1. Homology (vs analogy)

Homology and analogy describe two types of similarity between objects or organisms.

**Homology**: similarity due to shared history or relatedness

**Analogy**: similarity due to shared function or design

Q: why are they similar?
Why are the letters in the same arrangement?

Not because of a functional reason, letters could be anywhere on a screen (other arrangements work better). Due to a **shared history**: typewriters, keyboards, screens

The arrangement of letters is therefore **homologous**.
Why are these buildings similar?

**Same function**: large impressive buildings made with basic technology.

**Different histories**: the buildings are not similar because of shared cultural history.

The design is therefore **analogous**.

Evidence for evolution:
1. homology (vs analogy)
Evidence for evolution:
1. homology (vs analogy)

These limbs perform **different functions**, but use **similar bones**.

Why are these bones so similar?

Bones present are the same **due to historical ancestry**, not current function.

**HOMOLOGY**
Evidence for evolution:
1. homology (vs analogy)

Why do organisms use tRNA molecules for transferring amino acids to growing proteins?

Why are these translation molecules so similar?

Lots of structures should conceivably be possible, why do they *almost all* use the same one.
Evidence for evolution:
1. homology (vs analogy)

Why are these animals torpedo shaped?

Torpedo shape provides **same function**. These animals have non-torpedo shaped ancestors, **different histories**.

**ANALOGY**
Evidence for evolution:
1. homology (vs analogy)

Homology – similarity explained by common ancestry, differences due to different functions.

Analogy – similarity explained by similar function, differences due to different histories.

Convergent evolution leads to analogous traits.
Functional reasons lead to analogous structures. Historical reasons lead to homologous structures.

This sets up a situation in which there may be conflict.

Structures are constrained by their history, evolution makes the best design with what is available.

This should lead to cases of poor design (qwerty) and vestigial traits (pause/break).

This is a prediction of evolutionary theory.
2. Vestigial traits

These are traits that exist because they were present in ancestors, not because they have current utility.

Structural
Developmental
Genetic

NOTE: This is a strong prediction of a theory of evolution, a prediction distinct from a perfect design hypothesis. Failure to find poorly designed and vestigial traits would be strong evidence against an evolutionary explanation for biological diversity.
Structural vestiges

coccyx, "tailbone",

Also: muscles to move human ears
goose pimples
appendix
Developmental vestigies

Chicken limbs:
Extra digits start to develop, but disappear during development
(5 -> 3 in wings, 5->4 in feet)
Genetic vestiges

Ancestors had multiple copies of genes, mutations have deactivated some and made them into pseudogenes.
Vestigial traits result in poor "design"

Birth canal:
Wide for quadripeds, small for bipeds
Vestigial traits result in poor "design"

Recurrent laryngeal nerve:
- Straight line in fish ancestor
- Detoured now that body has evolved different shape
Vestigial traits result in poor "design"

Recurrent laryngeal nerve
3. Geologic record: age of the earth & fossils

Analysis of radioactive elements present in geologic deposits reveals that some regions are millions or even billions of years old.

The half-life of a radioactive material is the time it takes for one half of the initial material to decay into a daughter product.
Ex: **Uranium-lead** ($^{235}\text{U}/^{207}\text{Pb}$) deposits

Assume 100% $^{235}\text{U}$ at start

If deposit is 50% $^{235}\text{U}$, 50% $^{207}\text{Pb}$ age is one half life of decay, 733 million years

If deposit is 25% $^{235}\text{U}$, 75% $^{207}\text{Pb}$ age is two half lives of decay, 1466 million years

Ages determined for layers of rock were found to be older as the layer was deeper – and there was a **lot** of time.
By finding deposits in many locations the layers in a particular region can be dated even if it has no/few volcanic deposits.

Before radioactive dating geologists had already matched up the strata (rock layers) in different formations all over the world using rock types and fossils.

Radioactive dating allows us to put numbers on historical sequences already discovered.
Fossils revealed several facts strongly implying evolution

a. **Extinction** happened, organisms existed in the past that are not **extant**.
b. Fossils revealed transitional forms between seemingly distinct groups of organisms.
c. fossils and similar living organisms are spatially correlated

- Armadillos and glyptodonts in S. America

- Marsupials in S. America and Australia
4. Patterns of geographic distribution (penguins, marsupials)
- Seems senseless, but explained by historical pattern of continental drift
Evidence for evolution:
4. geographic distributions

E.g., Wallace's line - marsupials on East side, not West
Evidence for evolution

1. Homology (vs analogy)
2. Vestigial traits
   - structural, developmental, genetic
   - poor "design"
3. Geologic record
   - age of the earth
   - fossils
4. Patterns of geographic distribution
5. Fluidity of species barrier (vs typology)
   - ring species, hybrids
6. Direct observations of natural selection
7. Artificial selection
8. Logical/math argument (variation, selection, heredity)
5. Fluidity of species barrier (vs typology)

Hybrids between species show a special connection, they are not completely distinct "types"

male lion + female tiger = liger
male tiger + female lion = tigon

Ring species: apparently different species reproductively connected via intermediates

E.g., *Larus* sea gulls

Arrows show gene flow (breeding that transfers alleles), but in Europe no interbreeding occurs.
6. Direct observations of natural selection

*Biston betularia* (peppered moth) were historically white with black dots.

1848, first recording of a melanic (*carbonaria vs typica*) form, mostly black

By 1900 melanic form was > 90% in industrial areas of England
Biston betularia (peppered moth) were historically white with black dots.

1848, first recording of a melanic (carbonaria vs typica) form, mostly black

By 1900 melanic form was $> 90\%$ in industrial areas of England

Kettlewell performed experiments:

- Higher relative survival for light morph in unpolluted places
- Higher relative survival for dark morph in polluted places

Evidence for evolution:

6. Observed natural selection
Kettlewell performed experiments:

- Higher relative survival for light morph in unpolluted places

- Higher relative survival for dark morph in unpolluted places

This acts to cause changes in the prevalence of the dark color morph; as pollution has decreased, the frequency of the dark morph has as well

**Figure 1-6**

The changing frequency of the peppered moth’s melanic morph, *carbonaria*, near Liverpool in response to reduced pollution, indicated by sulfur dioxide (SO$_2$) levels, from 1959 to 1975. (Based on Bishop and Cook 1980.)
Identifying the exact basis of the genetic difference causing the two morphs is a work in progress:

**Industrial Melanism in British Peppered Moths Has a Singular and Recent Mutational Origin**

Arjen E. van’t Hof, Nicola Edmonds, Martina Dalíková, František Marec, Ilik J. Saccheri

The rapid spread of a novel black form (known as *carbonaria*) of the peppered moth *Biston betularia* in 19th-century Britain is a textbook example of how an altered environment may produce morphological adaptation through genetic change. However, the underlying genetic basis of the difference between the wild-type (light-colored) and *carbonaria* forms has remained unknown. We have genetically mapped the *carbonaria* morph to a 200-kilobase region orthologous to a segment of silkworm chromosome 17 and show that there is only one core sequence variant associated with the *carbonaria* morph, carrying a signature of recent strong selection. The *carbonaria* region coincides with major wing-patterning loci in other lepidopteran systems, suggesting the existence of basal color-patterning regulators in this region.
7. Artificial selection

The repeated use of selective breeding has created some very large changes in the characteristics of domesticated organisms.

At right are some domestic pigeons, the focus of a large portion of the first chapter of Darwin's *Origin of Species*.

He thought this to be one of the more powerful arguments for evolution by natural selection.

*Figure 2-9*
Varieties of pigeons produced from the wild rock dove, *Columbia livia* (top right), through artificial selection by humans. Top left, the jacobin; bottom left, the Indian fantail; bottom right, the English pouter, or Norwich cropper. (Illustration by Stephen Price.)
Evidence for evolution:
7. Artificial selection
Results of experiment selecting for heavier and lighter mice.

Magnitude of the change in only 10 generations:

- 21g to 14g
- 33% decrease in weight.

**NOTE**: selection required variation

_Figure 1-7_
Falconer’s (1953) experiment on artificial selection for large mice and small mice, with weights at 6 weeks of age provided. The dashed line indicates the common weight at the start of the experiment (generation 0).
Results of an experiment selecting for wing veins positions in *Drosophila*.

Note the magnitude of the change in only 29 generations (~1yr).

Evidence for evolution:
7. Artificial selection
Selection requires variation, selection must choose individuals with differences from others ... differences that are heritable.

Breeder's equation: \( R = h^2 S \)

- \( R \), the **response**, is the change in overall mean of trait from parental generation to next generation.

- \( h^2 \), the **narrow sense heritability** of the trait - a measure of how much offspring resemble parents (between 0 and 1).

- \( S \), the **selection differential**, is the difference in mean of trait between those selected and those in overall initial population.
Evidence for evolution:
7. Artificial selection

R, the response, is the change in overall mean of trait from parental generation to next generation.

S, the selection differential, is the difference in mean of trait between those selected and those in overall initial population.

h², the narrow sense heritability of the trait - a measure of how much offspring resemble parents (between 0 and 1).
Breeder's equation: $R = h^2S$

What are the limits of heritability and variation?

Almost everything varies in a heritable way, selection therefore generates a response and thus evolution is possible.

(Only exception: directional asymmetry)
Breeder's equation: $R = h^2 S$

$h^2$, the **heritability** is also the slope of the regression equation of the mean offspring trait versus parental mean trait.

Without heritability, $h^2 = 0$ and no amount of selection causes response.
Breeder's equation: \( R = h^2S \)

S, the selection differential, is the difference in mean of trait between those selected and those in overall population.

\[
S = 2.8 - 2 = 0.8 \\
S = 2.5 - 2 = 0.5 \\
S = 2 - 2 = 0
\]

Without variability, \( S = 0 \) and no amount of heritability allows response.
Breeder's equation: \( R = h^2 S \)

- **h^2:** Higher heritability means more response for given selection
- **S:** More variation allows bigger S and more potential response.

Evidence for evolution:
7. Artificial selection
8. Logical/math argument (variation, selection, heredity)

Breeder's equation: \( R = h^2S \)

Mathematically:

**If:** A reproducing population has heritable variation and

**If:** Some variants (due to the heritable differences) have a better chance of reproducing than others.

**Then:** Evolution of the population by selection will occur
If: A reproducing population has heritable variation
If: Some variants (due to the heritable differences) have a better chance of reproducing than others.

The book uses 4 conditions:
1. Individuals within the species are variable.
2. Some of these variations are passed along to offspring.
3. In every generation more offspring are produced than can survive. (similar to non-random survival)
4. Survival and reproduction is not random, ones who survive and reproduce have most favorable variants. They are naturally selected. (survival is really just part of reproducing)
If: A reproducing population has heritable variation
If: Some variants (due to the heritable differences) have a better chance of reproducing than others.
Then: Evolution of the population by selection will occur

NOTE: no DNA was required

Computer programs
Corporate strategies
Cultural ideas, memes

Variation
Heredity
Selection

Example: HIV reverse transcriptase makes many mistakes, creating variation.
R = h^2S, more variation means bigger potential S (slightly lower h^2 though) and faster response vs our immune systems