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 (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

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
  - 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

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

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?

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?

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)`
  - 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