

# Adaptation

# Natural Selection v Evolution

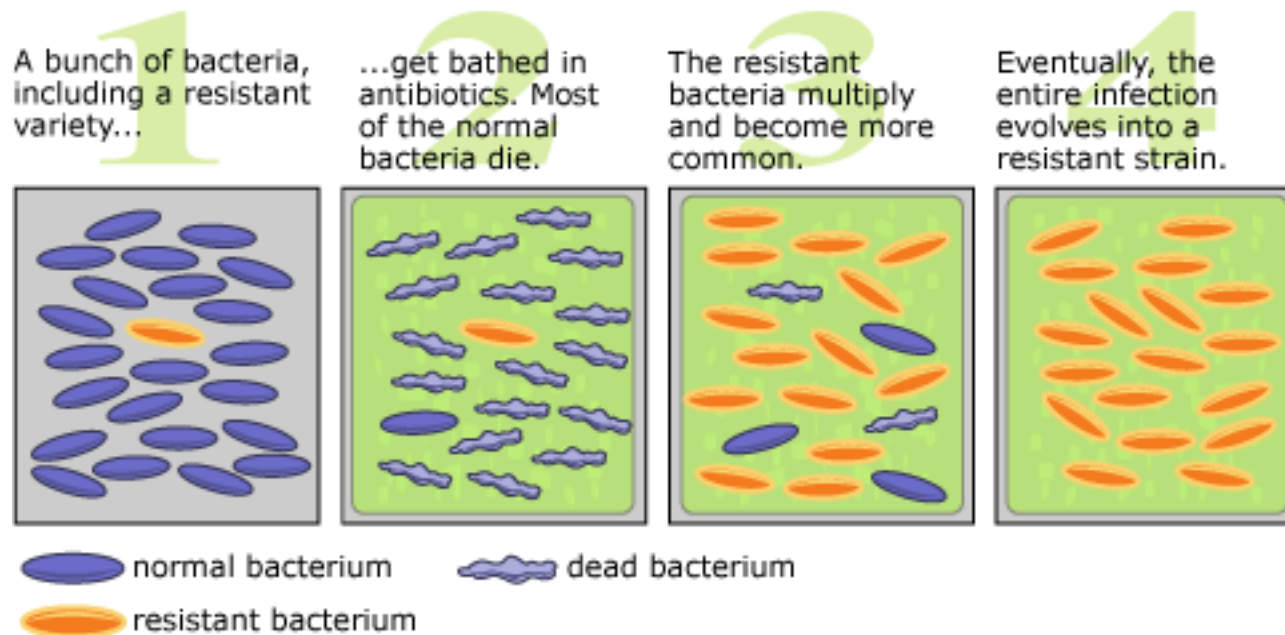
- Evolution = observed change in organisms over historic and geologic time
- Natural selection = one hypothesized mechanism for change
  - Has enormous body of supporting evidence

# What is natural selection?

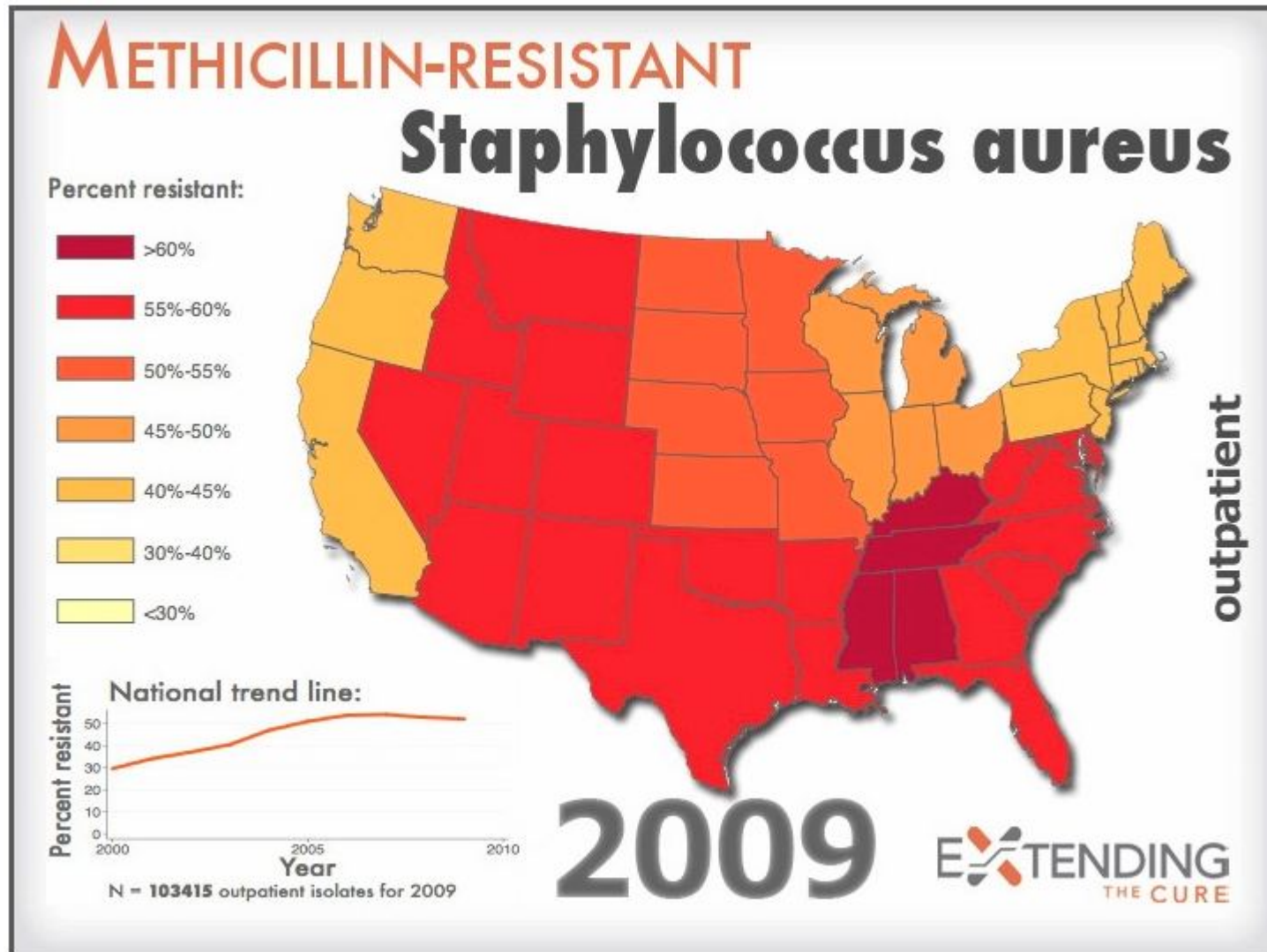
- Because organisms with greater reproductive success leave more offspring, they make a larger contribution to the gene pool. Any heritable characteristics that contribute to reproductive success will come to dominate the gene pool. The species changes in the direction of those characteristics.
- In other words, the currency of natural selection is **BABIES**. Survival is only important in promoting more babies.
- Natural selection occurs at the level of the **INDIVIDUAL**, not the species. Selection is driven by what is good for the individual, not what is good for the species.

# Examples of current evolution

Humans apply very strong selection pressure to bacteria when we take antibiotics. Only a few bacteria survive the antibiotic dose, but those that do can now out-compete the non-resistant bacteria. The resistant bacteria can come to dominate as microflora.



# Examples of current evolution



<http://www.neverevents.org/infections/mrsa-map.htm>

# Examples of current evolution

The Asian shore crab was introduced to the New England coast by ships. It has bigger crushing claws than the local crabs. Wherever the Asian shore crab has been introduced, the mussels now grow thicker shells.



[http://fl.biology.usgs.gov/pics/db\\_noncrustaceans0111.jpg](http://fl.biology.usgs.gov/pics/db_noncrustaceans0111.jpg)



<http://maggiesfarm.anotherdotcom.com/archives/3561-Mussels-for-Supper.html>

# Examples of current evolution

A new contagious facial cancer appeared in Tasmanian Devils in the 1990's. The cancer is spread by territorial fighting, and is 100% lethal, usually within a year or so. In the past decade, the age at which the animals reach sexual maturity has fallen.



<http://ndn2.newsweek.com/media/70/animals-cancer-tasmanian-devil-wide-horizontal.jpg>

# Examples of current evolution

In 1971, five breeding pairs of Italian wall lizards were deliberately introduced to a small island off Croatia. The descendents of those lizards are now very different from the species they evolved from. The original lizards ate largely insects; the Croatian lizards eat only vegetation. Their gut is quite different from the original lizards and they have much larger heads to anchor their larger jaw muscles for chewing leaves.



<http://listverse.com/2011/11/19/8-examples-of-evolution-in-action/>



# Necessary conditions for natural selection to occur

1. There must be variation within the population.
  - Variation from mutation, and from errors in sexual reproduction
2. The variation must be heritable.
3. The variation must change the likelihood of successful reproduction (including survival).

# Elements in Reproductive Success

- Survival of parent: better defense, better resource use, better adapted to physical environment
- Health and fertility adaptations: maximizing the number of viable offspring

**Scenario #1:**

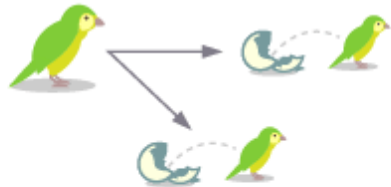
**few resources**



If a mother kakapo has a daughter...



...that daughter will likely grow up to produce some offspring of her own.



Higher fitness



If a mother kakapo has a son...



...due to the scarcity of resources, that son will likely be weak, small and unable to compete for a mate.



Lower fitness

The sex ratio of offspring depends on how plentiful resources are.

**Scenario #2:**

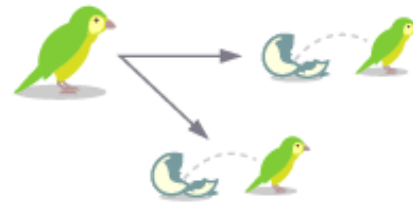
**plentiful resources**



If a mother kakapo has a daughter...



...that daughter will likely grow up to produce some offspring of her own.



Lower fitness



If a mother kakapo has a son...



...that son may be healthy, strong and able to mate with many females to produce many offspring.



Higher fitness

# Elements in Reproductive Success

- Ability to attract mates: **sexual selection**
  - Can include characteristics that threaten survival, as long as they enhance the probability of attracting a mate
  - Characteristic is a proxy for health or other positive characteristic



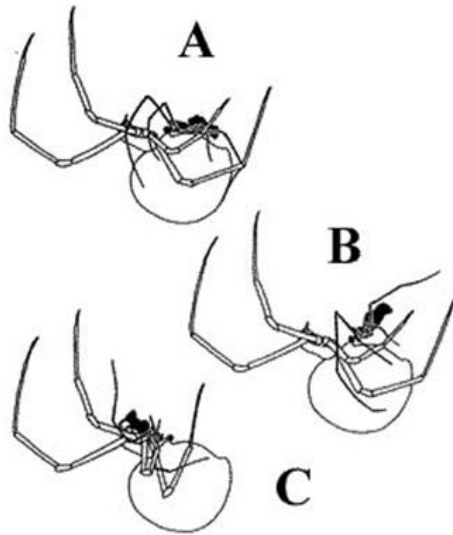
In birds of paradise, females are drab, but males have spectacular feathers – bright colors, big plumes, or long tails.

The long tails and bright colors make the males more likely to be eaten by predators.

But as long as the females strongly prefer the fancy males, and rarely mate with less fancy males, the fancy genes end up in more offspring in later generations.

So why do the girls prefer fancy males? The males with the most elaborate feathers have the lowest parasite loads – they are adapted to be healthier.

During mating, the male Australian redback spider actually flips up to present himself to the fangs of his mate.



Praying mantis and black widow spider females also eat their mates during copulation.

In some species, the male provides a boost of nutrition that results in healthier offspring.

In other species, the males that die deliver more sperm (and so have more offspring) than the males that survive.



[http://www.utsc.utoronto.ca/~mandrade/index\\_files/terminal.htm](http://www.utsc.utoronto.ca/~mandrade/index_files/terminal.htm)

[http://www.whatsthatbug.com/images/widows\\_mating\\_rus\\_2.jpg](http://www.whatsthatbug.com/images/widows_mating_rus_2.jpg)

<http://ryanellingson.wordpress.com/2013/05/14/survival-of-the-sexiest-seminal-toxins-and-sexual-cannibalism/>

# Elements in Reproductive Success

- Caring for young: altruism and self-sacrifice
  - Organisms may sacrifice themselves for relatives with whom they share a significant proportion of their genes



<http://theness.com/neurologicablog/index.php/altruism-in-squirrels/>

Squirrels do not form strong social groups, but they will adopt orphaned offspring of their close relatives.

Killdeer mothers pretend to have a broken wing to lead predators away from their nest on the ground.



<http://lemonbayconservancy.org/wp-content/uploads/2013/11/>

Killdeer-doing-broken-wing-act-near-nest-Oyster-Creek-Park-3.27.11-by-Bill-Dunson-P3270062.jpg



# Elements in Reproductive Success

- Survival of young to reproductive age:  
Two strategies
  - Parental care – have a few offspring and invest a lot in caring for them (mammals)
  - Independent offspring – have a zillion of them and let them fend for themselves (plants, most invertebrates)



The Cichlid Room Companion <http://cichlidae.com>

© Ron Coleman



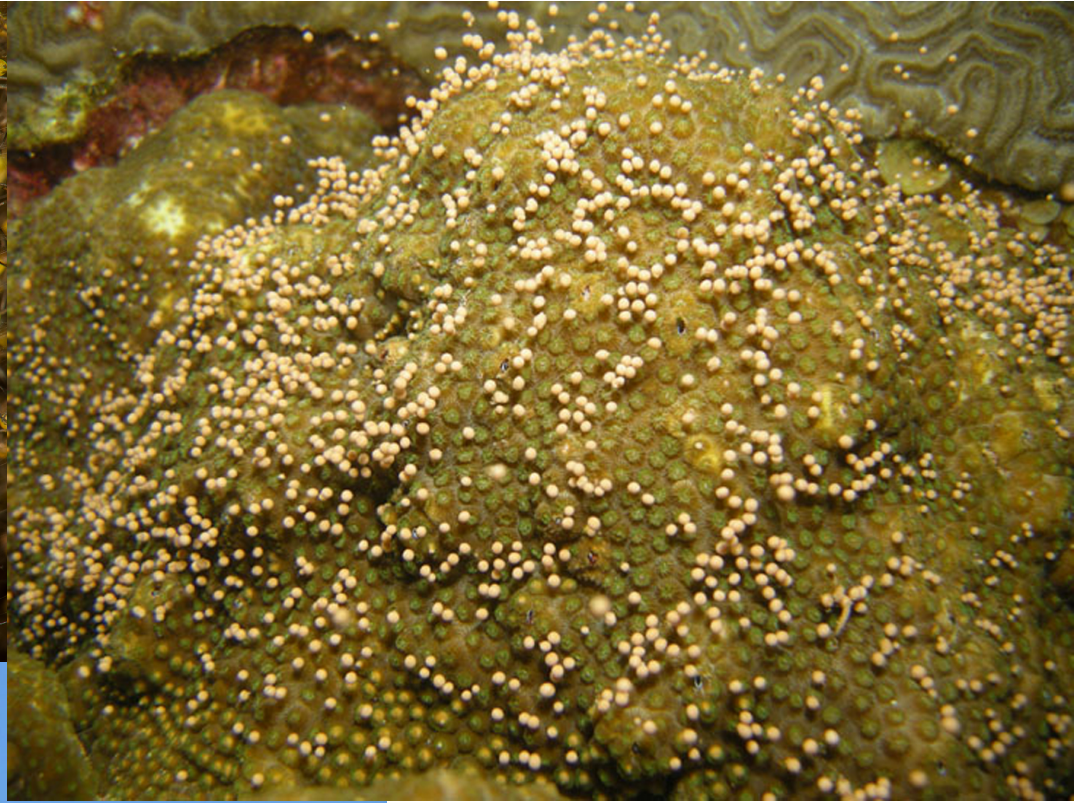
## Parental Care

<http://www.cichlidae.com/content/images/articles/a088-01.jpg>

[http://www-tc.pbs.org/wnet/nature/files/2008/12/610\\_unforgettable\\_family.jpg](http://www-tc.pbs.org/wnet/nature/files/2008/12/610_unforgettable_family.jpg)

<http://smithsonianscience.org/2013/09/beetle-moms-show-clear-signs-of-maternal-instincts-and-care/>

<https://www.nwf.org/news-and-magazines/national-wildlife/photozone/archives/2010/caption-contest-2010-winners.aspx>



Many offspring,  
little care

<http://1.bp.blogspot.com/-2B9yzJkDrGs/TwoTYTJbbmI/AAAAAAAAA6E/StURSX86JyA/s1600/pinecone2.jpg>

<http://www.naturestills.com/wp-content/gallery/invertebrate-stock-photography/spider-hatchlings.jpg>

[http://flowergarden.noaa.gov/image\\_library/expedition/coralspawn08/mfranksispawneh.jpg](http://flowergarden.noaa.gov/image_library/expedition/coralspawn08/mfranksispawneh.jpg)

# Dispelling myths of natural selection

- Adaptation does not involve trying
- Natural selection does not grant organisms what they “need”
- Natural selection is not a process of improvement toward “higher” organisms. It’s a process of adaptation in many directions – a tree, not a ladder.

# Looking at specific “maladaptive” adaptations

- Large antlers in deer
- Infanticide in horses
- Adoption of orphan quails by bachelor males
- Packs of dogs where only the alphas reproduce
  
- Can you find adaptive explanations for each?

# Does adaptation explain all characteristics of organisms?

- Neutral characters
- Pleiotropy
- Linked genes
- Spandrels

# Neutral characters

- Some characters have no impact on reproductive success, and change only by genetic drift
- Most existing variation in any species is neutral. Selection drives variation out of adaptive traits by selecting for the best form of that trait.
- E.g., ear shape



<http://news.softpedia.com/news/12-of-the-DNA-Differs-Amongst-Human-Races-and-Populations-40872.shtml>

Most of the variation in morphology that we can see among ethnic groups – eye and hair color, eye shape, body type, is in relatively neutral traits.

Most important adaptive traits – functioning of structures, fundamental biochemistry, growth and development – vary little among ethnic groups.

All humans share about 88% of their genes.



# Pleiotropy

- DNA codes for proteins
- Virtually all of these proteins serve multiple functions in the body.
- Or their resulting effects have multiple effects.
- E.g. sex hormones – trigger secondary sexual characteristics, change behavior, change other characteristics like muscle mass



The same gene that produces the brown points in Siamese cats can produce crossed eyes.

One gene that produces white coat color in cats can also produce blue eyes and deafness. If the cat carries only one gene for blue eyes and another for yellow, only the blue-eyed side is deaf.

[http://upload.wikimedia.org/wikipedia/commons/a/a7/Siamese\\_Cat\\_Cross-Eyed.jpg](http://upload.wikimedia.org/wikipedia/commons/a/a7/Siamese_Cat_Cross-Eyed.jpg)

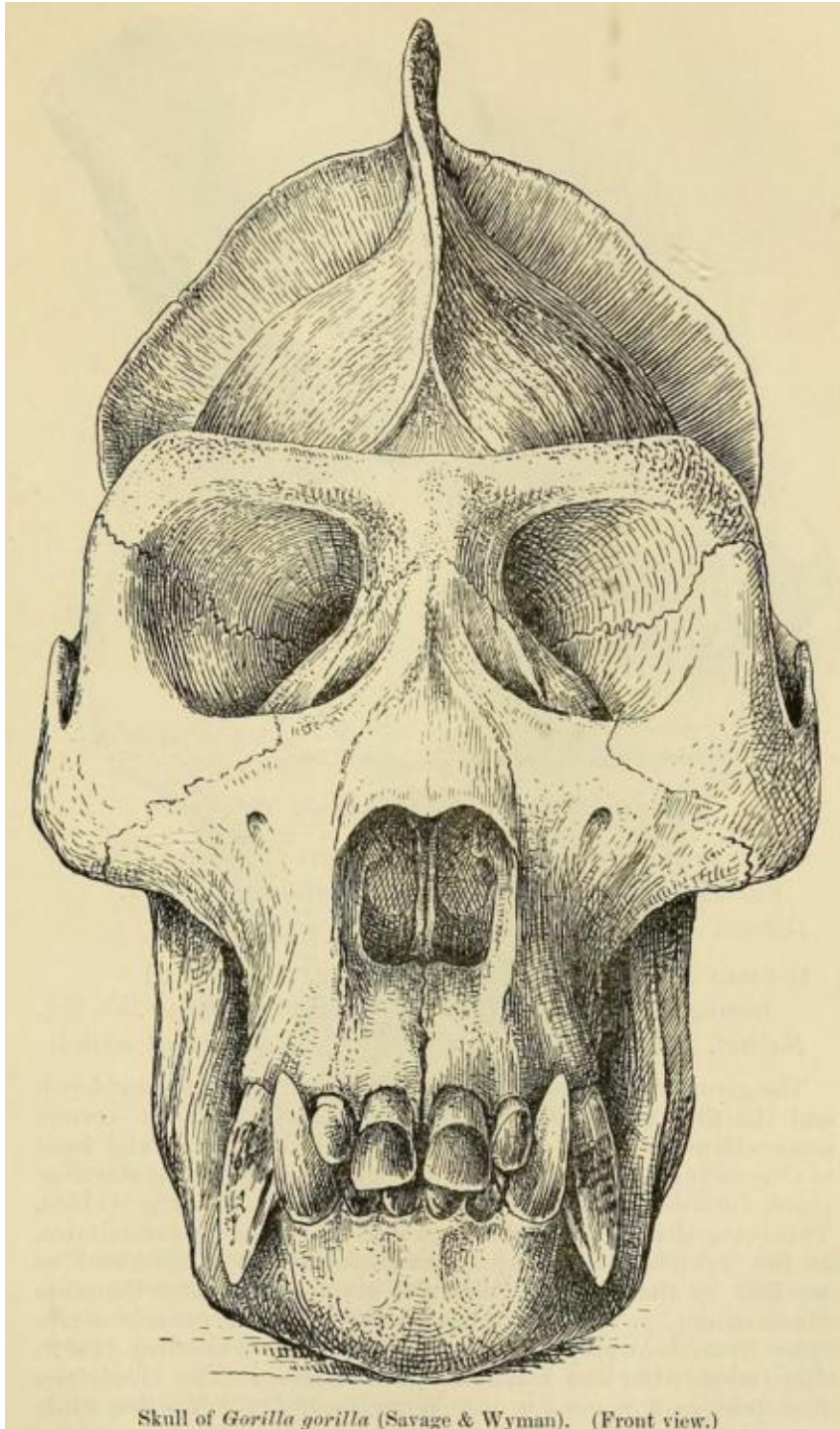
<http://www.thepetproductguru.com/wp-content/uploads/2010/10/white-cat1-300x202.jpg>

# Linked genes

- Genes near each other on a chromosome travel together in meiosis – tend to be inherited together
- E.g.
  - X-linked traits like hemophilia, color-blindness
  - Red hair, light skin

# Spandrels

- Feature that is direct structural consequence of another feature
- E.g., Skull crests in primates

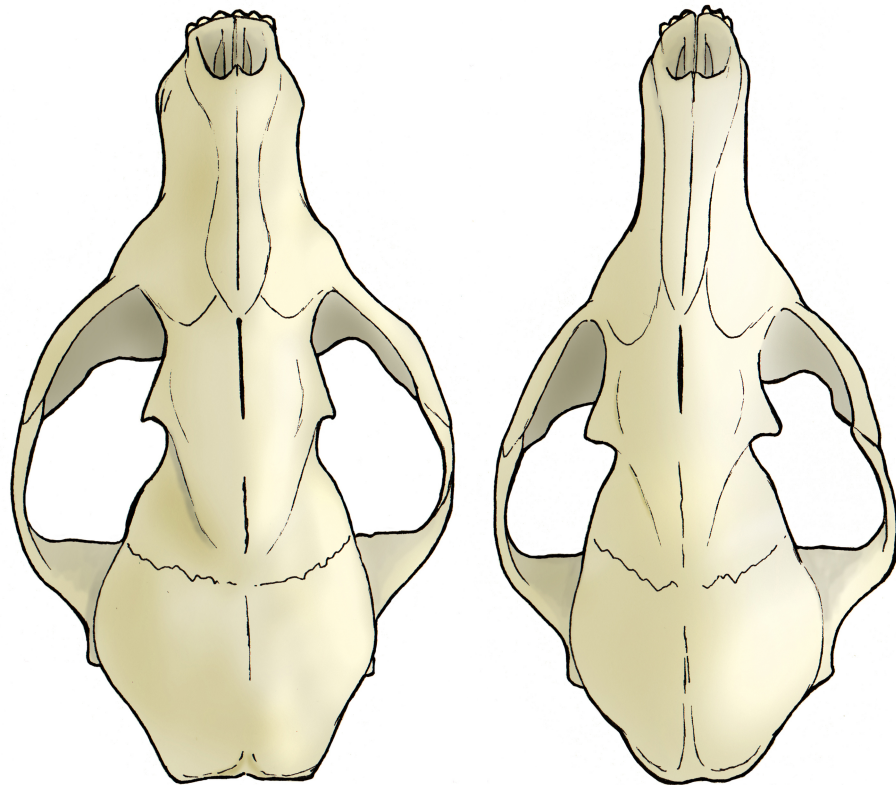


Skull of *Gorilla gorilla* (Savage & Wyman). (Front view.)

You might be tempted to look for an adaptive explanation for the big crest on the skull of a gorilla. But the crest is just the attachment site for the huge jaw muscles needed to grind the vegetation eaten by the gorilla. The size of the crest is determined by the size of the jaw. It's not a separate trait.

# Example: fox experiment

- Wild silver foxes kept on farms in Russia
- Tamest foxes were bred with tamest foxes
- What happened?



Maija Karala 2012

- After several generations, foxes looked different: curly tails, floppy ears, flatter faces, white markings – even though they were only bred for tameness, NOT for their looks
- Biochemistry of tameness somehow tied to all these morphological characteristics.
- WHY?

[http://3.bp.blogspot.com/\\_S6ta-lfb-d0/TODwJJaeswl/AAAAAAAAABc/jbpQe8vrEps/s1600/floppy.bmp](http://3.bp.blogspot.com/_S6ta-lfb-d0/TODwJJaeswl/AAAAAAAAABc/jbpQe8vrEps/s1600/floppy.bmp)

<http://hummingdinosaur.files.wordpress.com/2013/01/domesticated-and-wild-silver-fox-skulls-vulpes-vulpes-maija-karala1.jpg>

# Large Morphologic Change

- Does all change have to be through gradual increments? Or are there other mechanisms that create large amounts of change in a short time.
- “Macromutation” in structural genes – unlikely that a random change could produce something functional



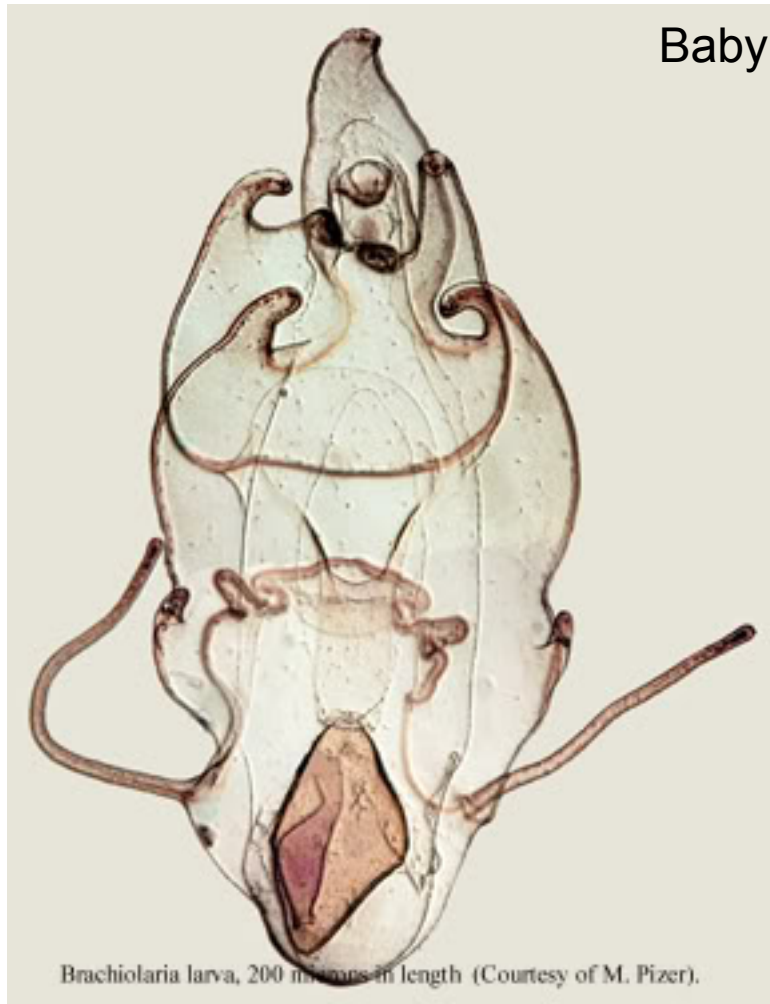
# More likely mechanisms for large morphologic change

- Mutation in regulatory genes
- Preadaptation

# Regulatory genes determine...

- Fundamental body architecture (Hox genes):
  - Bilateral v. radial is determined by 2 genes that either act together or they separately
  - E.g., starfish is bilateral as a baby and radial as an adult
- When features develop
  - Babies and adults often look nothing like each other because of the sequencing of how genes turn on and off

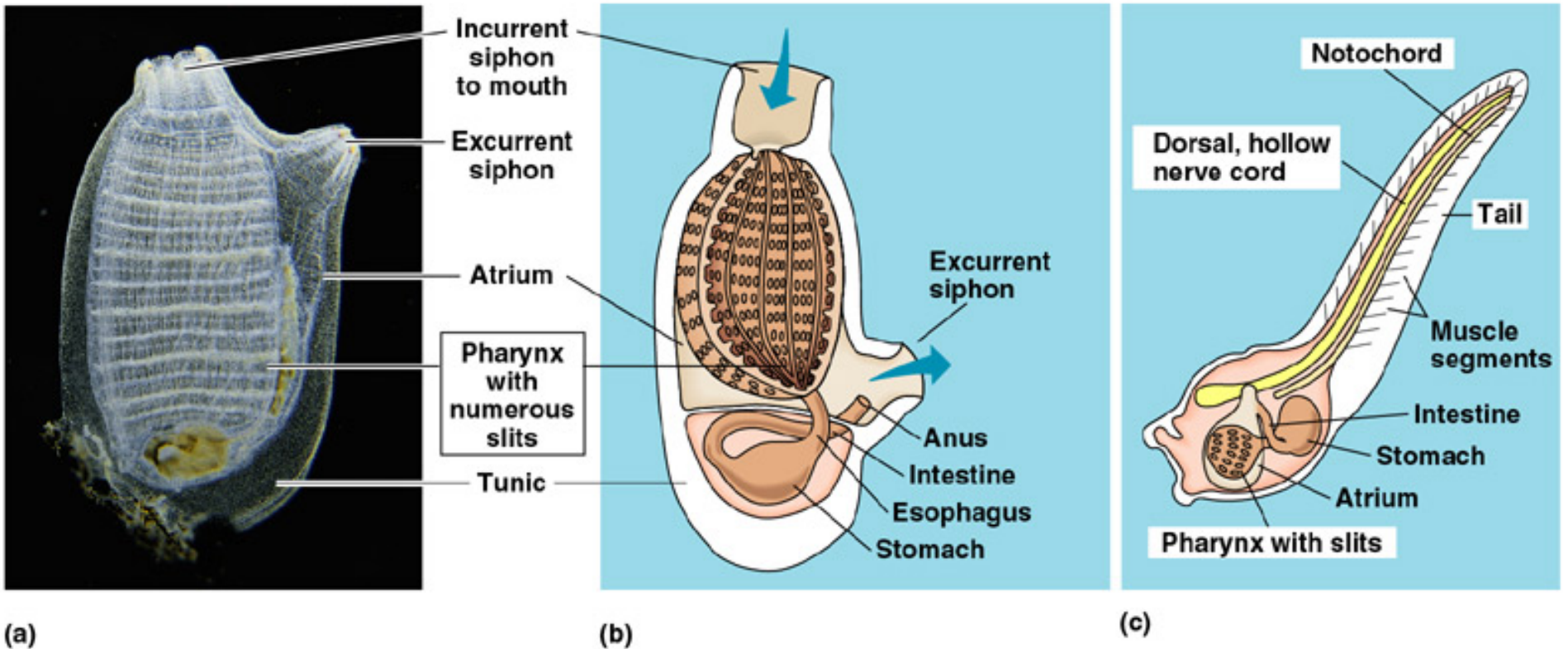
# Pisaster, the orange sea star



# Regulatory genes determine...

- Fundamental body architecture:
  - Bilateral v. radial is determined by 2 genes that either act in tandem or they don't
  - E.g., starfish is bilateral as a baby and radial as an adult
- When features develop
  - Babies and adults often look nothing like each other because of the sequencing of how genes turn on and off

# Tunicates



# Consider...



The girl is 8 years old. She has primordial dwarfism, a genetic endocrine disorder.

# Or...



Size in dogs  
can be  
controlled by a  
single gene.  
Small genetic  
change, large  
morphological  
change.

# So changes in regulatory genes...

- Can change body shape dramatically in one generation
- Can create adults that look like juveniles





# Consider...

Dogs are baby  
wolves with  
functioning  
reproductive  
systems



Consider...



# Neoteny

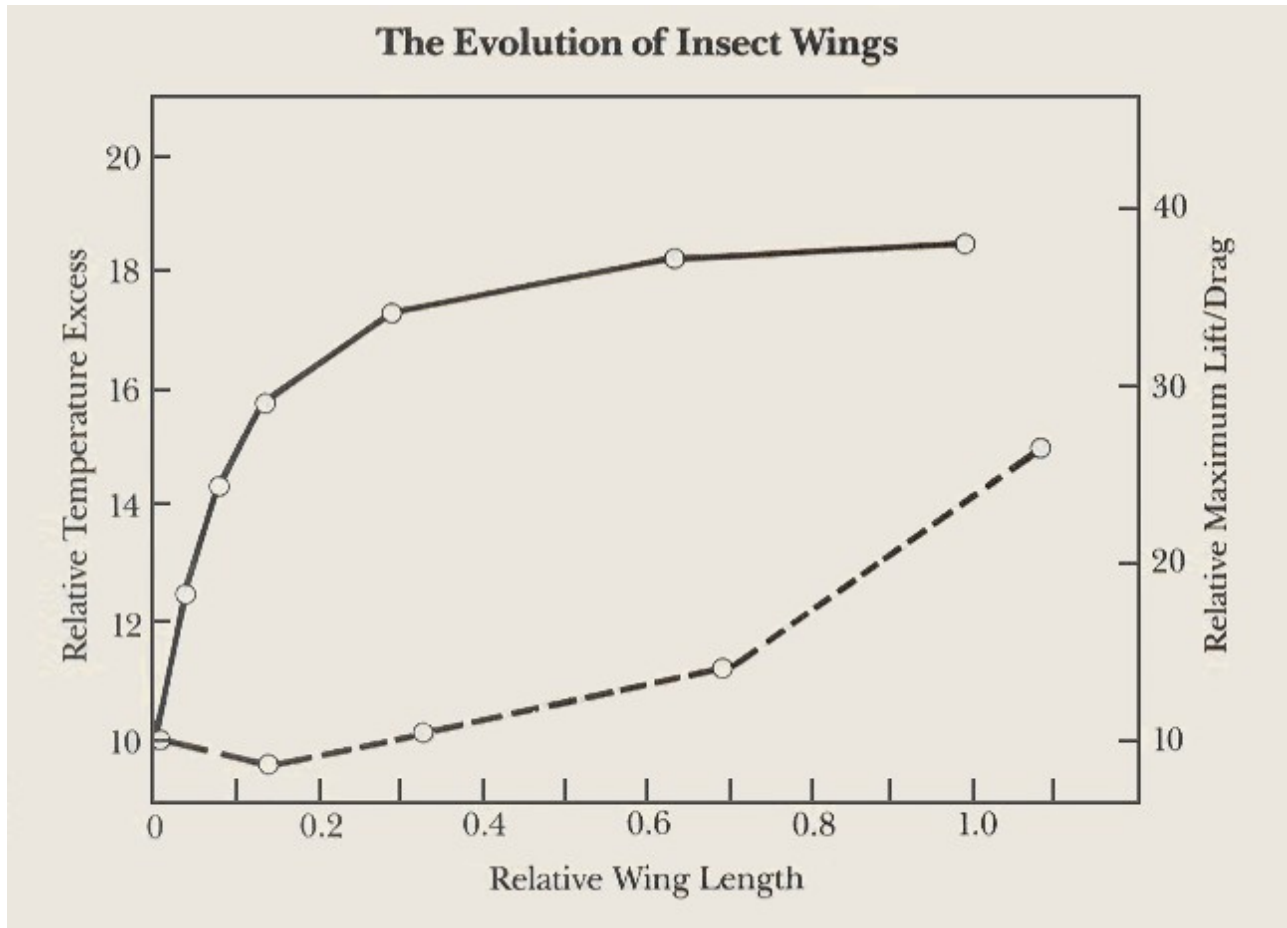
- Retention of juvenile physical traits into sexual maturity
- Vertebrates from tunicates
- Dogs from wolves
- Humans from ape-like ancestor
  
- Heterochrony is the word we use for any evolutionary shift in timing of development. It can also work the opposite way, where growth is prolonged or sexual maturity delayed.

# More likely mechanisms for large morphologic change

- Mutation in regulatory genes
- Preadaptation

# Preadaptation (Exaptation)

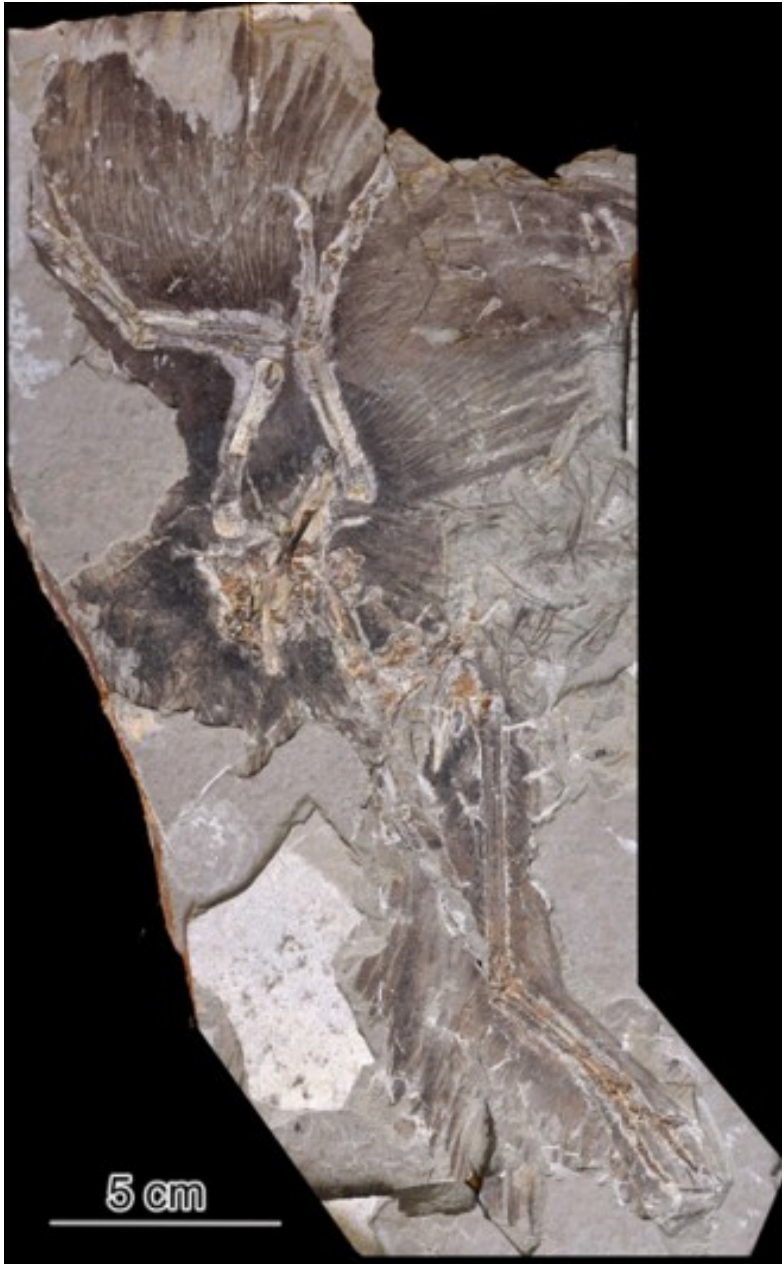
- Gradual change in one characteristic creates a characteristic that is adaptive for something else.
- That new characteristic can then evolve quickly due to strong selection pressure.



When insect wings are small, even a small increase in size gives a big increase in ability to shed excess heat (solid line). But the effect levels out as the wing gets bigger (0.6).

Insect wings don't become really useful at lifting the insect until it gets past 0.6.

So thermal regulation drove the growth of insect wings until they became big enough to be useful for flight.



Dinosaurs had no flight adaptations (very light bones, large sternum for attachment of big flight muscles, reduced fleshy tail) but some had feathers, and the feathers had color.

Colored feathers in modern birds are for sexual display. So one group of dinos was preadapted for flight & became birds.

# Moral of the evolutionary story

- Some evolution takes place in small steps.
- Some evolution takes place in large leaps.
- Perhaps most evolution of different body plans has happened in large leaps.