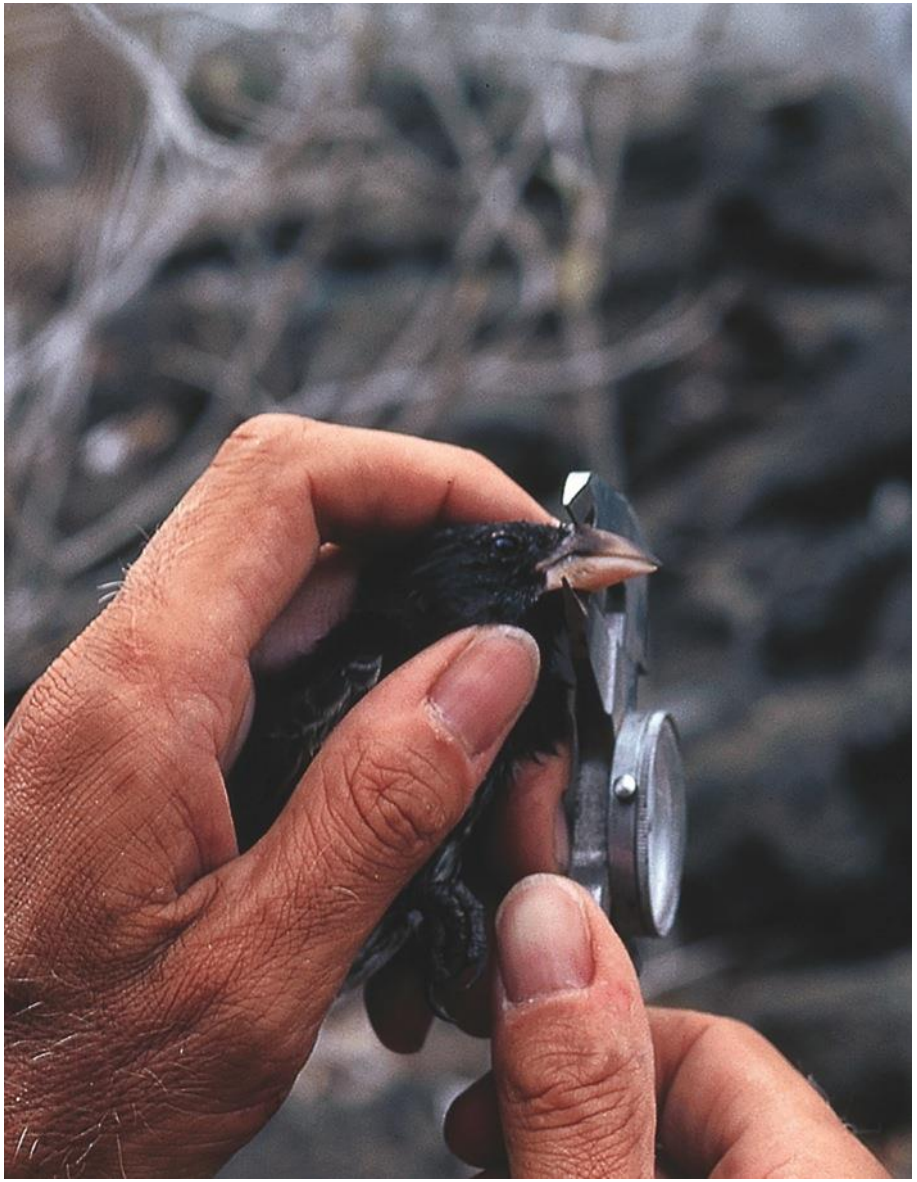
Chapter 10
Natural selection: empirical studies in the wild

We will go over many examples. How well do you need to know them?

No need to know exact species names but do get the basic story down. In addition, think about the take-away for each. Why did they choose to add this story into the text? What makes it unique?



Real Selection in Natural Populations

- Mice (text-you)
- Galls and Gallflies (text-you)
- Galapagos Finches (class and in text)
- Clover (class not in text)
- Human lactose intolerance (class and in text BUT **Is now in CH 8.7-**Will re-connect with last part of class on human evolution.)

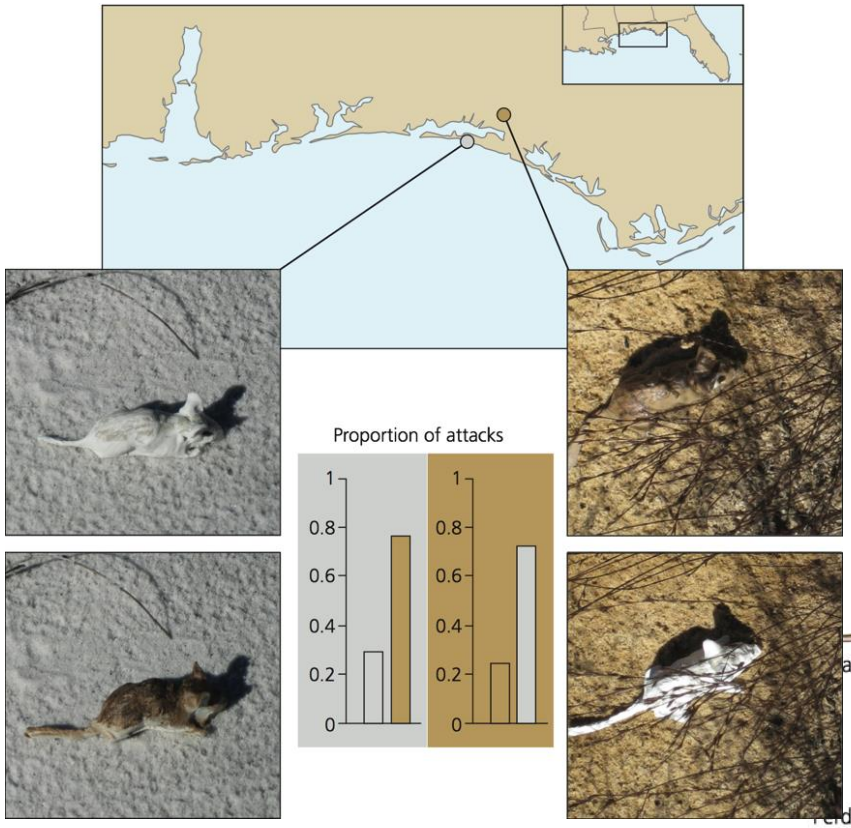
Incidental Selection by humans

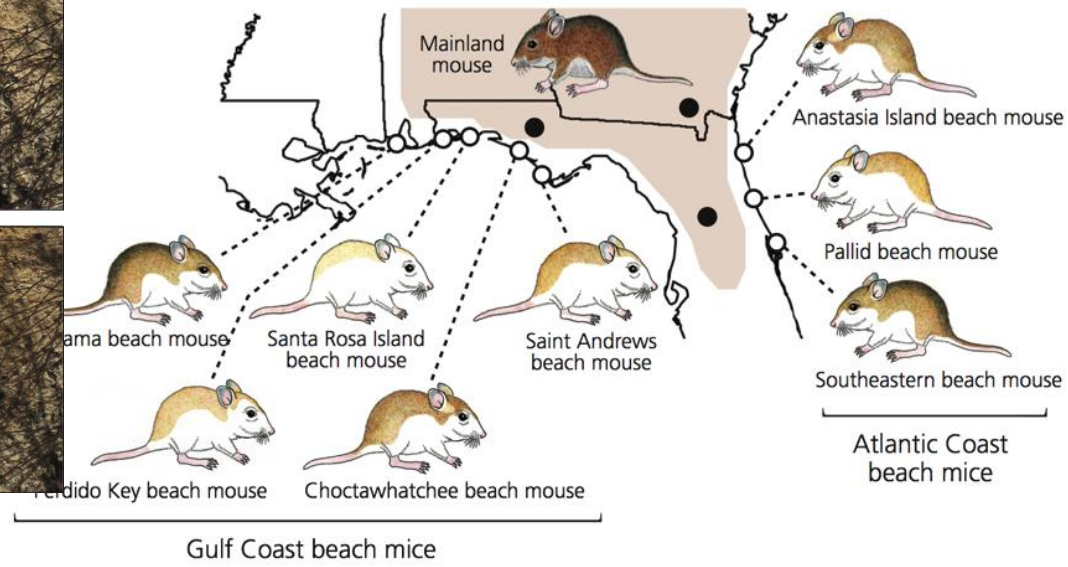
- Bighorn sheep
- Fish - Cod (in class not in text) and Salmon (text-you)
- Insecticide resistance Bt/Glyphosate resistance

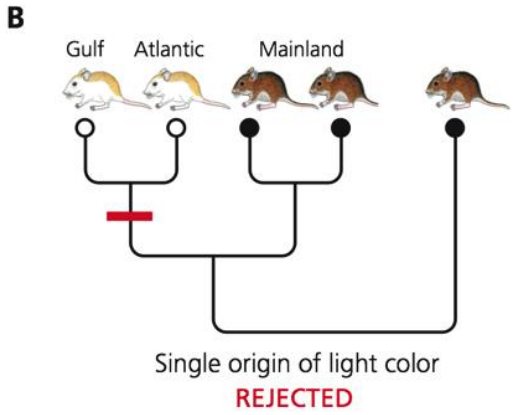
Artificial selection (selected purposefully by us)

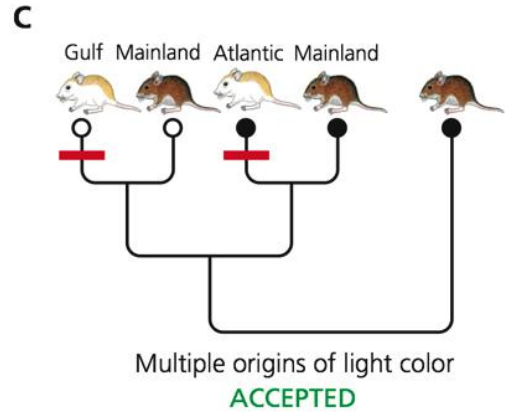
- Domesticated crops
- Dogs, Pigeons

You!


Proportion of attacks
1
0.8
0.6
0.4
0.2
0
1
0.8
0.6
0.4
0.2
0

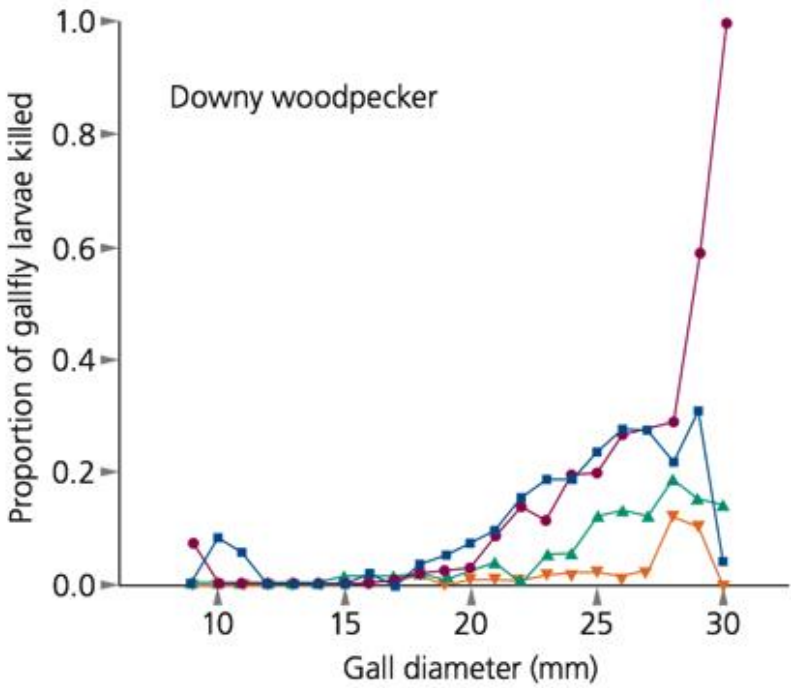

Mainland mouse
Anastasia Island beach mouse
Pallid beach mouse
Southeastern beach mouse
Atlantic Coast beach mice
ama beach mouse
Santa Rosa Island beach mouse
Saint Andrews beach mouse
Choctawhatchee beach mouse
Gulf Coast beach mice


B
Gulf
Atlantic
Mainland
Single origin of light color
REJECTED


C
Gulf
Mainland
Atlantic
Mainland
Multiple origins of light color
ACCEPTED

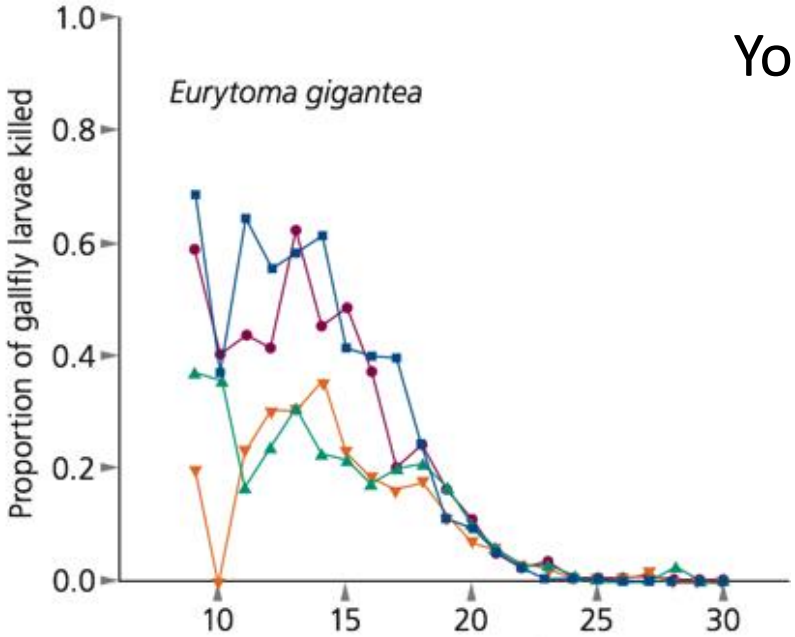
A

B


Downy woodpecker
Proportion of gallfly larvae killed
1.0
0.8
0.6
0.4
0.2
0.0
10
15
20
25
30
Gall diameter (mm)

C

D


Eurytoma gigantea
Proportion of gallfly larvae killed
1.0
0.8
0.6
0.4
0.2
0.0
10
15
20
25
30

You!

Ex. Galapagos Finches

Where are the Galapagos Islands?

Diversity in Darwin's finches

What is each of these different finch species eating?

A.

B.

C.

D.

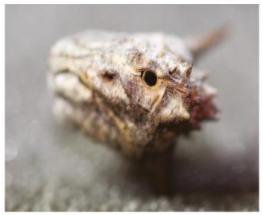
E.

F.

Medium ground finch
This is the species lots of the research is done on.

Think about it…What would a small delicate beak be good for?
What would a big, beefy “deep” beak be good for?
(beak depth is the top to bottom height near where the feathers are)

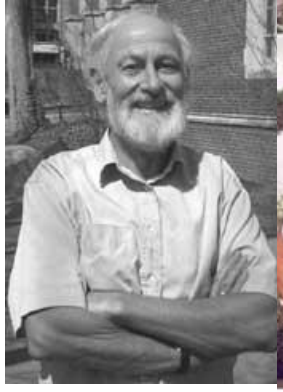
Which kind of beak would be more efficient at opening these big, hard prickly seeds?
(deep or not so deep)

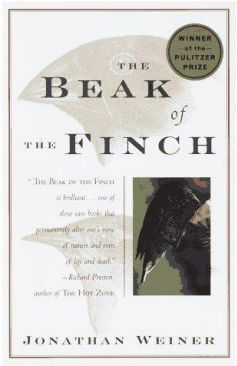


https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecm.1392

Which kind of beak would be more efficient at opening these small, difficult to pick up, softer seeds with a thinner seed coat? (deep or not so deep)

Peter and Rosemary Grant Since 1973 measured everything about every single bird!





Why are island populations great to work with?

How did El Nino play a role in their research?

Famous book about them.

Watch this video-

https://www.youtube.com/watch?v=mcM23M-CCog

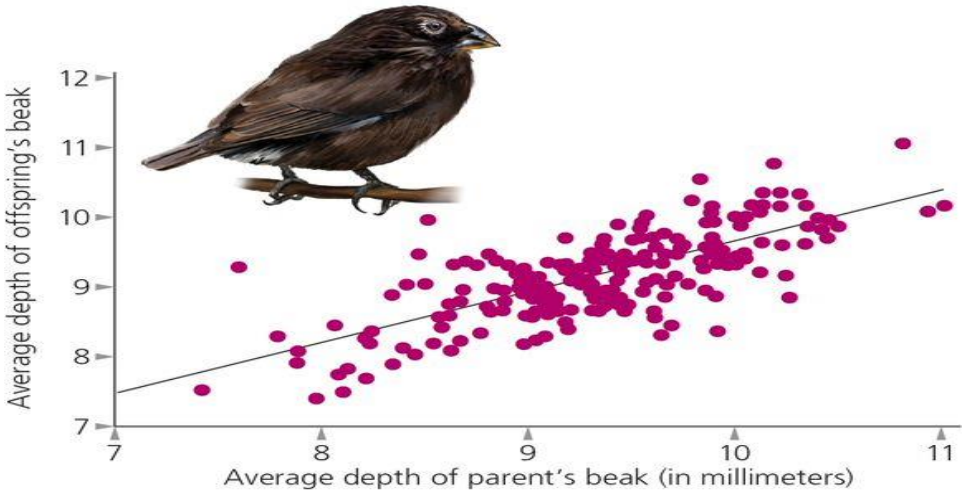
if link does not work search for it in youtube!

“Galapagos Finch Evolution HHMI Bio Interactive”

16 minutes Watch it!

What is top graph showing?

How does this relate to our conversation on Twins. Do you remember we looked at graphs of height?



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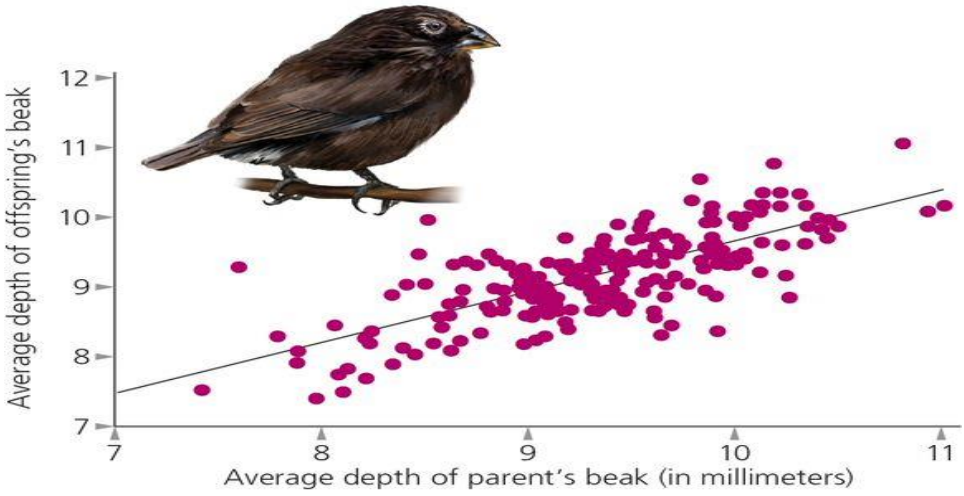
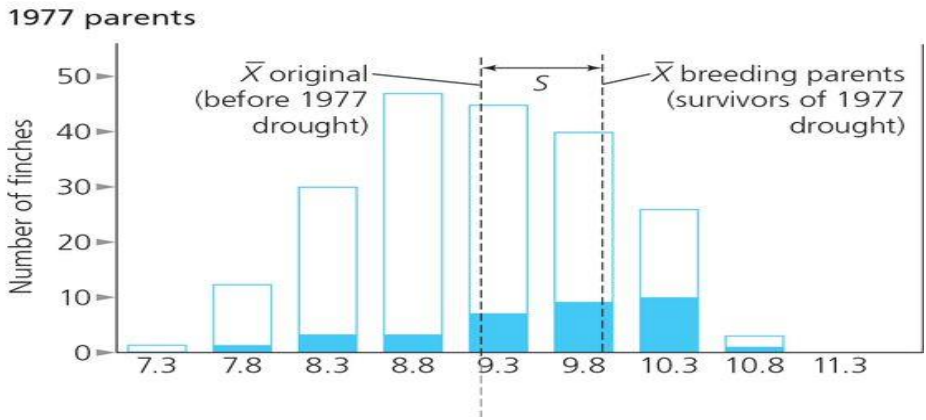
What is the “1977 Parents” graph showing? What are the blue bits at the bottom of the bars?





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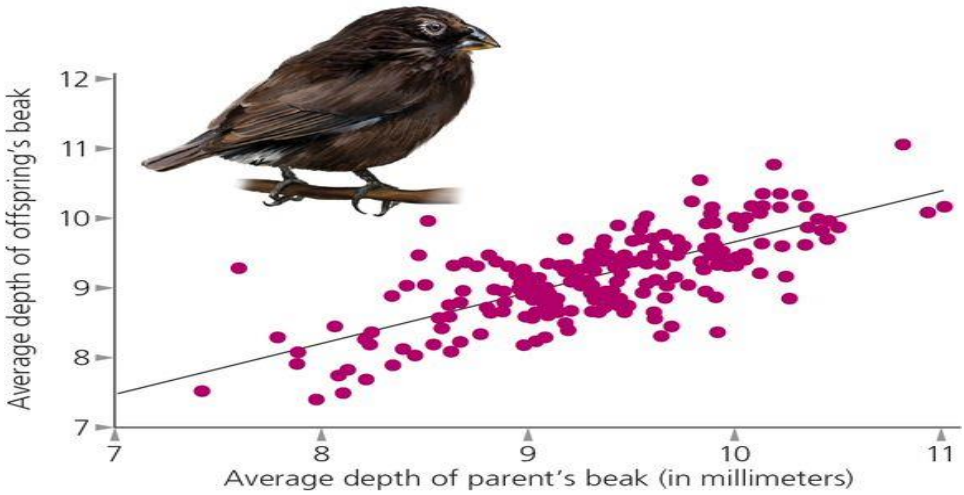
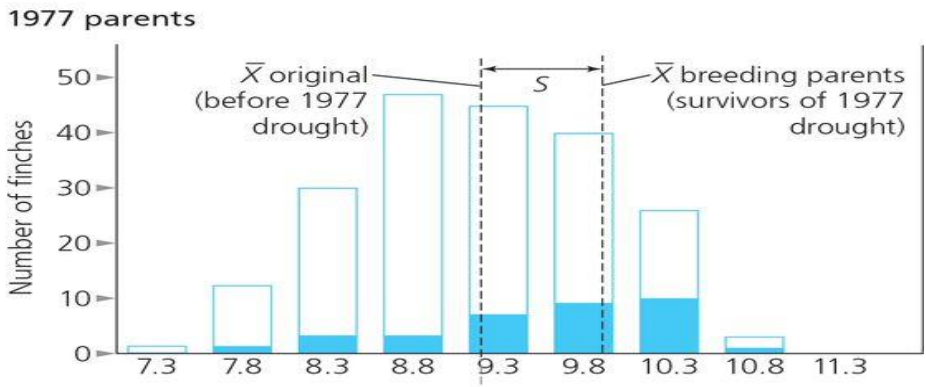
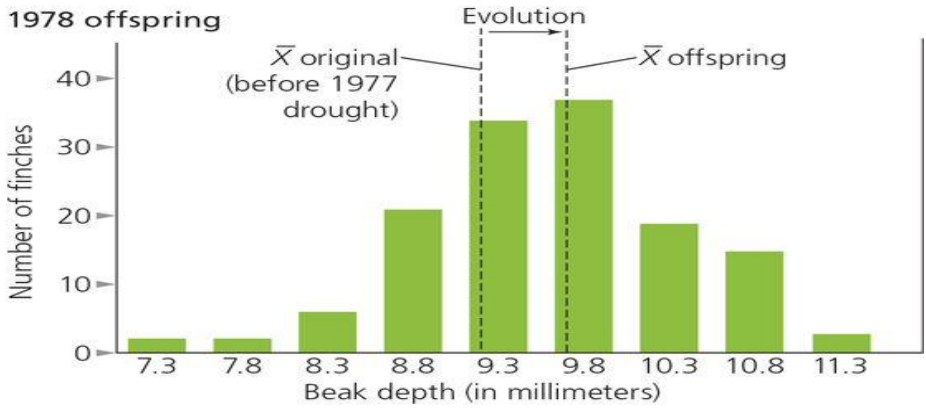
What is the “1978 Offspring” graph showing?





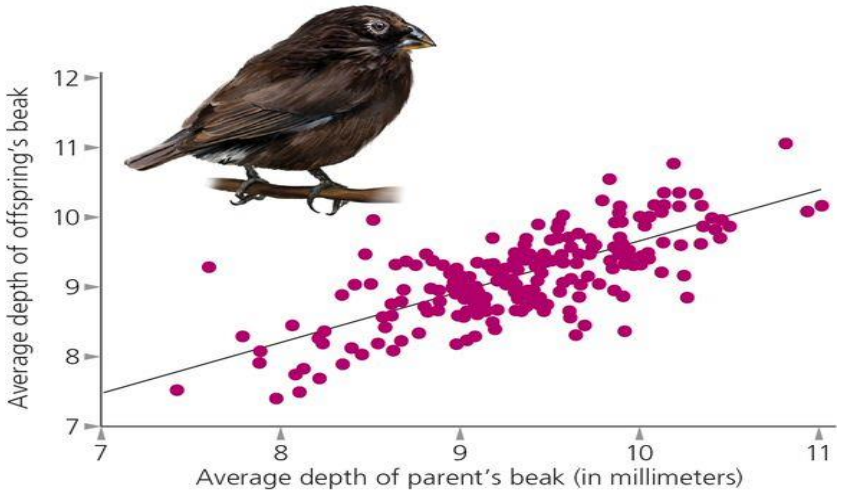


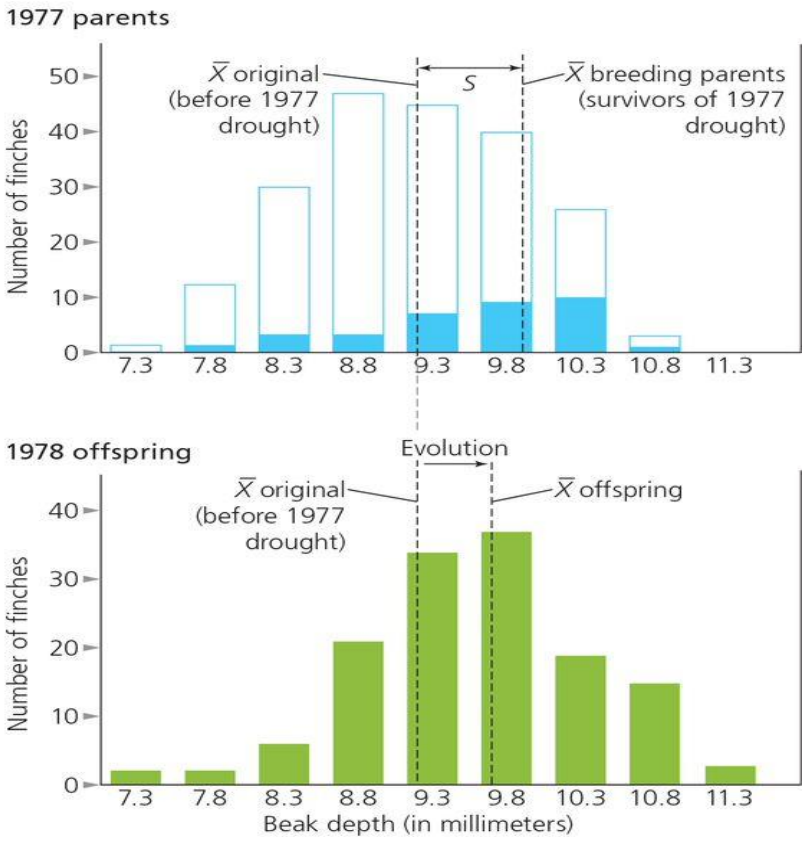
In the 1977 parents graph S (**selection differential**), is equal to the difference between the mean of survivors and the mean of the original parental population. (Survivors-Original)

Now check out the 1978 offspring graph. Did beak depth increase in the next generation?

Did it reach the average beak depth of the surviving parents?

Selection pulled up avg but it did not reach the avg of parents.





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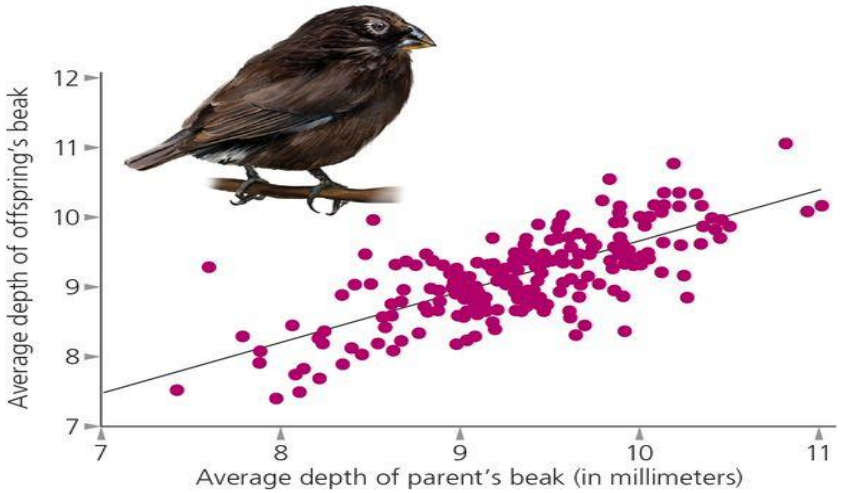
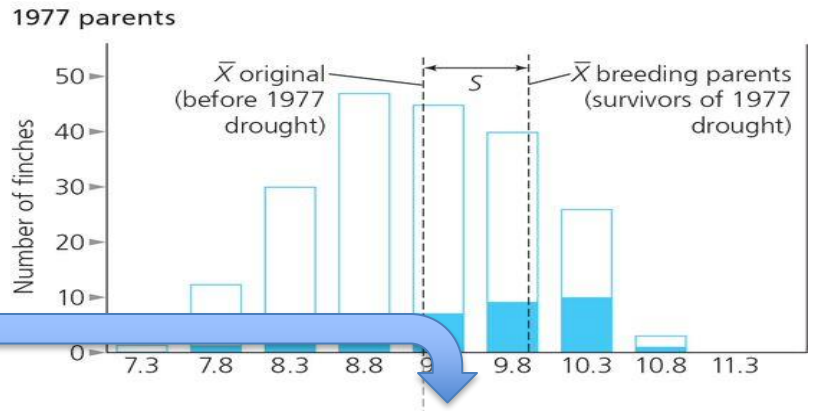
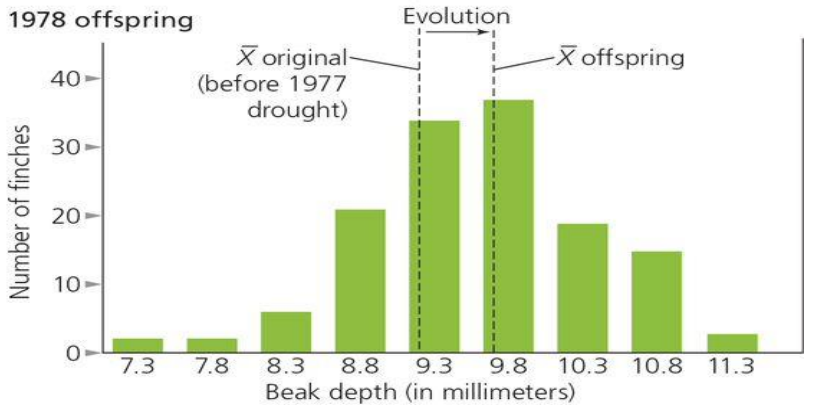
Lets define **R (response to selection)**
So there is a cool equation that connects the response to selection with the heritability of the trait and the selection differential.

R = h^2 x S (Breeder's Equation)





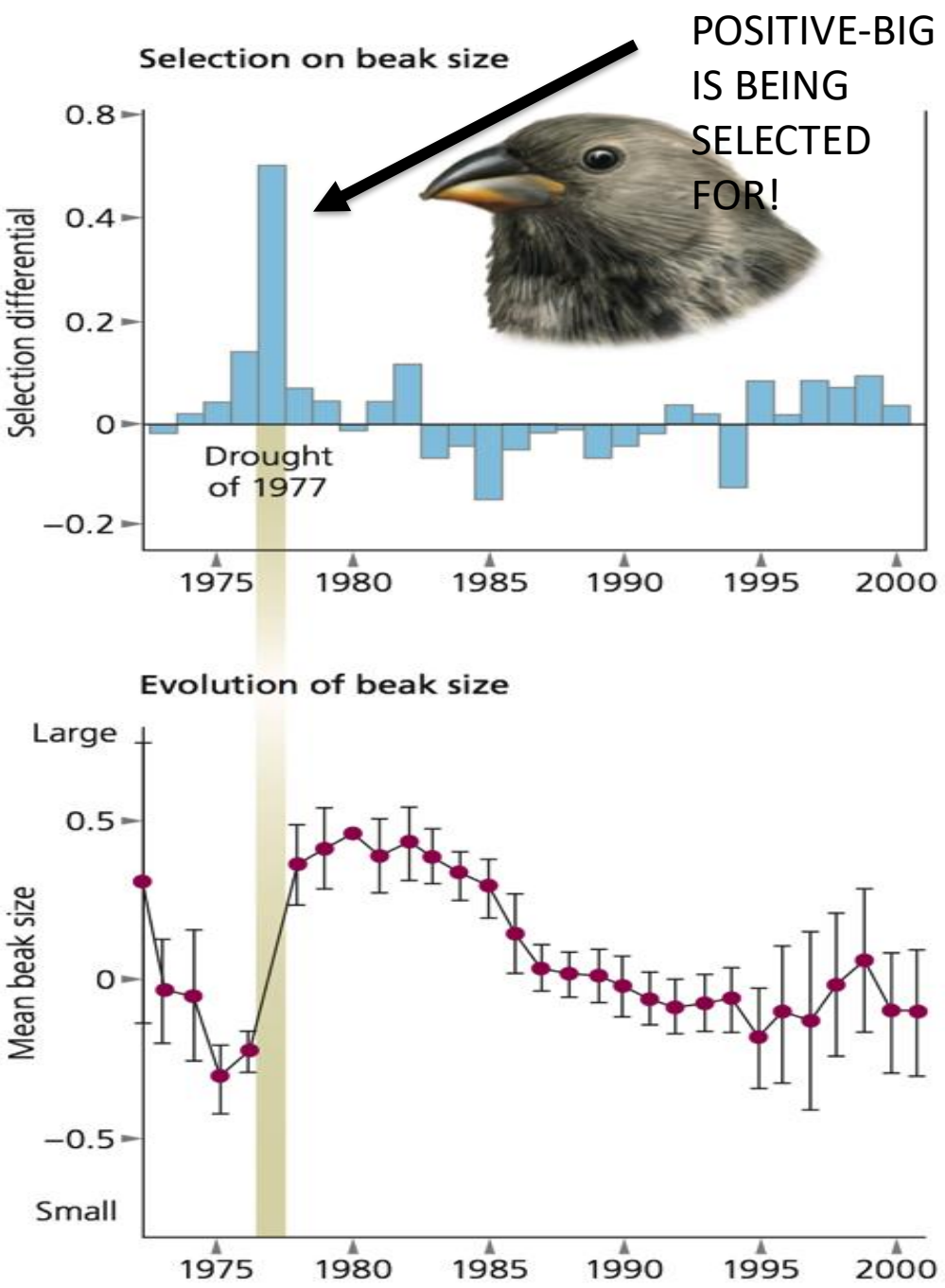


What do you notice?

Some yrs large beaks good! Survivors have bigger beaks than original parent population (Survivors-Original>0)

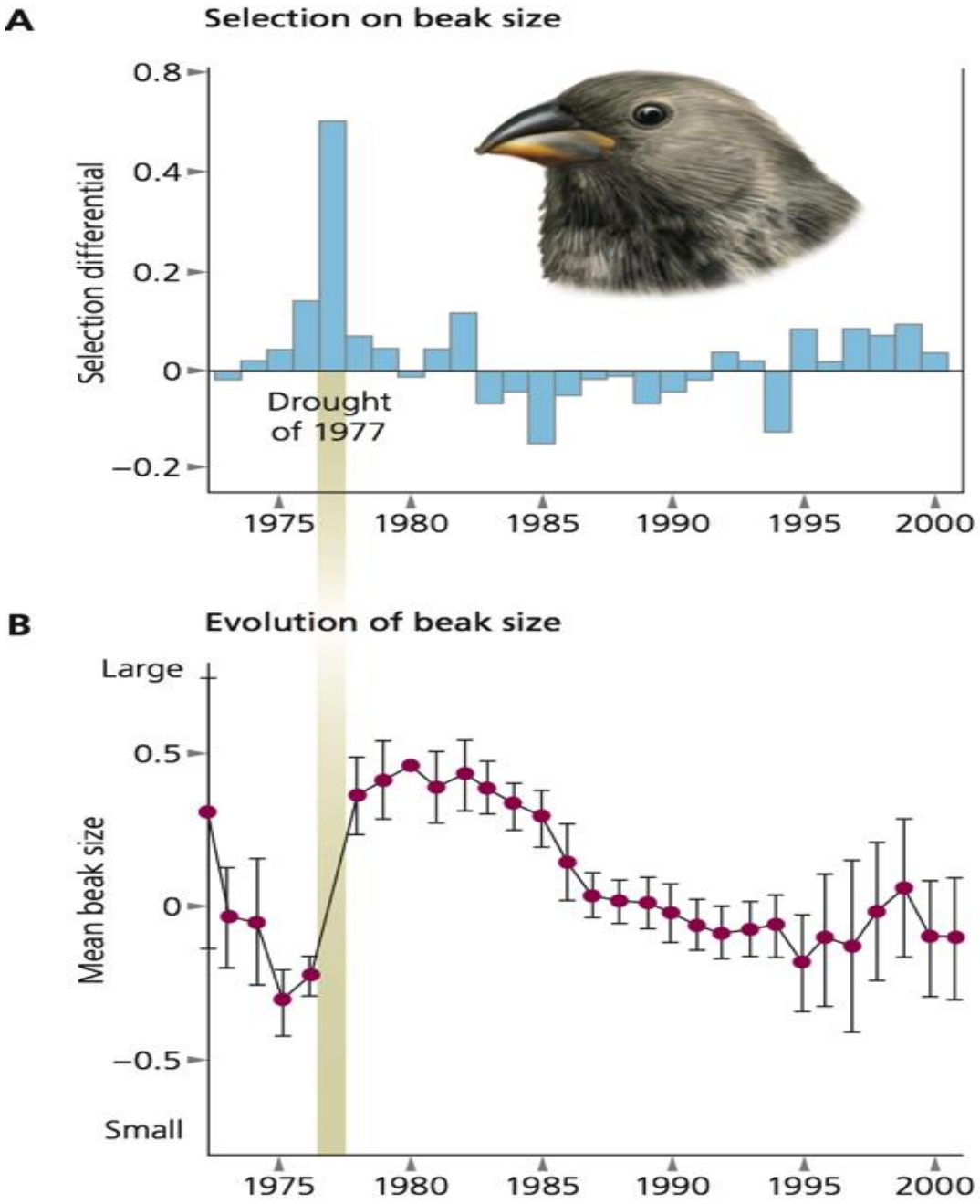
Other years small beaks good!
Survivors-Original<0
End of 1982, heavy rains, what happened?

Natural selection varies over **time** and can result in rapid evolutionary change



Is this pattern of selection for small beaks and then selection for bigger beaks and then selection for smaller beaks again what you though of when we first started talking about evolution?

Why or why not?



Mechanism?

What is selection actually acting on?

There are **several genes** involved in beak development.

One *(BMP4)* codes for (or "encodes") a signaling molecule which is a protein called BMP4.

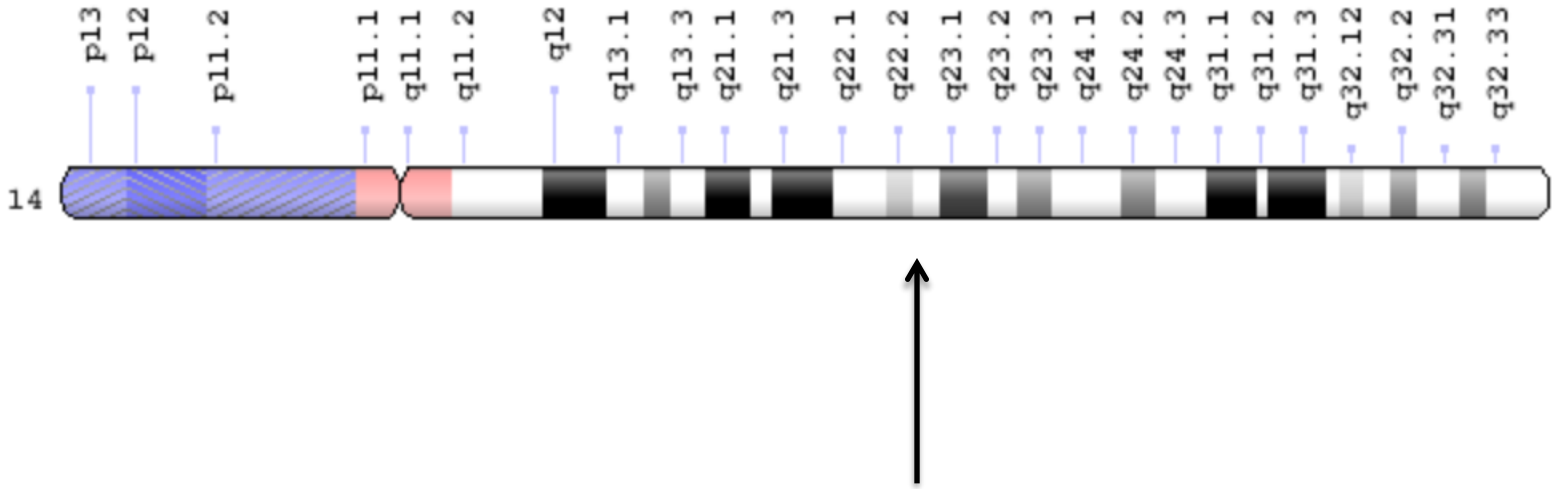
Notice that genes are italicized and the proteins they encode (make) are not!

A signaling molecule is just a molecule that triggers a cell to do something (in this case it probably triggers mitosis).

FYI…whenever you have a gene or its protein mentioned you can look it up in Wikipedia to see where it is and learn more about it.

Wikipedia says.....

"Bone morphogenetic protein 4 *is a protein that in humans is encoded by BMP4 gene.[4][5] BMP4 is found on chromosome 14 q22-q23"*



Somewhere in here perhaps!

Finches with big, deep beaks have more of this protein

In lab they sculpted the beaks by adding or subtracting the protein BMP4!

Why are birds great to work with when studying development?

(think access to developing embryo birds vs. mammals)

The same gene that shapes the beak of the finch in the egg also shapes the human face in the womb.

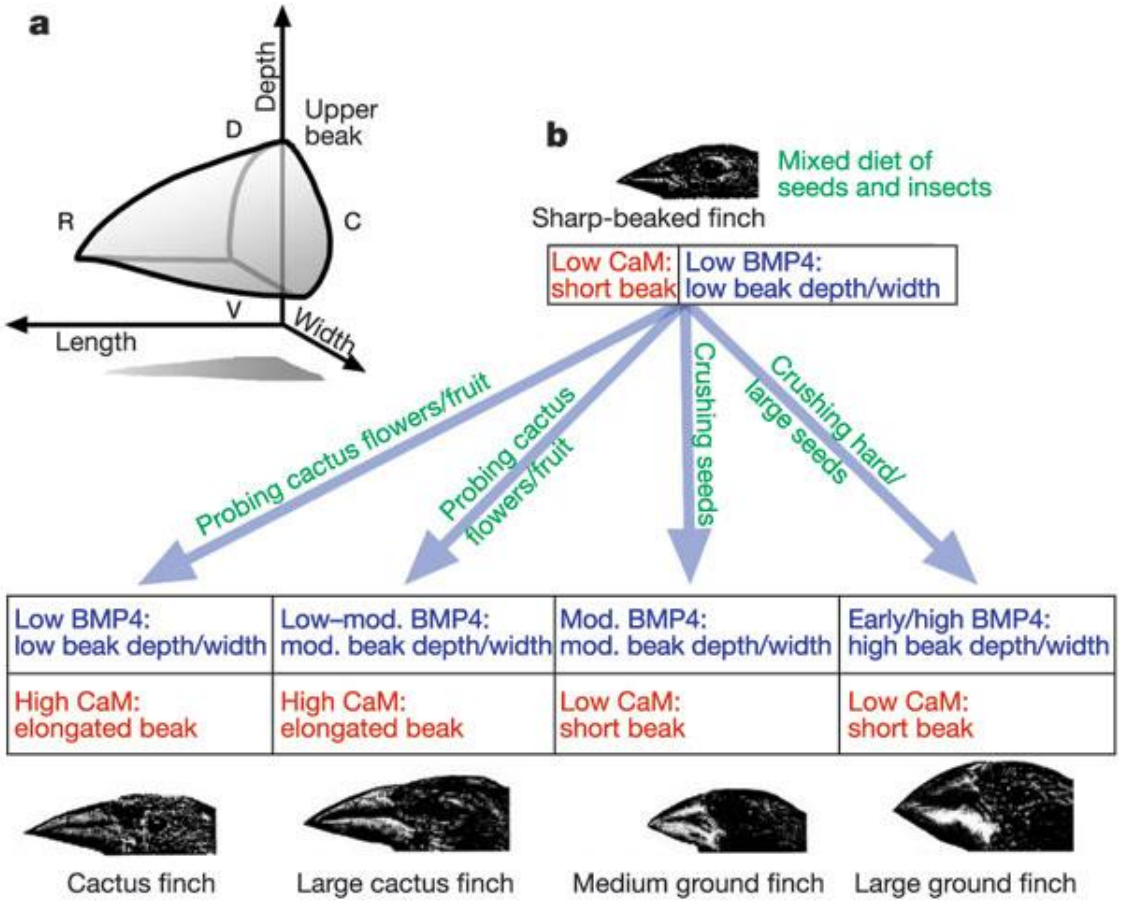
Does this mean this gene is highly conserved or is NOT highly conserved?

FYI…This is how they study this stuff!
Here they were looking at both BMP4 and CaM.
What does CaM *affect?*

The calmodulin pathway and evolution of elongated beak morphology in Darwin's finches

Arhat Abzhanov, Winston P. Kuo, Christine Hartmann, B. Rosemary Grant, Peter R. Grant and Clifford J. Tabin

Nature 442, 563-567(3 August 2006)



a, Developing avian beak is a three-dimensional structure that can change along any of the growth axes. b, A beak of the sharp-beaked finch reflects a basal morphology for Geospiza. The model for BMP4 and CaM involvement explains development of both elongated and deep/wide beaks of the more derived species. Abbreviations: C, caudal; D, dorsal; R, rostral; V, ventral.

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- **Clover (class not in text)**
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Ex. Clover (Dirzo and Harper)

Slugs eat clover

If you are a plant you cannot get up and run away but what can you do?

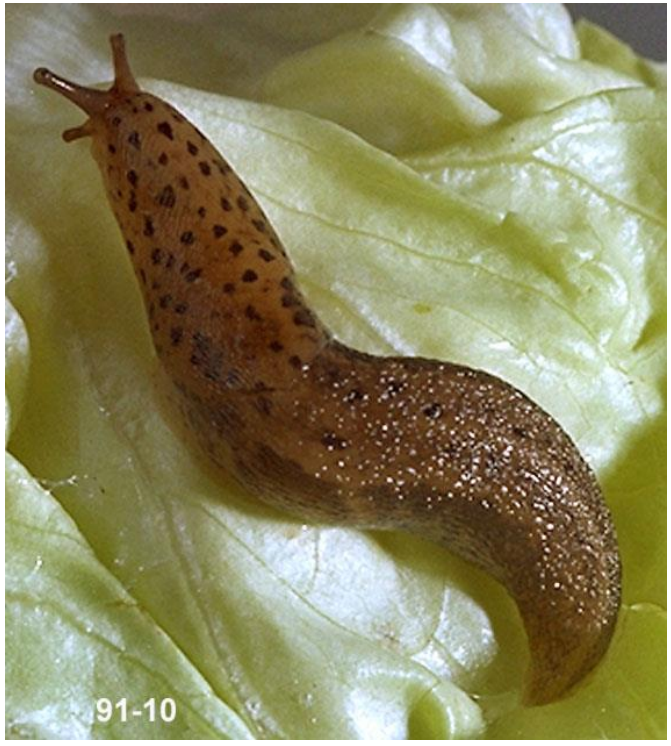
Make thick indigestible leaves.

Make trichomes, bristles, prickles.

Make a nasty chemical that taste bad.

Clover produces cyanide!

But…all clover doesn't produce cyanide? Hmmmm why not?



Depends on slug population!

If lots of slugs, large % of pop produce cyanide….(cyanide production has been selected for)

If few slugs only a small % produce cyanide because is costly to produce-evidence for this?

- grow more slowly
- produce fewer flowers

Also may depend on frequency of frost!

- Cyanide producing plants are more susceptible to frost..why? (freezing cells explode and cyanide goes all over the plant and damages it)

*There are **trade-offs** to producing cyanide.*
What does that mean?

While in finches selection varies OVER TIME (wet years and dry years), in clovers selection may vary over time and over space.

Imagine a situation where selection might vary over time and space in this system of clovers and slugs.

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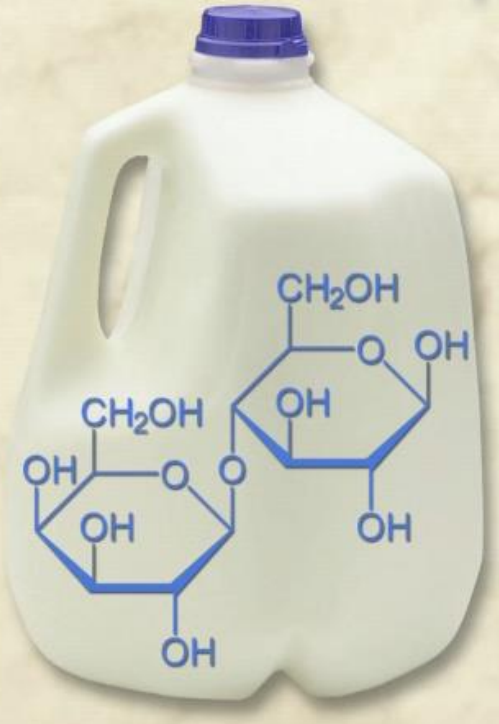
Lactase is an enzyme that breaks down milk sugar.
It is produced in cells of small intestine in **all mammal** babies.
Is normally shut down in mammal adults so most adult mammals are lactose interolerant.

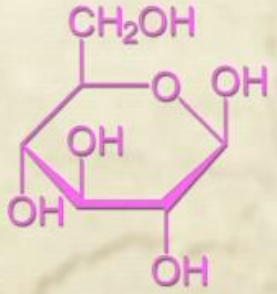
Some humans have a mutation that enables them to continue to produce the lactase enzyme!

They are **lactase persistent.**
(Lactase persistent=Lactose tolerant ☺)

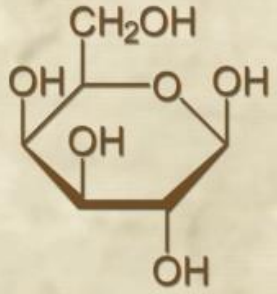
How We Digest Milk



+ Lactase



Glucose



Galactose

Milk contains the sugar lactose.

The enzyme lactase breaks it down to an absorbable form.

https://lbc.msu.edu/evo-ed/pages/Lactase/anthro_biogeogr.html

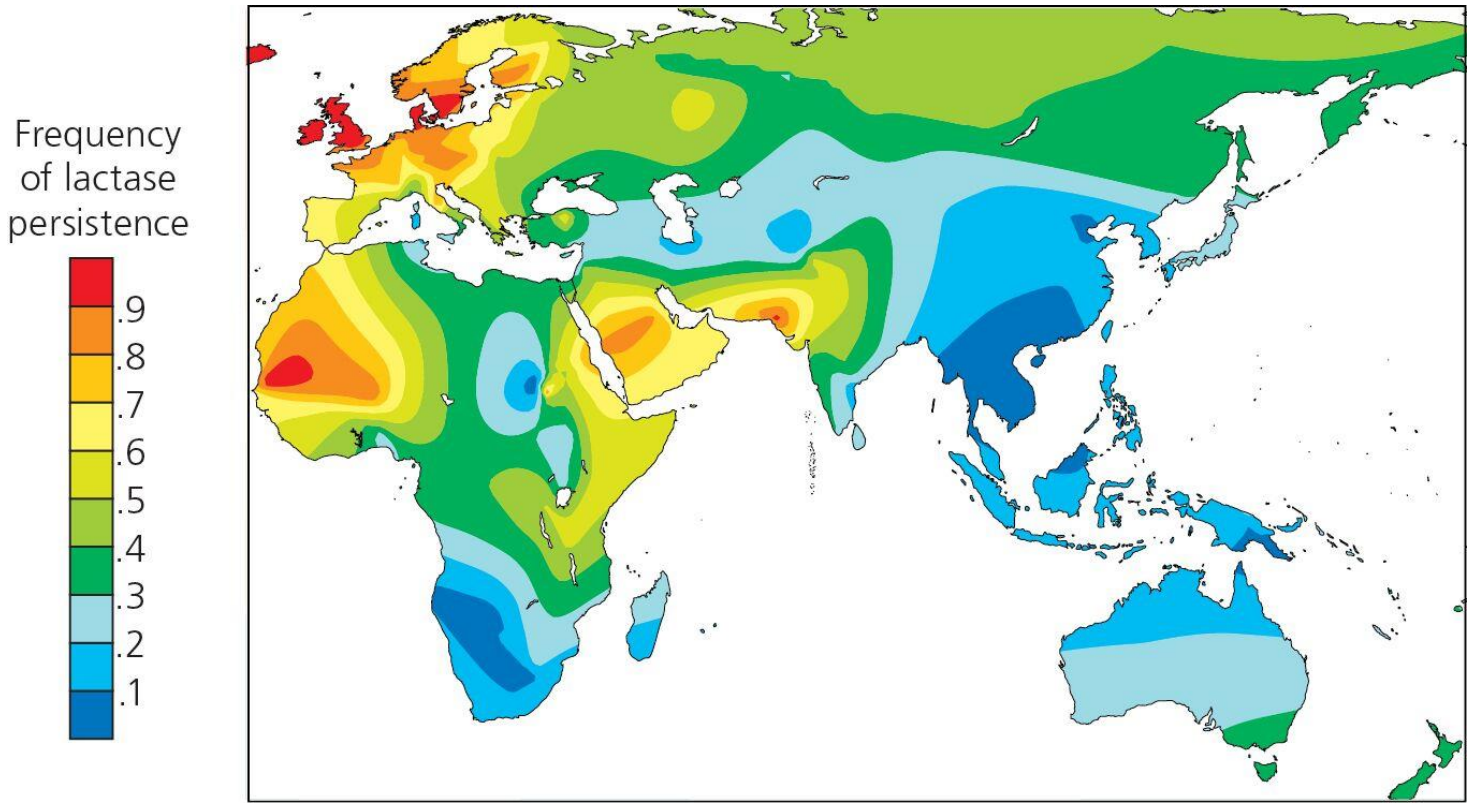
Evolutionary Advantages

There are significant nutritional benefits of consuming dairy products. Milk contains essential molecules such as water, sugar, fat, protein, and vitamins…... Additionally, dairy products could have been a life-saving source of calories during times of famine. Within a pastoralist culture, an individual with lactase persistence would have a distinct advantage in terms of nutrient acquisition.

Why are cows so convenient and kind of similar to big refrigerated cupboards?

Cattle were domesticated in two different places in the world at separate times.

They were domesticated **independently** both in Africa and in Europe



Geography of lactose tolerance generally overlaps with geography of cattle domestication.

Lactase Persistence is a recently evolved trait (also called a **derived** trait) and most of world (2/3^{rds})cannot digest.

How did lactase persistence evolve?

Did a whole new gene appear in the population?

Probably not!

Remember…

What are the different ways genes are regulated?

1. Epigenetic modifications
2. Transcription factors
3. Post-transcriptional modification or processing
4. By affecting whether the mRNA is translated into a protein (microRNA can block)
5. By modifying the polypeptide or protein after it has been made (**post-translational** level)

Many genes are turned on and off during development by transcription factors.

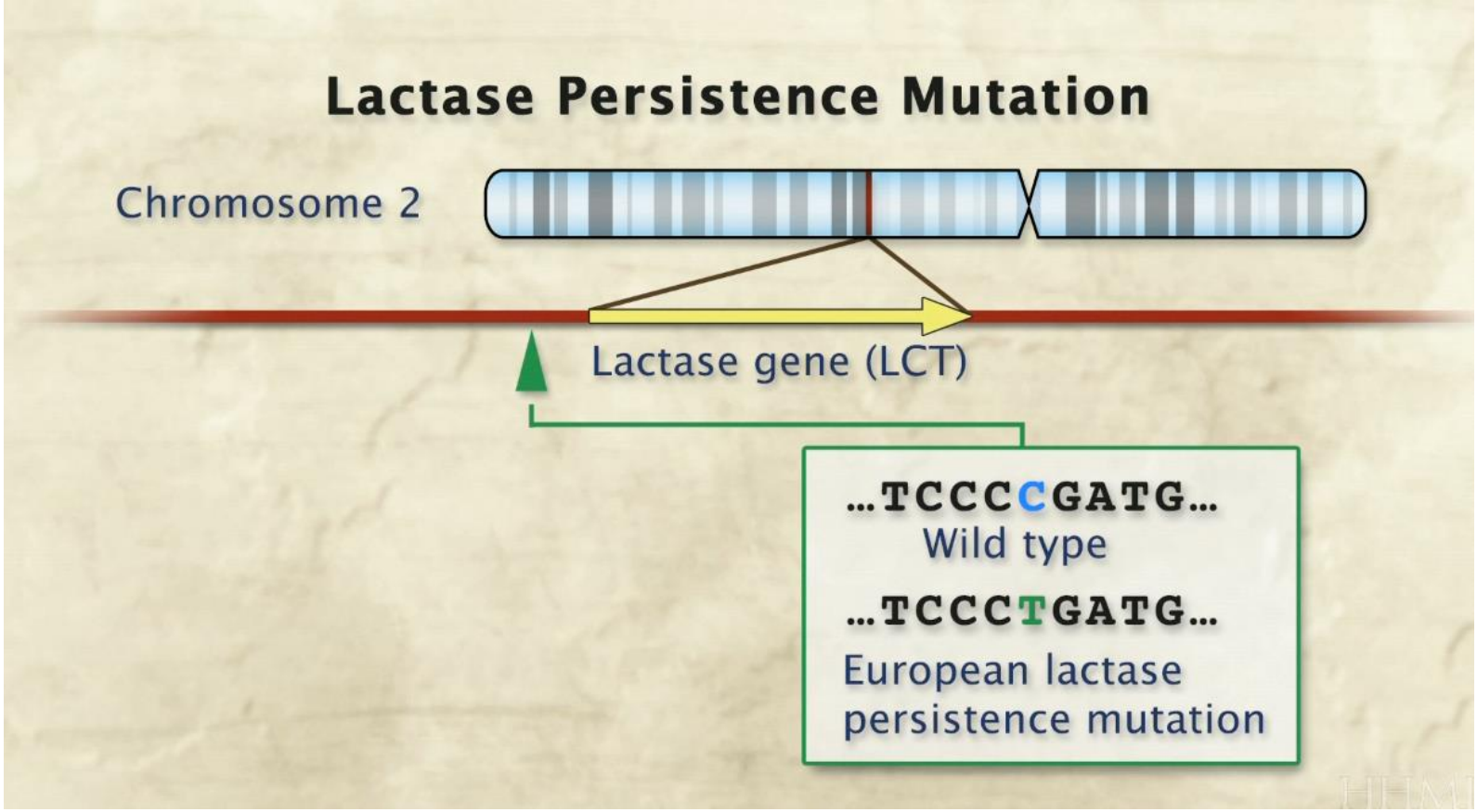
These transcription factors are proteins that are encoded by (made by) other genes.

We are lactose intolerant when a gene that makes enzyme lactase stops being expressed when you become an adult.

At some point in human evolution a mutation occurred in the region that affects the **transcription factor** for this gene. Allowed the enzyme to keep being produced in adults!

Note: There is variation in how and when the gene is **expressed**, not whether it exists since all babies can digest lactose.

Did a whole **new gene or DNA region** appear in the population?



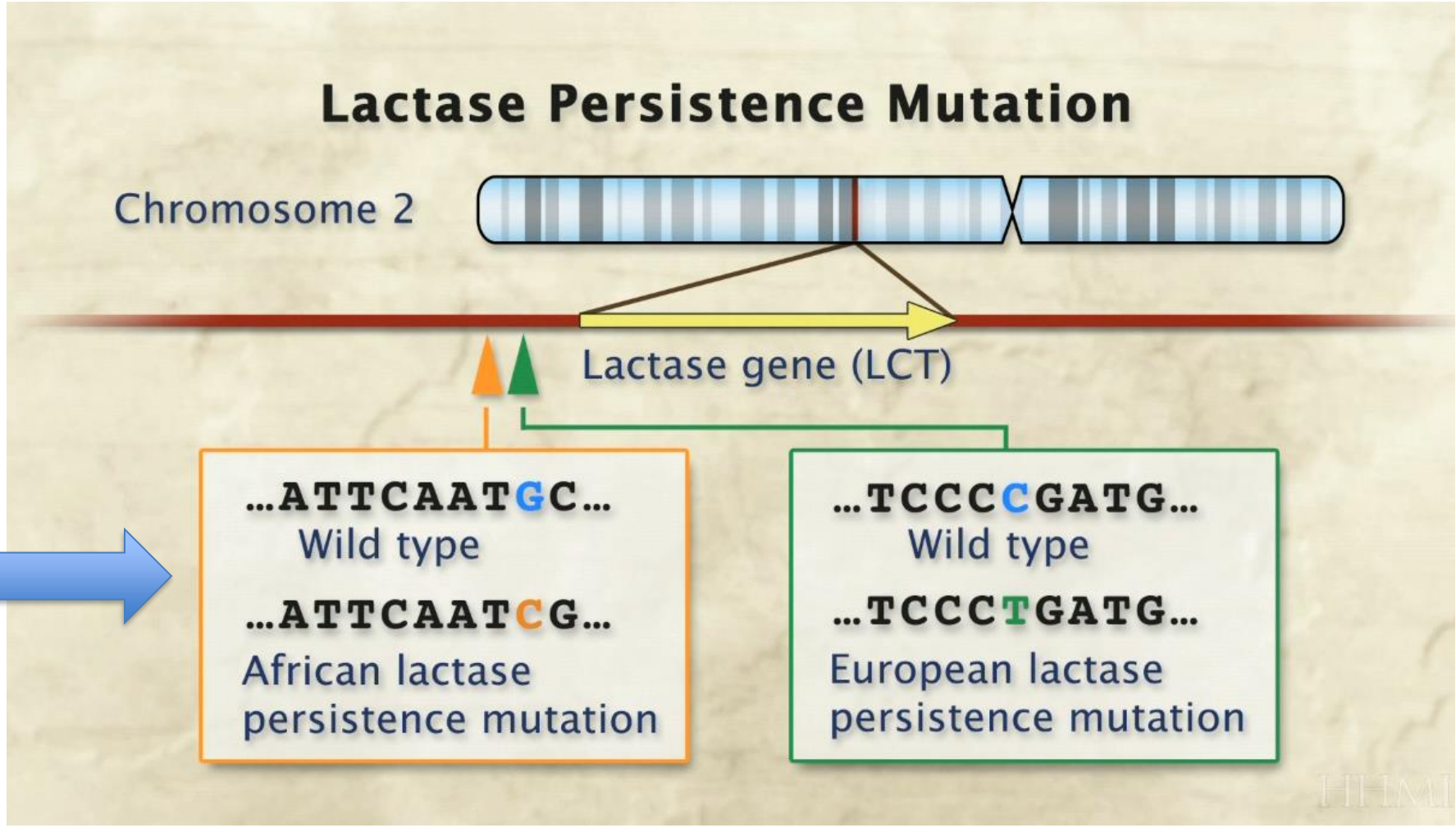
In Europeans, **point mutation** is in the **regulatory** region "upstream" (see green arrow) of the gene (yellow)

Three Genotypes are: CC=lactose intolerant because don't make lactase, CT= in-between, TT=Lactase persistent.

Is this co-dominance or incomplete dominance???

This website has good info!

http://www.vivo.colostate.edu/hbooks/pathphys/digestion/smallgut/lactose_intol.html



In African pastoralists (those that raise cattle)…

there is a **different point mutation**. It is also upstream of the lactase gene and affects the expression of that gene.

Three Genotypes are: GG=lactose intolerant because don't make lactase, GC= in-between, CC=Lactase persistent.

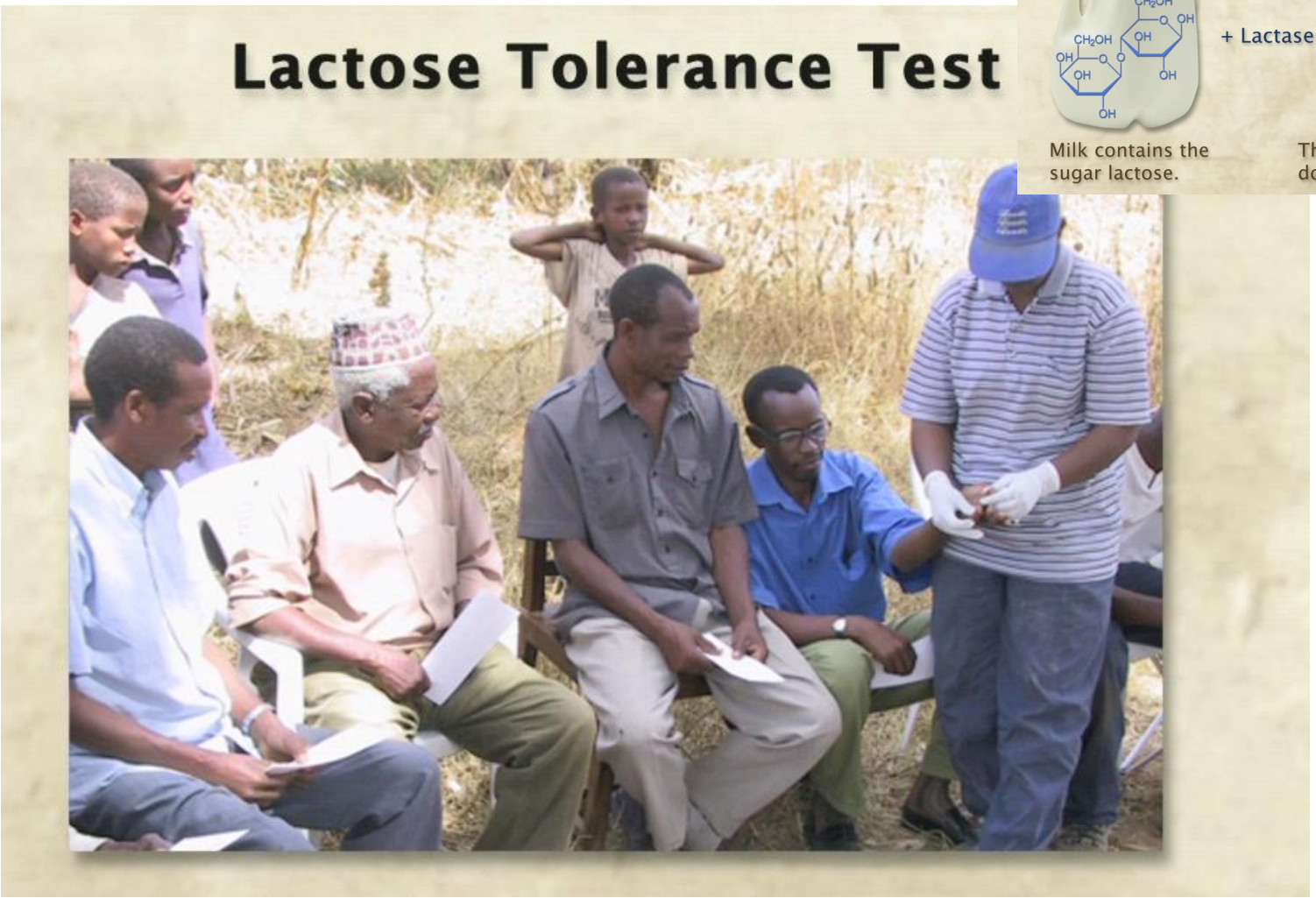
What is it called when two populations or lineages evolve the same phenotype…?

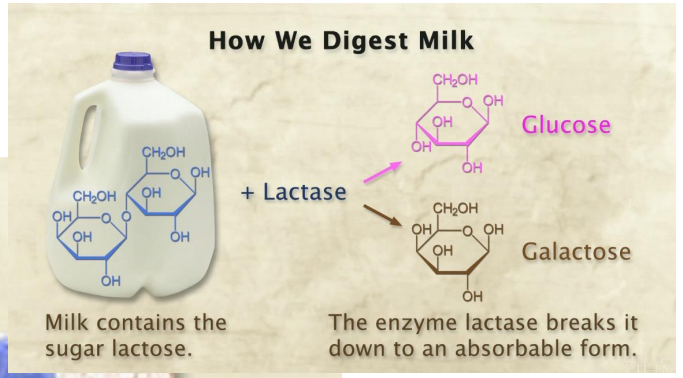
Remember gliding flaps evolved in marsupials and another lineage of mammals!

Is lactase persistance a convergent trait?
Is it a homologus trait?

Did it evolve in exactly the same way in both populations? Did the exact same mutation occur in both populations?

(FYI…How do they measure lactose intolerance?
Look at rise in glucose over time with diabetes blood test.)





How do we look for the footprint of natural selection in genomes?
How can we tell whether this lactase persistence gene has been selected for?

If a favorable mutation occurs and increases fitness of those that have it (like the ability to digest milk in some parts of the world) it will be selected for.

As selection works on this particular gene or region of the genome, neighboring regions will get dragged along.

This is because genes may be close to one another on a chromosome (**linked**) and will tend to be inherited together.

Recombination shuffles up a bit…but still see a pattern.

We covered linkage on the very first day of this section of the course!!

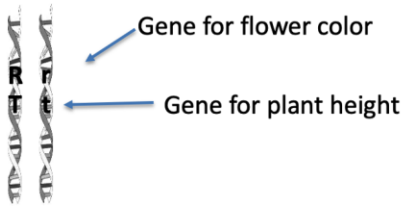
Posted as “Chapter 5 leftovers!”

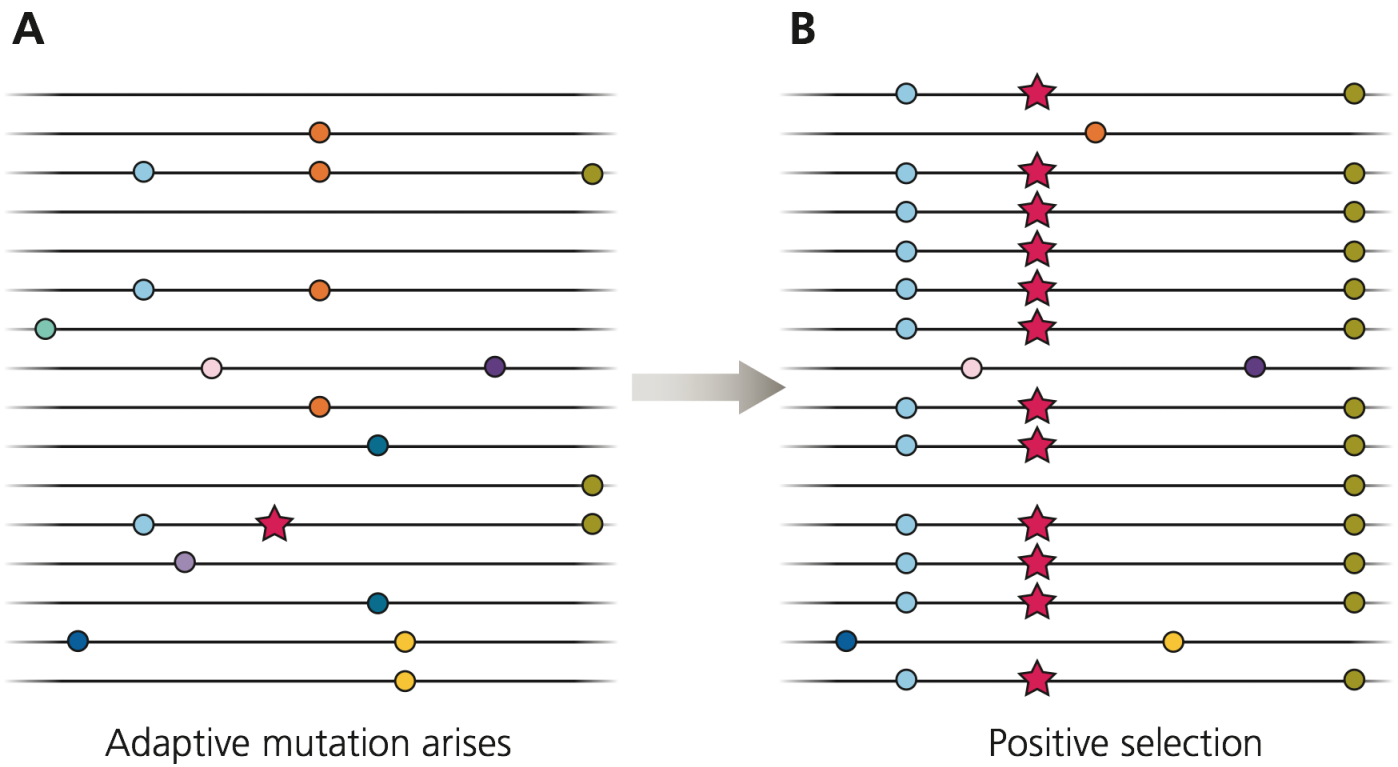
G. Two loci or genes (and thus the traits they code for) **may be linked** if they are close together on the same chromosome!

If close together recombination is unlikely to break them apart and pairs of alleles will likely be inherited together through meiosis.

If you inherit one you very likely inherit the other!

Remember each chromosome contains thousands of genes, “organized linearly on chromosomes like beads on a string.”





Each line is the same region of a chromosome in a different individual in this population.

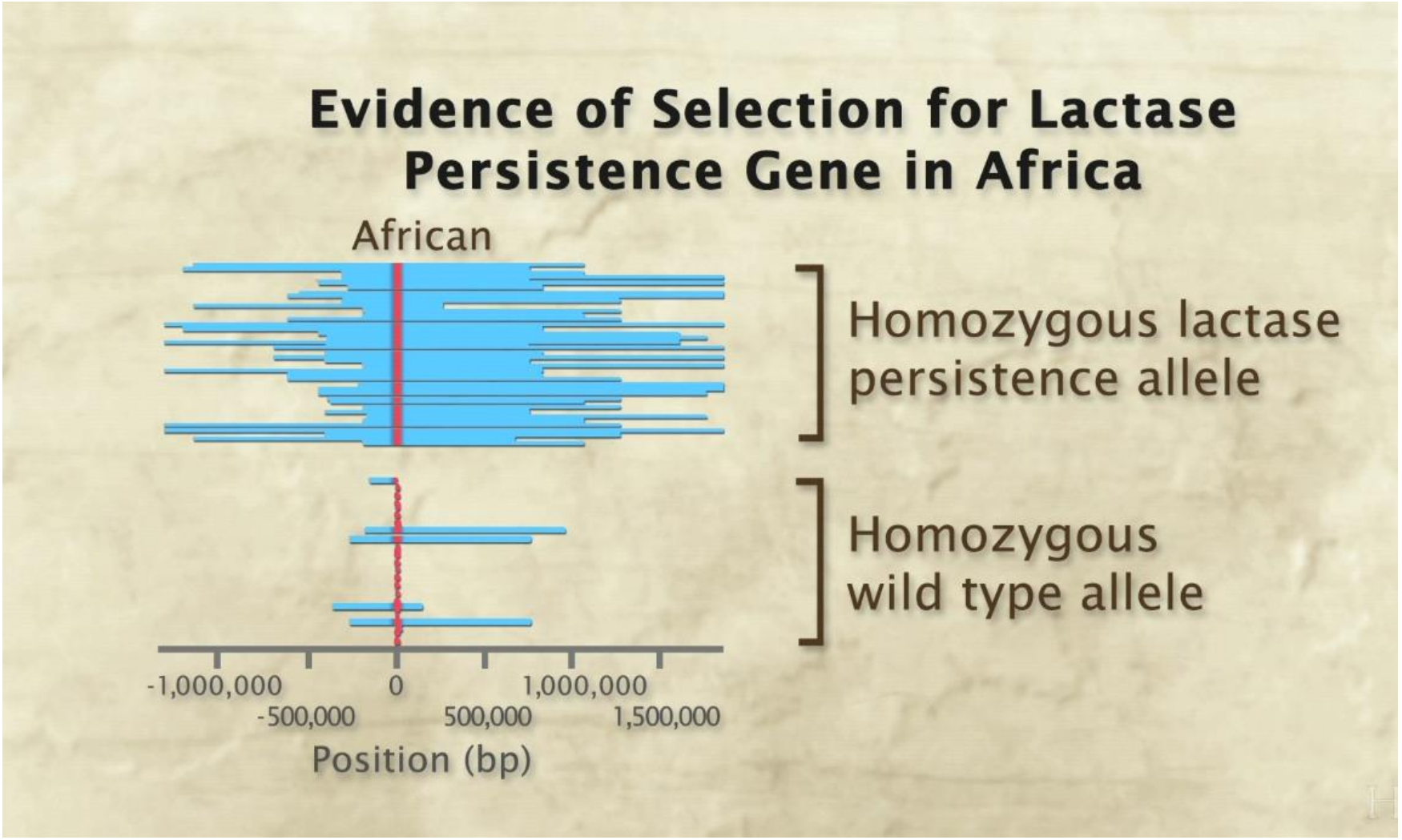
If star mutation is selected, not only will there be more star alleles in the population over time (see right) but the regions next to the star gene will also increase in frequency because they are physically linked (are neighbors) on the chromosome!

Sometimes we call those linked genes **hitchhikers**.

When other linked genes are dragged along or **hitchhike** along with a selected gene and increase in frequency we call this a….

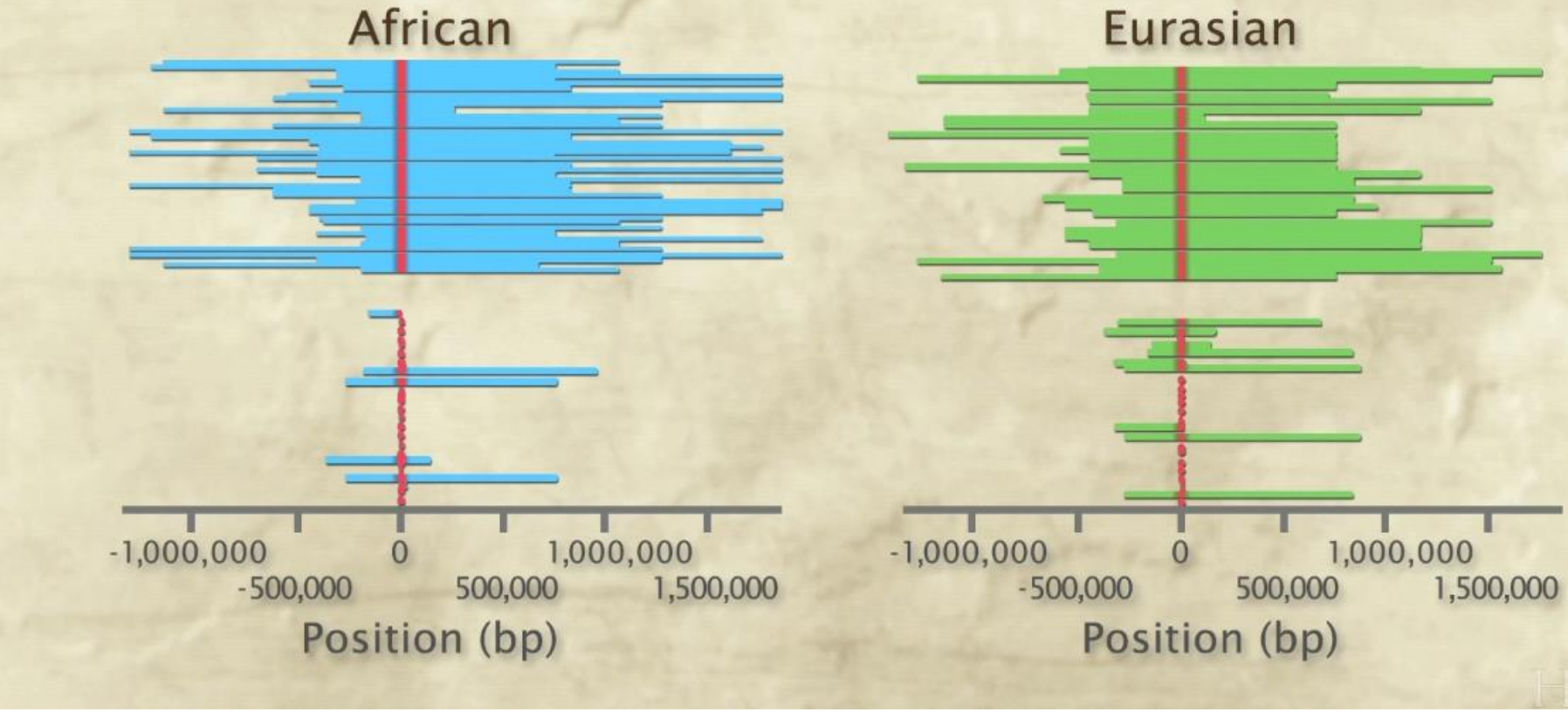
Selective sweep!

Basically it is when we see a gene under selection and we also see all its neighboring genes in many or all individuals in a population.

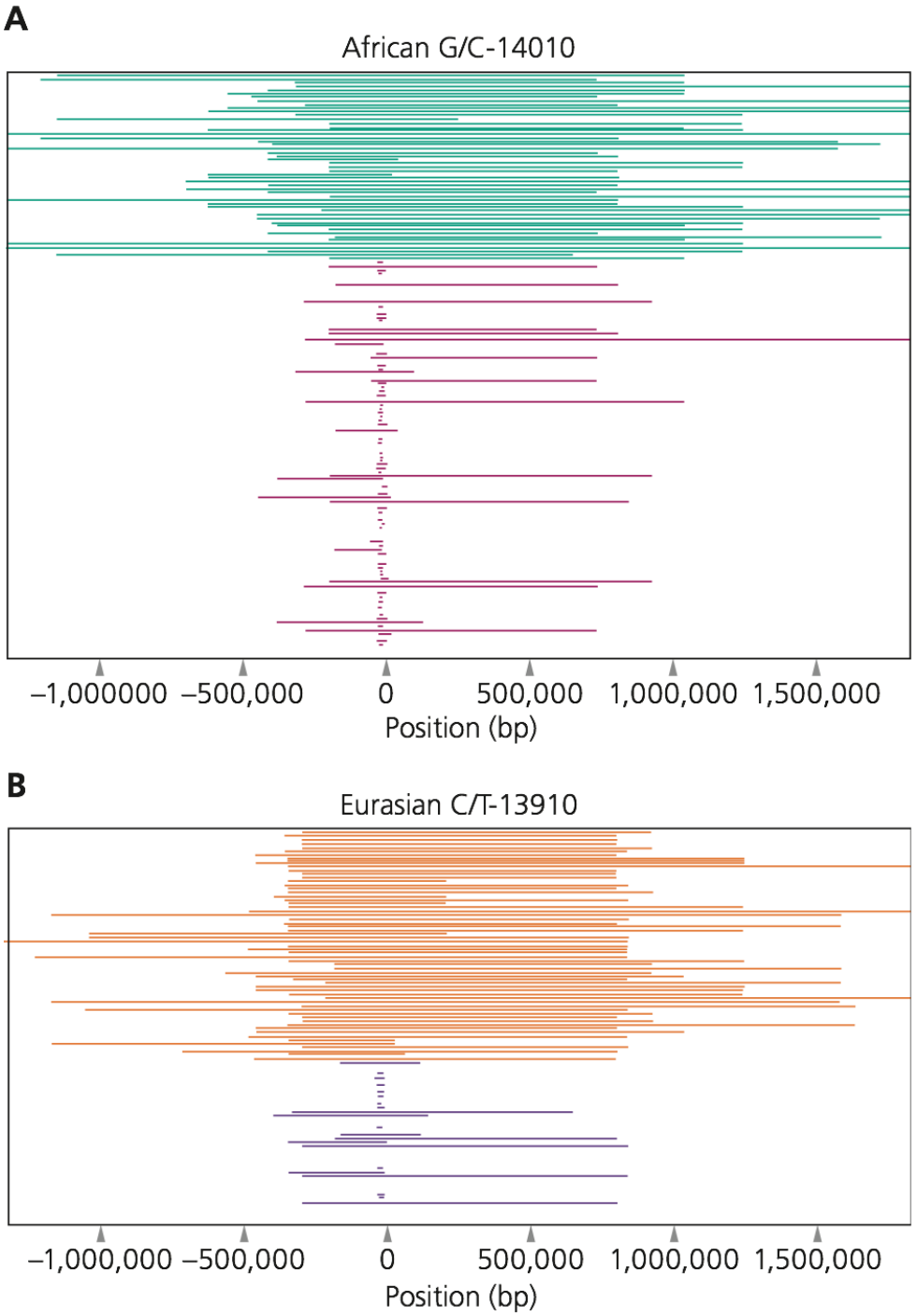


Blue lines are regions that are similar in different people. When selection is strong we will see similarities in large stretches on either side of the gene that is being selected for in many people in a population.

Different Lactase Persistence Mutations Rose to High Frequency Due to Selection



FYI…Your text has a slightly different image.



Real Selection in Natural Populations

- Mice (text-you)
- Galls and Gallflies (text-you)
- Galapagos Finches (class and in text)
- Clover (class not in text)
- **Human lactose intolerance** (class and in text BUT **Is now in CH 8.7**-Will re-connect with last part of class on human evolution.)

Incidental Selection by humans

- Bighorn sheep
- Fish - Cod (in class not in text) and Salmon (text-you)
- Insecticide resistance Bt/Glyphosate resistance

Artificial selection (selected purposefully by us)

- Domesticated crops
- Dogs, Pigeons