

Bio 1M: Evolution by natural selection

1 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?
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1.1 Change through time — Sec 22.2 (2ndEd pp. 457–459)

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
- The **fossil record** refers to the collection of all known fossils
- Chapter 25 (2ndEd 27) for more info about 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
 - In a very limited way
 - How convincing is it as support for the theory that species got here by gradual evolution?

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
- Fig 22.4 (24.4 2ndEd)

Vestigial traits

- A **vestigial trait** is a structure that has no function, but is similar to functioning structures in related species
- Examples?
- Fig. 22.5 (24.5 2ndEd)

Directly observed evolution

- Although much evolution occurs very slowly, some kinds of evolution can be, and have been, observed on faster time scales
 - Tuberculosis — pp.458–460 (2ndEd pp.465–466)
 - Ground finches — pp. 460–462 (2ndEd pp. 468–470)

1.2 Relationships between species — pp. 452–455 (2ndEd pp. 459–463)

- 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
- Fig. 22.6 (24.6 2ndEd)

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 — Table 22.1

- 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
- Fig 22.7 (24.10 2ndEd)

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

Identifying homologies

- 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
 - * We get consistent stories from different lines of evidence, e.g., whale example — p. 455

2 Natural selection — Sec 22.3 (2ndEd Sec 24.3)

- 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
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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:
 - Traits associated with good reproductive success will become more common

Natural selection (short version)

- Evolution by natural selection will occur if there is:
 - Heritable **variation** in traits
 - **Selection** (i.e., differential reproductive success) *based on* these traits
- Logical consequence?
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Fitness

- “Survival of the fittest” is not a very good name for this process
- **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
- Components of fitness:
 - survival, growth, reproduction

Example: Tuberculosis — Fig 22.10 (2ndEd Fig 24.13)

- 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. — Fig 22.14 (2ndEd Fig 24.17)
- Squirrels! — https://en.wikipedia.org/wiki/Black_squirrel

Activity

- How would you design an experiment to tell if beak depth is heritable?
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3 The nature of adaptation — Sec 22.5 (2ndEd Sec 24.5)

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 offspring

Goal-directed evolution

- This is the idea that organisms evolve towards specific goals
 - Complex, multicellular organisms
 - Big-brained humans
- If the organism is moving toward a goal, it should move more or less in that direction all the time

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?
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Activity

- What would be the key points of a similar experiment to test whether tail lengths respond to natural (actually, artificial) selection?
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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

Examples

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

- Why do we acclimate?
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- Are responses to changed conditions always good?
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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 — [https://en.wikipedia.org/wiki/Blind_spot_\(vision\)](https://en.wikipedia.org/wiki/Blind_spot_(vision))
 - Humans are not well designed to be upright

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