Today – Start Evolution Unit

Topics we will cover in this Unit:

- What is Evolution?
- Evidence for evolution
- 4 mechanisms of evolution
  - mutations
  - gene flow
  - natural selection
    - sexual selection
  - genetic drift
- Hardy-Weinberg (population genetics)
- Phylogenetic Trees
- Species Concepts /Speciation

Source: Wikimedia Commons

Information Session

Date: Wednesday Feb. 17th

Time: 7:00 PM

On Zoom!

Can't make it? email questions to:
ubc_ambassador@bamfieldmsc.com

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This Sunday

No assignments are due ☺.

iClicker Question– Midterm #1

iClicker Question – Finishing midterm #1

A. I finished with more than 5 minutes to spare
B. I finished with less than 5 minutes to spare
C. I did not finish – I needed 1 min – 5 min more
D. I did not finish – I needed 5 min – 10 min more
E. I did not finish – I need more than 10 min.

After the exams are marked, Brett and I will meet to discuss the exam.

At the moment, up to 5% of midterm #1 will be transferred to the final exam for every student that does better on the final exam than midterm #1

Group for the group project…

Group project – 10% of final grade

An opportunity for everyone to explore a topic in biology of particular interest to that individual

- also a way for me to reduce weight of exam mark ☺.

Examples of topics in the past:

- Human conditions (e.g. Alzheimer's, Hemophilia, Muscular Dystrophy)
- Technology (e.g. CRISPR, GMOs)
- A particular species (e.g. fainting goats)
- A particular phenomenon (e.g. bioluminescence, low cancer rates in elephants, communication amongst trees via fungi).

- Over Reading Week I will post some examples from last term.

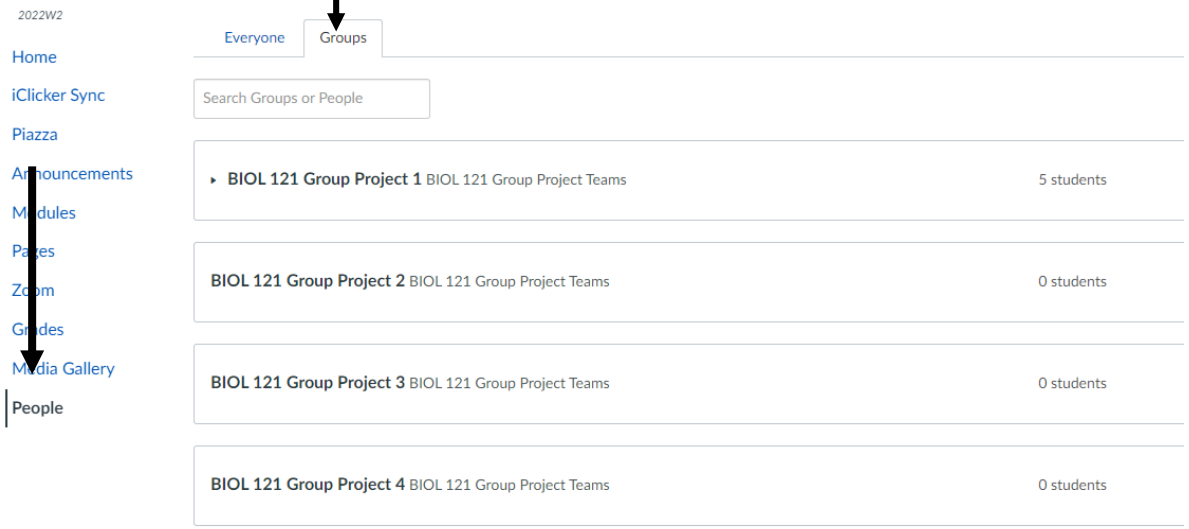
How to sign team up on Canvas

I will try to leave some time at the end of class to help people still looking for groups.
You can also post on Piazza. (Please think about what topic you might be interested in.)

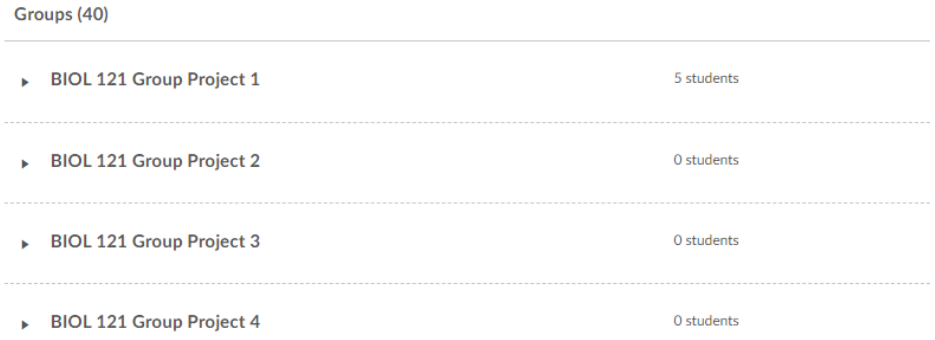
Short Canvas survey (team member names, chosen topic) is not due until February 26th.

Project itself is not due until March 26th.

Teams please sign up on Canvas > People > Groups



Choose a group with no people
- First person to sign up will be "leader"
- Change the number to something memorable ☺.



Organism of the Day – Rubber boa – *Charina bottae*

- The Rubber Boa is the only boa native to Canada
- They are small snakes (<70 cm long)
- Typically brown, with a lighter ventral (bottom) surface
- Not venomous, not aggressive
- Primarily found in low elevation mountainsides
- They have small eyes, with elliptical pupil
- They are largely fossorial (underground) existence
- In the summer, they are most active at night (primarily eat small rodents)

https://linnet.geog.ubc.ca/efauna/Atlas/Atlas.aspx?sciname=Charina%20bottae

Bonus question on the Evolution midterm will be about an Organism of the Day

https://commons.wikimedia.org/wiki/File:Charina_bottae.jpg

https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/northern-rubber-boa-2016.html

Rubber boa

- They have a tail that looks like their head.
- Skeleton is enlarged at the tail tip
- When threatened, they will curl into a ball, hide their head and raise their tail.

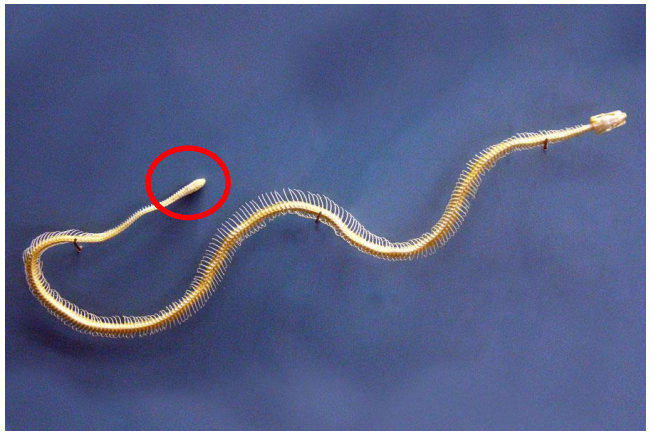
https://lpfw.org/our-region/wildlife/southern-rubber-boa/

https://www.deschuteslandtrust.org/news/blog/2017-blog-posts/little-boa-of-the-northwestern-woods

Could having a tail that looks like a head be an adaptation?

Adaptation = a heritable, functional trait that helps an organism to survive and/or reproduce.

Favoured by natural selection (to be discussed next week).



https://californiaherps.com/snakes/images/cbottaeskeletonnmnh314.jpg

Rubber Boa

- They also have vestigial remnants of a pelvic girdle and femur called spurs
- Not attached to the spine – float in muscle
- May be used during courtship

We will discuss vestigial traits as evidence of evolutionary change a bit later today.

Not a rubber boa!

https://en.wikipedia.org/wiki/Pelvic_spur

Evolution Unit

Pikaia from the Burgess Shale – earliest known Chordate (~500 million years old). Ancestor to humans?

https://commons.wikimedia.org/wiki/File:Pikaia_Burgess_Mus%C3%A9um_Grenoble_03082017.jpg

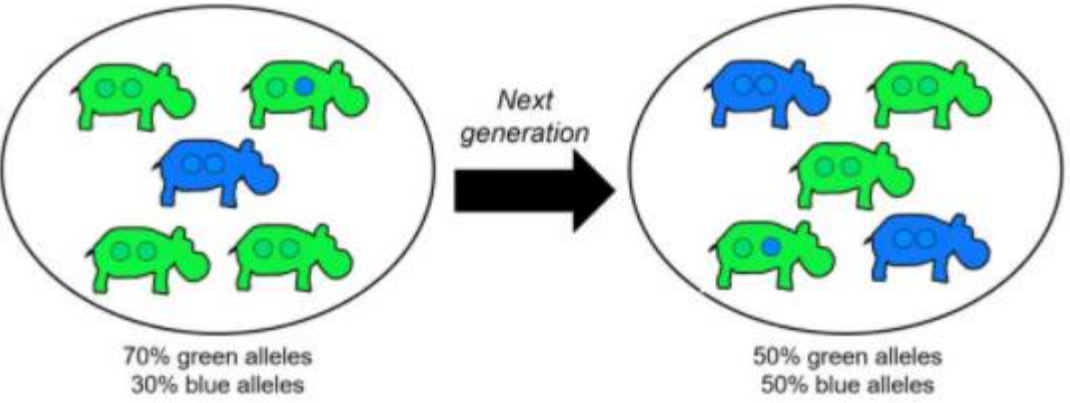
What is evolution?

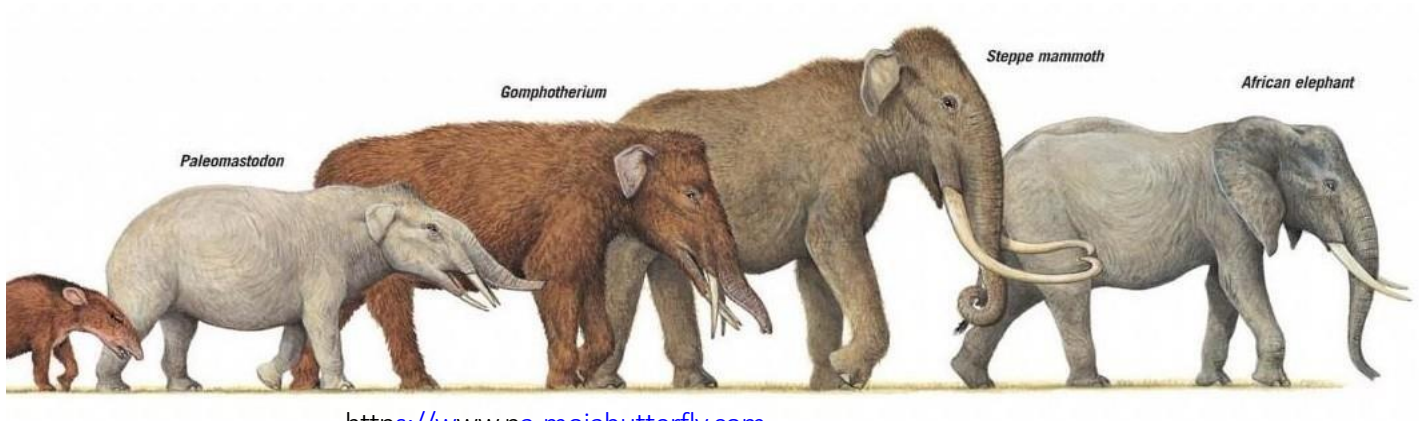
Biological Evolution = refers to a change in the (heritable) characteristics of a POPULATION over GENERATIONS.

2 categories of evolution

Microevolution

Macroevolution

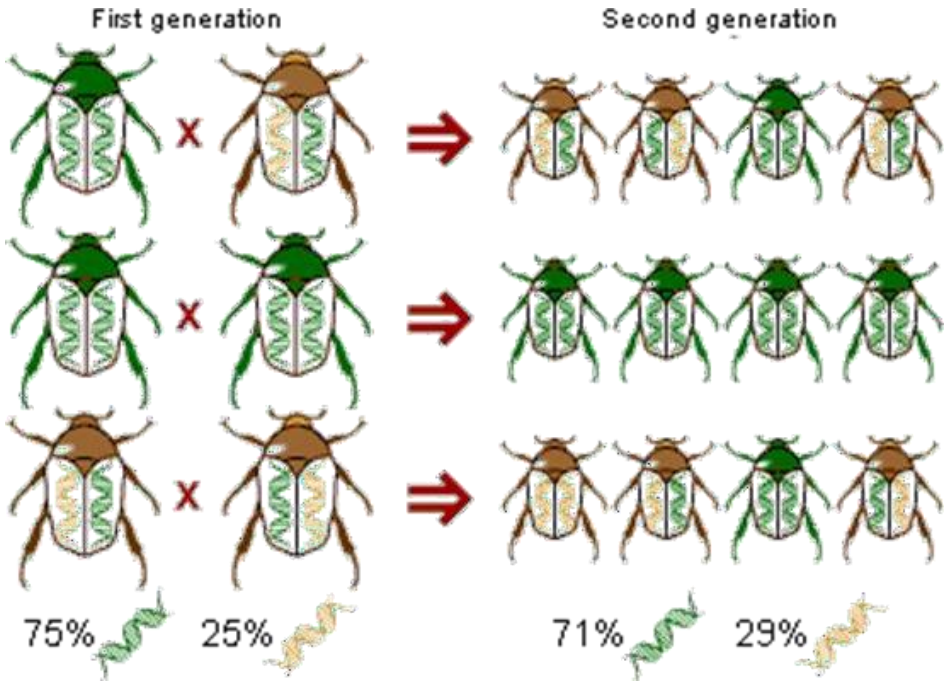




https://www.pa-mojabutterfly.com

Microevolution

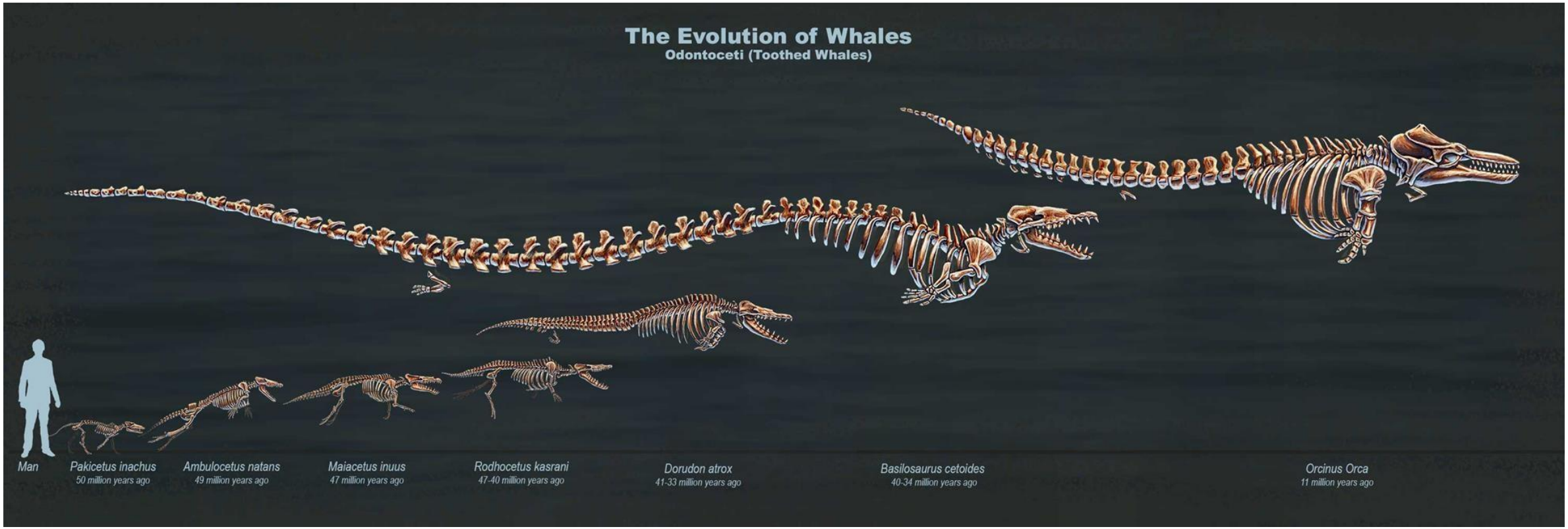
Changes in allele frequencies in a population in a relative short period of time (e.g. one generation)



http://evolution.berkeley.edu/evolibrary/images_pamphlets/micro_mech_3.gif

Macroevolution

Evolution that occurs at or above the species level, e.g. how do new species arise? Typically occurs over longer periods of time (millions of years).



The concept that populations evolve is relatively new

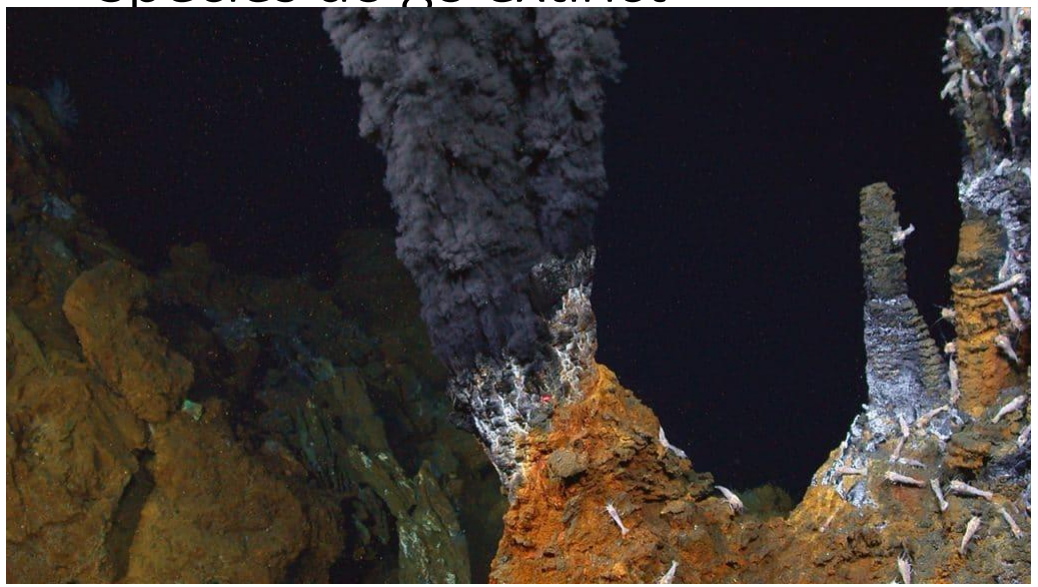
- Only 200 years ago people believed that
  - "species" were:
    - Not related to each other
    - eternal (no extinction)
    - unchanging
    - variations (within species) were oddities

- Ideas articulated by Plato & Aristotle

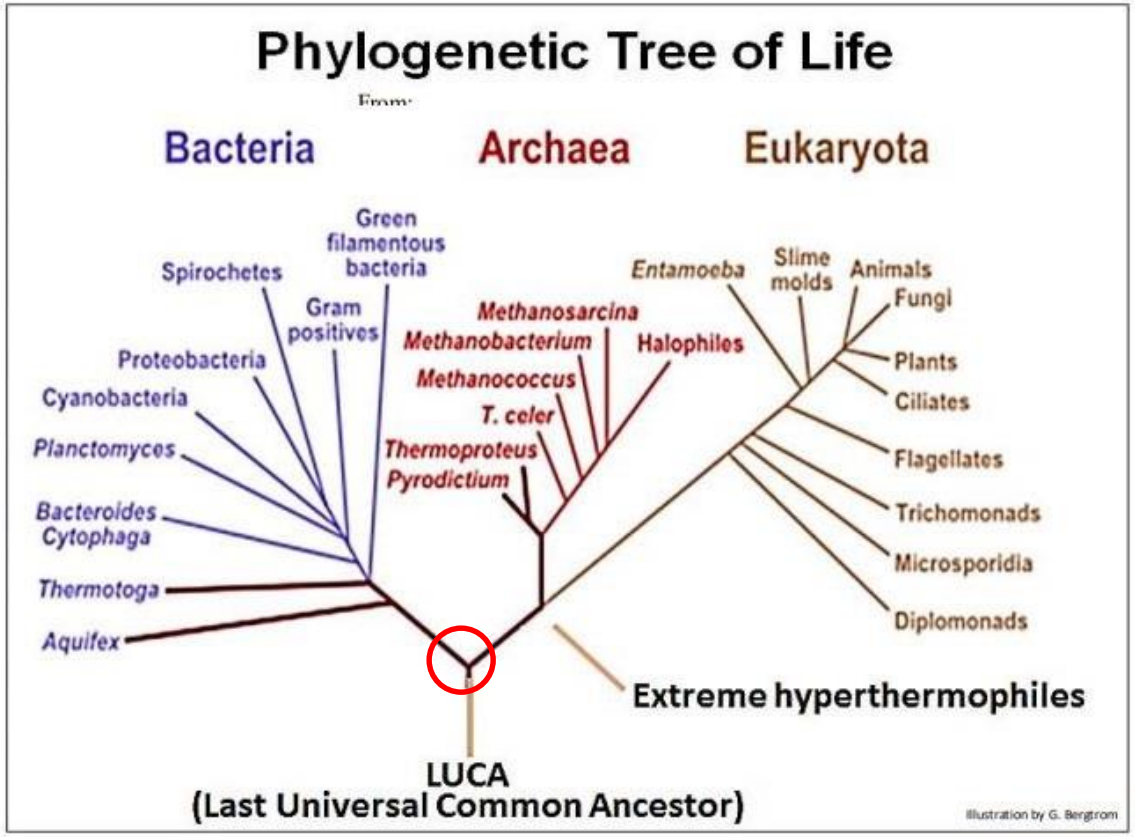
  - more than 2,300 year ago.

Scientists now believe that

- All species are related
  - Current theory - we all descended from a single celled common ancestor (LUCA) that existed about ~ 3.7 billion years ago.
- Species change through time
- Species do go extinct



https://www.whoi.edu/know-your-ocean/ocean-topics/seafloor-below/hydrothermal-vents/



Evolution – 3 Learning Goals for Today

Be able to explain and support, with examples or evidence, that:

1. All organisms are descended from LUCA (Last Universal Common Ancestor);
2. Organisms are related to each other (or share common ancestry)
   – homologous structures (structure, developmental, genetic); and
3. Species/populations change over time.

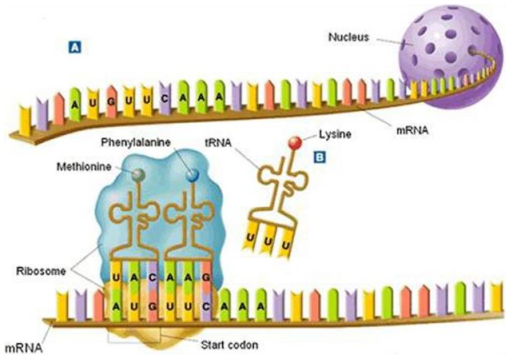
What features/traits do you, earthworms, cedar trees, bacteria, etc. share in common that could be used as evidence that at some point in evolutionary history you are all descendants of a universal common ancestor?

Evidence that ALL species share a common ancestor

- All living taxa are made of cells
- Universality of DNA as the genetic code
- Universal flow of biological information, DNA to RNA to amino acids/proteins
- Near universality of the genetic code (codons) and DNA replication and repair

The fact that we share a common ancestor is the reason why we can, e.g.

- use bacterial gene editing system to edit our own genon
    - insert the jellyfish gene that codes for a protein that green light into a cat.



Seond letter

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

Evolution – 3 Learning Goals for Today

Be able to explain and support, with examples or evidence, that:

- All organisms are descended from LUCA;
- Organisms are related to each other (or share common ancestry)
  – homologies (structural, developmental, genetic); and
- Species/populations change over time.

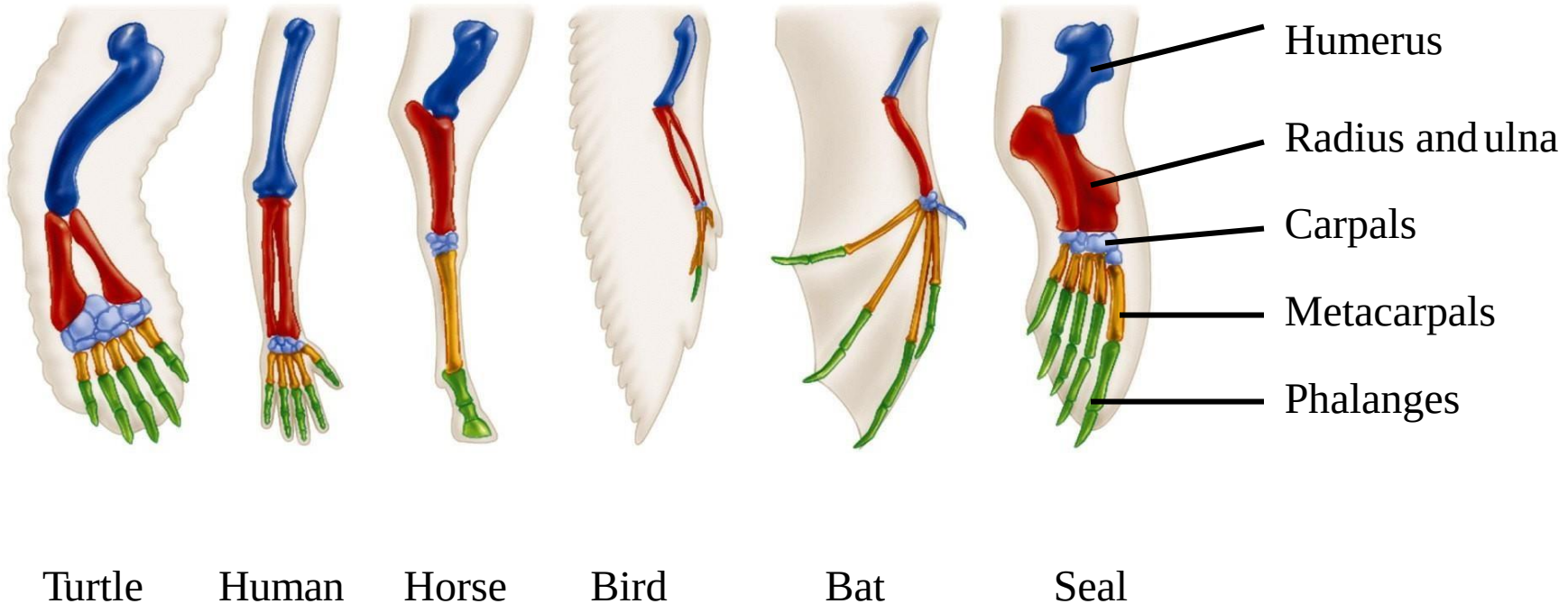
Evidence of evolutionary relatedness: homologies

- Homologies

  are traits present in two or more organisms that were inherited from their common ancestor

  - Anatomical/structural homologies
  - Developmental homologies
  - Genetic homologies

i. Anatomical/Structural homologies



The forelimb bones in these six taxa are considered homologous because they were inherited from a common ancestor that also had these bones.

Beaty Museum – Blue Whale

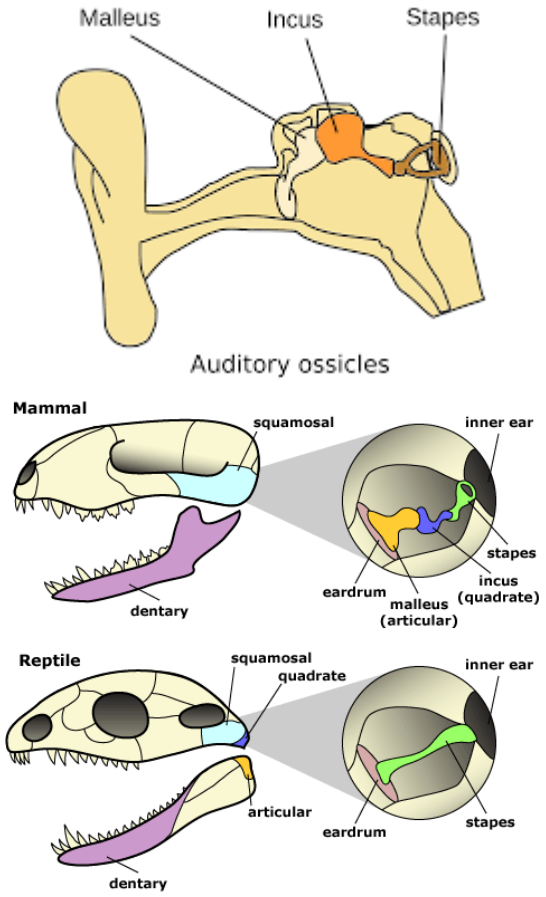
A point about homologous structures

Homologous structures may or may not be modified in different taxa, so:

- homologous structures may not look the same (although they often do)
- nor may they have the same function in different taxa.

Structural homologies – may differ in form and function

For example, developmental research suggests that two of the inner ear bones of mammals (malleus and incus) are homologous to the quadrate and articular bones in the upper/lower jaws of other non-mammalian vertebrates.



https://www.zoology.ubc.ca/~millen/vertebrate/Bio204_Labs/Lab_3__Skull.html

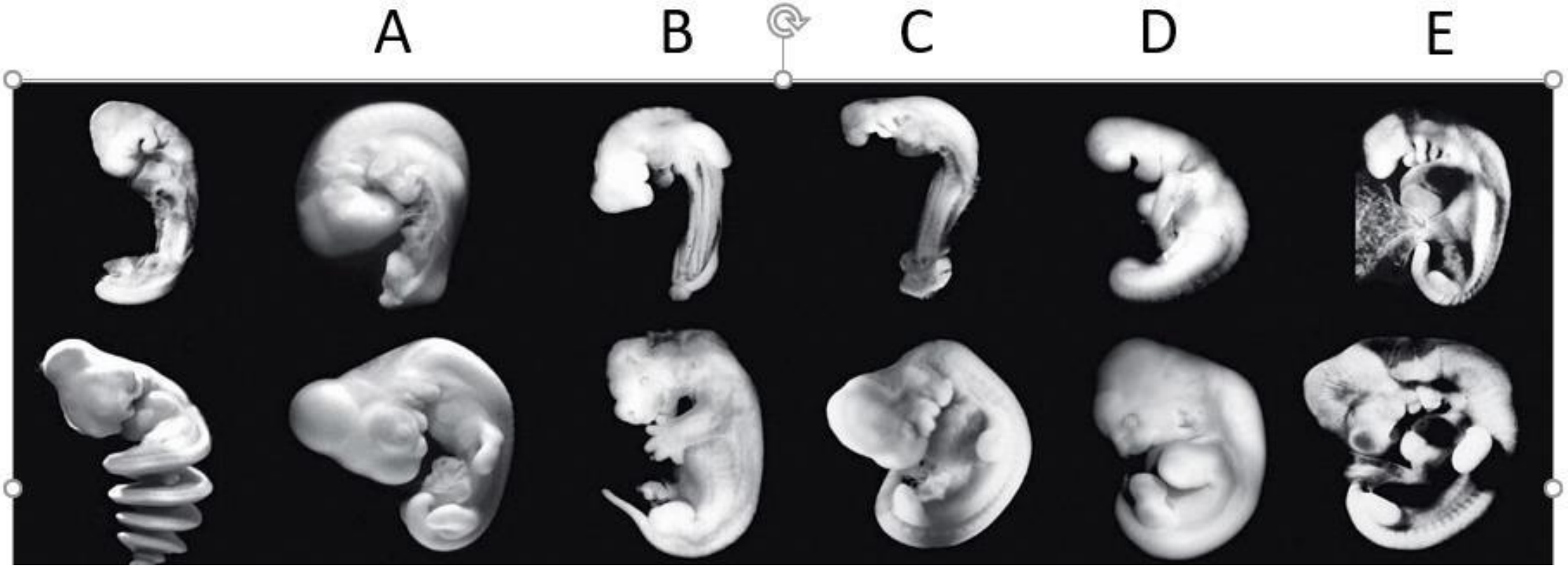
I will not test you on these bones. This is more of a BIOL204 question.

I just want you to understand that structures with different functions may be homologous, if they were inherited from a common ancestor

ii. Developmental homologies – iClicker question

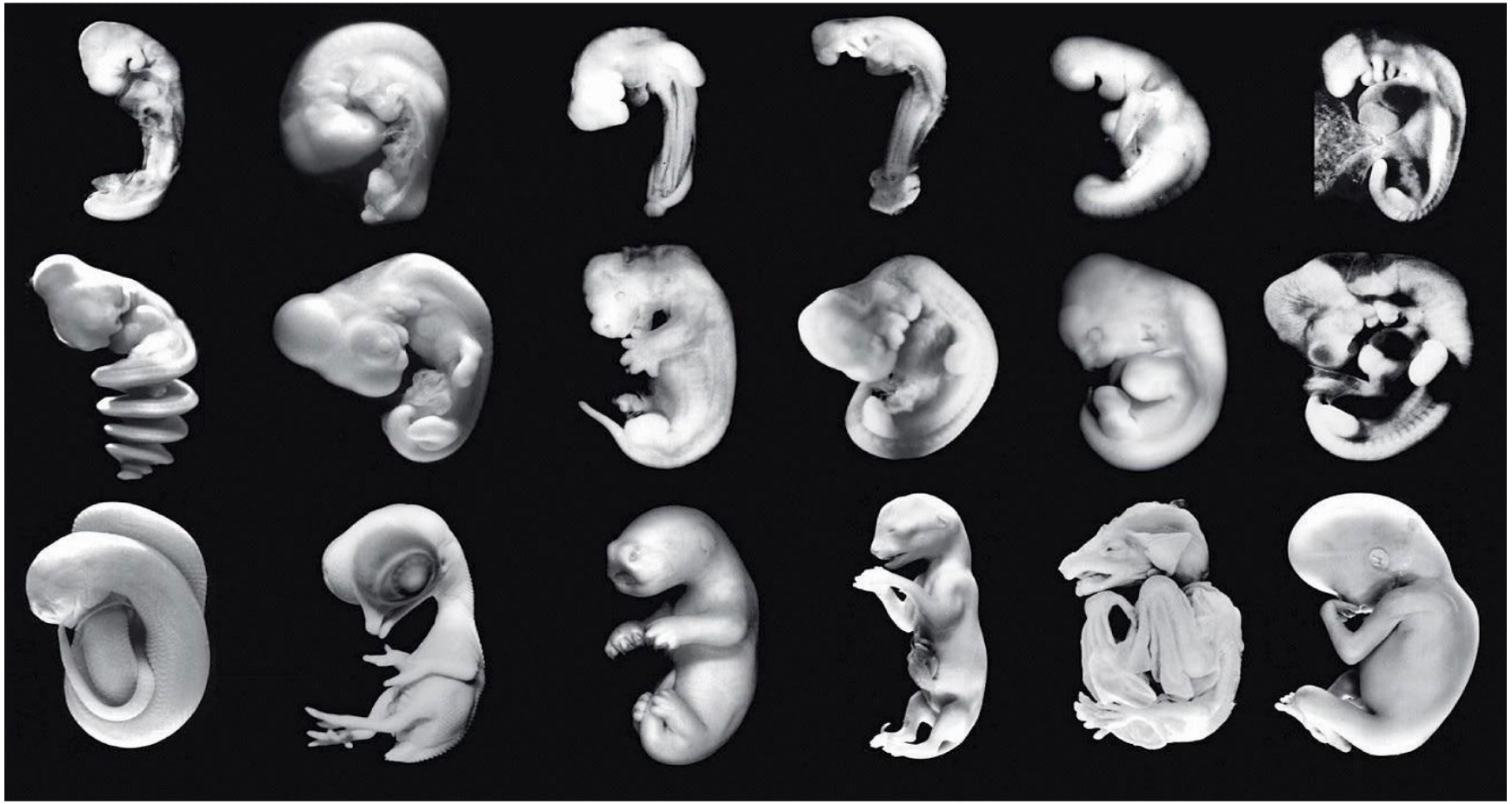
Developmental similarities between organisms during early embryonic stages (due to inheritance of developmental processes from a common ancestor)

Which individual is a human: A, B, C, D, or E?



Developmental homologies

Snake **Chicken** **Opossum** **Cat** **Bat** **Human**



We had gills and a tail during development = developmental homology that we share with, e.g. cats and chickens

iii. Genetic Homologies

Genetic similarities between organisms due to common ancestry.

Humans & Chimpanzee DNA is about 99% the same

Humans & Mouse protein coding regions 85% identical

https://www.genome.gov/10001345/importance-of-mouse-genome#:~:text=On%20average%2C%20the%20protein%2Dcoding,are%20only%2060%20percent%20identical.

Mouse *Pax6* gene:

GTATCCAACGGTTGTGTGAGTAAAATTCTGGGCAGGTATTACGAGACTGGCTCCATCAGA

Fly *eyeless* gene:

Genetic similarity to mouse: 76.66%
Protein similarity to mouse: 100%

GTATCAAATGGATGTGTGAGCAAAATTCTCGGGAGGTATTATGAAACAGGAAGCATACGA

Shark eye control gene:

Genetic similarity to mouse: 85%
Protein similarity to mouse: 100%

GTGTCCAACGGTTGTGTCAGTAAAATCCTGGGCAGATACTATGAAACAGGATCCATCAGA

Squid eye control gene:

Genetic similarity to mouse: 78.33%
Protein similarity to mouse: 100%

GTCTCCAACGGCTGCGTTAGCAAGATTCTCGGACGGTACTATGAGACGGGCTCCATAAGA

Flatworm eye control gene:

Genetic similarity to mouse: 71.66%
Protein similarity to mouse: 100%

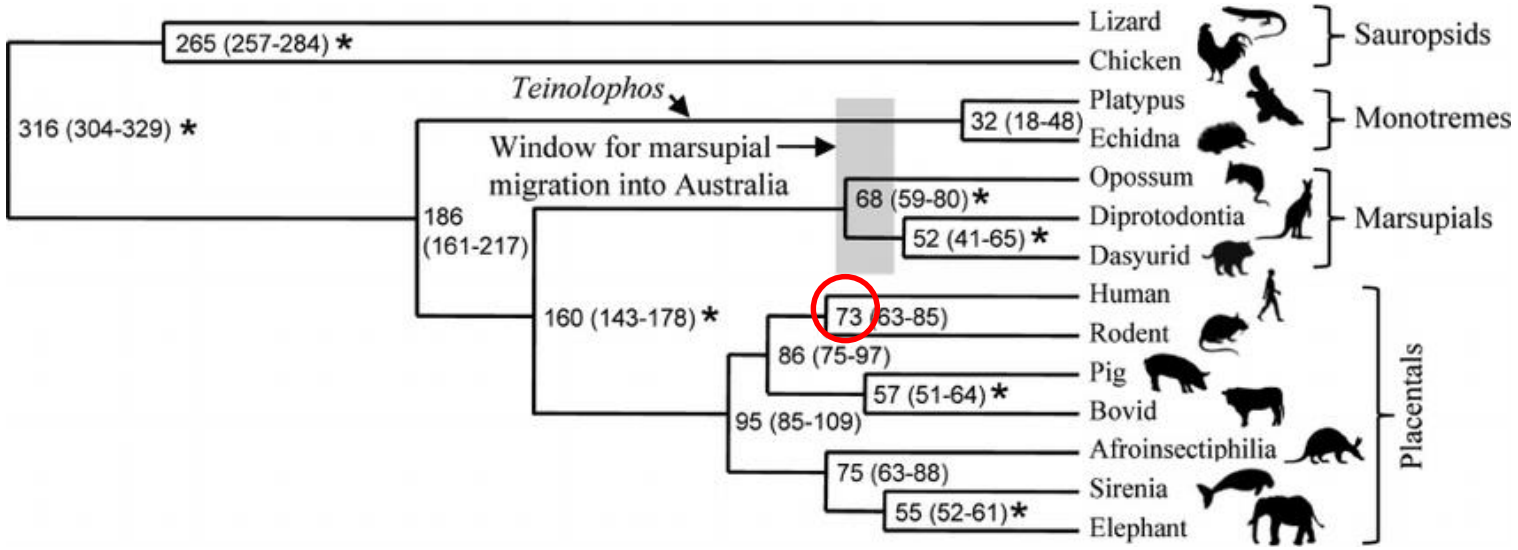
GTGTCTAATGGTTGTGTTAGTAAAATACTTTGCCGATATTATGGAACAGGTTCTATTAAA

Pax6 gene involved in the development of the eye +

Shared ancestry allows us to study other organisms and apply that knowledge to help us...

- As you probably know, mice and rats are used a model organisms for biomedical research (e.g., to study of diseases/effects of vaccines, etc.)

- Although we last shared a common ancestor about 73 mya, the anatomy, physiology and genetics of mice and rats are still very similar to humans. Therefore, we can extrapolate results from these studies.



https://www.researchgate.net/figure/Time-scale-of-mammalian-evolution-in-Ma-as-median-and-95-HPD-estimates-from-BEAST_fig1_26871276

iClicker Question

Not all traits that look the same and have the same function are necessarily inherited from a common ancestor.

- Do you think the stream-line shape and fins of Orca and sharks are homologous?

A. Yes

B. No

C. Not sure

iClicker Question

- Not all traits that look the same and have the same function are necessarily inherited from a common ancestor.

- Do you think the stream-line shape and fins of Orca and sharks are homologous?

A. Yes

B. No

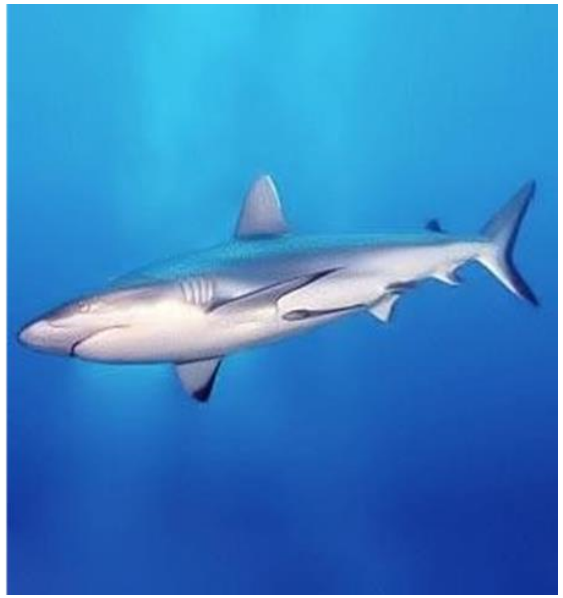
C. Not sure

- Whales and sharks did not inherit these traits from a common ancestor (whale ancestor was terrestrial).

Analogous traits or homoplasies

- Analogous traits or homoplasies arise due to **convergent evolution (testable)**, i.e. independent solution to an environmental demand – not inherited from a common ancestor

- The streamlined shape and fins represents a similar solution to the same environmental demand (moving efficiently through the water).



Break time (4 min.) – can you see find the rabbit?

Evolution – 3 Learning Goals for Today

Be able to explain and support, with examples or evidence, that:

- All organisms are descended from LUCA;
- Organisms share common ancestry (i.e. more recent ancestor than LUCA)
  – homologous structures (structural, developmental, genetic); and
- Species/populations change over time (i.e. evidence for evolutionary change).

Evidence of evolutionary change through time

Evidence:

a) Extinctions – In the past (fossils) and today

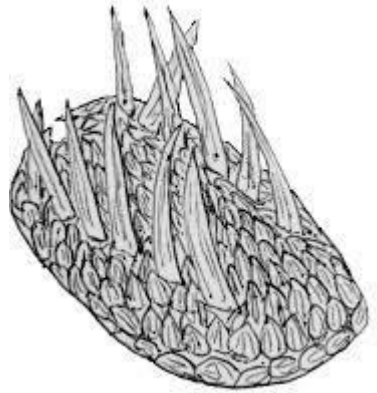
b) Transitional features

c) Vestigial traits

d) Real time evidence of change

a) Evidence of evolutionary change through time – extinction

So species not static, immutable



A 110 million year old nodosaur fossil from the Fort McMurray area

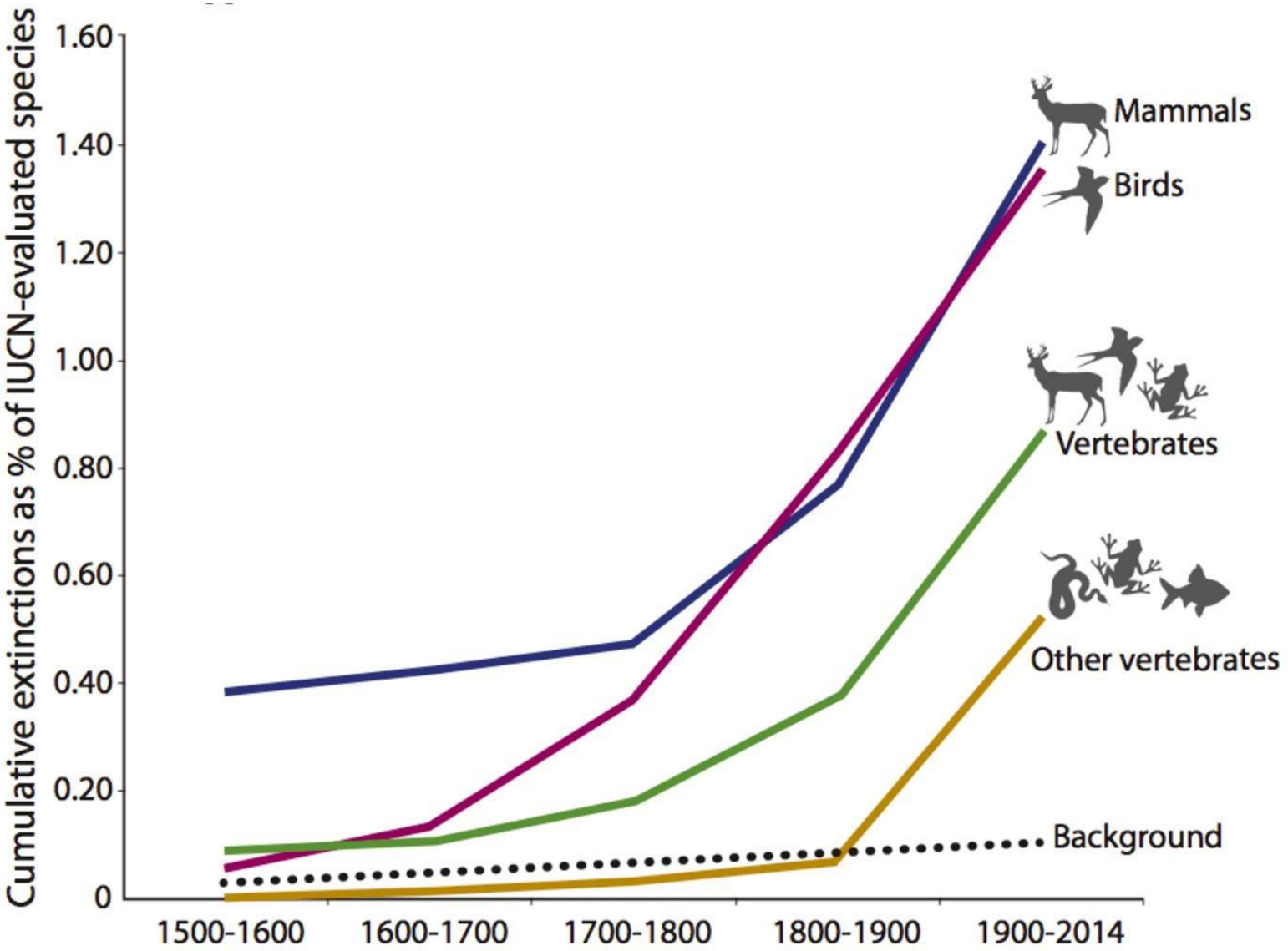
http://www.cnn.com/2017/05/14/americas/perfect-dinosaur-fossil-alberta-canada-museum-trnd/index.html

Extinctions still happening today

Sudan, the last male northern white rhinoceros and his caretaker,
Mr. Joseph Wachira. Sudan died in 2018

https://time.com/5482842/time-top-10-photos-2018-sudan-northern-white-rhino/

Evidence strongly suggests that we are in a mass extinction event – human caused



https://www.iflscience.com/plants-and-animals/earth-s-sixth-mass-extinction-has-begun-new- study-confirms/

b) Evidence of evolutionary change through time - transitional features

Transitional features = trait in a fossil species that is intermediate between those of ancestral (older) species and derived (younger species).

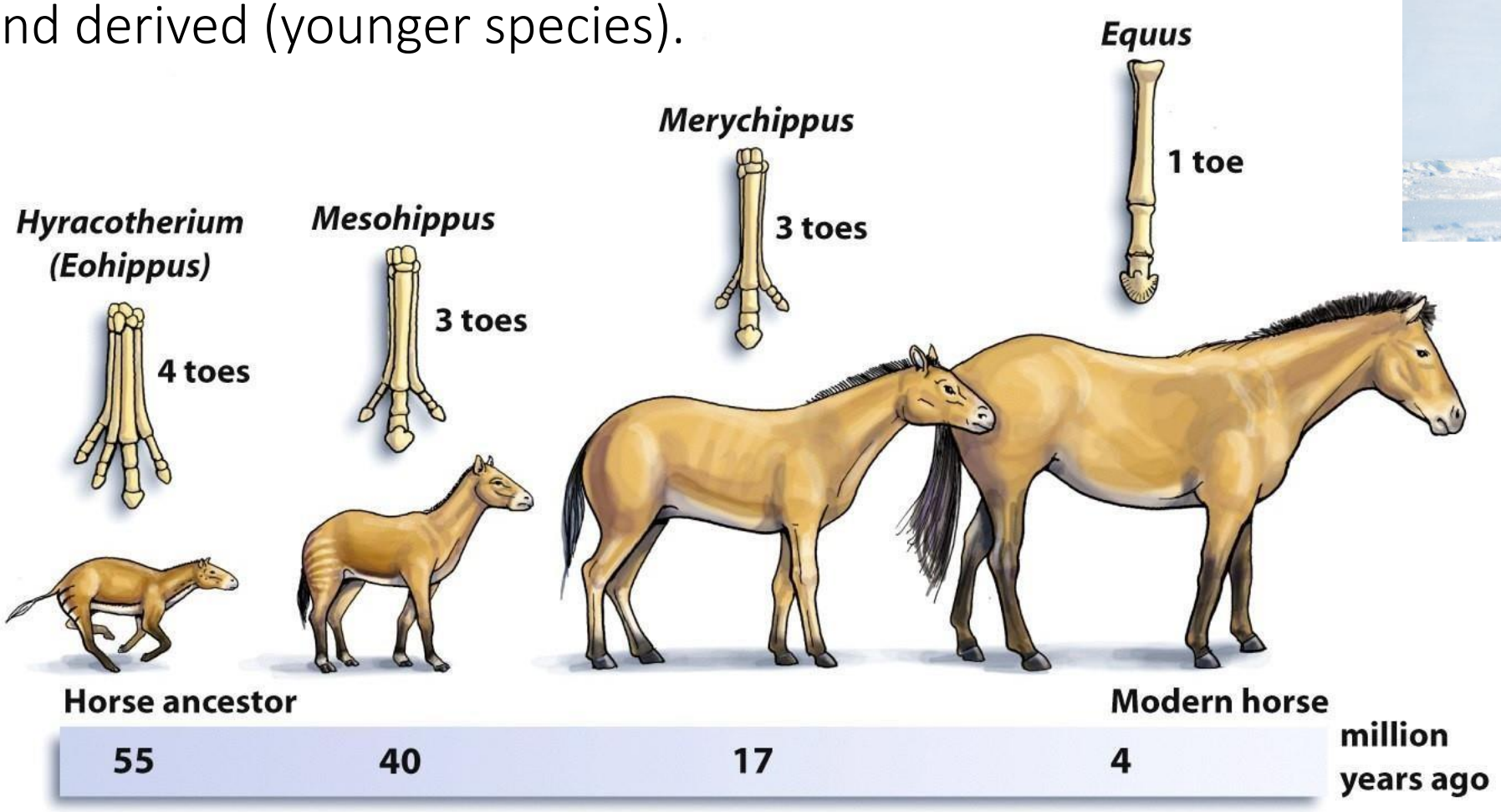
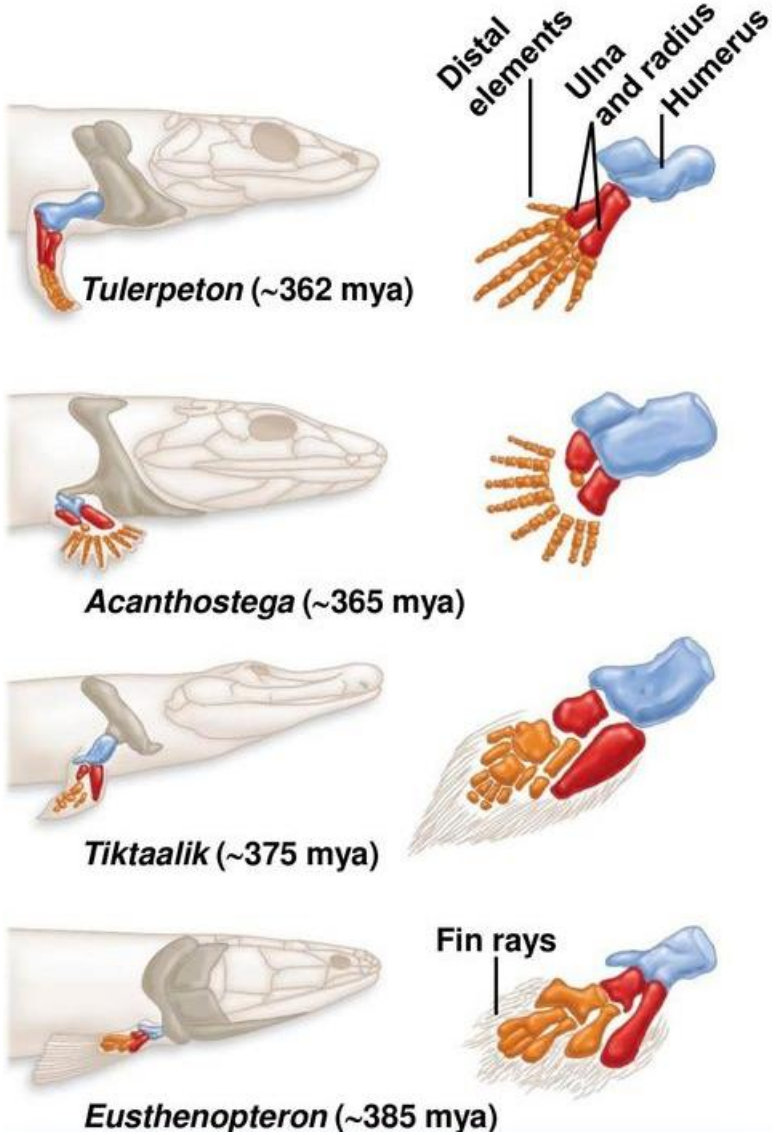


Figure 9-28 Biology: Science for Life, 2/e

Transitional features during the evolution of the limbs in horses (e.g. change in number of toes over 55 million years)

Transitional features in the evolution of the forelimb

Time



Semi-aquatic

Gradual change from fins in aquatic organisms to limbs in terrestrial organisms.

Aquatic

From your textbook, page 451

c) Evidence of change through time - vestigial structures

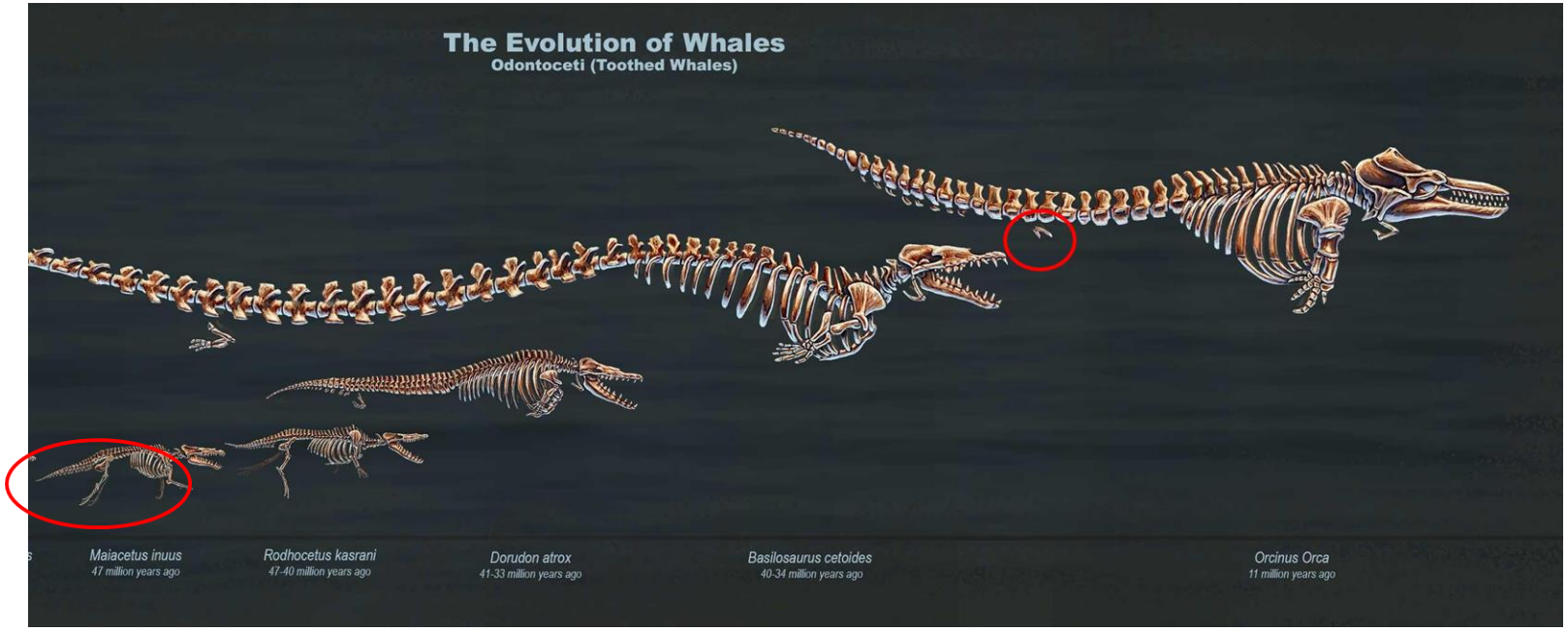
Vestigial structure = structure that was inherited from an ancestor that now has no function or has reduced function

- Form when a lineage experiences a different set of selective pressures than its ancestors

(e.g. 50 million years ago the ancestor of whales was terrestrial and required a functioning pelvic girdle to support body weight; but modern whales are aquatic, and no longer need a means to support weight of body; so in whales the pelvic girdle is a vestigial trait (may play some function as a site for muscle attachment).

- Vestigial structures are homologous to fully functioning structures in related lineages.

(e.g. The vestigial hip bone is whales is homologous to a bone in your pelvic girdle)

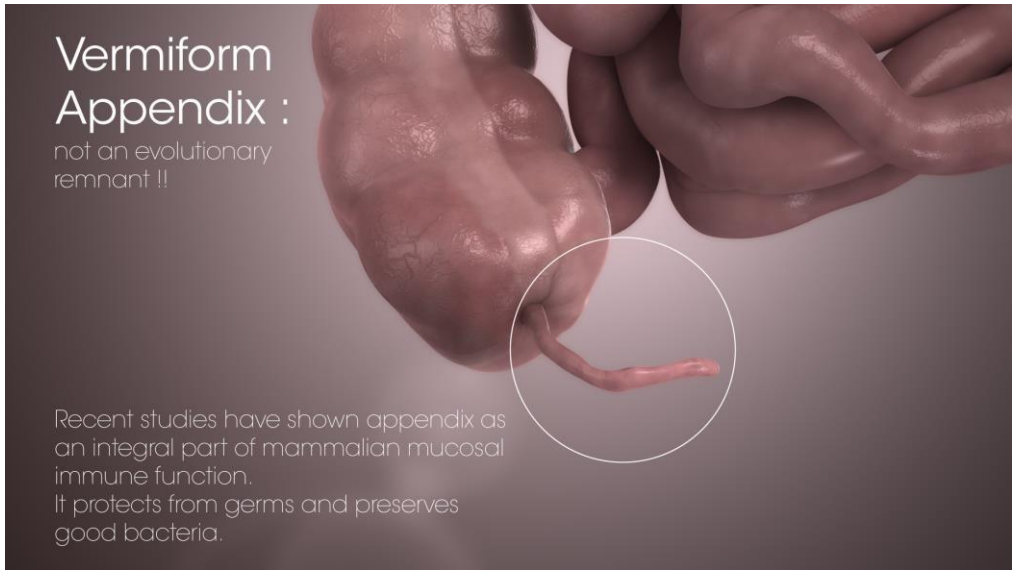


Evidence of change through time - vestigial structures

https://www.reptilefact.com/rubber-boa.html

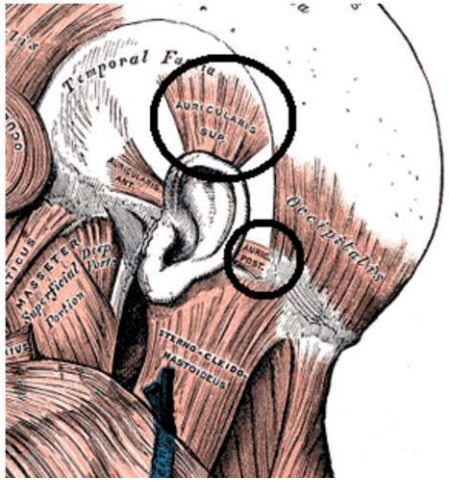
Remnants of pelvis and femur

Vestigial structures – in us



Human Appendix (semivestigial)

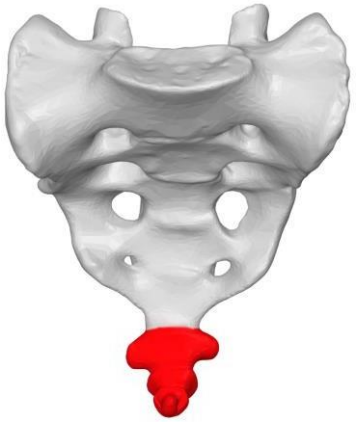
https://www.scientificanimations.com/human-appendix-vital-organ-or-ticking-time-bomb/



Ear muscles to change direction of ears

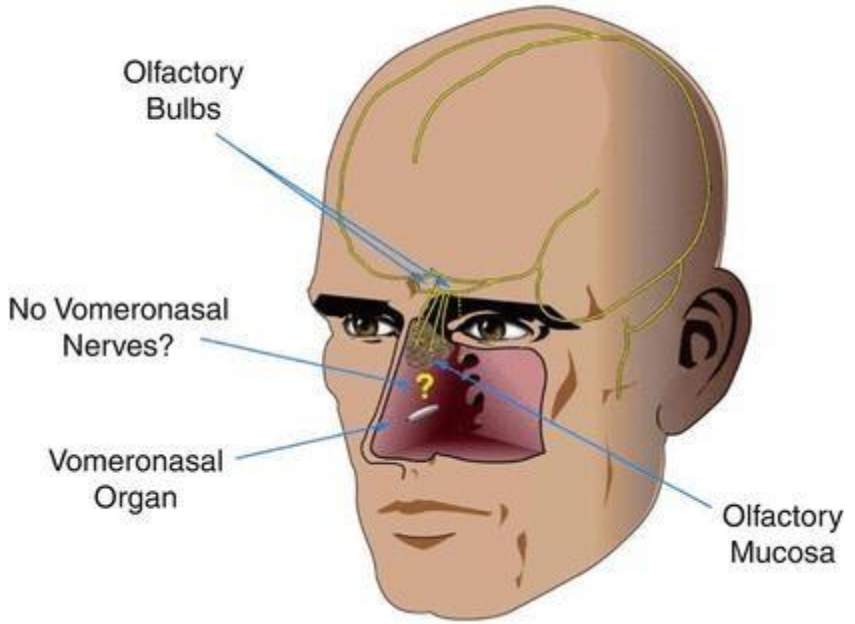
getting goosebumps when you feel afraid or cold because you have smooth muscles in your skin called arrector pili

Coccyx



Vestigial structures

Vomernasal organ (Jacobson's organ)



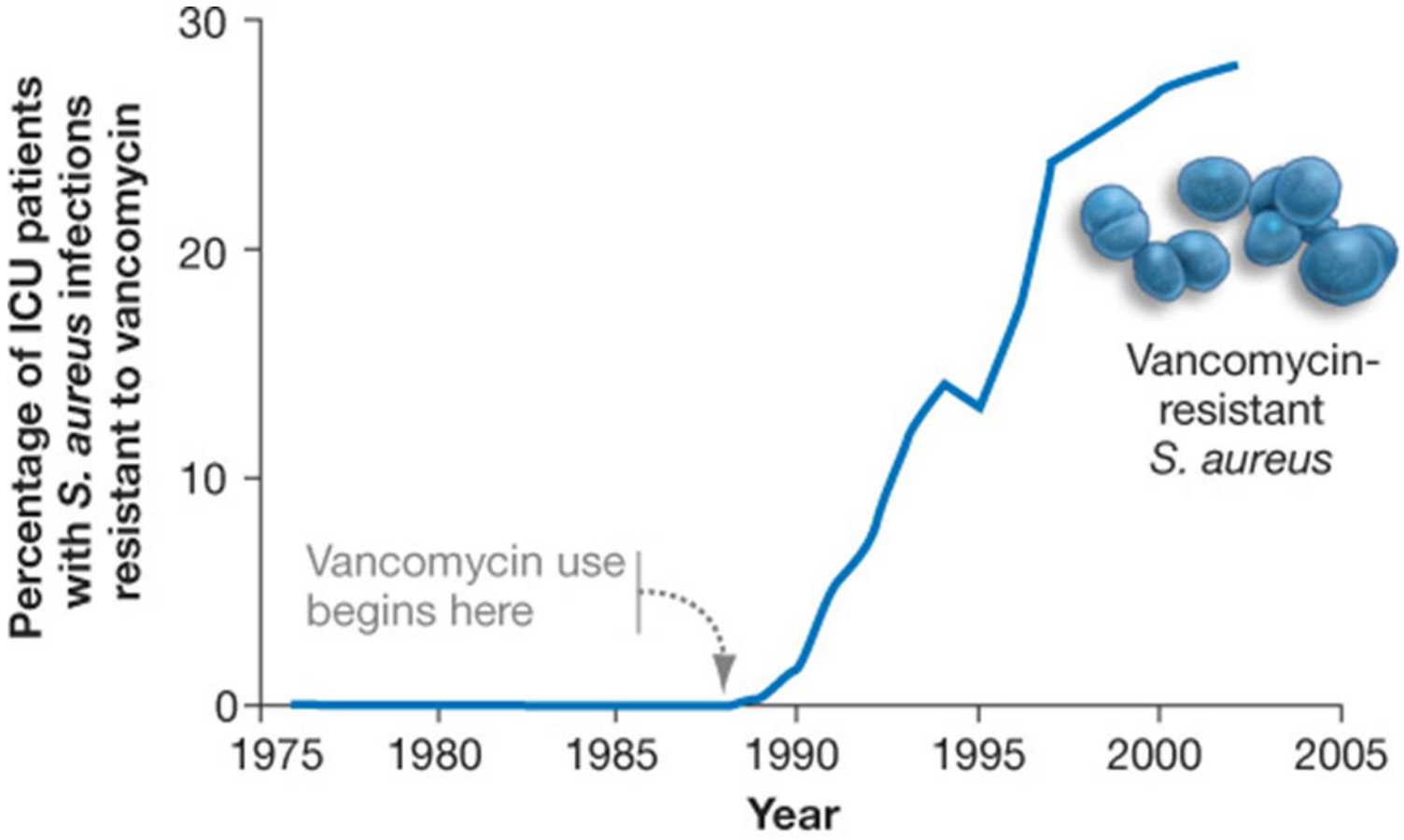
https://link.springer.com/referenceworkentry/10.1007%2F978-1-4939-3474-4_29

- Found along nasal septum; contains sensory structures related to the sense of smell
- Prominent in infants
- Appears to be vestigial in adult humans

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6050168/#:~:text=In%20humans%2C%20the%20vomeronasal%20organ,rich%20vascular%20and%20glandular%20network.

d) Real time evidence that populations can change over time

e.g. Evolution of antibiotic resistance in bacteria



Real-time evidence that populations can change overtime – but always over generations

https://www.youtube.com/watch?v=plVk4NVIUh8

iClicker Question

Which of the following statements about evolution is/are true?

A. Evolution is a change in the heritable traits in a population across generations.

B. Evolution is a property of populations not individuals (or populations evolve not individuals).

C. Evolution is a change in allele frequencies through time.

D. All of the above

E. A & C

iClicker Question

Which of the following statements about evolution is/are true?

A. Evolution is a change in the heritable traits in a population across generations.

B. Evolution is a property of populations not individuals; or populations evolve, not individuals.

C. Evolution is a change in gene frequencies through time.

D. All of the above

E. A & C

Any questions?

https://www.wshu.org/post/dinosaurs-and-burnt-toast-more-common-you-may-think#stream/0

Mechanism of evolutionary change

1. Mutations
2. Gene flow
3. Natural selection (plus sexual selection)
4. Genetic Drift

i.e. mechanisms that affect allele frequencies in a population over generations.

Today: Mutations (may not finish)

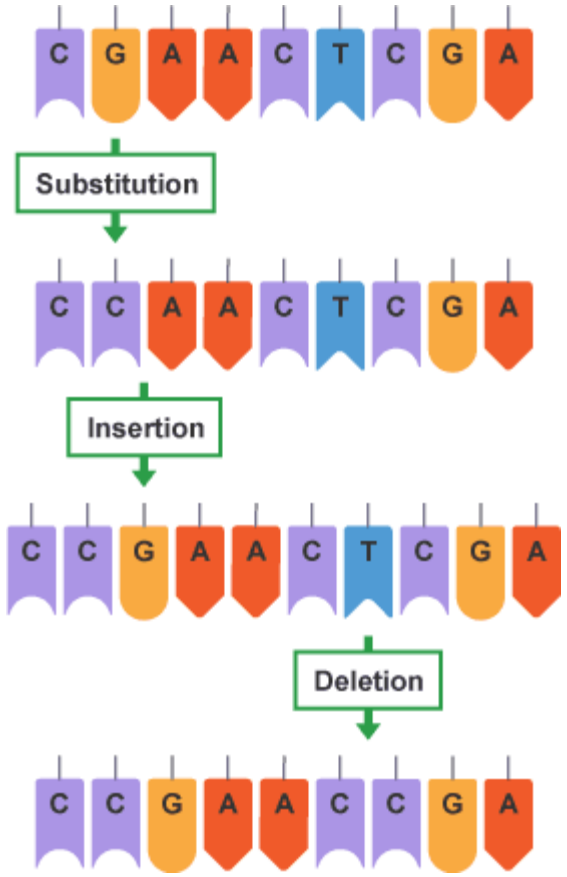
Evolution - Learning objectives continued

- Be able to apply your knowledge of mutations to explain changes in allele frequencies over time.

- Be able to explain why mutations are an essential, but weak evolutionary mechanism.

Mechanism #1 - MUTATIONS

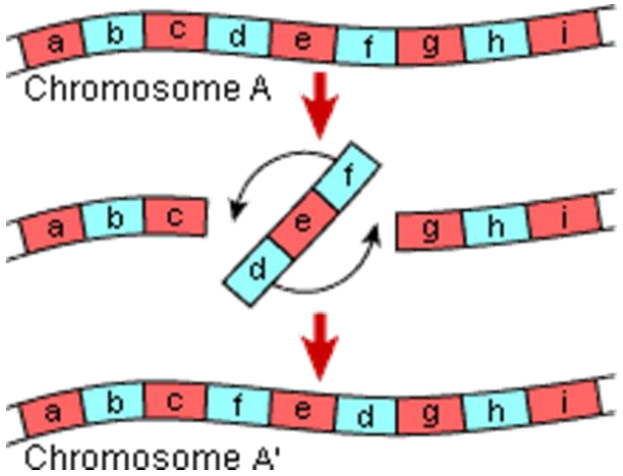
What are mutations? A mutation is any change in the nucleotide sequence of the DNA



Source: www.bbc.co.uk

Mutations range in size:

- from a change in one nucleotide (SNiP)
- to a large segment of a chromosome that affects multiple genes



http://entomology.umd.edu/news/inversion-immersion-how-chromosomal-architecture-leads-to-speciation

Mutations are essential to evolution

Mutations create new alleles (e.g. A3 allele)

- increasing genetic diversity, and the potential for individuals to differ in phenotype

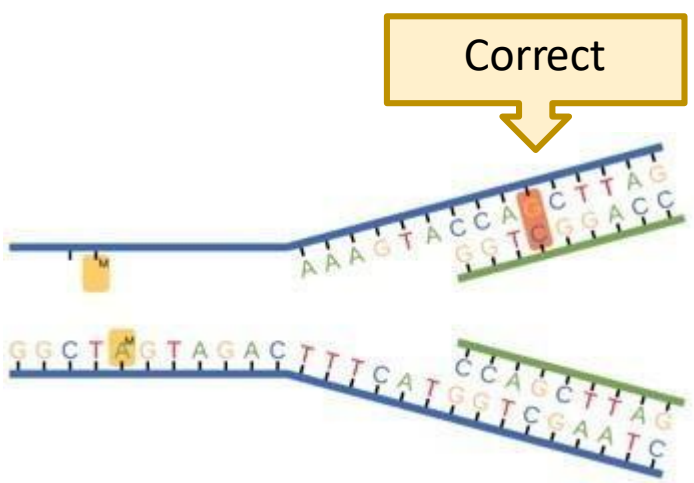
This generates the genetic/phenotypic variation on which natural selection (and other evolutionary mechanisms) can act.

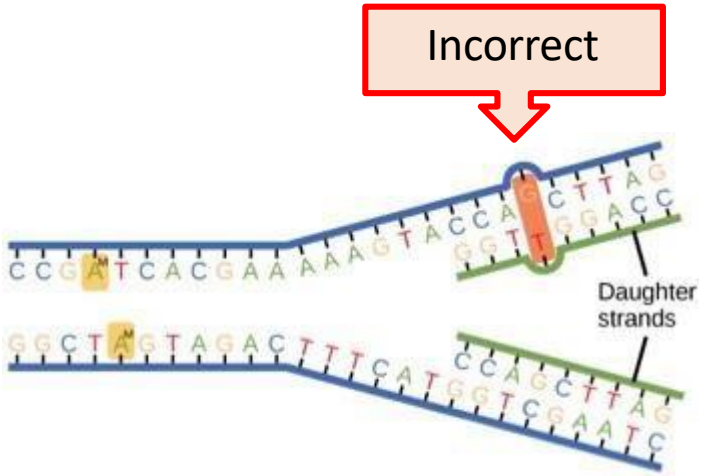
Without mutations, evolution could not occur.

Mutations – 2 causes

#1 Mistakes are made during DNA replication (most common source)

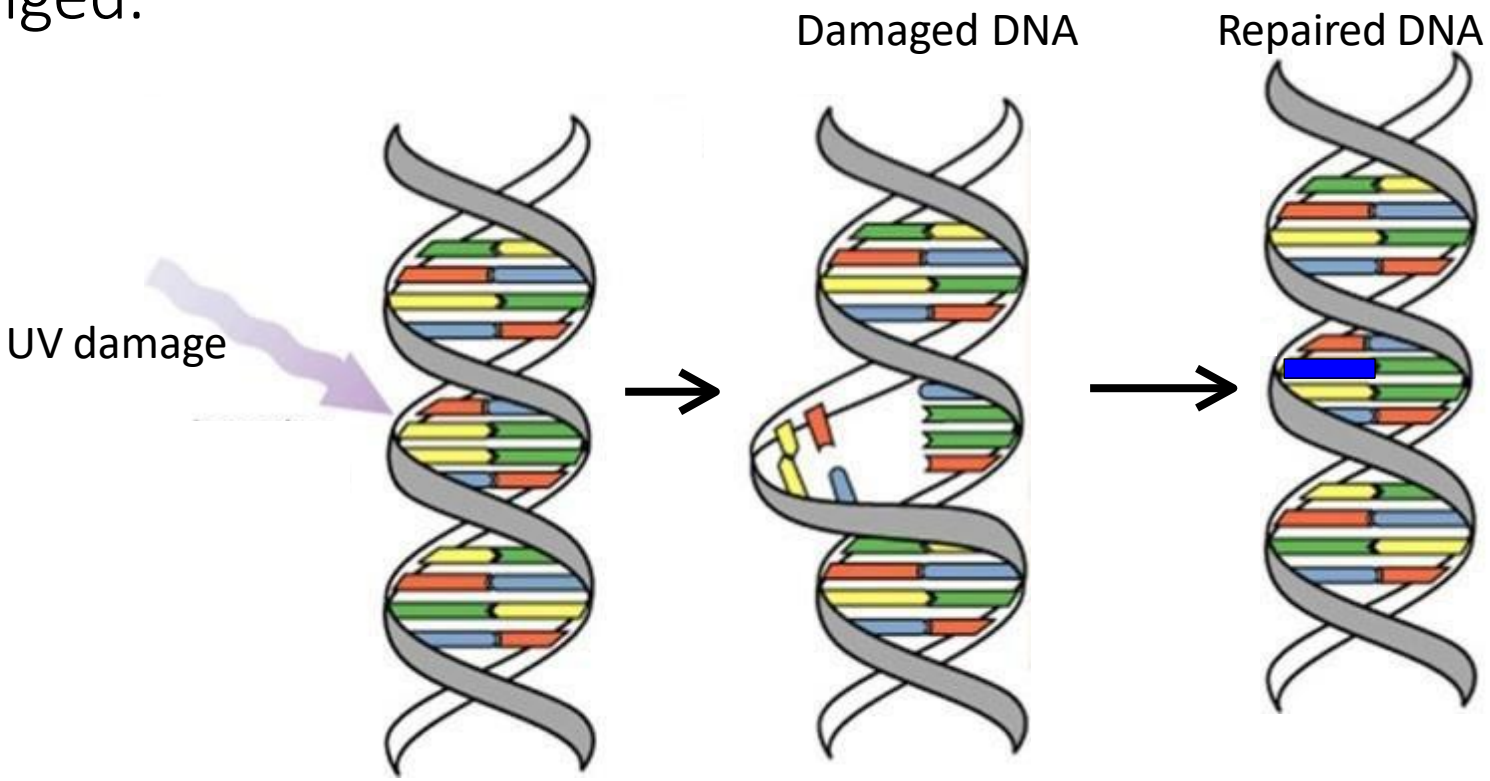
- mistakes not caught by proof-reading system.





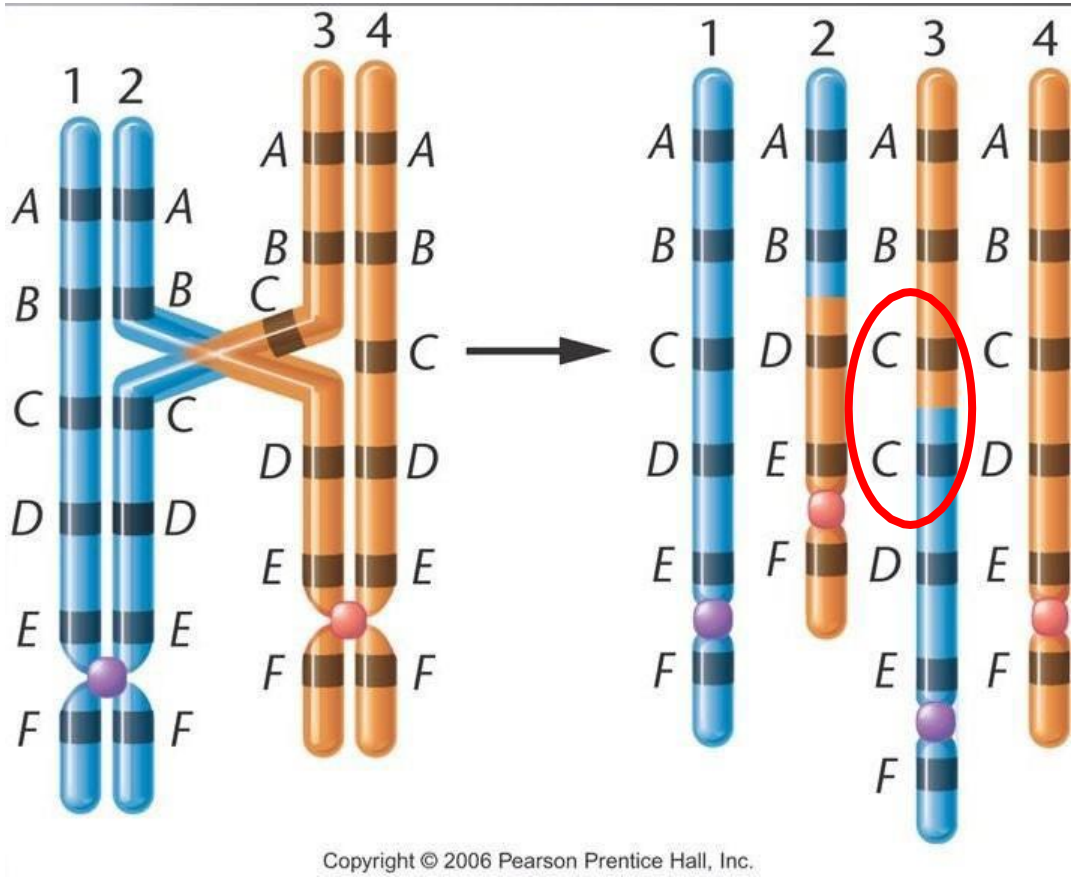
Causes of mutation #2 – Environmental

- Exposure to some chemicals and/or radiation can cause the DNA to breakdown.
- When the cell repairs the DNA it does not do a perfect job; so, DNA is changed.



Other causes of mutation, e.g. unequal crossing-over when chromosomes misalign (not testable)

- Results in gene duplication or deletion
- May affect multiple genes



Two categories of mutations

Germline mutations

– Occur in gametes (eggs or sperm).

- Especially important for evolution because these mutations can be transmitted to offspring (i.e. they are heritable).

Somatic mutations

– Occur in non-reproductive cells. So, not heritable.

- May or may not affect individuals during their lifetime.
- Less interesting to evolutionary biologists unless they change an individual's survival or reproductive success.

Mutation rates vary amongst species

- Organisms that undergo meiosis/mitosis more frequently will tend to have higher mutations rates. *(not surprising given most mutations occur due to errors in DNA replication.)*

- Organisms that reproduce more frequently will pass on those mutations to the next generation at a faster rate (IF the mutation occurred in germ line cells).

- Organisms than invest more in DNA protection and repair will have lower mutation rates.

Mutations are random

What this means:

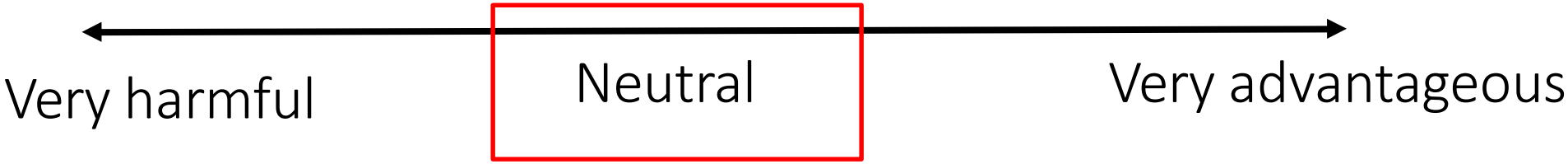
Mutations can be beneficial, harmful, or neutral for an organism.

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.

Effects of mutations

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



Most mutations are neutral with respect to fitness

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

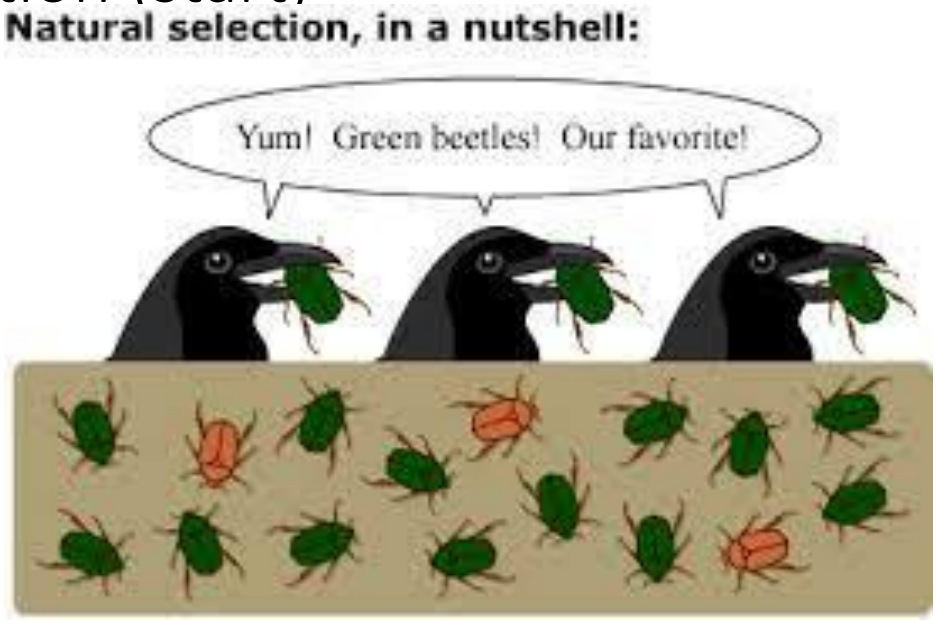
B) A bird that lives for 8 years, and produces 1 healthy offspring each year

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

Next class

Next Class - Continue with mechanisms of evolution:

- Mutations (continued)
- Gene Flow
- Natural Selection (start)



https://evolution.berkeley.edu/evolibrary/article/0_0_0/bergstrom_02