Evolution:

(*Note: The book doesn't do a great job with evolution (the "advanced" version of the same text is much better!). We will cover about 2/3rds of chapter 13, and just a very little of chapter 14. We won't follow the order in which the book does things (The seventh edition has made things worse rather than better!!*).

Evolution is the foundation of biology.

It explains why animals (and other organisms) look the way they do, how they are related, and even why they do what they do. Basically it can explain just about anything in biology.

So what is evolution?

The change in organisms over time. Or more precisely, a change in the genetic makeup of a population over time.

(But we're not done for a while!)

Note:

This definition says nothing about fossils, mimicry, adaption, etc. These are the results of evolution. The definition merely talks about genetics.

So let's delve into evolution in more detail. Five parts:

I - History II - Mechanism III - Evidence IV - Genetics

V - Evolution in action/examples

I - History

[several OVERHEADS, not in book (mostly pictures of the following folks)]

Linnaeus:

Grouped similar animals into similar categories, and established a hierarchy of groups, where the higher up one goes, the more diverse the animals in each group.

Sometimes called the "Father of taxonomy".

Lamarck:

First to propose evolution as a concept. But his mechanism was weird.

If an animal uses a particular part of its body a lot, then that part will develop more (e.g., athletes).

Thus, animal "acquires" certain characteristics.

These are then passed on to the offspring (this idea is basically wrong).

But Lamarck had great foresight - the idea of evolution was a breakthrough - it explained the fossil record, and opened up the possibility of a long period of time for things to happen (e.g. animals to change).

Lamarck also did something else that's important to Biology...

Cuvier:

Didn't like the idea of evolution, and helped to ridicule Lamark.

But he was the first to recognize that the age of fossils varies in different rock strata. Assumed many fossils represented species that had died out in “that location”, but were still alive elsewhere.

“Father of paleontology” - he made many contributions to anatomy as derived from fossil material.

Hutton and Lyell:

Scottish geologists.

Hutton noted that rock formations, landscapes, etc. can all be explained by processes going on today. Formation of river valleys (Grand Canyon probably the most spectacular example), mountains, etc.

Gradualism - big changes can take place over long periods of time.

Lyell developed *uniformitarianism*, as well as elaborated and polished Hutton’s ideas (Hutton's style of writing was very difficult to read).

Uniformitarianism - things happen today in the same way as they did years ago. For example, the action of wind, water, volcanoes was (and is) the same throughout history. It is true that this is an assumption of evolution.

Together these ideas had an important implication - the earth is much older than was thought up until then.

We can summarize what has happened to this point:

1) The age of the earth is very old.

2) Evolution as a concept had been considered, though the mechanisms didn't make sense.

Darwin

See the text for more details of his life.

(If you're really interested, “Darwin and the Beagle” by Moorehead, is a very readable book).

In brief:

Was born in 1809 (we celebrated the 200th anniversary of his birth not long ago)

Grew up with an intense interest in biology.

Entered Cambridge to become a member of the clergy (most naturalists were clergy at the time).

Shipped out on a five year voyage aboard the Beagle in 1831.

[OVERHEAD, fig. 13.1C p. 257]

While traveling across South America, particularly the Galapagos, he started to notice similarities and differences in animals and plants. Started to develop some of his ideas.

Published many papers on his return to England, but even though he wrote up a large "essay" on evolution, he did not publish this until much later.

In 1859, spurred by Wallace (see below), he finally publishes "The Origin of Species" (200th anniversary of his birth coincided with the 150th anniversary of the publication of *The Origin of Species*).

Major breakthrough in biology. Carefully argued, with extensive notes, examples, etc.

What was different? The mechanism. There was finally a mechanism (natural selection) that could explain evolution. More on this in a moment.

Lived for many more years, publishing numerous more books, including the first treatise on human evolution. Also an expert on worms. He died in 1882, and was buried in Westminster Abbey.

Two more people you should know (or remember):

Wallace - another great naturalist that independently developed evolution through natural selection (did most of his work in Southeast Asia). Spurred Darwin to write up his essay for publication.

Mendel - We already know about Mendel, considered the "Father of genetics". With genetic understanding, all the pieces of how evolution works were finally in place. Mendel read "The Origin of Species", and Darwin had a reference to Mendel's paper on his bookshelf (though he didn't know what to do with it).

II. Mechanism of evolution

Natural selection - Darwin's (and Wallace's) great insight:

1) Organisms vary. In any group of animals (organisms), not all are the same (look around room). Incidentally, most differences, but not all, are due to genetics.

2) All organisms produce more offspring than can survive. (Roach display at Museum of Natural history). Malthus - the first to realize this - attributed much misery to populations outstripping food supply; populations can't keep growing indefinitely (even today, population growth is considered a major problem).

3) Therefore only some offspring survive. Which ones?

The ones best suited to their environment. For example, the quickest, the ones with the best camouflage, (or the least clumsy), the most intelligent, etc. The number of organisms with this trait will then increase at the expense of others - in other words, the population can change (particularly if the environment changes (# 4)). The organisms with these genes (alleles) will survive to pass on their genes to the next population.

4) If the environment changes, then the population will respond by changing with it (or die!). Thus, if a new predator is introduced, population will hopefully become faster (NOT by "wanting" to be faster, but because faster individuals survive).

See page 258 in you text for a different breakdown (it's the same thing, but explained a little differently).

III. Evidence of evolution

Antibiotic and insecticide resistance - Evolution is an ongoing process and is happening right now!

Both insecticide & antibiotic resistance are major problems right now:

[OVERHEAD, fig. 13.3B, p. 259]

Fossil record:

Probably the most obvious evidence.

Fossils are records of past life. What kind?

Most obvious, bones or hard parts.

Often preserved by being submerged in areas with low oxygen - prevents/slows rotting. Compressed, then bones are often replaced by minerals seeping in from the surrounding rock. Literally turns tissues into rock.

Under rare circumstances may preserve soft parts. (Mammoth - obvious example).

[OVERHEAD, fig. 13.4, p. 260].

As one examines fossil record, one sees organisms changing as one moves from older rocks to newer rocks. Also, some organisms (dinosaurs) disappear, others (humans) appear (gradually) **[OVERHEAD, fig. 15.13, p. 307]**.

Comparative anatomy.

Similar structures in living organisms. As one looks at animals which are more closely related, one sees structures that are more similar. Well see several examples of this in lab (both the taxonomy and evolution labs).

Gives rise to some more concepts:

*Convergent evolutio*n - animals that are different evolve similar structures due to similar environmental pressures. A classic example is the body shape of fish, dolphins & ichtyosaurs (extinct). These animals are unrelated, yet have very similar body shapes.

Homologous structures - structures that have a ***common origin***, but may be used for different things **[OVERHEAD fig. 13.5A]**

Analogous structures - structures that look similar, but have different origins (e.g. wings in birds and insects).

An example: Wings in birds and bats are analogous. BUT, most of the bones that make up these wings are homologous. If you understand this, you have a decent grasp of the concepts involved.

The bones can be traced to a common ancestor.

The wings can not (even though they're made up of similar bones) **[OVERHEAD, not in book]**.

Embryology.

Embryos show common ancestors. Gill slits in human embryos. Many embryos from totally different species look identical at various stages in their development [**OVERHEAD, not in book**]

Biochemistry (what the book calls "molecular biology").

Mostly based on DNA or derived molecules (e.g. proteins).

Similar species have DNA (i.e. genes) that are very similar. This can be used to establish lineages and other relationships.

This is used even in society to establish identity of criminals as well as parentage (DNA fingerprinting is based on this idea), etc.

For example, children will have DNA more similar to their parents.

This works even on a larger scale such as between species. **[OVERHEAD, not in book]**

Biogeography.

This is one of the things Darwin noticed:

The further away he got from "home", the more different the species were from those he recognized. In particular, older animal groups often were more widespread.

The closer (geographically) related animals were, the more likely they were to be similar.

Animals (and other organisms) that are closer haven't had as much time to separate and become really different (more on this later).

E.g., Australia, Llamas, etc.

Artificial selection **[OVERHEAD, fig. 13.2, p. 258 & not in book]**.

One of Darwin's more powerful arguments.

Humans have been breeding plants and animals for thousands of years. Today, many are completely different from ancestral species.

Dogs, Cats, Horses, Wheat, etc. are all good examples.

Humans decide which organisms are "allowed" (or encouraged) to reproduce.

Other evidence.

Camouflage/adaptation.

Moths in northern England - industrial pollution. **[TWO OVERHEADS, not in book]**

Dark moths started appearing with the onset of pollution in the 1850's.

Population studies have confirmed that birds are the selecting force.

Recently, with new environmental regulations, the trend is being reversed.

For protective coloration in general see p. 259 in your book.

Mimicry.

Some animals have evolved to look like other animals. Why?

Classic example - One animal is toxic or venomous (Coral Snake, Scarlet King snake). Other animals take advantage of this by looking (or sounding) like the dangerous one so they won't be bothered.

IV. Genetics.

We already know that appearance (phenotype) is controlled by:

1) Genes (genetic makeup)

2) Environment (e.g. suntan)

Environmental factors (suntan) are not passed on to offspring (that was Lamarck's idea).

Genes are passed on to offspring.

Suppose that a recessive allele is lethal (all mice with brown coat colors die).

We have:

BB - normal
Bb - normal (carrier)
bb - brown coat color, but also lethal (mice die before they can reproduce)

What happens to frequency of brown allele?

It decreases (obviously!)

→ Evolution! (**a change in genetic makeup of population**)

Lethal genetic diseases do work this way (e.g., Cystic fibrosis) in humans.

(Once an allele is very rare, it is difficult to get rid of (there will be very few homozygous recessives). This is one reason why some of these things stay with us so long).

Sickle cell anemia survives because heterozygotes have a huge advantage **[OVERHEAD, not in book(?)]**.

Last bit for genetics:

Note that the book makes a big deal about microevolution. Sometimes microevolution will refer changes from one generation to the next, but otherwise it's defined exactly the same way (some other folks may define it a little differently). We'll ignore this concept.

Hardy-Weinberg (see the text for some of this, though it’s a bit confusing):

Suppose there are just two alleles (e.g. coat color in mice, but this time brown won't be lethal).

Let’s assume that in mice we have the following:

BB - black Bb - black bb - brown

But let’s just think about just the alleles for a minute:

B - black b - brown

Now, let's call the proportion of black alleles '*p*'.

The proportion of brown alleles well call '*q*'.

Obviously, $p + q = 1$ (or 100%).

> (and $p = 1 - q$, and $q = 1 - p$)

So, the probability of being:

> $BB = p \text{ x } p = p^2$
>
> $bb = q \text{ x } q = q^2$
>
> (why? - "rule of multiplication" from probability, but see also the binomial expansion))

What about Bb?

> $Bb = 2pq$
>
> (why? binomial expansion from algebra. Or, think about the fact that there are two ways of being heterozygous: Bb or bB (yes, they're both identical, but there are two ways of getting one "B" and one "b").

But now note that everybody is either BB, Bb or bb. Therefore:

> $BB + Bb + bb = p^2 + 2pq + q^2 = 1$

So, we can now use this to figure out how common alleles are in populations.

How? Measure people (or other organism) on a trait. If it is dominant/recessive, then we can tell apart the individuals that are (BB + Bb) or bb (we can't tell the difference between BB and Bb). Thus:

> We know the number of recessives (bb)
>
> > If $bb = q^2$, then b $= \sqrt{q^2} = q$
>
> Then we remember that:
>
> > $p = 1 - q$, so we also know *p*
>
> So then we can just plug everything into the following:
>
> > $BB = p^2$
> > $Bb = 2pq$
> > and we already know bb ($= q^2$).

Let's do a specific example (see page 267 in text):

PKU (genetic disease in humans) occurs once out of every 10,000 births.

So we have:

UU = homozygous normal
Uu = heterozygous normal
uu = homozygous recessive (has PKU)

(I'm using u instead of p since we're using *p* in the Hardy-Weinberg equations.)

So individuals with PKU make up 1/10,000 births, which implies that:

$$\text{uu} = \frac{1}{10{,}000} = 0.0001 \ = \text{frequency of recessives.}$$

The rest is pretty straight forward:

$$\text{uu} = q^2 = 0.0001$$

and we get u:

$$\text{u} = \text{q} \ = \sqrt{q^2} = \sqrt{10{,}000} = 0.01$$

then we get p:

$$p = 1 - q = 1 - 0.01 = 0.99$$

now get p^2 (or UU):

$$p^2 = 0.99^2 = 0.9801$$

and finally we get $2pq$ (or Uu):

$$2pq = 2(.01)(.99) = 0.0198 \approx 0.02$$

=> about 2% of human population is a carrier for PKU.

(and that's about as bad as math gets in Bio103!)

Hardy-Weinberg *equilibrium*, however, states that the genetic makeup of a population does not change. Why is this useful?

1) This is sort of backwards, but it shows under what conditions the genetic makeup of a population DOES change.

2) Allows us to take a "snapshot" of a population and figure out genetic makeup (as above).

Rules for a population to stay in Hardy-Weinberg equilibrium:

1) Large population size (no random effects from really small populations) **[OVERHEAD, not in book]**.

2) No movement of genes in or out of population.

3) No net mutations.

4) Random mating.

5) No natural selection.

Obviously, very few of these are true over time (give some examples). But the principle is useful for getting snapshots, particularly with organisms having large generation times.

Finally, a word about mutations:

Where do "new" alleles come from?

→ *Mutations*. As mentioned, most are harmful, many are irrelevant, a few are beneficial (i.e., increased speed, etc.)

Causes - environment. Damage to DNA.

Mutations are the original source of variability in populations (they provide the raw material for evolution).

Mutations are the driving force behind evolution and the ultimate source for variability (which natural selection can work on).

Miscellaneous topics related to evolution:

Other mechanisms of evolution. Natural selection isn't the only way for species to evolve.

Artificial selection has already been mentioned.

Sexual selection (recognized by Darwin).

What about obviously silly characteristics like colors in birds, silly behaviors (e.g. humans), etc.?

Characteristics selected by opposite sex

(e.g., females like longer trunk, brighter tails, etc.).

There is often a trade off between sexual selection and natural selection

If character becomes too bizarre, natural selection may put a halt to it.

(why does sexual selection exist? - because if you have silly characteristics and can still survive, this indicates you're doing pretty good.)

Speciation - formation of new species.

So now that we understand evolution a little bit, how do new species arise?

Two possibilities from evolution **[OVERHEAD, not in text]**:

A single species changes

A single species gives rise to several species (origin of diversity) - generally more interesting.

So how do we define a species?

A group of organisms that can interbreed, but who cannot produce viable offspring with a different species.

This definition isn't very good, but it's the best we really have (think of things like wolf/dog hybrids or many plants).

Incidentally, *species* is the only "objective" category that we have in the traditional Linnean classification system.

What prevents two different species from producing viable offspring? Some examples:

Habitat	- living in areas where there is no mixing of species.
Behavioral	- behave differently so that opposite sex is not attracted.
Temporal	- reproductively active at different times of the day/year etc.
Mechanical	- simply can't consummate reproductive act.

Methods of speciation

Generally involves geographical barriers (e.g. **[OVERHEAD, not in book]**).

Allopatric - living in different areas

Sympatric - living in the same area.

Allopatric speciation is generally caused by reproductive isolation.

Organisms on each side of barrier evolve in their own direction.

Nice example in book (p.282) - Grand Canyon. Birds are the same on both sides of canyon, but rodents (squirrels, which can't easily cross) are different (but still a little similar).

Adaptive radiation & island chains **[OVERHEAD not in book]**.

- A 'burst of speciation' from one or a small number of original species.

- Especially good case can be made in island groups.

  - Each island has a slightly different species, adapted for local conditions.

    - E.g., Darwin's finches, Galapagos tortoises.

- Also note that many groups are missing in islands. Only successful survivors make it onto islands.

  - Often this means that groups that do reach the islands are much more diverse than mainland relatives because they can fill areas usually occupied by other species back home.

- A real example - **[OVERHEAD, not in book]**, though this is a little simpler than what was presented above.

- Also, **[OVERHEAD, not in book]**, the Galapagos finches studied by Darwin are an excellent example of this.

Sympatric speciation?

- Can occur, but is very rare (your text does describe a few examples).

Finally, a few concluding remarks about evolution.

- Evolution as a "theory" - evolution is considered fact by any serious biologist/scientist.

  - In general, among scientists, a theory is generally considered a fact (e.g., Atomic theory, Theory of Relativity, almost any math "theory").

- Some scientists will argue about evolution. This is not about the "Theory of evolution", but rather about some details.

  - Punctuated equilibrium vs. gradualism (good evidence that both occur). **[OVERHEAD, fig. 14.11, p. 289]**

    - Punctuated equilibrium helps explain the lack of "transition fossils"

    - - species change faster during times of environmental stress.

- Evolving from: Humans did ***not*** evolve from apes - on one ever said that.

  - What biologists do say is that humans and apes evolved from a common ancestor.