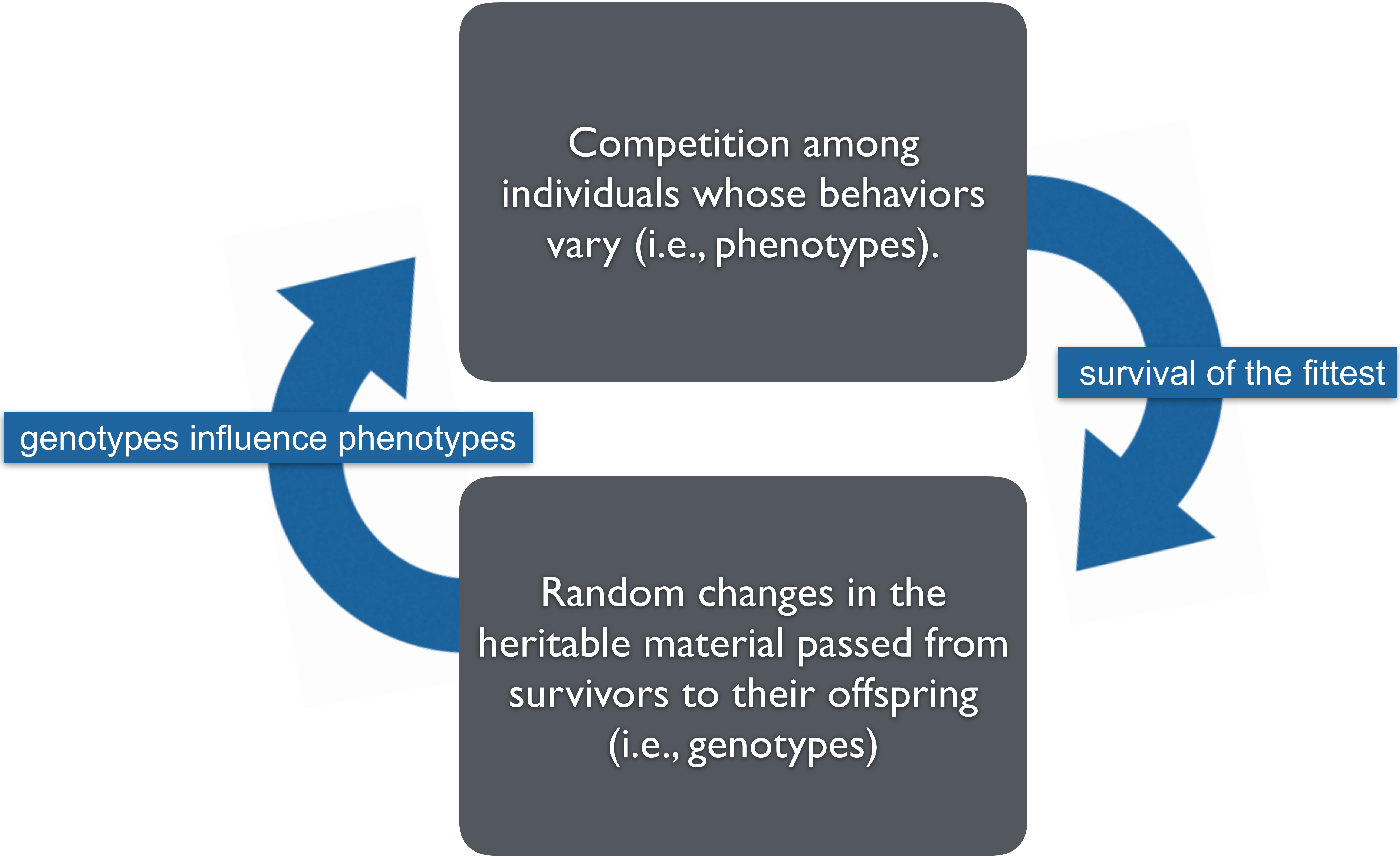
<Evolutionary algorithm sandbox>

Evolution as algorithm*

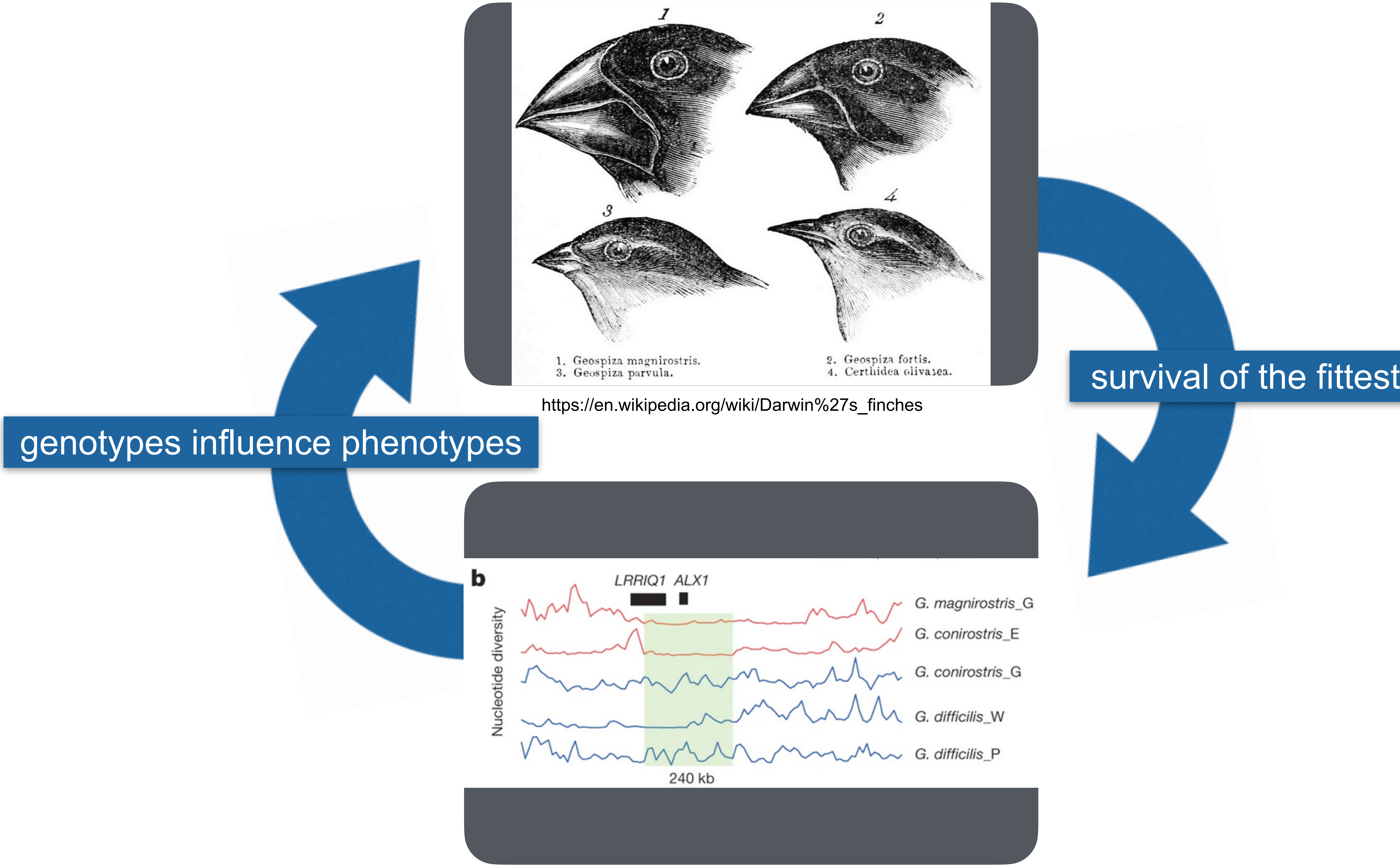


*By algorithm, we simply mean to represent that a few things must be happening for evolution to happen. We do not mean to imply any higher purpose to the process.

Evolution as algorithm



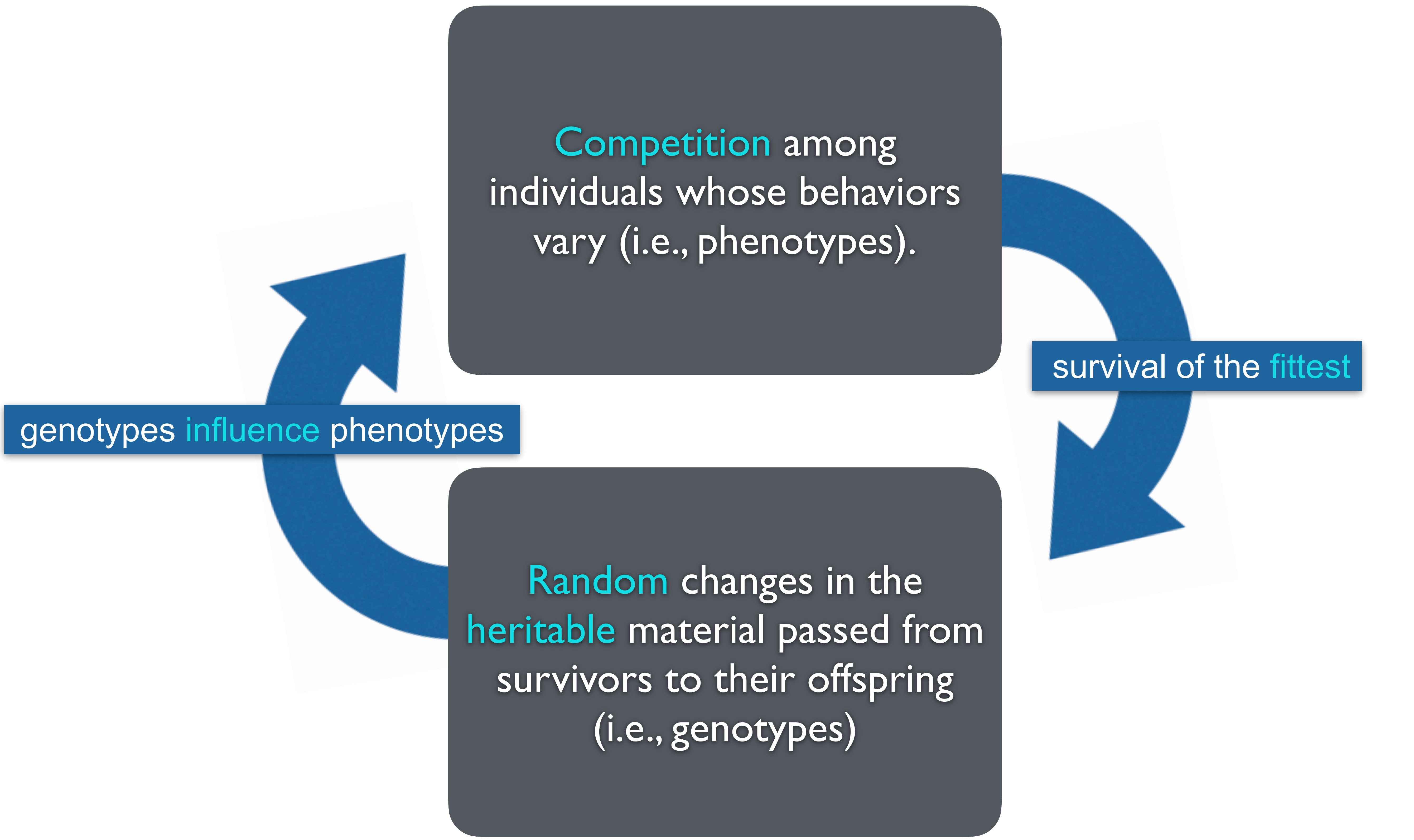
Evolution as algorithm



https://en.wikipedia.org/wiki/Darwin%27s_finches

https://www.nature.com/articles/nature14181

Evolution as algorithm



Evolution as substrate agnostic algorithm

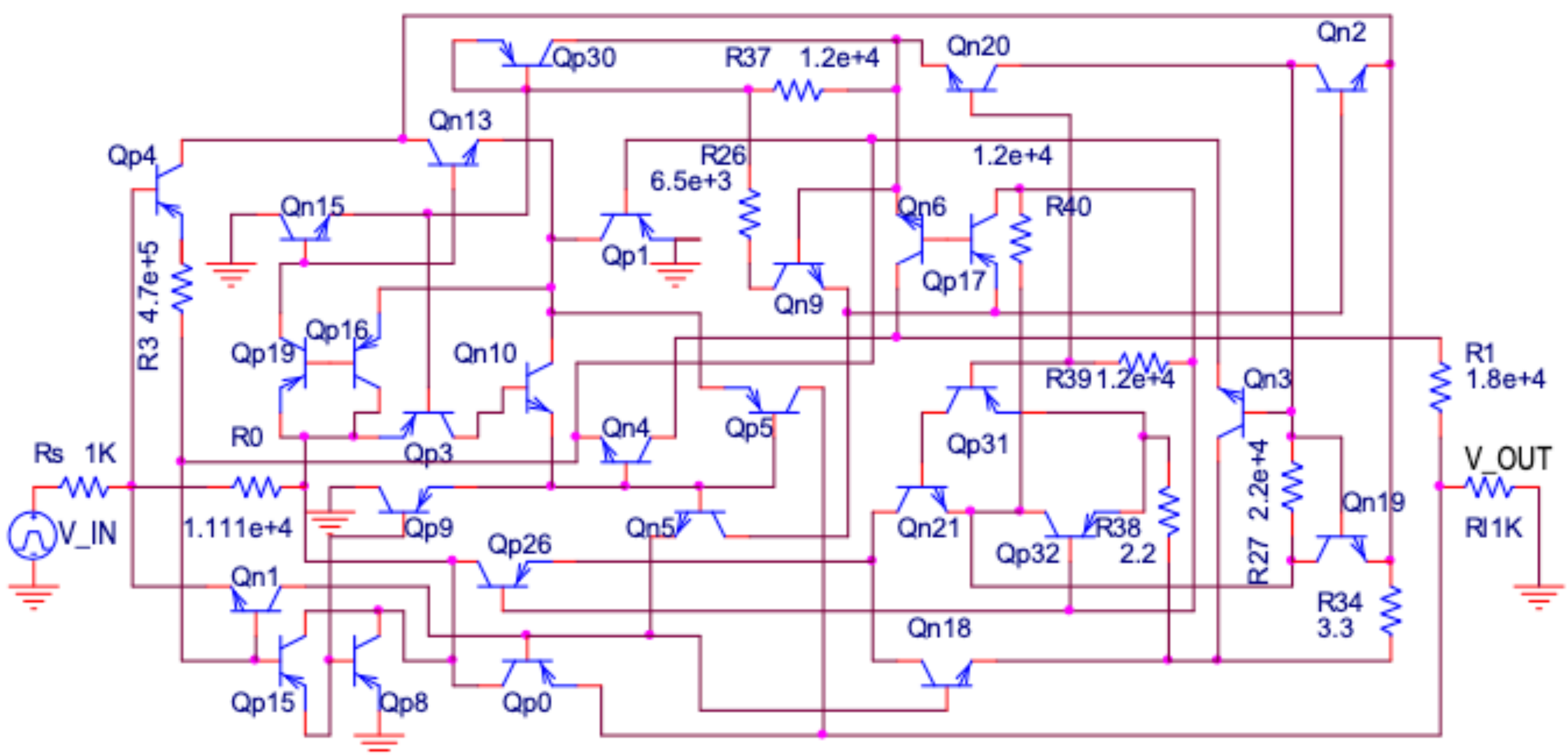


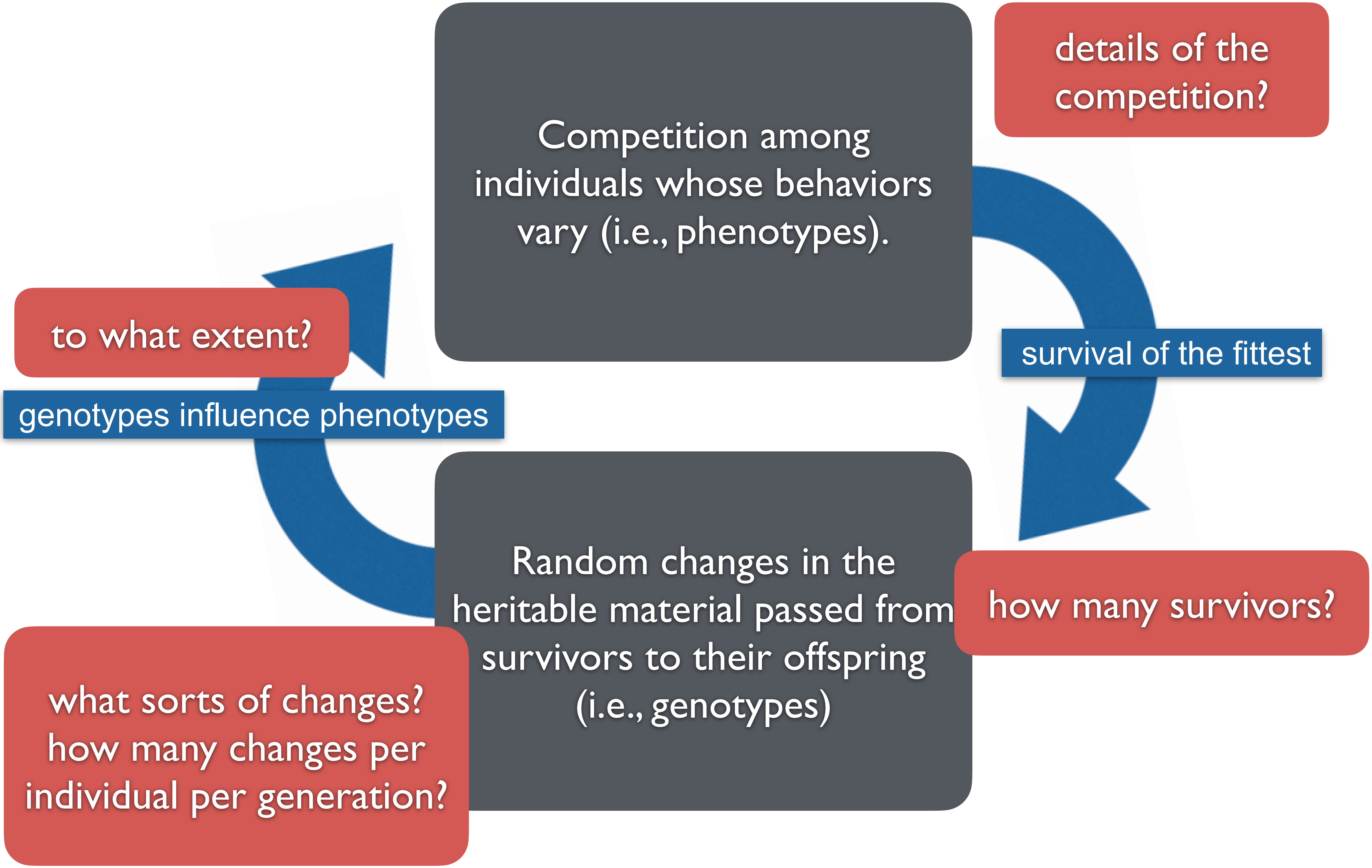
Figure 6. The evolved cube root circuit.

Q. how to evolve electrical circuits?

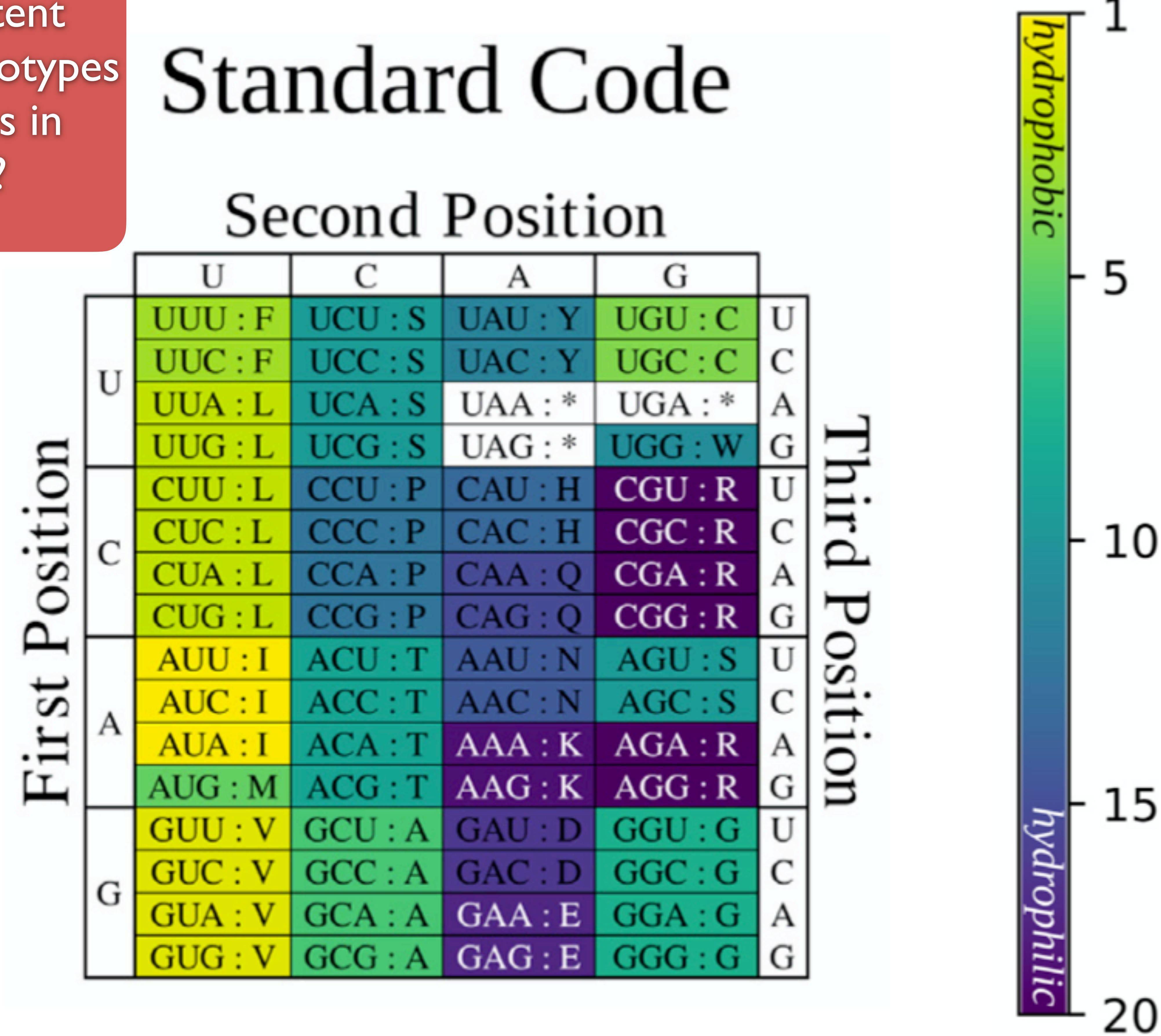
Q. what else can be evolved?

https://www.scirp.org/journal/paperinformation.aspx?paperid=3201

Factors influencing evolution



E.g., to what extent (do changes in genotypes result in changes in phenotypes)?

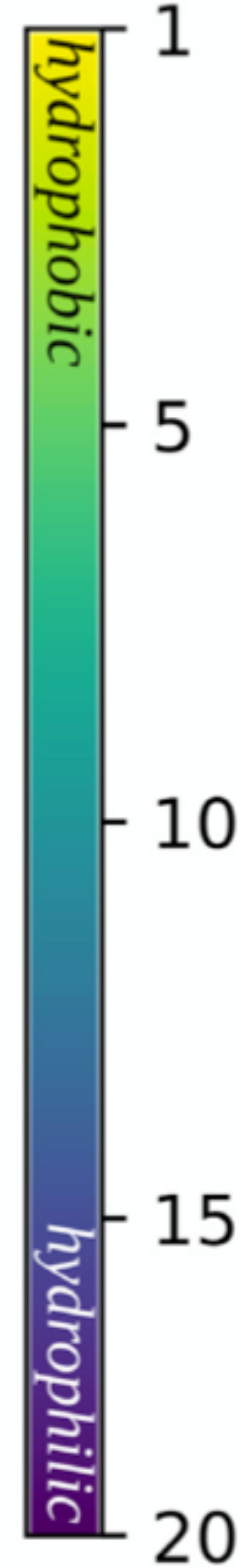


https://academic.oup.com/nar/article/47/19/10439/5568210

Random Code

Second Position

First Position	U	C	A	G	Third Position
U	UUU : V	UCU : V	UAU : L	UGU : S	U
U	UUC : D	UCC : G	UAC : E	UGC : C	C
U	UUA : R	UCA : A	UAA : Q	UGA : T	A
U	UUG : M	UCG : I	UAG : F	UGG : P	G
C	CUU : H	CCU : H	CAU : N	CGU : A	U
C	CUC : M	CCC : *	CAC : E	CGC : A	C
C	CUA : H	CCA : V	CAA : M	CGA : H	A
C	CUG : M	CCG : F	CAG : G	CGG : L	G
A	AUU : I	ACU : H	AAU : K	AGU : G	U
A	AUC : Q	ACC : D	AAC : S	AGC : M	C
A	AUA : S	ACA : Y	AAA : E	AGA : V	A
A	AUG : K	ACG : C	AAG : *	AGG : L	G
G	GUU : M	GCU : E	GAU : I	GGU : Q	U
G	GUC : C	GCC : W	GAC : I	GGC : D	C
G	GUA : W	GCA : P	GAA : E	GGA : Y	A
G	GUG : G	GCG : *	GAG : C	GGG : M	G

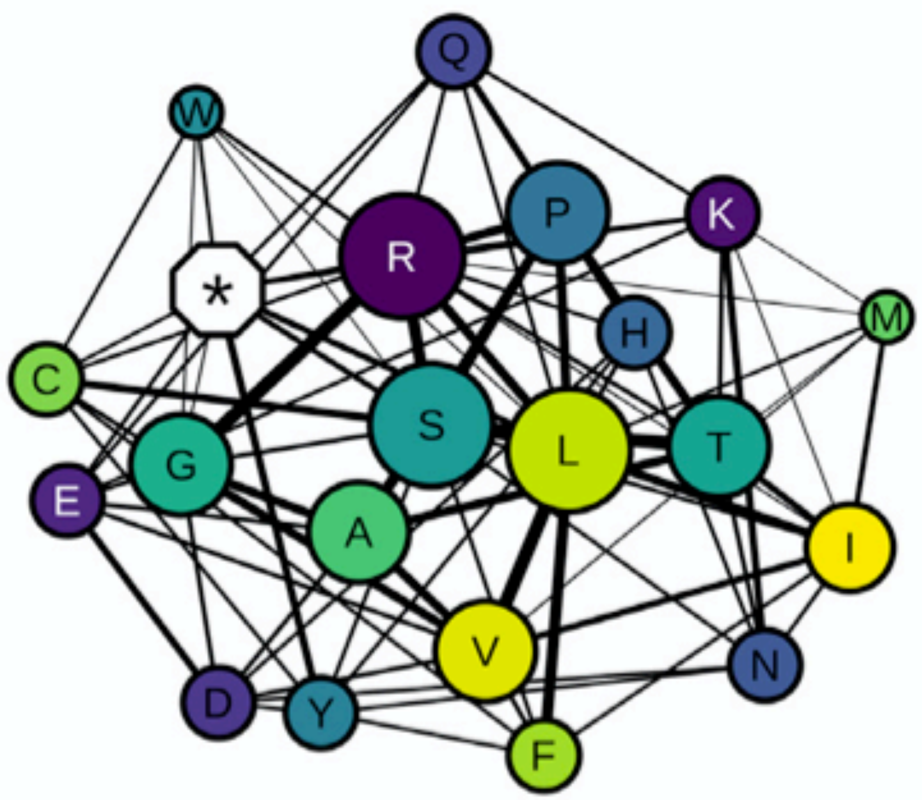


https://academic.oup.com/nar/article/47/19/10439/5568210

Standard Code

Second Position

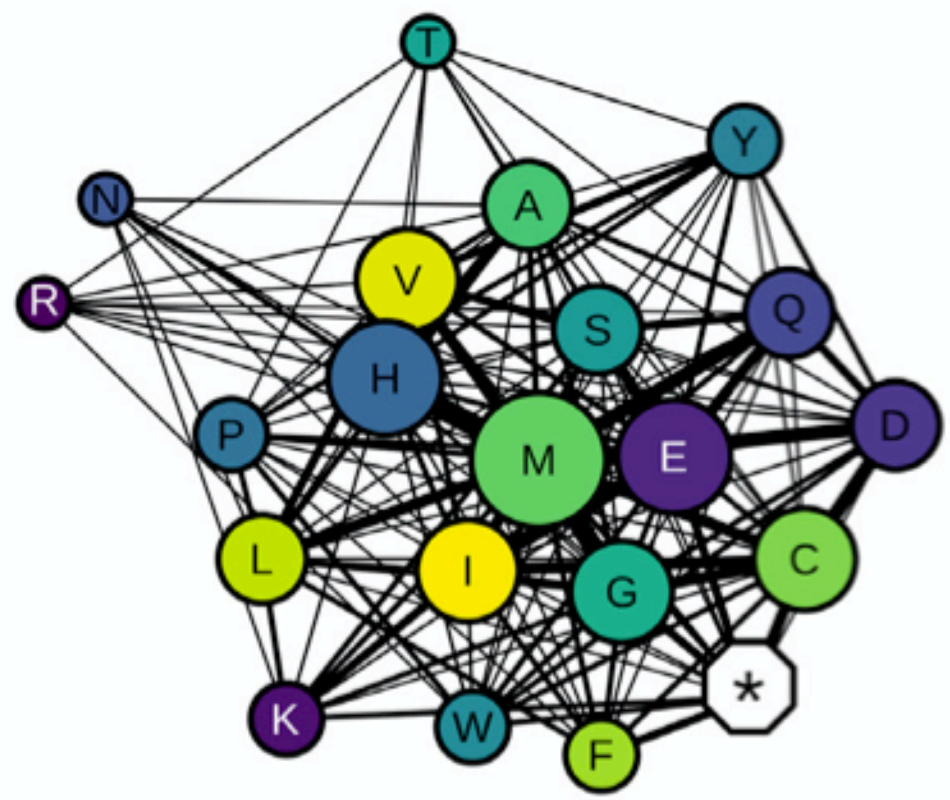
First Position	U	C	A	G	Third Position
U	UUU : F	UCU : S	UAU : Y	UGU : C	U
	UUC : F	UCC : S	UAC : Y	UGC : C	C
	UUA : L	UCA : S	UAA : *	UGA : *	A
	UUG : L	UCG : S	UAG : *	UGG : W	G
C	CUU : L	CCU : P	CAU : H	CGU : R	U
	CUC : L	CCC : P	CAC : H	CGC : R	C
	CUA : L	CCA : P	CAA : Q	CGA : R	A
	CUG : L	CCG : P	CAG : Q	CGG : R	G
A	AUU : I	ACU : T	AAU : N	AGU : S	U
	AUC : I	ACC : T	AAC : N	AGC : S	C
	AUA : I	ACA : T	AAA : K	AGA : R	A
	AUG : M	ACG : T	AAG : K	AGG : R	G
G	GUU : V	GCU : A	GAU : D	GGU : G	U
	GUC : V	GCC : A	GAC : D	GGC : G	C
	GUA : V	GCA : A	GAA : E	GGA : G	A
	GUG : V	GCG : A	GAG : E	GGG : G	G

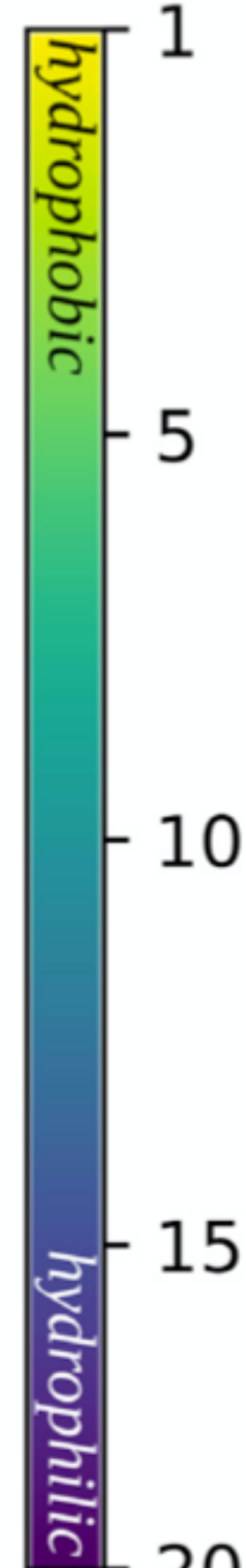


Random Code

Second Position

First Position	U	C	A	G	Third Position
U	UUU : V	UCU : V	UAU : L	UGU : S	U
	UUC : D	UCC : G	UAC : E	UGC : C	C
	UUA : R	UCA : A	UAA : Q	UGA : T	A
	UUG : M	UCG : I	UAG : F	UGG : P	G
C	CUU : H	CCU : H	CAU : N	CGU : A	U
	CUC : M	CCC : *	CAC : E	CGC : A	C
	CUA : H	CCA : V	CAA : M	CGA : H	A
	CUG : M	CCG : F	CAG : G	CGG : L	G
A	AUU : I	ACU : H	AAU : K	AGU : G	U
	AUC : Q	ACC : D	AAC : S	AGC : M	C
	AUA : S	ACA : Y	AAA : E	AGA : V	A
	AUG : K	ACG : C	AAG : *	AGG : L	G
G	GUU : M	GCU : E	GAU : I	GGU : Q	U
	GUC : C	GCC : W	GAC : I	GGC : D	C
	GUA : W	GCA : P	GAA : E	GGA : Y	A
	GUG : G	GCG : *	GAG : C	GGG : M	G





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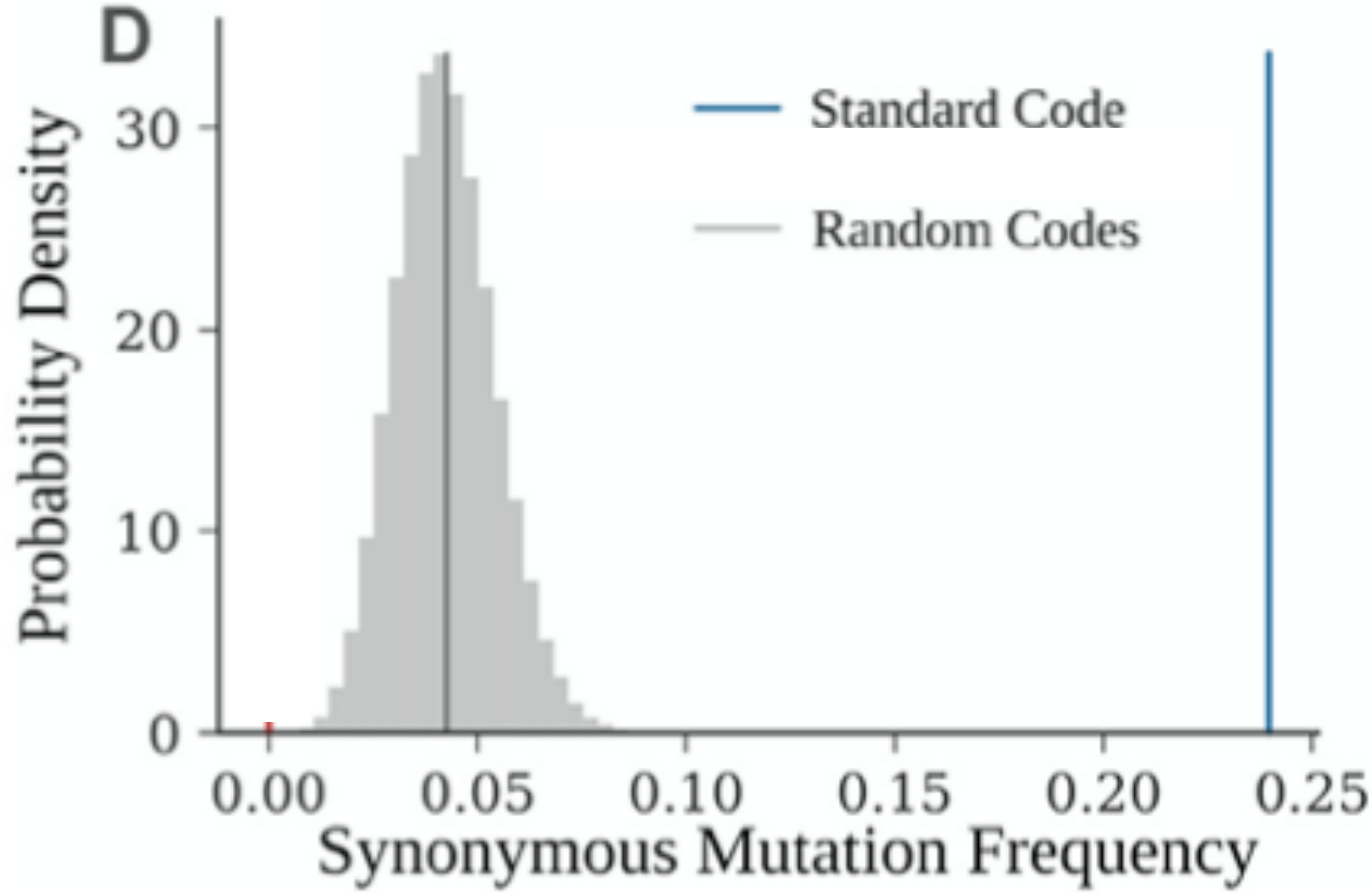
Q. why is the standard genetic code six-fold less likely to change an amino acid given any point mutation in an open reading frame?



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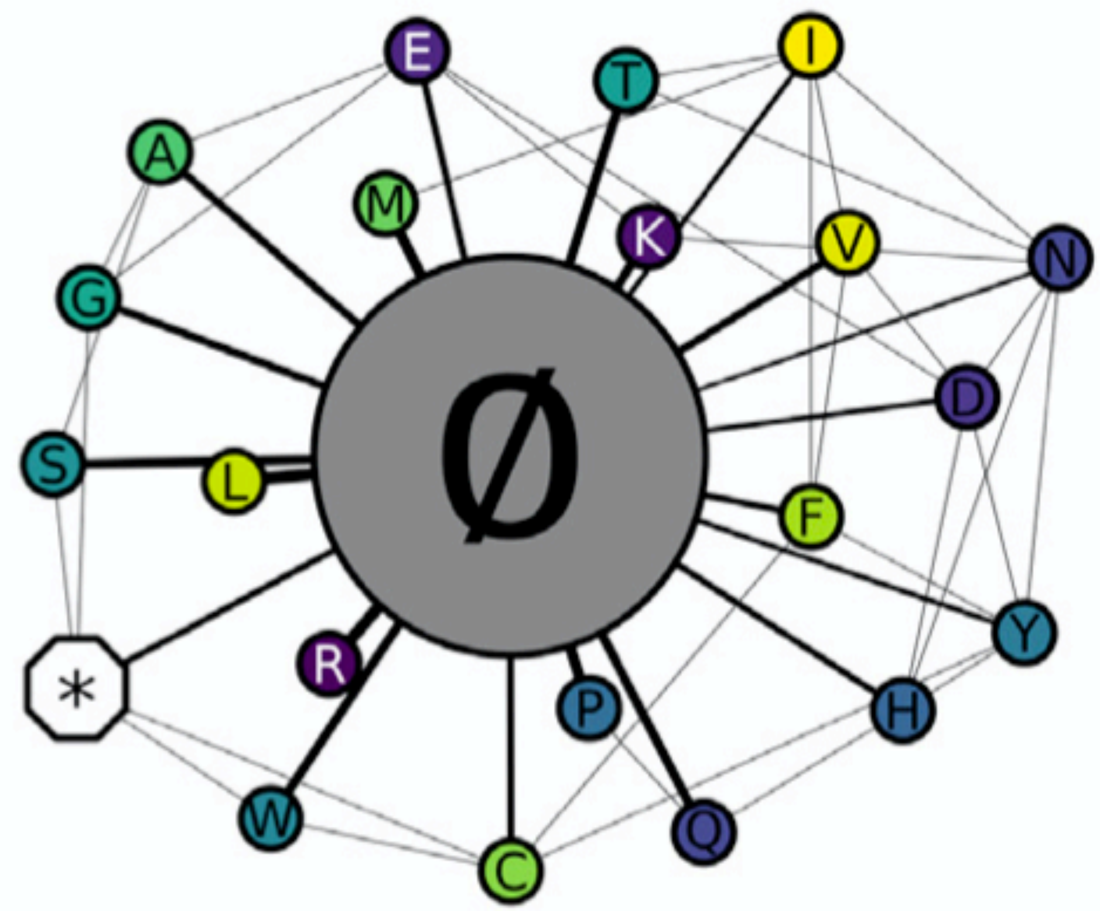
Q. what would be the expected impact on evolution for organisms in which most point mutations land on codons that cannot be decoded?

RED20

Second Position

First Position	U	C	A	G	Third Position
U	UUU : 0	UCU : 0	UAU : 0	UGU : 0	U
	UUC : F	UCC : 0	UAC : Y	UGC : C	C
	UUA : 0	UCA : S	UAA : *	UGA : *	A
	UUG : 0	UCG : 0	UAG : *	UGG : W	G
C	CUU : 0	CCU : 0	CAU : 0	CGU : R	U
	CUC : 0	CCC : 0	CAC : H	CGC : 0	C
	CUA : L	CCA : 0	CAA : 0	CGA : 0	A
	CUG : 0	CCG : P	CAG : Q	CGG : 0	G
A	AUU : 0	ACU : 0	AAU : 0	AGU : 0	U
	AUC : I	ACC : T	AAC : N	AGC : 0	C
	AUA : 0	ACA : 0	AAA : K	AGA : 0	A
	AUG : M	ACG : 0	AAG : 0	AGG : 0	G
G	GUU : 0	GCU : 0	GAU : 0	GGU : 0	U
	GUC : V	GCC : 0	GAC : D	GGC : 0	C
	GUA : 0	GCA : A	GAA : E	GGA : G	A
	GUG : 0	GCG : 0	GAG : 0	GGG : 0	G



https://academic.oup.com/nar/article/47/19/10439/5568210

The origin of mutants

John Cairns, Julie Overbaugh & Stephan Miller

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Nucleic acids are replicated with conspicuous fidelity. Infrequently, however, they undergo changes in sequence, and this process of change (mutation) generates the variability that allows evolution. As the result of studies of bacterial variation, it is now widely believed that mutations arise continuously and without any consideration for their utility. In this paper, we briefly review the source of this idea and then describe some experiments suggesting that cells may have mechanisms for choosing which mutations will occur.

Claim — mutations are not random in occurrence, rather genes whose mutating would be most beneficial for fitness in a given environment are somehow preferentially mutated…

Q. How would this work?

A. Evolution is cleverer than we are*

Evidence That Selected Amplification of a Bacterial *lac* Frameshift Allele Stimulates Lac+ Reversion (Adaptive Mutation) With or Without General Hypermutability

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ABSTRACT

In the genetic system of Cairns and Foster, a nongrowing population of an *E. coli lac* frameshift mutant appears to specifically accumulate Lac$^+$ revertants when starved on medium including lactose (adaptive mutation). This behavior has been attributed to stress-induced general mutagenesis in a subpopulation of starved cells (the hypermutable state model). We have suggested that, on the contrary, stress has no direct effect on mutability but favors only growth of cells that amplify their leaky mutant *lac* region (the amplification mutagenesis model). Selection enhances reversion primarily by increasing the mutant *lac* copy number within each developing clone on the selection plate. The observed general mutagenesis is attributed to a side effect of growth with an amplification—induction of SOS by DNA fragments released from a tandem array of *lac* copies. Here we show that the *S. enterica* version of the Cairns system shows SOS-dependent general mutagenesis and behaves in every way like the original *E. coli* system. In both systems, *lac* revertants are mutagenized during selection. Eliminating the 35-fold increase in mutation rate reduces revertant number only 2- to 4-fold. This discrepancy is due to continued growth of amplification cells until some clones manage to revert without mutagenesis solely by increasing their *lac* copy number. Reversion in the absence of mutagenesis is still dependent on RecA function, as expected if it depends on *lac* amplification (a recombination-dependent process). These observations support the amplification mutagenesis model.

*see Orgel's rules…

https://en.wikipedia.org/wiki/Orgel%27s_rules

In-progress project assessments

Group-1	Green
Group-2	Yellow - Red
Group-3	Red
Group-4	Yellow - Red
Group-5	Yellow - Red
Group-6	Yellow-Green
Group-7	Red
Group-8	Green
Group-9	Yellow - Red
Group-10	Yellow-Green
Group-11	Yellow-Green
Group-12	Yellow-Green
Group-13	Yellow - Red
Group-14	Yellow - Red
Group-15	Yellow-Green
Group-16	Yellow-Green
Group-17	Yellow
Bioe Baddies	Yellow