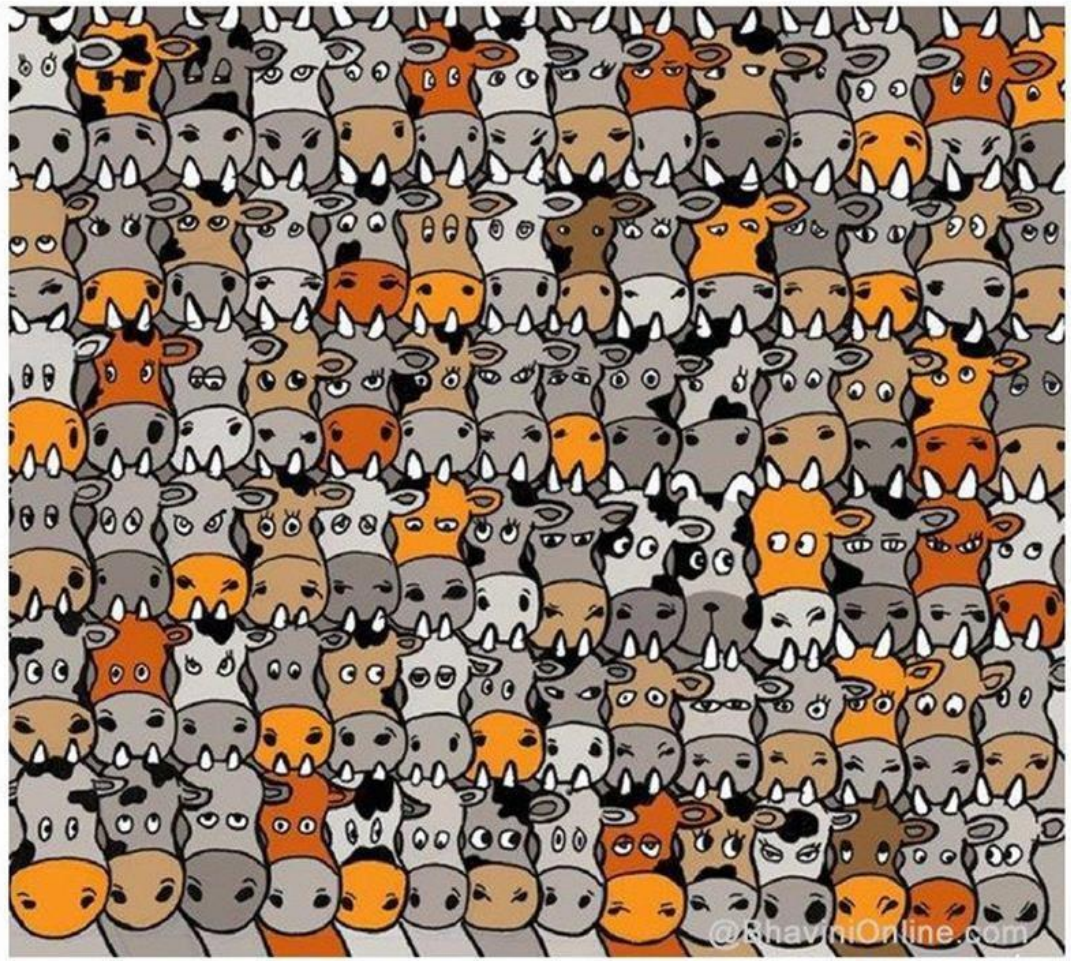
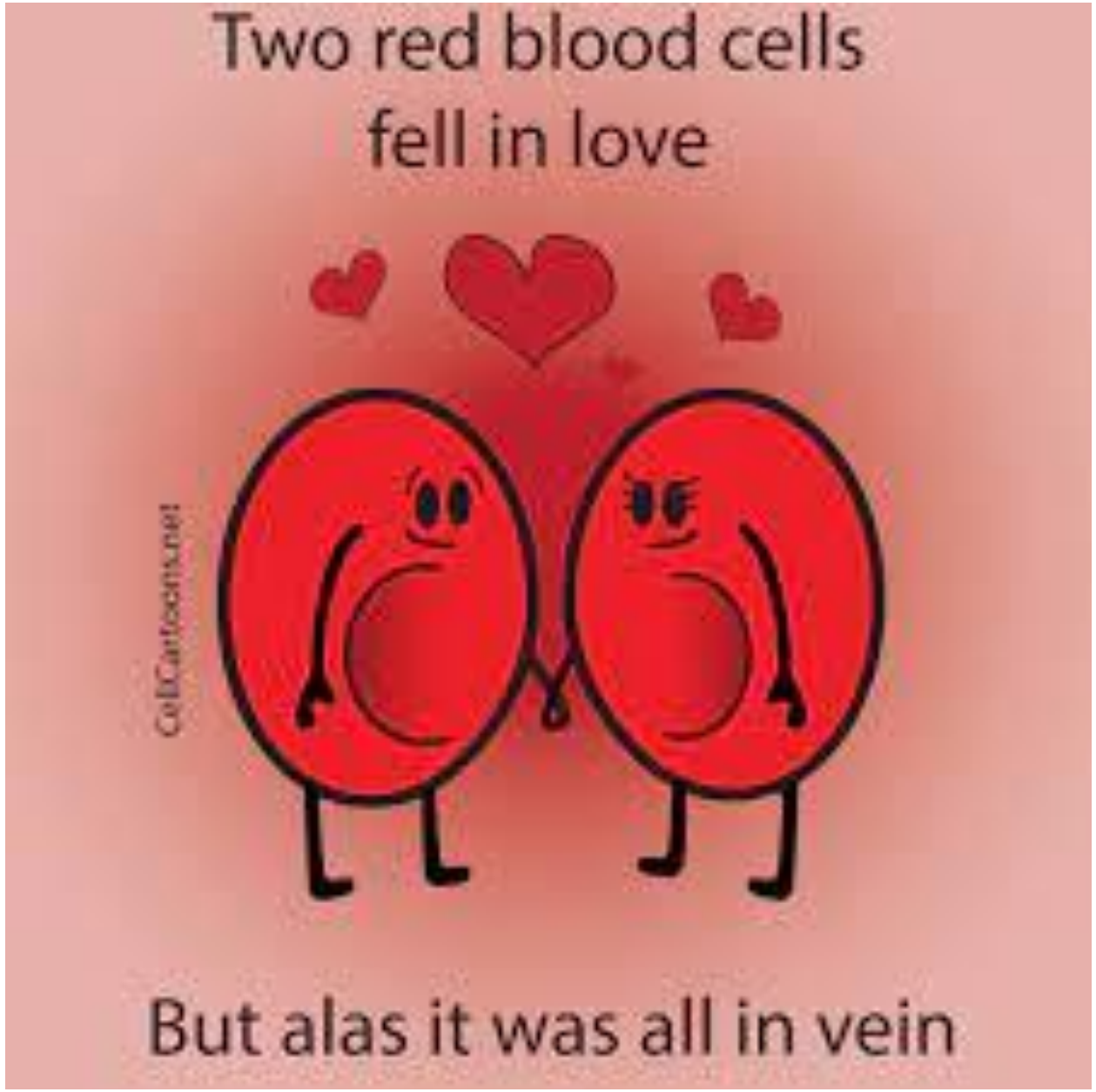
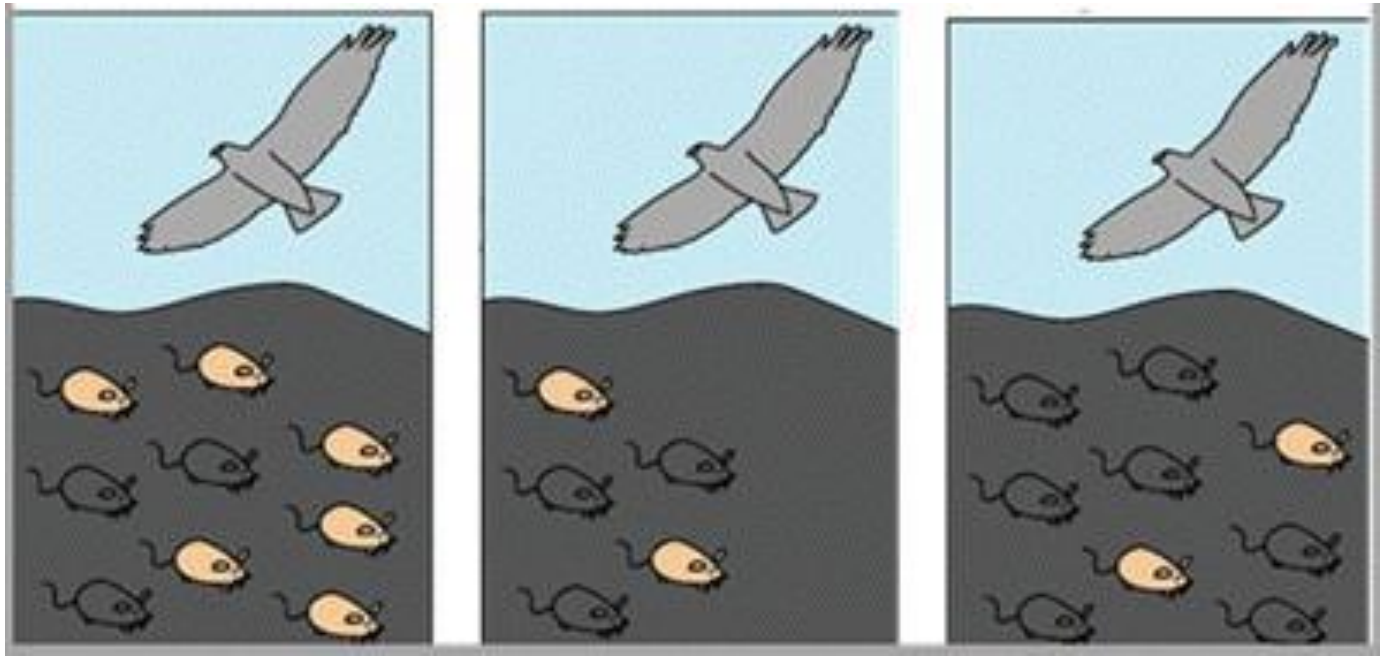
Find the dog in the Picture




Two red blood cells
fell in love
CellCartoons.net
But alas it was all in vein

Today's class – Evolutionary Mechanisms cont.

#1 Mutations - continued
#2 Gene Flow
#3 Natural Selection - start



Source: unknown

Post-Pandemic Professional Development Event

Group Project:

Is there a team (-221) working on CRISPR that has space for another team member? If so, please send me an email (lnorman@zoology.ubc.ca).

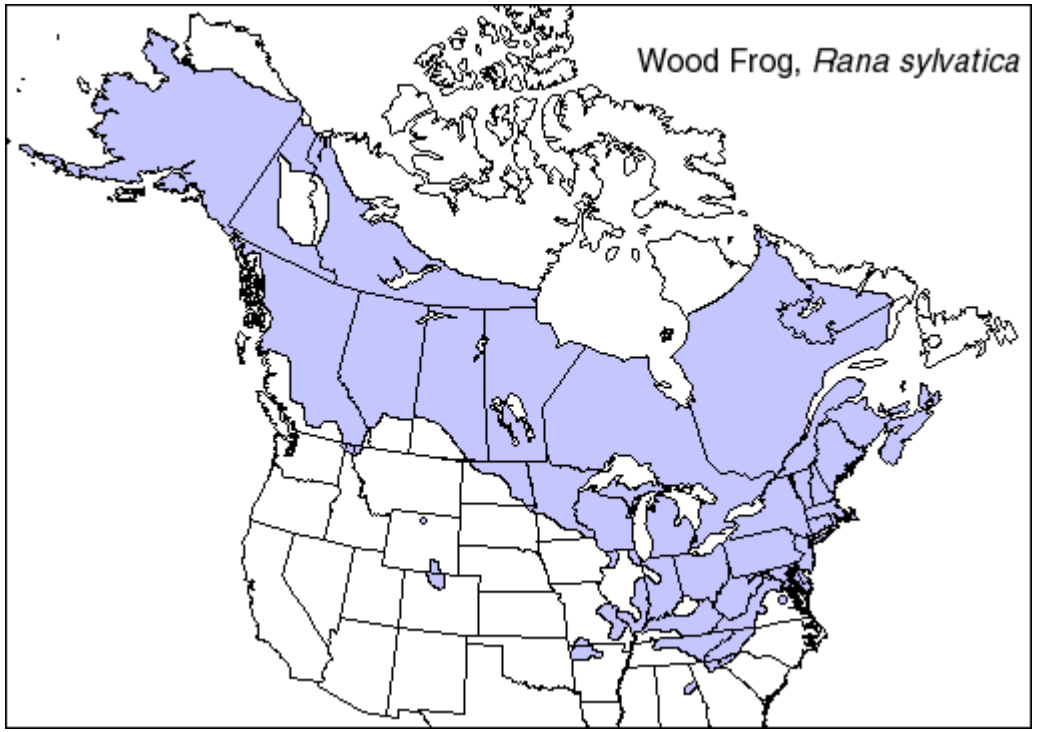
If you are still looking for a team, or if you are team still looking for people, please send me an email by Wednesday at 2pm. In the subject line, please write “looking for a team”.

Organism of the Day – Wood Frog

Rana sylvatica or *Lithobates sylvaticus*

https://www.inaturalist.org/taxa/66012-Lithobates-sylvaticus

- Small frogs that grow up to about 70 mm in length.
- Usually brown (but not always) with a brown face mask.
- Adults – live in moist forests, where they eat invertebrates - feeding triggered by movement.
- They breed in shallow, seasonal pools (with no incoming or outgoing streams)



- They have a broad distribution in North America
- Found further north than any other amphibian in Canada.

https://commons.wikimedia.org/wiki/File:Rana-sylvatica_Range.gif

A trait that allows them to survive so far north

https://www.youtube.com/watch?v=pLPeehsXAr4

Last class

What is evolution?

Evidence for evolution:

- ALL species are related, i.e. descended from a universal common ancestor
  - e.g. all living things made of cells, university of DNA as genetic code, flow of information (DNA to RNA to Amino Acid/Protein)

- Common ancestry
  - Homologous traits (structural, developmental, genetic)

- That species/populations change over time
  - Extinctions (fossil record and current extinctions)
  - Transitional fossils
  - Vestigial structures in living organisms
  - Real time evidence: Bacteria – antibiotic resistance

iClicker Question

A giant volcano erupts and kills 90% of the population of a species. As a result, the frequency of the "A" allele changes from 0.8 to 0.7, and the frequency of the "a" allele changes from 0.2 to 0.3. This influenced the allele frequencies in the next generation. Has evolution occurred?

A. Yes. Evolution is a change in allele frequencies in a population over generations.

B. No, this change is allele frequencies is not significant.

C. No, 90% of the population has been killed, so this is not a fair comparison

D. No, because there are still more A alleles than a alleles.

E. I am not sure

Answer

A giant volcano erupts and kills 90% of the population of a species. As a result, the frequency of the "A" allele changes from 0.8 to 0.7, and the frequency of the "a" allele changes from 0.2 to 0.3. This influenced the allele frequencies in the next generation. Has evolution occurred?

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iClicker Question

The embryos of mice and humans have gill structures during development.

This is an example of:

A. Developmental homology

B. Genetic homology

C. Structure homology

D. Transitional form

E. Vestigial Trait

Answer

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This is an example of:

A. Developmental homology

B. Genetic homology

C. Structure homology

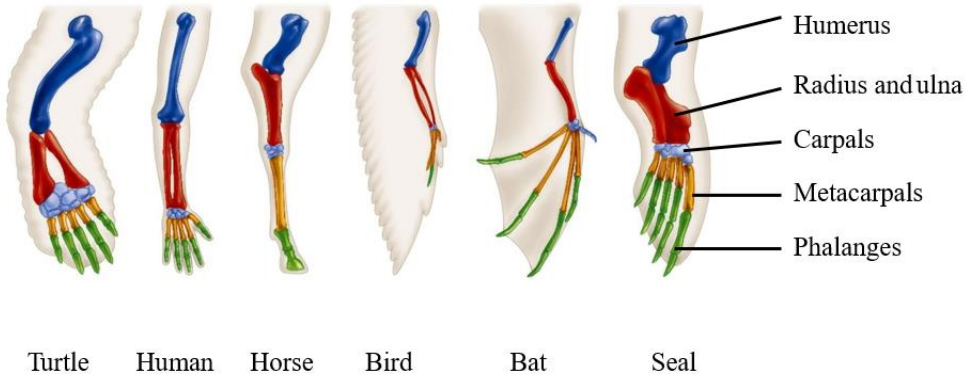
D. Transitional form

E. Vestigial Trait

Homologous Traits

A great Piazza Post by Anonymous Calc (-224)

"The word homologous is used to compare traits (e.g. structures, nucleotide sequences) in different organisms. So, you can't just say "forelimbs are homologous". You have to say, e.g. "the humerus in the forelimbs of turtles is homologous to the humerus in the forelimbs of humans, horses, birds, bats and seals"



Or, the incus bone in your middle ear is homologous to the quadrat bone in the upper jaws of reptiles.

We will return to homologous versus analogous traits when we discuss phylogenetic trees.

iClicker Question

The presence of gill structures in the embryos of mice and humans supports the conclusion that:

A. Mice and humans are descended from LUCA

B. Mice and humans share common ancestry (i.e. share a common ancestor)

C. Mice and humans have changed through time

D. None of the above

Answer

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iClicker Question

According to evolutionary theory, all species are related. Four of the following examples provide support for this prediction, but one is irrelevant. Which one of these examples does not support the claim that species are related?

A. The endostyle of lancelets (invertebrate chordates) and the thyroid gland of vertebrates develop similarly and both absorb available iodine.
B. The three garter snake species found in British Columbia all have embryonic gill slits.
C. All prokaryotes and eukaryotes use DNA to carry their genetic information.
D. Before synthetic insulin was available, diabetics used injections of purified pig insulin to manage their disease.
E. Dinosaurs and many other taxa went extinct following a huge asteroid impact at the end of the Cretaceous.

Answer

According to evolutionary theory, all species are related. Four of the following examples provide support for this prediction, but one is irrelevant. Which one of these examples does not support the claim that species are related?

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C. All prokaryotes and eukaryotes use DNA to carry their genetic information.

D. Before synthetic insulin was available, diabetics used injections of purified pig insulin to manage their disease.

E. Dinosaurs and many other taxa went extinct following a huge asteroid impact at the end of the Cretaceous. (evidence of evolutionary change).

iClicker Question - Mutations

Last class – started a discussion of Mutations (1 of 4 evolutionary mechanisms)

Which statement(s) is/are not true about mutations:

A. Mutations are the ultimate source of genetic variation in a population
B. Mutations can produce new alleles
C. Mutations in somatic cells can be inherited
D. Mutations can be caused by one base-pair change in the DNA
E. Mutations can be caused by mistakes in DNA replication

Answer

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Mutations are random

What this means:

Mutations can be beneficial, harmful, or neutral for an organism.

The consequences of a mutation have no impact on whether that mutation will or will not occur, i.e.

- mutations are not more likely to occur because they would be beneficial to an organism;
- Nor are they less likely to occur because they would be harmful.

Fitness

New term:

Evolutionary (or Darwinian) fitness is measure of the relative reproductive success of individuals.

or

an individual's relative contribution of genotype (or phenotype) to future generations.

- individuals that pass more genes to the next generation have a higher evolutionary fitness than individuals that pass fewer genes to the next generation.

iClicker Question

Which individual has a higher evolutionary fitness:

A) A bird that lives for 2 years, but produces 5 healthy offspring each year; or

B) A bird that lives for 8 years, and produces 1 healthy offspring each year

Answer

Which individual has a higher evolutionary fitness:

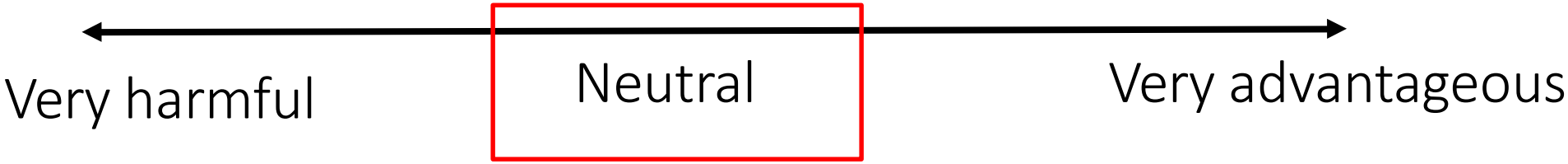
A) A bird that lives for 2 years, but produces 5 healthy offspring each year; or

B) A bird that lives for 8 years, and produces 1 healthy offspring each year

A common mistake is to think fitness is related to survivorship. Survivorship is only relevant to fitness if it affects an individual' s reproduction.

Effects of mutations

Mutations can have a wide range of effects on **fitness**:



Most mutations are neutral with respect to fitness

Most mutations are neutral re: fitness (#1 & #2)

#1 Mutations that occur in a stretch of DNA with no function is unlikely to affect the phenotype/fitness of an individual (called silent mutations).

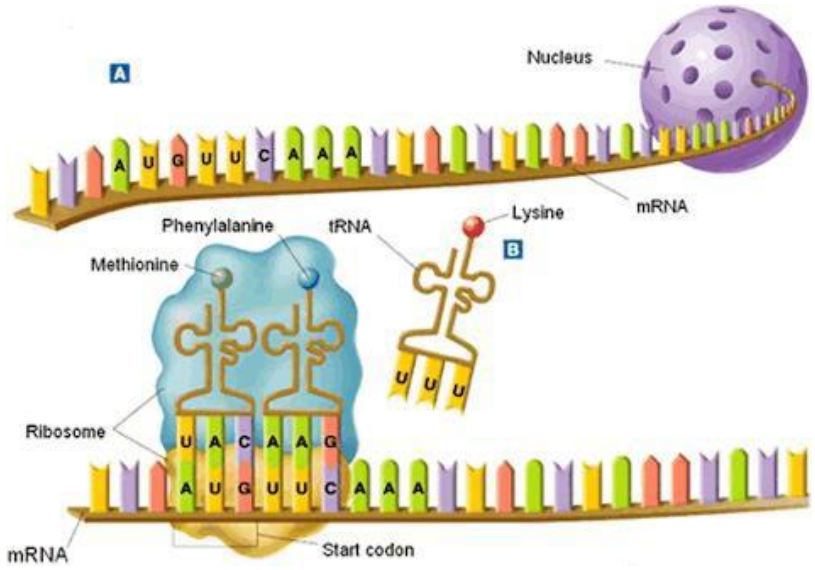
-only 2% of our DNA codes for proteins

#2 Even if mutations occur in a protein-coding region of the DNA, there may be no effect on the sequence of amino acids, and subsequently the protein function.

- This is due to redundancy in the genetic code.
- The genetic code is written in 3 letter combinations of nucleotides (codons)
- A single amino acid (the building blocks of proteins) is coded for by more than one codon.

Redundancy in genetic code

2-6 codons code for the same amino acid for most amino acids (redundancy)



First letter	Seond letter: U	Seond letter: C	Seond letter: A	Seond letter: G	Third letter
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gin	CGA Arg	A
	CUG Leu	CCG Pro	CAG Gin	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG Met	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

https://sites.google.com/site/translationchsbiology/

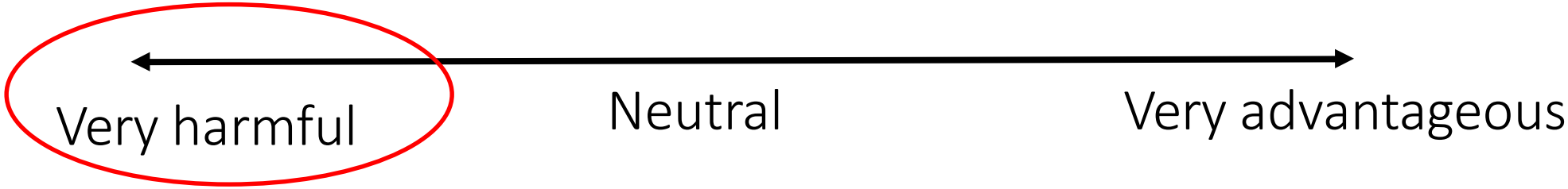
www.Wikipedia.org

Why most mutations are neutral with respect to fitness (#3)

#3 Mutations that have a noticeable phenotypic effect may not help nor harm an individual.

- For example some people have a mutation that results in cilantro tasting like soap.
- Is this mutation likely to affect an individual's survival/reproductive success?

Effects of mutations - harmful



- Harmful mutations: reduce an organism's fitness, i.e. by reducing the survival and reproductive success/fertility of an individual

For example, **cystic fibrosis** (a lethal, recessive disease) is caused by a mutation in the gene that codes for the CFTR protein. Illness affects digestive and respiratory tracts.

If interested, watch "65 red roses" on You-tube. About a young person from the lower mainland, Eva Markvoort, who died from c.f. at 25. She blogged about her experience

Cancers are generally caused by mutations that affect the cell cycle (5-20% inherited).

Harmful effects of mutations

For example, individuals that carry a mutated copies of the *BRCA1* or *BRCA2* allele have a higher risk of developing certain types of cancers (e.g. breast and ovarian cancers).

- These alleles code for a protein that helps to repair DNA.
- The mutation reduces the protein's ability to repair damaged DNA
- This may leave cells very vulnerable to DNA damage, including damage that can result in uncontrolled cell growth.

Effects of mutations - beneficial

Very harmful — Neutral — Very advantageous

- Beneficial mutations: increase an organism's fitness, by increasing likelihood of survival and reproductive success/fertility of an individual.
  - e.g., a mutation that provides better camouflage to predators and prey would be beneficial.

- DDT resistance in insects is caused by a single mutation, which helps the insects that use our crops live long enough to reproduce.

Interesting fact – not testable

- If all cells were equally are equally susceptible to mutations that can lead to cancer, then cancer risk should increase with body size (because bigger bodies = more cells).

- Based on this logic, elephants should be more susceptible to cancer than humans.

- But elephants have an overall lifetime chance of dying from cancer of <5%. For humans it is about 20%.

(=Peto's Paradox – why larger animals with .more cells do not have a higher cancer risk.)

- Why would it be lower in elephants?

Interesting fact – not testable

The *TP53 gene* codes for the protein P53 (remember "guardian of the genome").

Humans have one *TP53 gene*, with 2 alleles (one inherited from each parent).
The *TP53 gene* is mutated in most human cancers.

Having only one functional TP53 allele causes Li-Fraumeni syndrome, which is characterized by a 90% lifetime risk of cancer! Less apoptosis (death of cells with damaged DNA).

Elephants have at least 20 TP53 genes (+40 TP53 alleles).
https://academic.oup.com/mbe/article/39/7/msac149/6632613?login=true

A comparison of elephant and human cells with damaged DNA showed that elephants have significantly higher cell death rates.

https://www.nih.gov/news-events/nih-research-matters/how-elephants-defend-against-cancer

Elephants and the Zombie gene – not testable

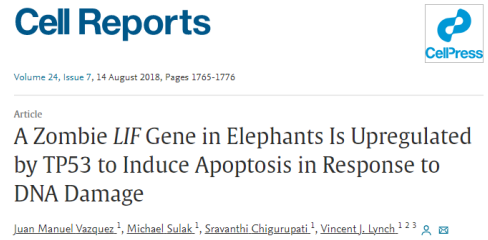
All mammals carry a gene called *LIF (Leukemia Inhibitory Factor)*

This gene is dormant/inactive in most mammals (called a pseudogene).

Researchers are speculating that this gene has been “resurrected” in elephants (hence the name Zombie gene).

Elephants possess the *LIF6* allele, which is alerted to DNA damage by the TP53 gene (I need to confirm).

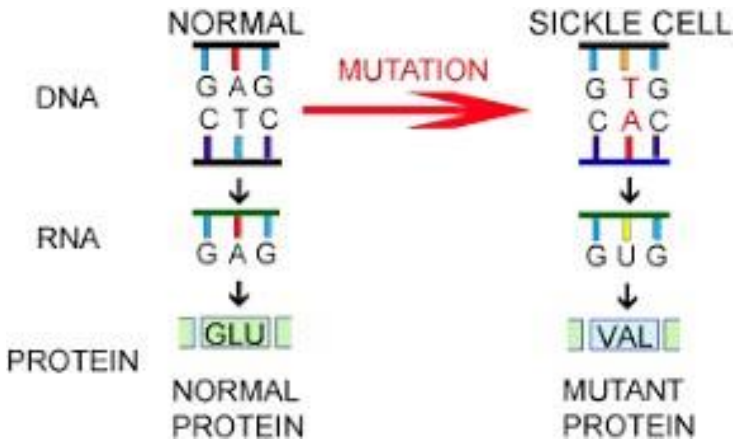
The *LIF6* gene codes for a protein that targets the mitochondria* of a cell with damaged DNA (energy power of the cell), stabbing the mitochondria multiple times triggering cell death.

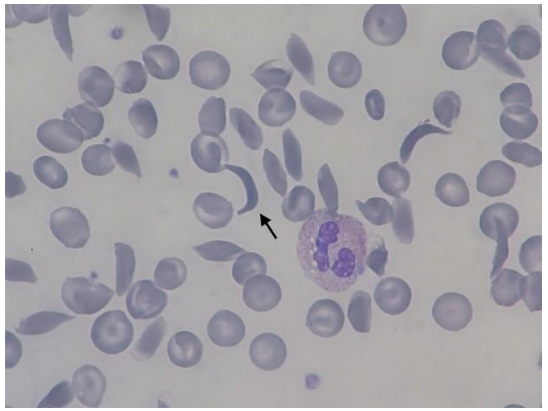


https://www.sciencedirect.com/science/article/pii/S2211124718311458?via%3Dihub

For non-neutral mutations - fitness effects can be influenced by the environment (e.g., sickle cell anemia)

- Sickle cell anemia is genetic disease caused by a recessive allele that produces abnormal hemoglobin proteins in red blood cells.



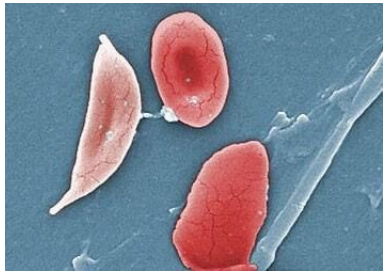


- Causes red blood cells to become sickle-shaped.

Sickle cell anemia – fitness effects affected by environment

- Reduce oxygen carrying capacity of the blood – oxygen deprivation can lead to organ damage and stroke.
- Blood cells break down prematurely, leading to anemia.

- But, carriers of the sickle cell allele (i.e. heterozygotes) are resistant to malaria, a potentially deadly disease that affects hundreds of millions of people.
- The parasites that cause malaria (*Plasmodium* sp.) die in the sickle-shaped blood cells.
- Mutant allele is beneficial in environments where malaria is common, but deleterious where malaria is rare.



Fitness effects can be influenced by environment

During the day, Kermode bears are less visible to fish (e.g. salmon) than their black counterparts.

Consequently, Kermode bears are 30% more successful at catching fish during the day than the black bears

At night, both white and black bears are equally successful at foraging.

Dr. Tom Reimchen, U.Vic.

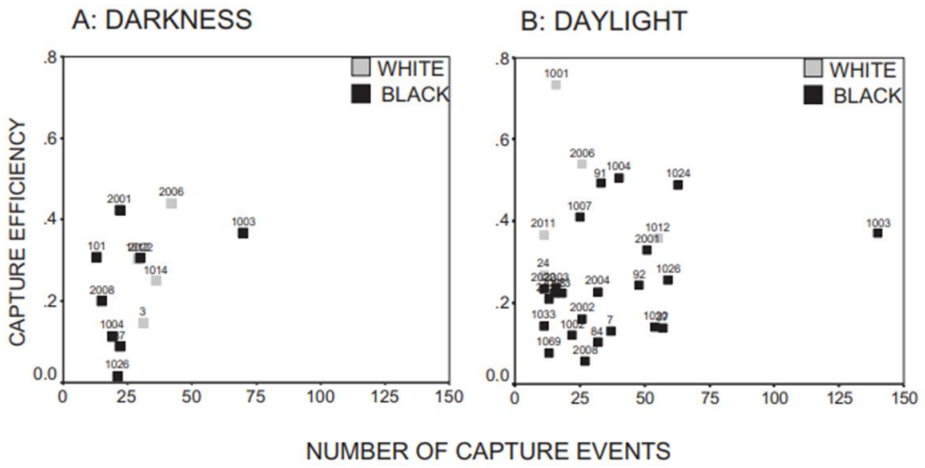


Figure 2. Salmon capture efficiency by individual black and white bears within darkness, and daylight on Gribbell Island, coastal British Columbia during the fall of 2000–2002. A, darkness. Salmon capture efficiency during darkness ($F = 0.12$, d.f. = 1, $P = 0.74$). B, daylight. Salmon capture efficiency during daylight ($F = 10.9$, d.f. = 1, $P = 0.003$).

Take home message #1 - mutation are important to evolution!

- Ultimate source of all genetic variation
- Increases genetic variation (within a population or species) by producing new alleles
- Can result in new phenotypes
- Raw materials for evolution to take place
- Without mutations, evolution could not occur

Take home message #2 – mutations are a weak evolutionary mechanism by themselves

- Most mutations are neutral with respect to fitness – they do not matter to evolution.
- Mutations only affect one individual (the individual with the mutation).
- Must occur in a germline cell to be passed on to future generations.
- It takes other evolutionary mechanisms (e.g. natural selection) to increase or decrease the new allele frequency in the population.
- Only mutations with a very strong selective advantage are likely to sweep through a population.

Mutations – Learning Objectives

Predict and explain how mutations may affect populations in terms of their genotype and phenotype frequencies through time.

Be able to explain why mutations are an essential evolutionary mechanism, but also a weak evolutionary mechanism by themselves.

5-minute break

Camel adaptation song shared by Katie ☺.

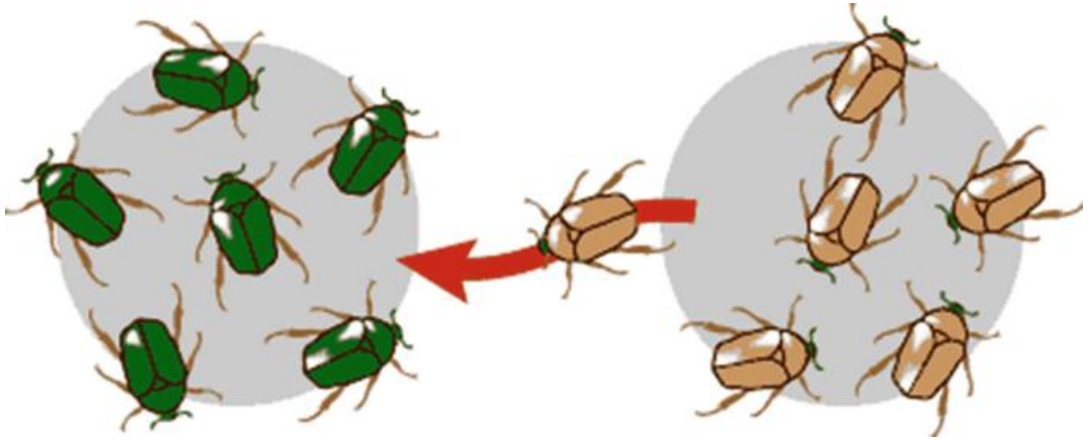
https://www.youtube.com/watch?v=YpGg-m8wyY4

Evolutionary Mechanism #2 - Gene flow

Gene flow refers to the movement of genes/alleles from one population to another.

For many animals, the movement of genes from one population to another population occurs when individuals disperse from the population in which they were born to a new population.

This often happens just before an individual reaches sexual maturity (natal dispersal) or after reaching sexual maturity (adult dispersal).



Movement of beetle carrying the allele for brown colouration into a population of green beetles.

https://evolution.berkeley.edu/evolibrary/article/evo_2 1

Gene flow

- In mammals, both males and females can disperse (e.g. to reduce the risk of inbreeding, minimize competition for limited resources with relatives).
- In the Vancouver Island Marmot, males tend to disperse more frequently (at the age of 2-3). They roam between 2 and 20 km. *https://marmots.org/about-marmots/animal-profile*

https://www.env.gov.bc.ca/wld/documents/recovery/rcvrystrat/vi_marmot_rcvry_strat_2008%20.pd

Gene flow

- In grey wolves, sex differences only occur in some populations (with males showing higher rates of dispersal).
- In other populations, females and males disperse at a similar rate.
- Gray wolf (O-54), a young 3-4 year-old female, called Journey, wandered more than 8,000 miles after leaving her pack in Oregon in search of a mate.
- Sadly, she died in California before finding a mate; so gene flow did not occur.

BIOLOGICAL REVIEWS
Cambridge Philosophical Society

Original Article | Open Access

Patterns and determinants of dispersal in grey wolves (*Canis lupus*)

Ana Morales-González, Alberto Fernández-Gil, Mario Quevedo, Eloy Revilla

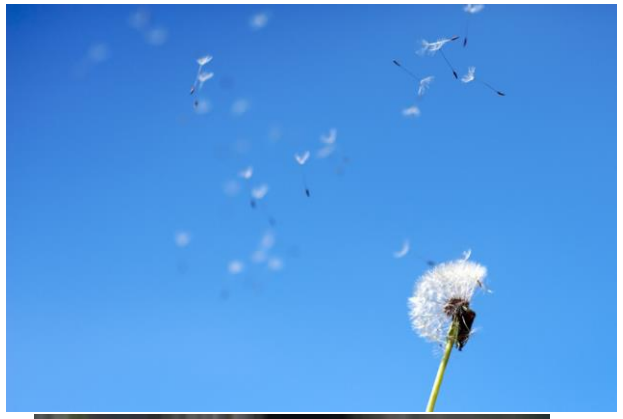
First published: 18 October 2021 | https://doi.org/10.1111/brv.12807 | Citations: 5

Gene flow

For plants that cannot move from one location to anther by themselves, gene flow occurs through processes that move either spores, gametes, and/or seeds.

For example, animals, such as birds, mammals and invertebrates (e.g. bees) may intentionally or unintentionally transfer pollen, spores or seeds from one population to another resulting in gene flow.

Air and wind may also transport gametes or individuals from one population to another.



wikicommons

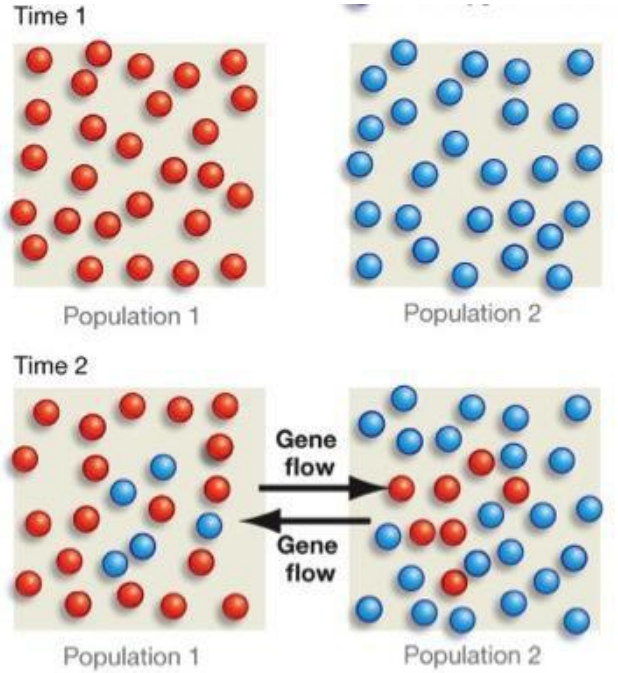
https://www.honeybeesuite.com/how-bees-transfer-pollen-between-flowers/

https://www.science.org/content/article/amazing-african-elephants-may-transport-seeds-farther-any-other-land-animal

Outcome of Gene flow – if individuals moving between 2 populations

If individuals (or gametes) from two (or more) populations are moving between populations:

- it tends to homogenizes allele frequencies
  <u>between populations</u> over time
  (i.e. make them more similar genetically).



Little or no gene flow

Restricted or no gene flow between populations can lead to the genetic divergence of the two populations (as allele frequencies are not homogenizing); and, if it persists, can lead to speciation .

Discuss in more detail in two weeks – in class on speciation.

Gene Flow – Learning Objectives

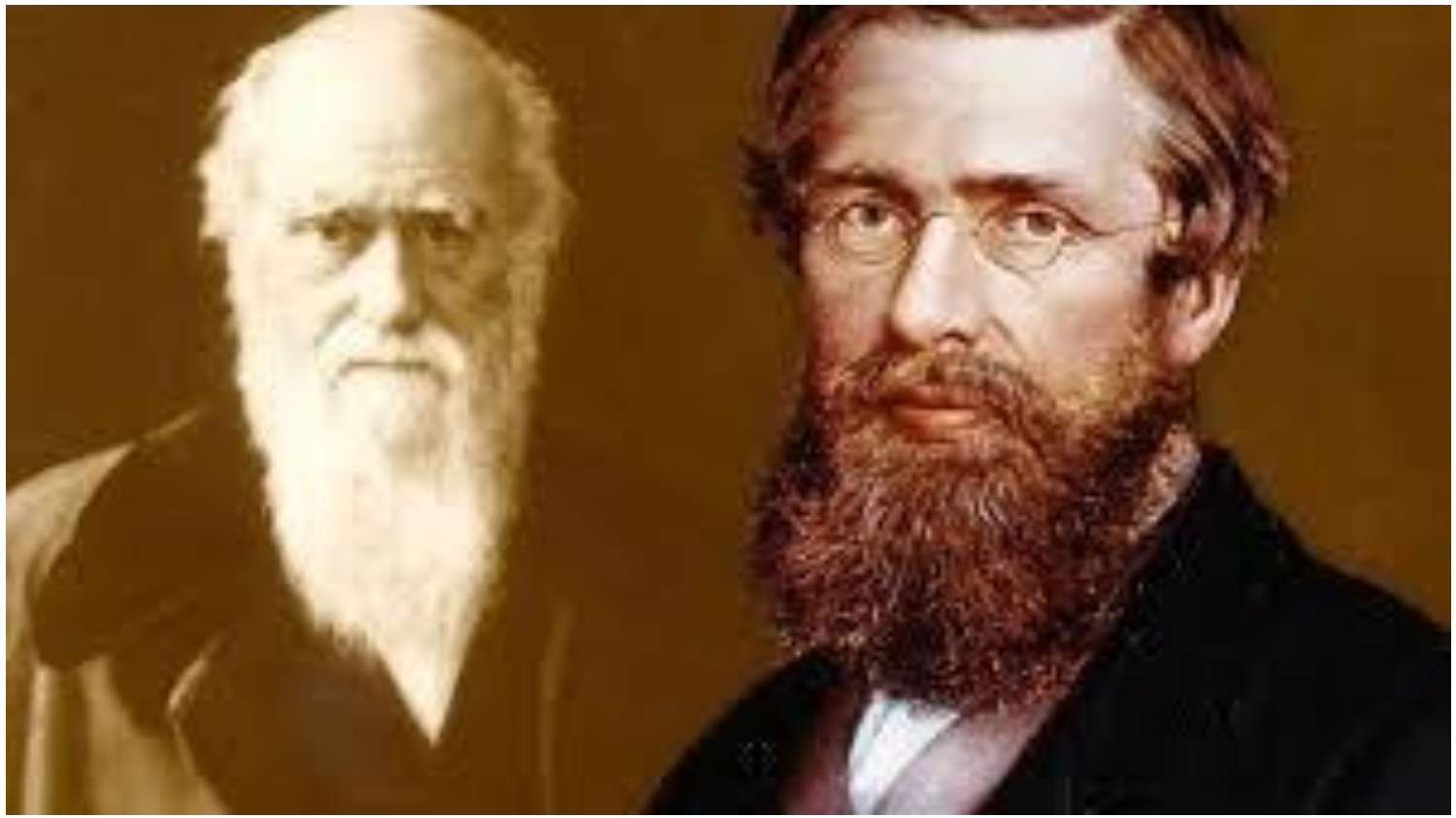
Be able to:

- Predict, explain, describe how gene flow may affect populations in terms of their allele, genotype and phenotype frequencies.
- A key point: gene flow requires that the individuals that moved to a new population need to reproduce – or allele frequencies will not be affected over generations.

Note: Mutations and gene flow are the two mechanisms that can introduce new alleles into a population.

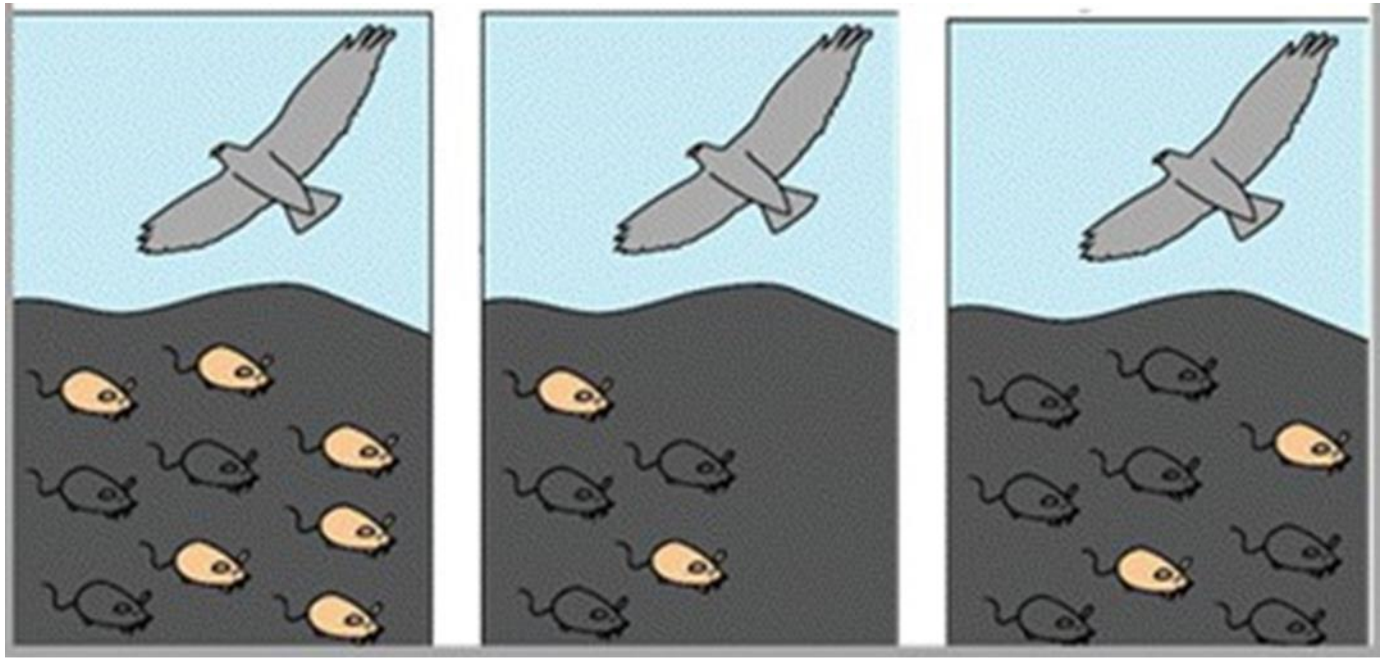
Mechanism of evolution #3 - Natural selection

Charles Darwin and Alfred Russell Wallace – introduced the idea of evolution by natural selection in the 1800's



What is natural selection?

- Natural selection refers to **non-random differences** in the survival and reproduction of individuals with certain genotypes and the associated phenotypes in a population over time (generations). (Contrast with genetic drift, which we will cover next Tuesday)



Source: unknown

3 requirements for natural selection to occur

For natural selection to occur

1. There must be **VARIATION** in trait/phenotype amongst individuals in the population.

- Natural selection acts on the phenotype of individuals
- Without variation in phenotype, natural selection cannot select one phenotype over another.

3 requirements for natural selection to occur

For natural selection to occur, there must be:

2. **DIFFERENCES IN FITNESS (survival/reproduction)** <u>associated with the difference in phenotypes</u>.

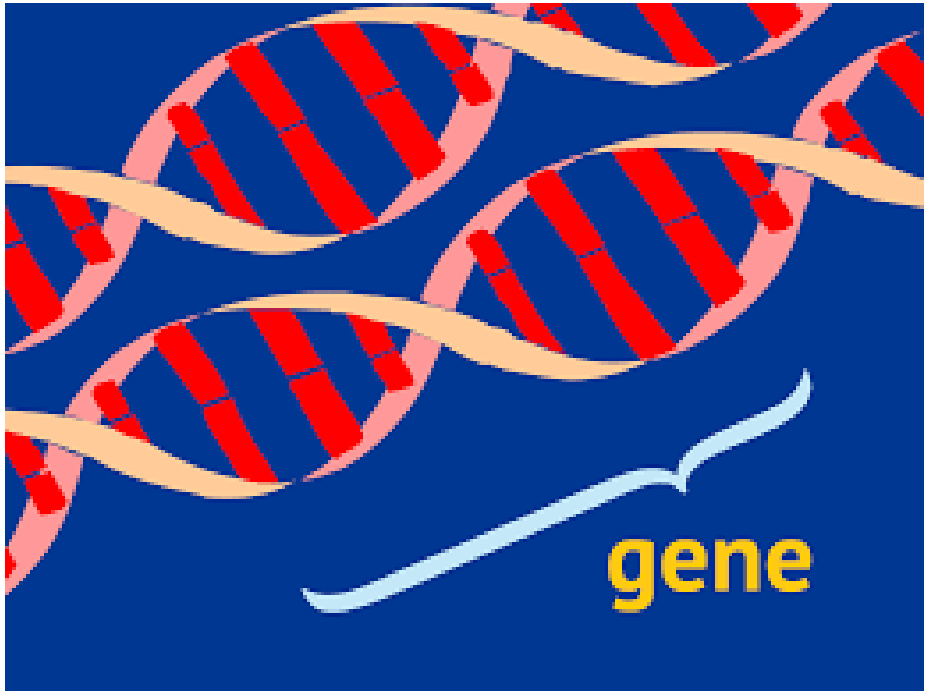
Some individuals in the population must have a phenotype that allows them to better survive/reproduce than other members of the population without that phenotype.

Even if an organism is not eaten, there may be differences in reproduction because some individuals (e.g. bigger individuals, more aggressive individuals) may be better at acquiring essential resources.

3 requirements for natural selection to occur

For natural selection to occur:

3. The **PHENOTYPE MUST BE HERITABLE** (genetic component).



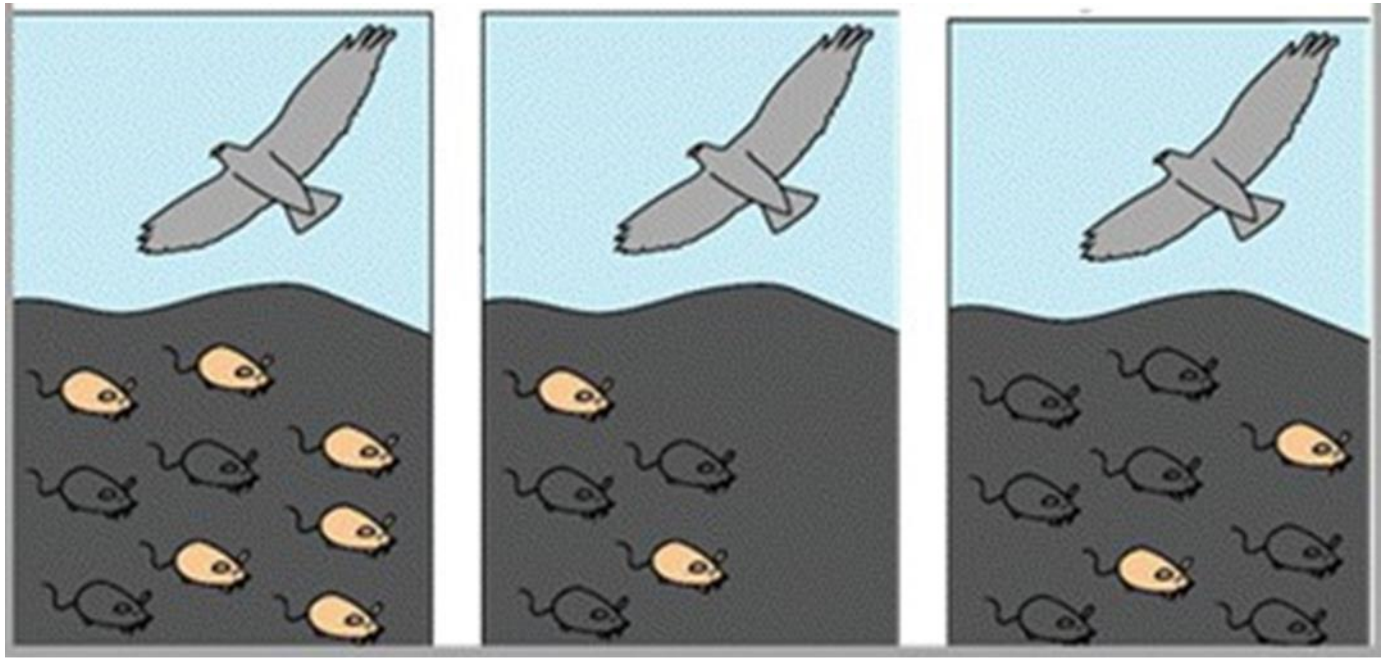
https://www.amnh.org/explore/ology/genetics/what-is-genetics

So, that the survivors or the individuals who were able to acquire more (or more optimal) resources for reproduction leave offspring with the same phenotype.

Outcome of natural selection

There will be an increase in frequency of individuals with the advantageous phenotype in the population over generations, and an increase in frequency of the beneficial allele (and a decrease in frequency of the less beneficial allele).

The population becomes more well adapted to the environment. But, if the environment changes, so can the direction of selection.



Source: unknown

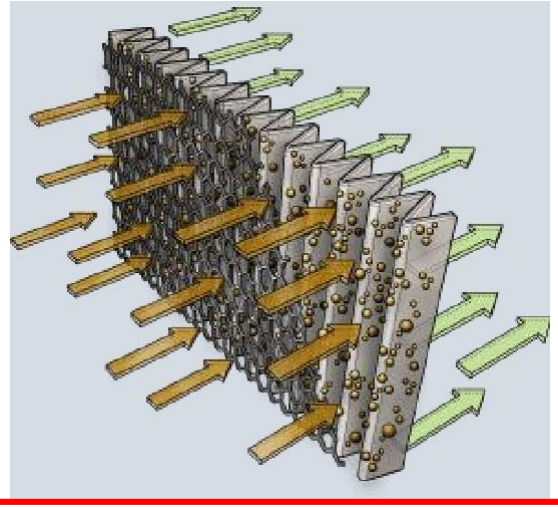
Rock pocket mouse video shown in class: https://www.youtube.com/watch?v=sjeSEngKGrg

Non-random differences in survival and reproduction

Although the origin of a new allele (via mutation) is random with respect to the fitness of an organism, the probability of that allele being passed on to the next generation is not random, if it affects the survival and reproduction of the organism with that allele.

Natural selection acts as filter between generations in a population ("shaping" the population)

Generation 1



Generation 2

- Beneficial (selected) alleles pass through the filter (i.e. beneficial alleles =those allele that increasethe likelihood of survival and reproductive successpassto the next generation)
- Undesirable alleles remain on one side (it depends, in part, on the strength/specificity of the filter/selection)
- Some alleles that are "good enough" will make it through the filter (so not a perfect filter)

Next class

- Finish natural selection – Adaptations, plus 3 modes of natural selection (directional, stabilizing and disruptive; balancing selection is beyond scope of BIO121)

- Sexual selection (a type of natural selection)
  - individuals differ in their ability to obtain a mate, which helps to determine which alleles passed to the next generation