Evolution by natural selection

Evolution

Natural selection

The nature of adaptation

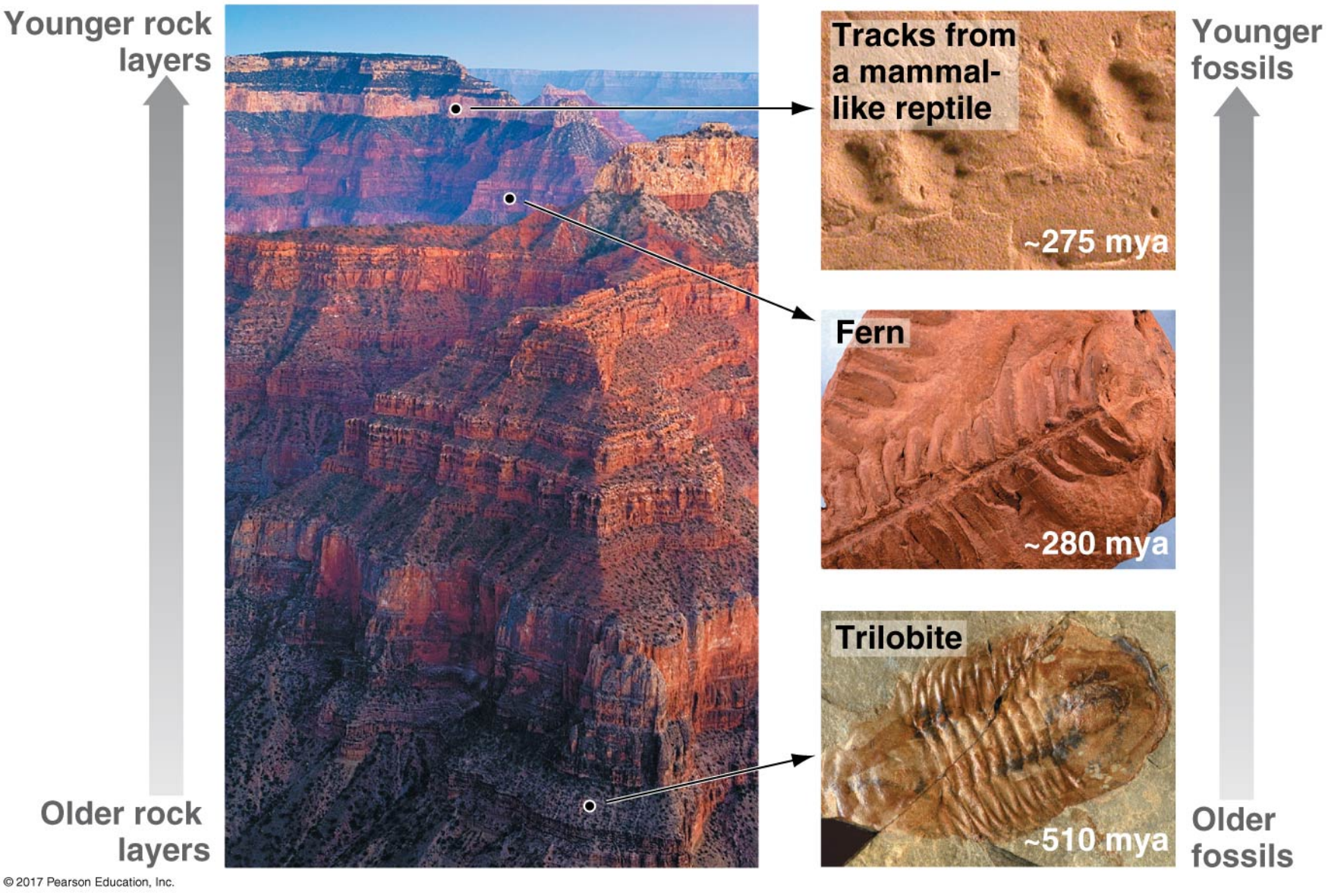
Outline

Evolution

- The theory of **evolution** has replaced the theory of **special creation** in science.
- The theory of special creation asserts that each species is a unique "type", created by God.
- The theory of evolution asserts that species have changed through time (**evolved**).
- Does this mean that scientists don't believe in God?
  - * Many scientists do believe in God
  - * Scientists learn about the world through experiment and observation
  - * Scientists don't treat religious texts as *literally* true

Outline

Fossils



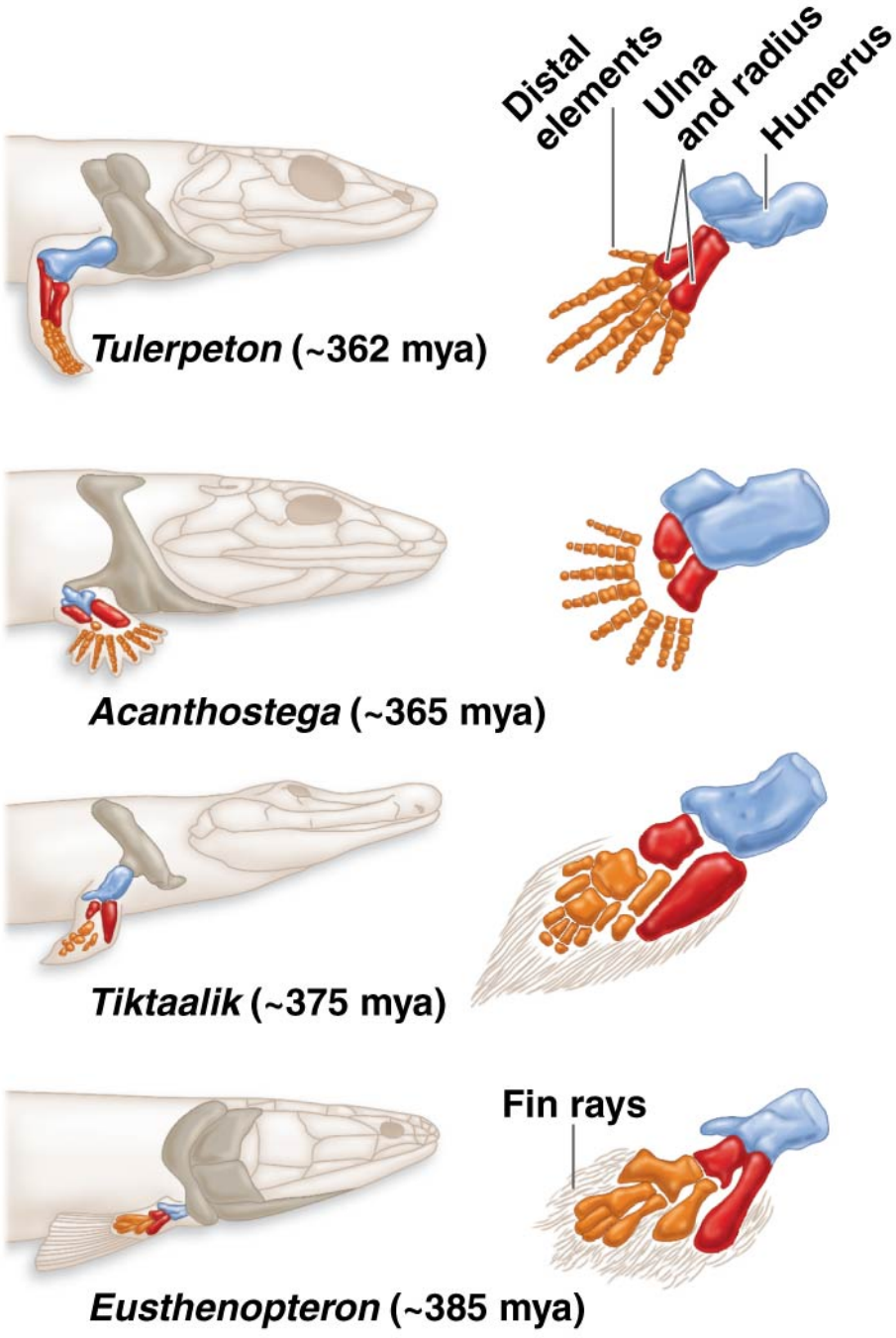
Fossils

- A **fossil** is a physical trace of an organism that lived in the past
- Fossils can be dated using (complicated) radiometric and geological techniques
- Fossils provide information about the history of life (see Chapter 27)
- The **fossil record** refers to the collection of all known fossils

Extinction

- Many fossils have been left by organisms that are no longer around
  - We say such organisms are **extinct**
- Extinction is one piece of evidence that species are changing
  - *But not very convincing evidence!*

Transitional forms



- When a species disappears from the fossil record, a similar species often appears
  - This often happens in the same geographic area
- Consistent with species evolving: changing through time

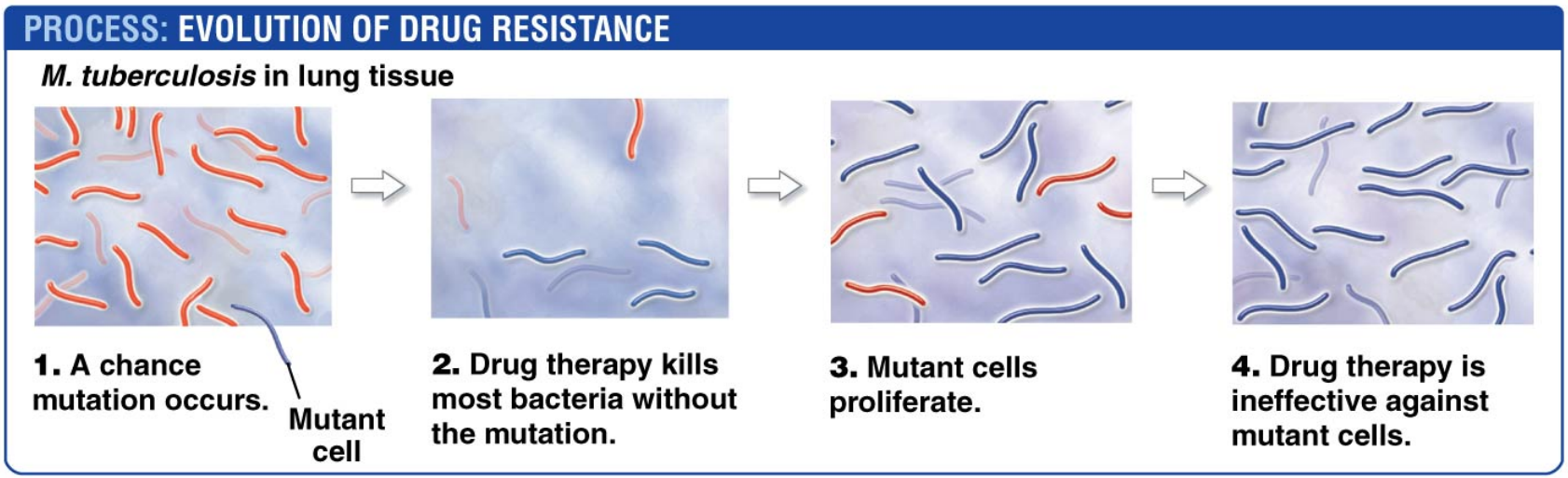
Vestigial traits

- A **vestigial trait** is a structure that has no function, but is similar to functioning structures in related species
- Examples?

Directly observed evolution

- Although much evolution occurs very slowly, some kinds of evolution can be, and have been, observed on faster time scales
  - Tuberculosis
  - Ground finches

Tuberculosis

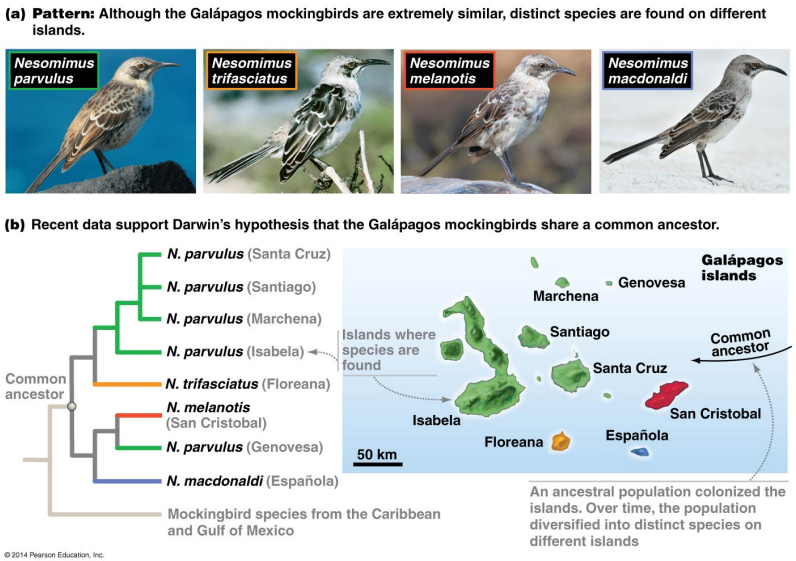


Outline

Relationships between species

- If species evolved from a common ancestor, we expect to see evidence that they are related to each other
  - Species fall naturally into groups
    - *: e.g., mammals, flowering plants*
  - Geographic patterns of relatedness
  - Homology

Geographic relationships



- Species in the same geographic area (e.g., nearby islands) often seem to be closely related
- This is what we would expect if these species evolved independently, starting from a common ancestor in the region
- Support for the theory of evolution

Evolution and similarity

- In nature we observe many, often surprising, similarities between organisms
  - Almost identical developmental genes in fruit flies and people
  - Similar limb bone structure in turtles and people
- The theory of evolution explains these similarities as **homologies**

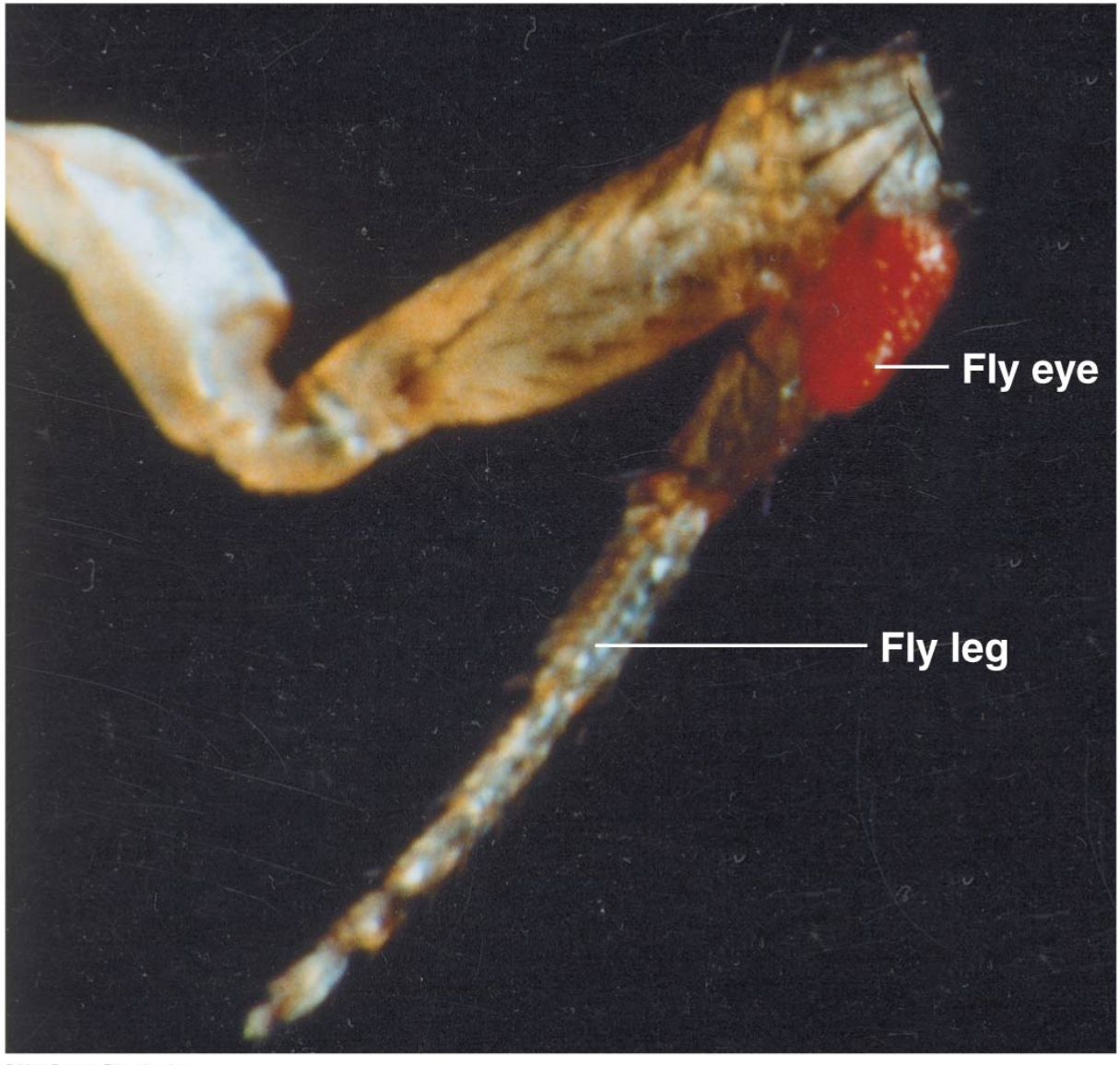
Homology

- A **homology** is a similarity that is due to common ancestry
  - Similarities apparently due to homology are widespread. This is a strength of the theory of evolution.

Genetic homology

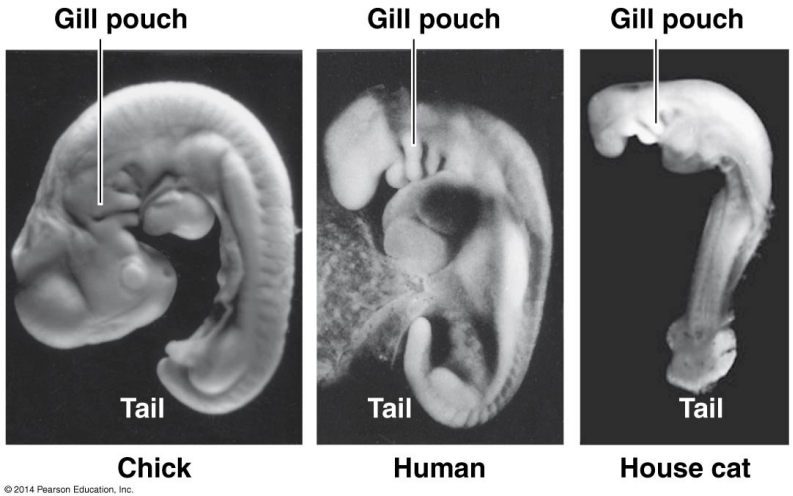
- **Genetic homology** is homology at the level of genetic coding.
- Examples:
  - The genetic code itself is shared (with rare, minor exceptions) by all living organisms
  - Some genes involved in development are very similar all the way from insects to mammals

Genetic homology



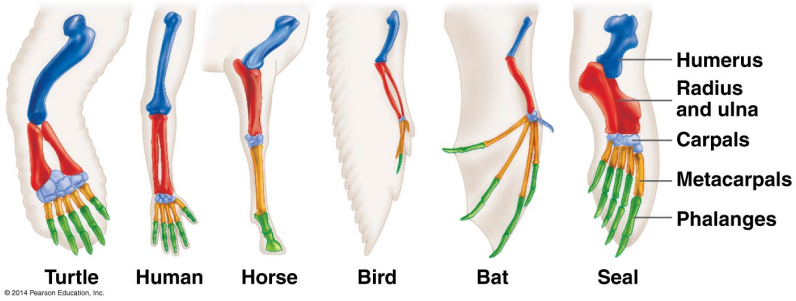
- *An eye-promoter gene from mice promote eye growth in flies!*

Developmental homology



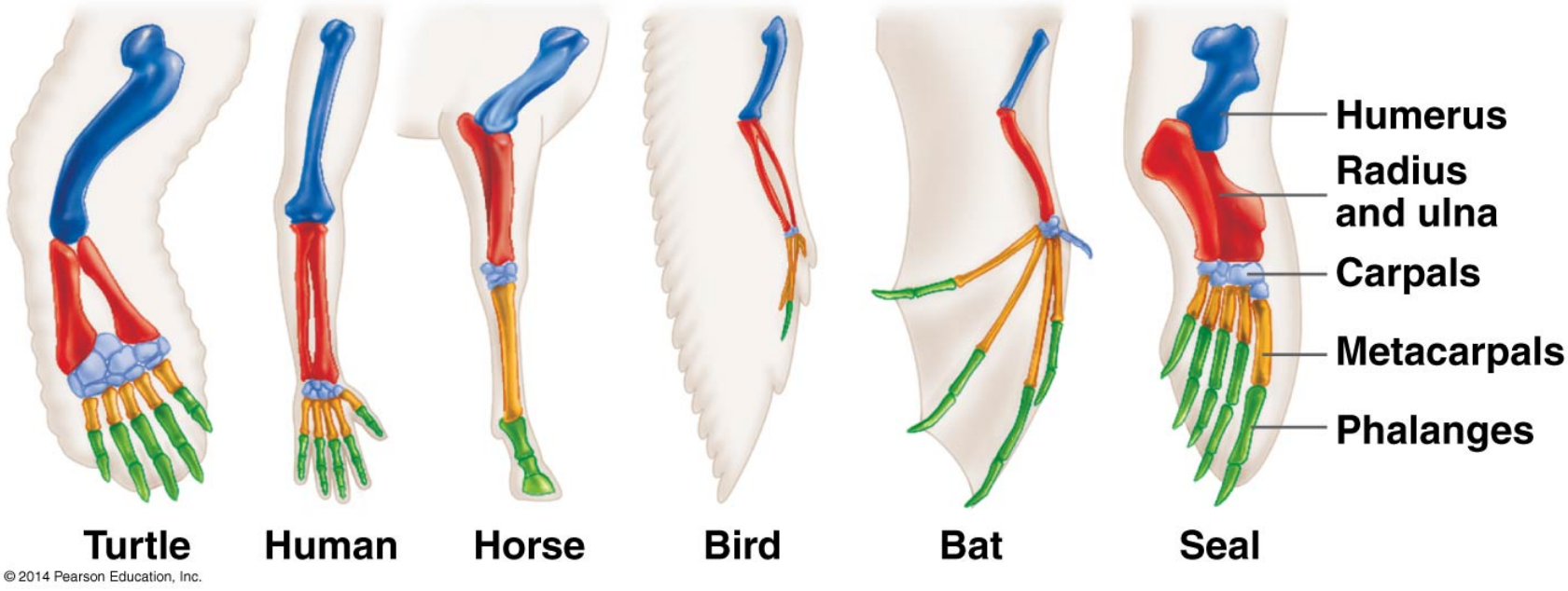
- **Developmental homology** is homology in the traits of **embryos** (developing organisms)
  - Embryos of all vertebrates show striking similarities

Structural homology



- **Structural homology** is homology at the level of developed organisms.
  - Tetrapod limbs

Tetrapod limbs



Identifying homologies

- A tricky subject
  - How do we know whether similarities are due to common evolution?
  - Homologies assume evolution; how can they be used as evidence for evolution?
- The idea that many similarities are due to homology seems to explain many observed patterns
  - Organisms fall naturally into groups
  - Genetic evidence and morphological evidence often agree

Outline

Natural selection

- Darwin's big idea was not evolution, but natural selection
- The first real theory of evolution was developed by Lamarck
  - More famous for being wrong about how evolution occurs
  - *He thought* acquired characteristics *were inherited*

Natural selection drives evolution

- Darwin's theory of natural selection can be explained using four logical steps:
  - **Variation:** The individuals that make a population vary in the **traits** they possess, like size, shape, physiological details.
  - **Heritability:** Some of these differences can be inherited by offspring. For example, tall people may be more likely to produce tall offspring.
  - **Differential reproductive success:** In each generation, some organisms leave more offspring than others
  - **Selection:** Reproductive success is not random, but is influenced by differences in traits, including heritable traits
- If all four of these assumptions hold, we expect evolution to occur.

Natural selection (short version)

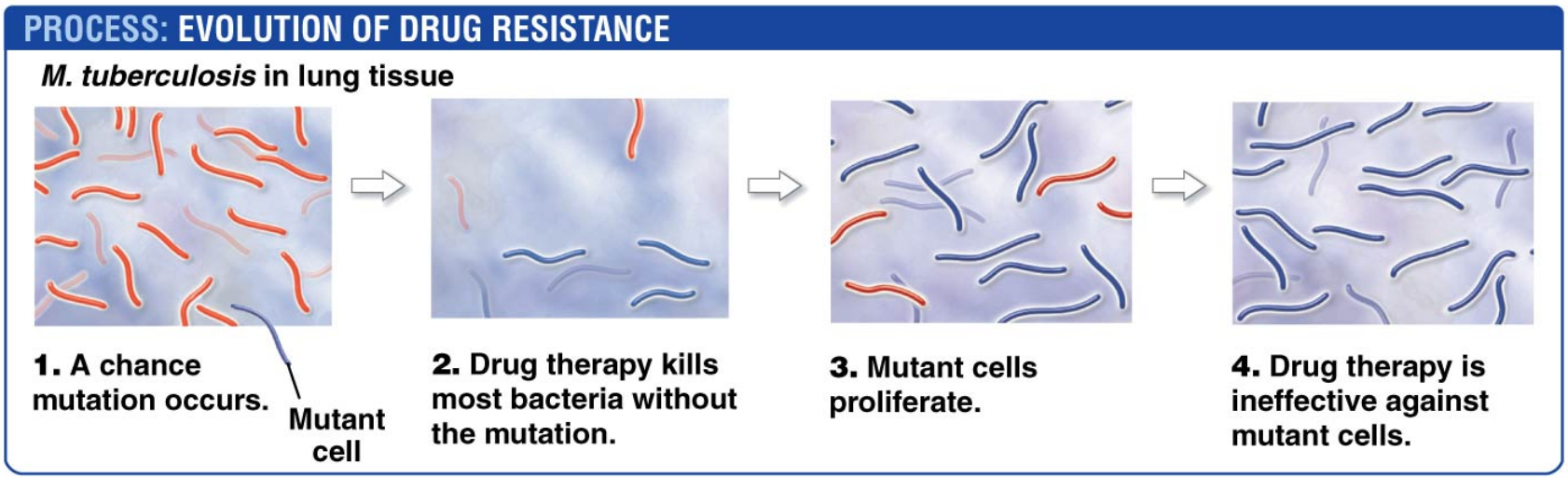
ADD Do a better job about survival of the fittest – how does it work at the group level?

- Evolution by natural selection will occur if there is:
  - Heritable **variation** in traits
  - **Selection** (i.e., differential reproductive success) *based on* these traits
    - Survival is one component of reproductive success; if you don't survive, you can't reproduce.

Fitness

- **Fitness** in biology, or **Darwinian fitness**, means simply an ability to do well under natural selection
- Fitness is thus defined as average reproductive success, given a suite of heritable traits

Tuberculosis



Example: Tuberculosis

- What if there were no variation?
  - Where does variation come from?
- What if variation were not heritable?
- What if there were no selection?

Other examples

- Galapagos finches' beak sizes evolve as availability of seed resources changes.
- Squirrels!

Squirrels

Finch beaks

RESEARCH

QUESTION: Did natural selection on ground finches occur when the environment changed?

HYPOTHESIS: Beak characteristics changed in response to a drought.

NULL HYPOTHESIS: No changes in beak characteristics occurred in response to a drought.

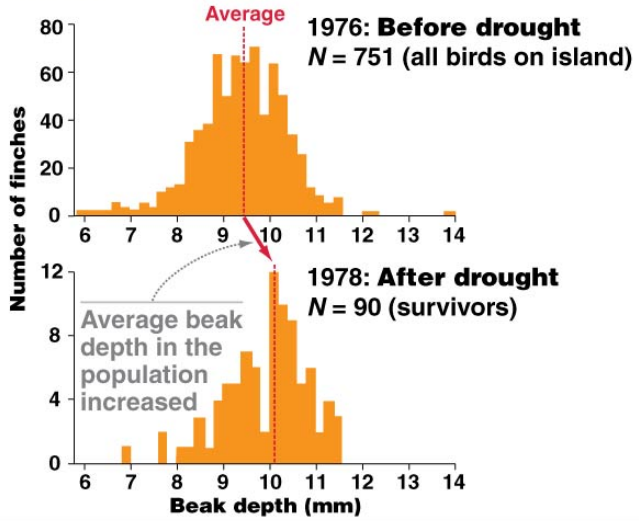
EXPERIMENTAL SETUP:

Weigh and measure all birds in the population before and after the drought.

PREDICTION:

PREDICTION OF NULL HYPOTHESIS:

RESULTS:



CONCLUSION: Natural selection occurred. The characteristics of the population have changed.

Activity

- How would you design an experiment to tell if beak depth is heritable?
  - * Raise offspring from different combinations of mothers and fathers, and compare their beaks
    - * You might also want to try raising them in different conditions (wet or dry, more or less food available)
  - * **Replicate**. Repeat the experiment with different offspring (using different mothers and fathers).
  - * **Control**. Make all factors except for the beak depths of mothers and fathers as similar as possible

Outline

Other models

- Natural selection is not the only possible model for how evolution could occur
  - Inheritance of acquired characteristics (Lamarck)
  - Goal-directed evolution

Inheritance of acquired characteristics

- This is the idea that individuals change in response to their environment, and pass those changes on to their offspring
  - Example: giraffes reaching for food
- It is now known that while individuals do often change in response to their environment, such changes are not (usually) passed on to
- This is the idea that organisms evolve towards specific goals
  - Complex, multicellular organisms
  - Big-brained humans

Evaluating competing hypotheses

- We challenge hypotheses with experiments and observation

Inheritance of acquired characteristics

- Raise a population of mice in the lab
- Every generation stretch (or chop off) their poor little tails
- Measure natural tail length at the beginning of the experiment, and after 100 generations.
- How could this experiment be improved?
  - * Add a control group
  - * Use replicate populations (e.g., three control and three experimental populations)
    - * Or three "choppy" and three "stretchy" populations

Activity

- What would be the key points of a similar experiment to test whether tail lengths respond to natural (actually, artificial) selection?
  - * In each generation, allow mice with longer (or shorter) tails more chances to breed
  - * Compare results with a control population.
    - * Let them breed how they want?
    - * Make couples, and choose 2 offspring from each?

Goal-directed evolution

- There is a great deal of observational evidence against goal-directed evolution:
  - Vestigial traits
  - Bidirectional evolution
    - Finch beaks get larger, then smaller
    - Birds gain, then lose, flying ability
    - Things that become parasites may become much smaller and simpler

Adaptation vs. acclimation

- **Acclimation** is the ability of organisms to respond directly to their environment
  - When organisms **acclimate** this does not affect the traits of their offspring
- **Adaptation** is genetic change that increases the fitness of organisms
  - Adaptation does not occur as a direct response to the environment
  - Adaptation is usually very slow
  - Adaptations are passed on to offspring, and form the basis of evolutionary change

Adaptation and acclimation

Examples

- If you exercise every day, you will be stronger, but this will not make your children stronger.
  - * acclimation
- After swinging through trees for millions of years, chimpanzees have very strongly built arms.
  - * adaptation
- Polar bears have thick fur, and thick layers of fat under their skin.
  - * adaptation
- Humans raised in hot climates have more sweat glands than those raised in cold climates.
  - * acclimation

Acclimation

- Why do we acclimate?
  - * It has probably evolved because acclimation is beneficial
- Are responses to changed conditions always good?
  - *Digging holes*

The good of the species

- Selection operates on individuals; individuals are not adapted to act for the good of the species
- The evolution of co-operation always involves tension between what is good for the group, and what is good for the individual
  - If 'cheating' strategies can evolve, they will
  - A **cheater** benefits from co-operation, but does not participate
- Do lemmings commit suicide?

A lemming not committing suicide

Tradeoffs

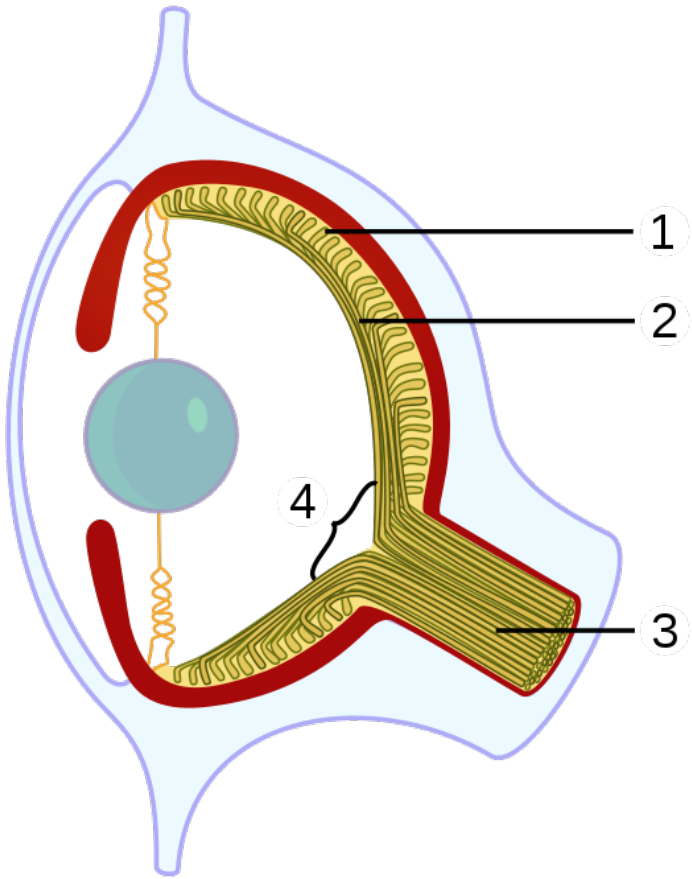
- Much of adaptation is the result of compromise between conflicting goals
  - Brightly colored individuals are more attractive to mates, and to predators
  - Larger individuals compete more effectively, but are less efficient at reproducing

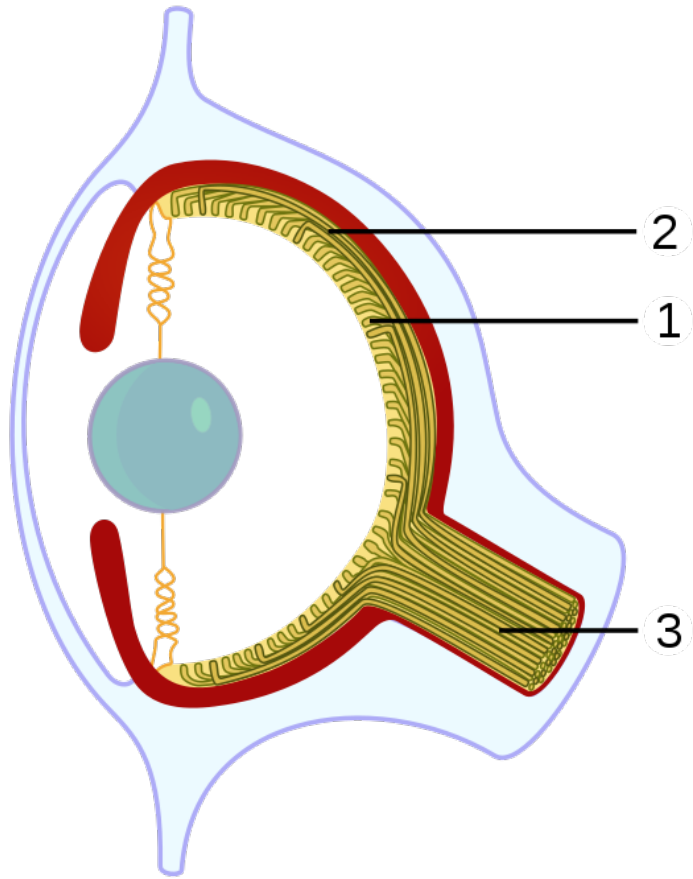
Historical constraints

- Evolution proceeds by small steps
  - What is possible is guided by what has gone before
- Examples
  - Vestigial traits
  - Blind spot in the vertebrate eye
  - Humans are not well designed to be upright

Vertebrate blind spot

ADD References to wikipedia here





Evolution by natural selection – Summary

- There is strong evidence that species have evolved through time
  - Fossil record, patterns of relatedness, homologies
- There is strong evidence that this change is driven by natural selection
  - Darwin's logical postulates: heritable variation in traits; differential reproductive success based on traits
  - Direct observations of natural selection (TB, finches, moths)
- Natural selection by (gradual) evolution imposes important constraints
  - Species are not perfectly adapted