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Addressing Misconceptions about Evolution

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Why are misconceptions prevalent?

- Students are not a blank slate
- Knowledge comes with implications in the minds of students (whether real or imagined)
- Understanding and context of knowledge influenced by environment (peers, family, politics, media, etc)
- Must acknowledge this as we teach

Why must we address this?

- Students are not naturally reflective, and will not consider their own misconceptions unless they are prompted to (or they are pointed out on an assessment).
- Unaddressed misconceptions tend to “stick” even when in conflict with new, correct, information
- Lack of confidence in understanding can lead to new misconceptions even if previous understanding is more accurate

Tips and Tricks: Full Disclosure

- Tell the students ahead of time that it' s ok to have misconceptions (and that they will)
- Stress that part of the goal of your curriculum is to help them address these using evidence they can see themselves
- Make it an expectation that they will reflect on their learning and how their understanding has changed
- Give context: Most people out in the world don't know this, so learn enough to be the informers!

Tips and Tricks: Full Disclosure

- Make it an expectation that they will reflect on their learning and how their understanding has changed
  - "Identify a misconception that you had on your pre-test and explain where it came from/why you thought that way. How was your understanding changed"
  - Have students address the misconceptions of others
    - Essay response to a friend who doesn't want to learn Evolution because it's "just a theory"
- Give context: Most people out in the world don't know this, so learn enough to be the informers!

Tips and Tricks:

- Be careful not to accidentally exacerbate the misconceptions but don't be afraid to show your own!
  - students are confused if you go back and forth between common use of terms (like theory) and scientific use
  - Be a good model for learning: students respond well to personal anecdotes like "when I first learned this… This is what I thought"–

Tips and Tricks: Make them Write

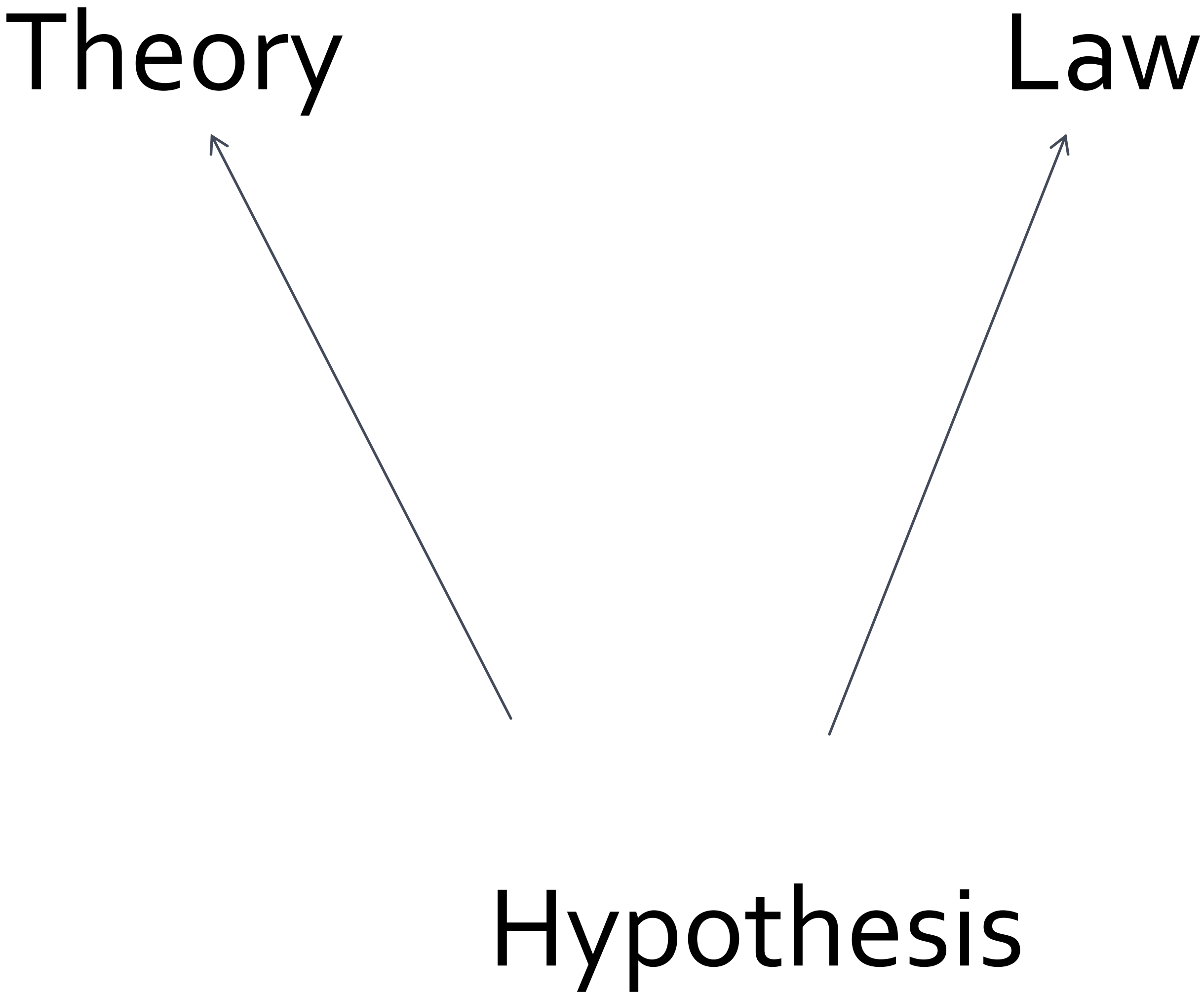
- Most misconceptions are invisible and easy to hide
- Giving choices means partially correct understanding can mask misconceptions
  - True/False test: mix of success
  - Changing to an Essay assessment: less than 1% got answers correct (esp. related to definitions of theory, etc)
    - Led to good conversations in class and a discussion abot why some of the misconceptions were so prominent

Terminology: student misconceptions

- Hypotheses are educated guesses (but inability to define what 'educated' means)
- Laws are the end all be all of scientific facts, most reliable, they are the TRUTH
- Theories are….
  - Somewhere in the middle, better than hypotheses, not as good as laws
  - Not supported enough to be laws
  - Hypotheses that some/many scientists agree with
  - Not a law because there it is not 100% absolute Truth

Terminology: the reality

- Educated means knowledgeable in that specific subject area (i.e. I wouldn't hypothesize about history)
- Laws are descriptions (equations, etc)
  - She was carrying a very large text book
- **Theories are explanations**
  - She had a biology test she was planning to study for
- Theories and laws are equally supported by the scientific community (with no exceptions)
- Hypotheses, with enough support, can become laws if they describe, or theories if they explain


Theory
Law
Hypothesis

Terminology: the importance

- **<u>Misunderstanding what a theory means undermines its credibility to students (and society at large)</u>**
- *Assuming that a theory could become a law if "good enough" also implies that is shaky enough to be rejected at any time*
- *Knowing that there are both descriptions and explanations enriches understanding of the subject*

Common Ancestry: student misconceptions

- Evolution
  - Says we descended from apes.
  - Talks more about change
  - Still has "gaps" in its record
  - Relatedness doesn't have much evidence

Common Ancestry:reality

- Evolution
  - suggests shared ancestry, not direct descent
  - Explains differences **as well as similarities** between species
  - Many transitional fossils found (Inner Fish!)
  - Homologous structures provide evidence

Searching for Evidence

- Identifying homologous structures
  - Defined as having:
    - Similar shape and make up- bone, etc.
    - Similar organization- where it's at in the body
    - Similar development- from embryo/early stage, how it forms
  - These characteristics support that they share a common ancestor
    - Common ancestry should not be a criteria for being homologous if you're using it as evidence!

In the Lab

Figure 2: The various skulls of humans over time are shown

Figure 4: Shown here are skeletons of a various animals with the human in front

Figure 1: Various vertebrate skeletons. The vertebrae are homologous structures.

Digital samples are improving if you don’t have physical ones!

http://gencept.com/stunning-monochromatic-exploration-of-vertebrate-skeletons-by-patrick-gries

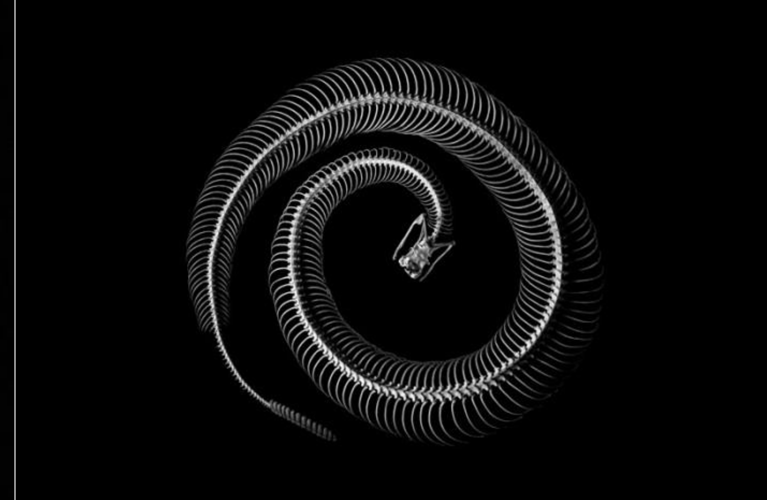


Figure 3: The human, horse, and pig leg are shown from left to right respectively.

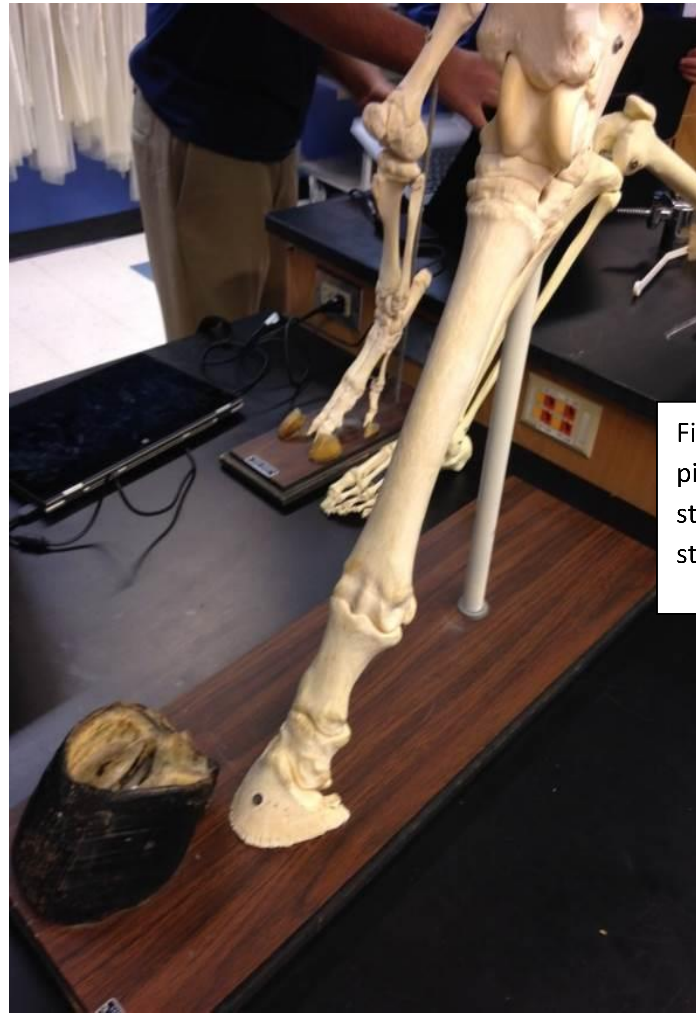


Figure 2: Horse leg, human leg, and pig leg. The horse has a vestigial bone structure. The legs are homologous structures.

Searching for Evidence

- Analagous Structures
  - Defined as having:
    - Similar function
    - Not meeting any of the other requirements for homology
  - These characteristics do not support that species have a recent common ancestor, but do help support natural selection
    - Makes sense that if particular characteristics develop independently (like ability to move quickly) it will be selected for

Figure 6: Analogous structures: Armadillo shell and turtle shell with skeleton. Turtle skeleton is attached to its shell.

Figure 7: Butterfly with bird skeleton. Their respective pairs of wings are analogous structures.

Searching for Evidence

- Identifying vestigial structures
  - Defined as having:
    - Having a reduced function or no function
    - Usually small in appearance
  - The existence of these structures can only be explained in light of ancestry: at one time they had an ancestor in which it was functional
  - These characteristics support common ancestry with organisms that have similar fully functional structures

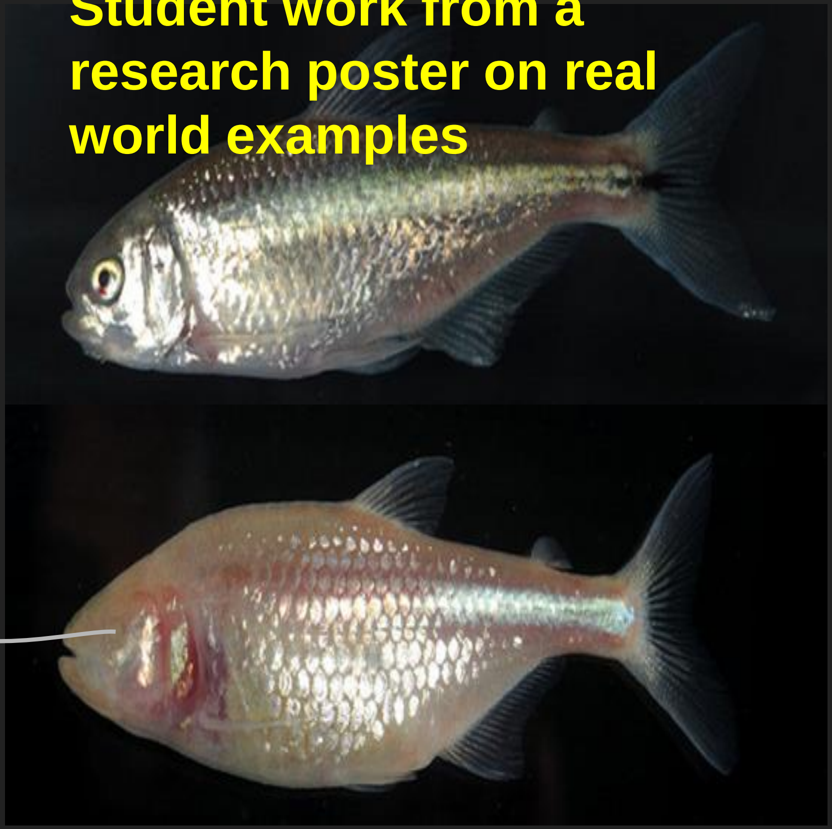
Vestigial Eyes and Pigmentless Bodies in *Astyanax mexicanus*

Introduction

There are two categories of the *Astyanax mexicanus*: the blind cavefish and the surface fish. Mutations in the blind cavefish were naturally selected to improve its fitness in the cave environment, thus diverging from its surface counterpart (Jeffrey 2003).

Vestigial Eyes

Because fish with good eyesight did not survive better than fish with worse eyesight in dark caves, they degenerated into vestigial structures. This also allowed the blind cavefish's other sensory organs to be enhanced, which benefit the cave animal more (Jeffrey 2003). The cornea, iris, and ciliary body do not develop, although neural crest cells migrate into the eye region (Jeffrey 2005). Plus, exposed eyes can get infected and damaged, so it is better they are hidden away.



Pigmentless Bodies

In cave environments, because there is no light, fish cannot see or be seen. Thus, having a pigment is a waste of energy, which could be put into other functions that better aid the fish in survival. Pigmentation improves survivability in a normal environment, with light, by attracting mates or blending into the environment to be safe from predators.

Works Cited

Jeffrey, W., Strickler, A., and Yamamoto,Y. (2003, Aug 1). *To See or Not to See: Evolution of Eye Degeneration in Mexican Blind Cavefish.* Retrieved from http://icb.oxfordjournals.org/content/43/4/531.long

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Melina R. (2012, Jan 23). *In Images: The Extraordinary Evolution of 'Blind' Cavefish.* Retrieved from http://www.livescience.com/18069-evolution-blind-cavefish-image-gallery.html

Natural Selection: student misconceptions

- The biggest, strongest, fastest survive, i.e. fitness
- All about predators and prey
- Selection is the only way that evolutionary change can happen
- Selective pressure means that species develop characteristics because they need them to survive.

Natural Selection: the reality

- Fitness is about successful reproduction (being big, fast, and strong is just sometimes helpful for that)
- Fitness is not just about competitors or predators, can also be about ability; how they use other resources in the environment, what foods they can eat, and other factors.
- Selection is just one mechanism of Evolution

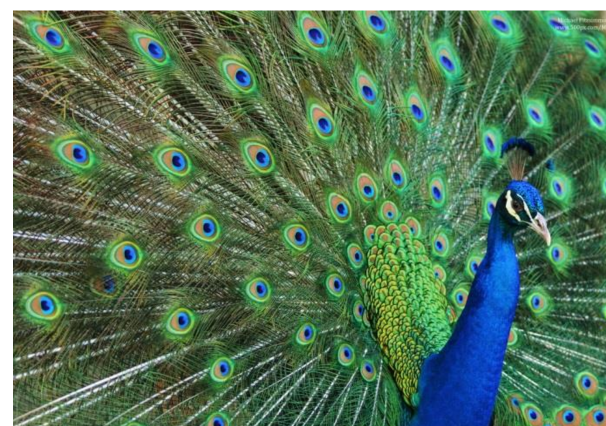
Natural Selection: the reality

- The Big One: Characteristics cannot develop based on need.
  - Characteristic must exist first
    - Stresses the essential nature of mutations for any evolutionary change
  - Then selective pressures can result in an increase/decrease of the characteristic

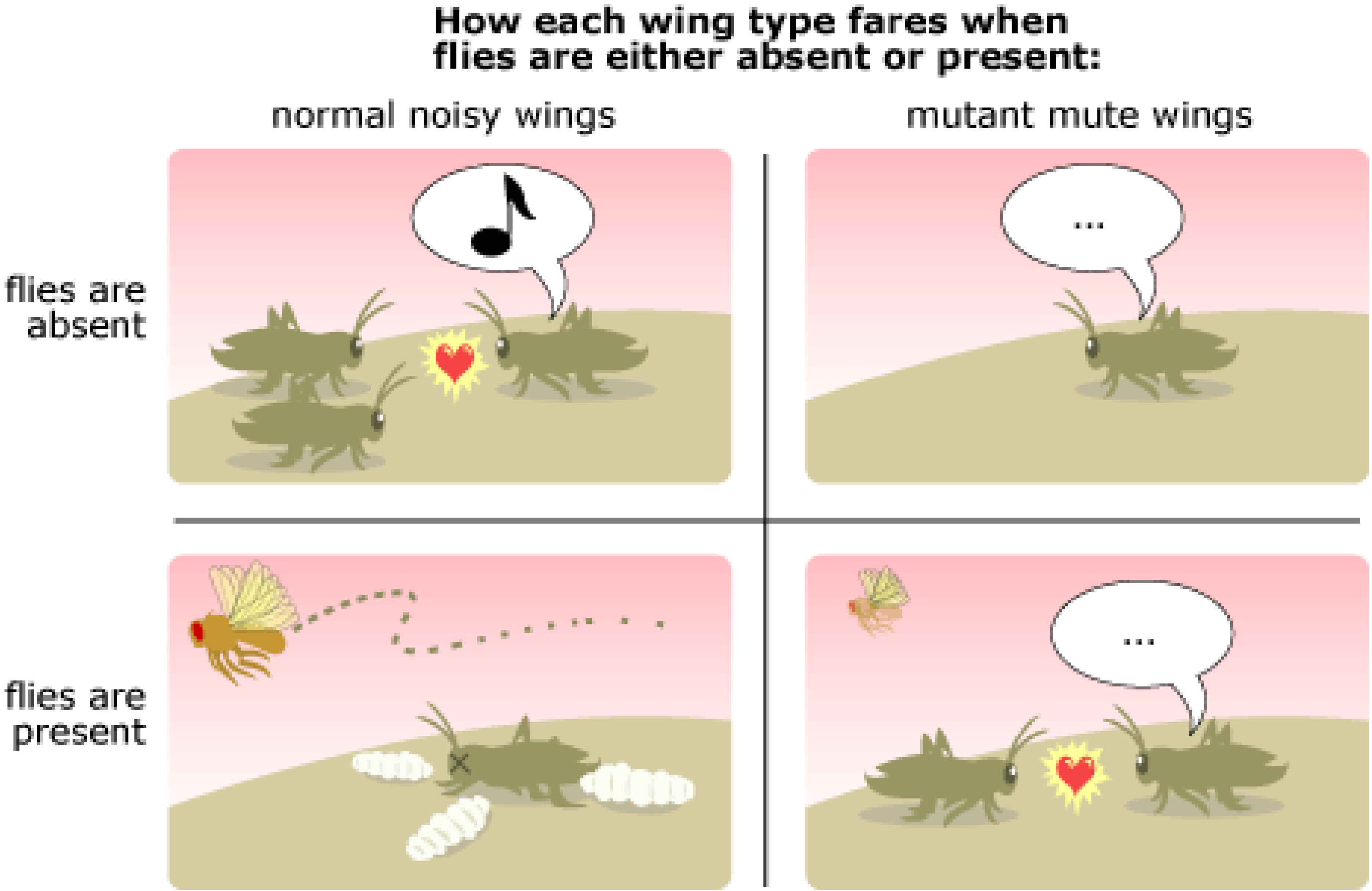
  - Major pieces of evidence: if characteristics could be based on need, all changes would be beneficial, extinctions would be unlikely.

Evidentiary Examples

- Special cases of Sexual Selection
  - Peacocks- tails
  - Silent crickets- parasitic fly finds them with sound; but chirping is a mating strategy
  - Praying Mantis-female cannibals



Crickets



http://evolution.berkeley.edu/evolibrary/images/news/fliescrickets.gif

Genetic Drift: student misconceptions

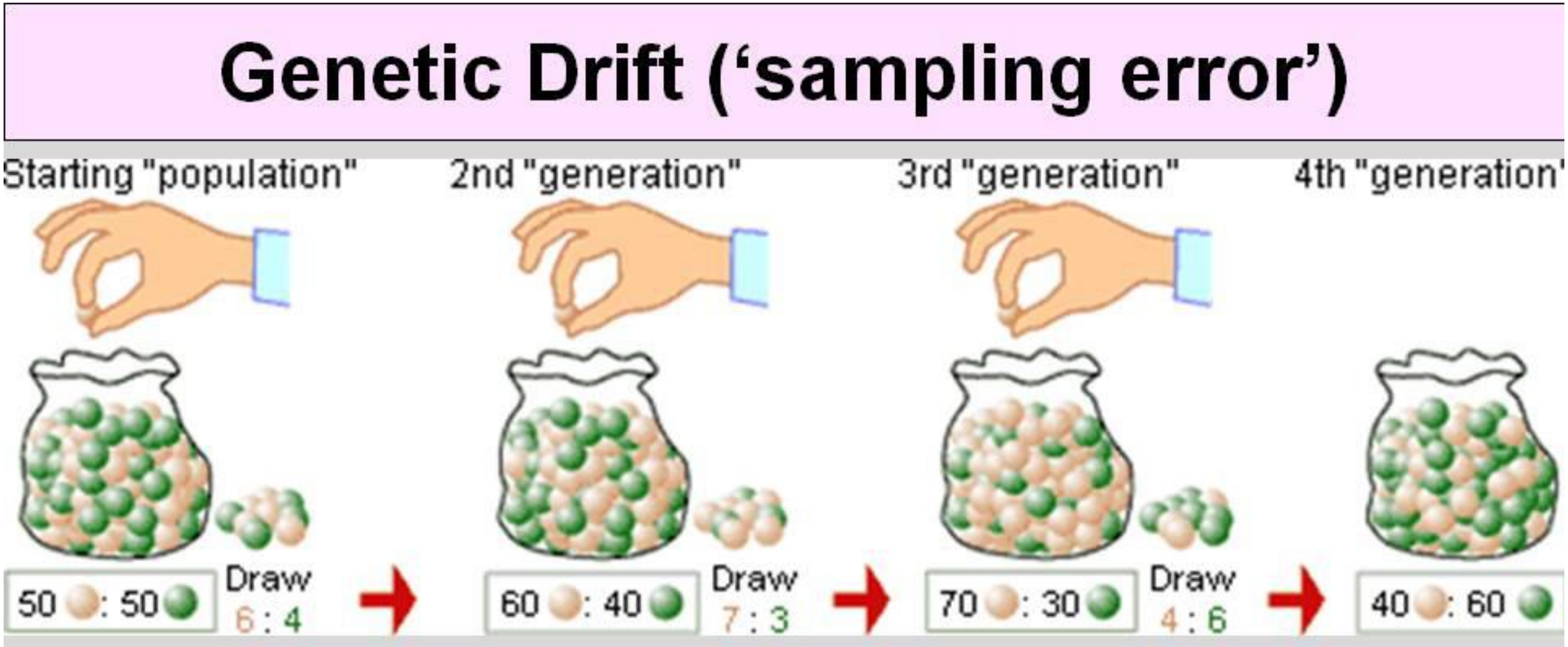
- Usually confused with gene flow
- Assume that it's all externally caused
- Or just flat out not understood
- Only happens in small populations

- Reality:
  - Random fluctuations in gene frequency: can be attributed to probability in reproduction
  - WILL occur in a large population, but may just not have as much of an impact.

Genetic Drift: Simulation

- Simulations of Drift using different alleles and populations
- @ end can see how many generations it took to lose either A or a allele
- Can repeat the experiment with a larger population to see differences
- Look at existing data

Drift Simulation



http://evolution.berkeley.edu/evosite/evo101/IIID1Samplingerror.shtml

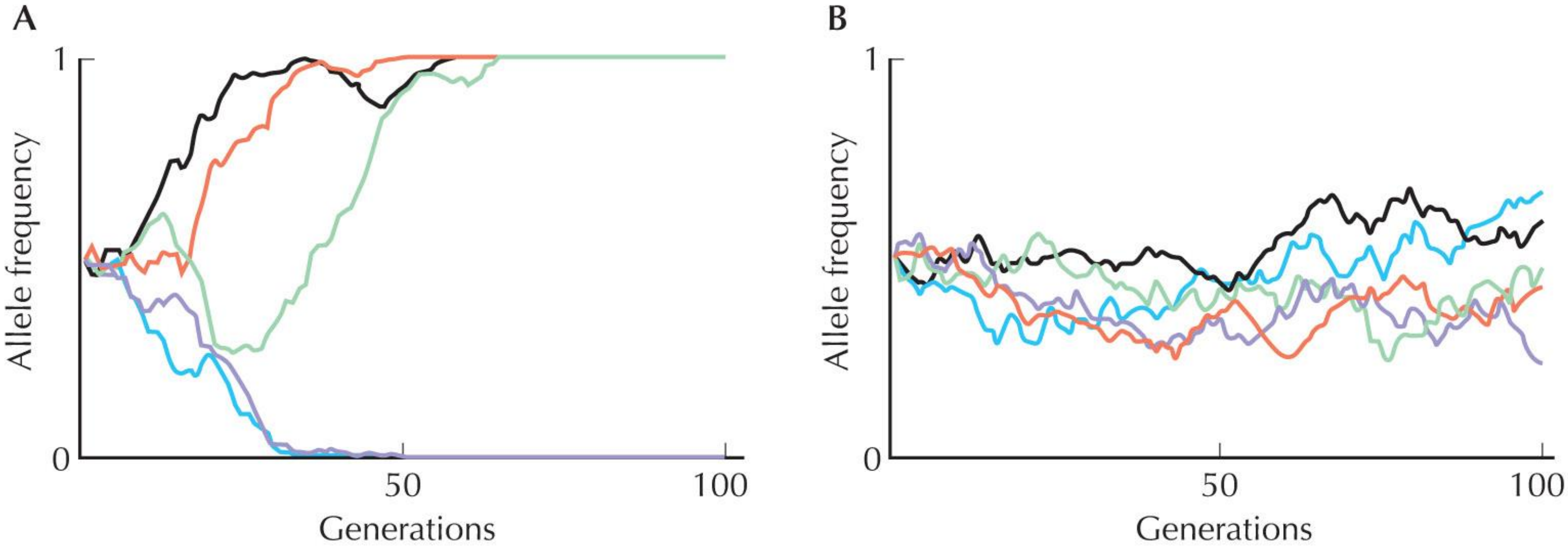
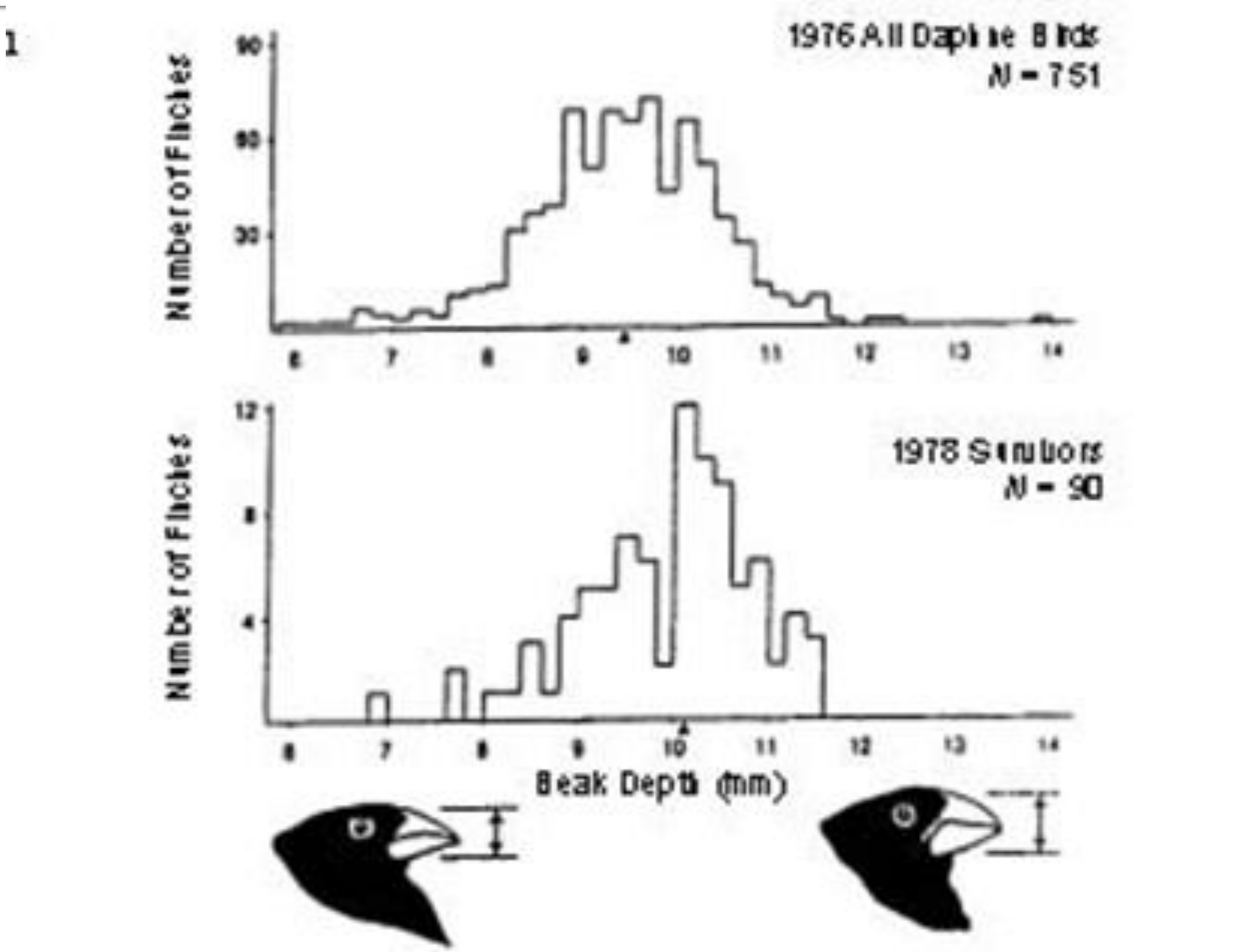


FIGURE 23.19. Inherited variation in fitness increases the rate of random genetic drift—a process known as the Hill–Robertson effect. (*A*) Neutral allele frequencies increase or decrease at random, as they become associated with fit or unfit genetic backgrounds. For example, one replicate (*green*) increases steadily between generations 30 and 50, because it happens to be in a particularly fit background. Across five replicates, neutral variation is lost by 70 generations. The simulation shows a population of 400 genomes, with a variance in relative fitness of 0.1 and a recombination rate of 0.05. (*B*) With no selection, allele frequency fluctuations are not correlated from one generation to the next, and so neutral variation persists for much longer.

Other misconceptions

- Evolutionary change takes extraordinary amounts of time

Peter and Rosemary Grant’s work with Finches



http://www-tc.pbs.org/wgbh/evolution/library/01/6/pdf/l_016_01.pdf

Other misconceptions

- Humans are “exempt” from the process at this point

Smelly t-shirts

- The t-shirts that females most associated with associate mates were from males with dissimilar MHC complexes.
- Opposite true for association with family

ndent mate preferences in humans C. Wedekind and others 247

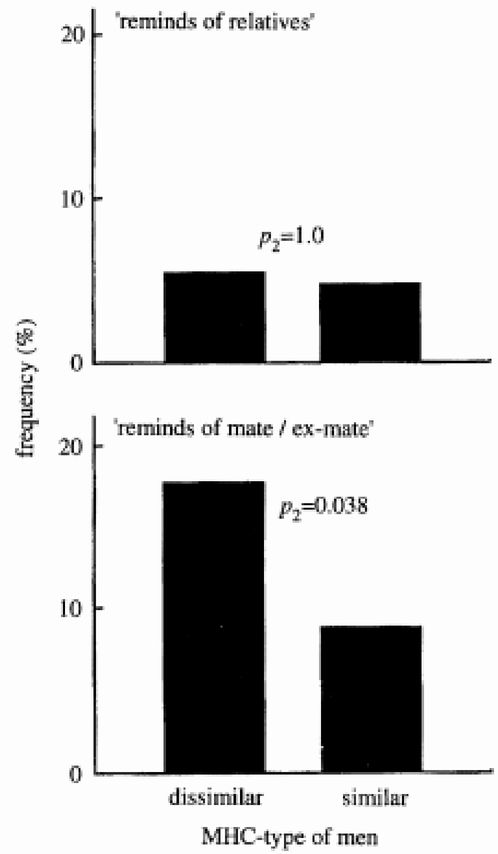


Figure 4. Frequency of women's memory associations by sniffing the odours of MHC-dissimilar men and of MHC-similar men with relatives, and with current or previous mates, respectively (Fisher exact tests, two-tailed). Most of the memory associations in the lower graph were by women who stated that they were sure they had not taken the contraceptive pill when they chose the particular mate they were remembered during the experiment (31 of total 39 cases, $Z = 3.68$, $p < 0.01$).

http://www.coherer.org/pub/mhc.pdf

Take Aways

- Be upfront about the misconceptions
- Be aware ahead of time of what they can be
- Have students identify their own and reflect on them later
- Writing is much more informative
- Use data and evidence so they can build their own understanding
- Good to have real world context- get them excited to share!